The UNESCO Source Book for Science Teaching

Published by:
UNESCO
7 Place de Fontenoy
75700 Paris
France

A new edition of this book, THE NEW UNESCO SOURCE BOOK FOR SCIENCE TEACHING, costs $13.75

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Charles E. Tuttle Company
2-6, Suido 1-chome
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Japan

UNESCO SOURCE BOOK FOR SCIENCE TEACHING

Revised and enlarged edition

UNESCO

Published by the United Nations
Educational, Scientific and Cultural Organization
Place de Fontenoy, 75 Paris-7e
First edition 1956
Second revised edition 1962
Twenty-third impression 1970
Printed by Chaix-Desfossés-Néogravure, Paris

Printed in France
SC.68/D6mk/A

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Introduction

Science is perhaps unique as a subject in the curriculum of schools all over the world. This uniqueness results from the variety of materials and experiments necessary for its effective teaching. Most other subjects can be learned if ordinary tools are available, such as pencil, paper, blackboard, textbooks and a few supplementary aids. These are also essential for the teaching of science but, if they are the only tools, science becomes a dull and uninteresting subject.

If it is to be learned effectively science must be experienced. It must be learned and not learned about. Science is so close to the life of every boy and girl that there is no need to confine its study to the reading of textbooks or listening to lectures. Wherever you may go in the world, science is an intimate part of the environment—living things, the earth, the sky, air and water, heat and light and forces such as gravity. No teacher need ever be without first-hand materials for the study of science.

Good science teaching must be based on observation and experiment. There can be no substitute for these. But performing experiments and learning to make close observations require special facilities, and these are lacking in many parts of the world, especially at the elementary and early secondary levels. As a result, science teaching suffers a severe handicap in these regions. It is often believed—though erroneously—that to introduce laboratory teaching, even at the elementary level, requires elaborate equipment made by commercial manufacturers. Such materials are prohibitively expensive for most elementary and early secondary teaching, and in many parts of the world are quite unobtainable because they are not manufactured locally and cannot be imported because of the cost.

At the close of the second world war, many schools in many countries had been destroyed. As these schools began to revive, there was a great need for science equipment; for these countries had a tradition of basing science teaching on observation and experiment. To meet this need, Unesco sponsored the production of a small volume entitled *Suggestions for Science Teachers in Devastated Countries*. This book was written by Mr. J. P. Stephenson (science master at the City of London School; member of the Royal Society Committee for Co-operation with Unesco, United Kingdom). While it proved very useful for the devastated areas, it has had a phenomenal success in regions where previously there had been little or no equipment. Emphasizing the making and use of equipment from simple materials, the book has filled a great need in those countries where teachers are just becoming aware of the necessity for first-hand science experiments even at the lowest levels of instruction. It has gone through several editions, and has been translated into French, Spanish, Chinese, Thai and Arabic.

Over the past few years, Unesco has sent many science teaching experts on field missions into areas where the need for the production and use of simple equipment is acute. These experts have had opportunities to make and try out the materials and experiments suggested in the Stephenson book. They have also had opportunities to go further in discovering other materials and devising new experiments, more suitable for tropical regions for which the Stephenson book was not originally intended. The work of these field experts, together with the Stephenson book, has produced an array of simple equipment and science experiments which needed to be assembled and described in one volume. This need has provided the impetus for the production of the present *Unesco Source Book for Science Teaching*.

Due acknowledgement of the source of the material brought together in this book will be found on pages 11 and 12.

Believing that science and the scientific method of problem solving should play a significant role in any modern educational scheme, Unesco offers this book in the hope that it will assist science teachers everywhere in their important work. The point of view taken is that science is most effectively taught and learned when both teacher and pupils practise the skills of problem-solving by engaging in group and individual study. The devising of experiments and the improvising of simple equipment for carrying them out should form no small part of such study. Thus, the present book includes instructions for the making of many pieces of simple apparatus from materials usually found in almost any region. It also proposes a wide array of science experiments from which a teacher may select those most suitable for providing the observations upon which effective learning may be based.

These improvisations should not in any manner be regarded as makeshifts. The experiments and the exercise of constructing the apparatus are in the best traditions of science teaching. Many of the great masters of science have used such improvised apparatus and many of the great discoveries have been made with improvised equipment.

No claim for completeness is made for this book. The array of available materials has made it difficult to decide exactly what should be included. But it is hoped that these pages will serve as a guide, and as a stimulus to teachers and pupils to define their own science problems and then to improvise (from things that may be locally available) the necessary equipment for experimenting.

Acknowledgements

Science is universal and knows no boundaries. This great store of human knowledge has been gleaned from a reluctant nature by workers of many lands. It is altogether fitting and proper that this *Unesco Source Book for Science Teaching* should be a compilation of the work of experienced science teachers from many countries. It is through the sharing of experience that science teaching can be improved and enabled to move forward.

To give credit to all who have contributed to the making of this volume would be quite impossible. Much of the material included has its origin buried deeply in the past and has come to be a part of a common heritage of science teachers everywhere. Among those whose direct contributions have made this volume possible mention should first be made of Mr. J. P. Stephenson of the City of London School. To him and his collaborators we are indebted for the use of a large part of the material from the earlier Unesco publication *Suggestions for Science Teachers in Devastated Countries*. The impact of this little volume on science teaching has been world-wide and it is already considered a classic in the literature of science education.

Credit and appreciation are also due to: Dr. Glenn Blough of the University of Maryland and Dr. Paul Blackwood of the United States Office of Education, Washington, D.C., for permission to use parts of two bulletins on teaching elementary science, of which they were co-authors; the National Science Teachers' Association of the United States, Mr. Robert Carleton, secretary, and through them, to Mr. Guy Bruce of the Newark Teachers' College, for generous permission to use material from the series entitled *Science Teaching Today;* and the New York State Department of Education which granted permission to use material from the two volumes of their publication, *The General Science Handbook*, Volumes I and II.

Since the first appearance of the *Unesco Source Book for Science Teaching* in December 1956, many valuable comments and suggestions have been received, and reviews have appeared in journals in all parts of the world. This has led to minor revisions being made in each of the reprints. The first edition in English was reprinted eleven times, and the French edition is in its fourth impression. Translations have been published in seven other languages, while fourteen additional translations are in preparation.

The following were among the contributors of useful suggestions: Dr. F. J. Olsen of the Department of Education, University of Queensland, Australia, and a former President of the Australian Science Teachers' Association; Dr. W. Llowarch of the University of London Institute of Education and Dr. Vida Risberg, a former Unesco specialist in science teaching to the Philippines.

Note on the second edition

In this revised edition, note has been taken of further suggestions received from all parts of the world. Based on these, fifty new experiments have been added to the text, including new sections on 'Electricity and Chemistry', 'Optical Projection', and an extension to the section on 'Gravity'.

A chapter on recent tendencies in science teaching with special emphasis on physics has been added and the appendixes have been modified. The list of publishers has been replaced by a list of textbooks useful for a science teachers' library. The list of periodicals has also been brought up to date.

Grateful thanks are due to the following for their generous help. Suggestions for the book list were contributed by: M. A. Dolmazen (France); Dr. R. Eddy, Dr. I. Freeman, Dr. E. S. Obourn, and The National Science Teachers Association (USA); Mr. Silin (USSR). Many other useful suggestions and experiments were given by Mr. Bernacer (Spain), Mr. N. Dikwel (Holland), Mr. J. M. Cros (Honduras), Mr. Figved (Bandung), Mrs. Haggis (Ghana), Mr. Risan (Norway), and the World Federation for the Protection of Animals. The Educational Services Inc. (Washington, D.C.) and the Charles Heath Company also gave their kind permission to include in the text some of the ingenious experiments from the Physical Sciences Study Committee course.

J.P.S.

The purposes of this book

There are many places in the world where both facilities and equipment for science teaching are at present inadequate. Such places are to be found in areas that are more advanced in the applications of science, as well as in other regions. This volume has been produced to help the trend of upgrading science instruction in schools and training colleges everywhere by basing it more and more on observation and experiment.

The basic purposes may be summarized as follows:

1 To provide a basis for better instruction in methods of teaching science in teacher-training institutions.

2 To provide a useful source of learning experiences and materials for science teachers in the elementary and secondary schools.

3 To provide a manual which may be used as a partial basis of instruction in science teaching methods for workshops and courses for the in-service training of teachers.

4 To provide a basis for the assembling of a loan collection of teaching kits containing simple equipment for science.

To provide some suggestive materials for science clubs and for other amateur science activities.

To provide a model or pattern so planned and developed that it can easily be adapted to science teaching conditions in many countries and translated into the national language.

SUGGESTED USES FOR THIS BOOK

In teacher-training institutions

Young teachers in training do not learn the methods of effective science teaching merely by listening to lecturers in colleges; they must have some contact in their training period with the many problems to be met later in the classroom. The teaching of science must have special consideration above and beyond what is usually given in a general methods course—this because science is unique as a subject in the school curriculum as using specialized materials, equipment and methods of approach. If the standards of science instruction are to be raised, such a special course in the techniques of teaching it must be in the curriculum of every teacher-training college.

A large part of a course in the methods of teaching science should be devoted to the practical or laboratory phase in which young teachers are given instruction in the devising, designing and construction of simple laboratory equipment from materials available in the community where they will teach. Only through such training will they be stimulated to base their teaching on observation and experiment.

In this practical course, the young teacher should find the opportunity to construct many pieces of equipment to carry out to his first teaching assignment. He might even be encouraged to begin the assembly of a nucleus of teaching kits.

A source book for science teachers

Many teachers who have not had an opportunity to study science appear to be afraid to teach it. In many cases this fear of the subject arises because they do not know how to assemble apparatus or to marshal the specialized learning experiences required. This book can be used by such teachers as a source of instruction for making the simple equipment needed and as a source of a variety of learning experiences for teaching almost any topic in the curriculum. In this way the teaching can be improved and enriched.

This book should also help to create and maintain a higher level of interest in science on the part of the pupil. Every child is by nature an experimenter. He is curious about why things happen and likes to try out his ideas. Even outside the school, children are constantly experimenting. Many young people will like helping to construct apparatus and to test the ideas proposed in their classroom experiences.

Pupil committees may be used in the building of many of the pieces of apparatus suggested as well as in assembling them into useful kits to be used in later experiments. If there is a workshop in the school, the teacher may co-operate by letting pupils make science equipment as special projects.

As a basis for workshop study conferences in science teaching

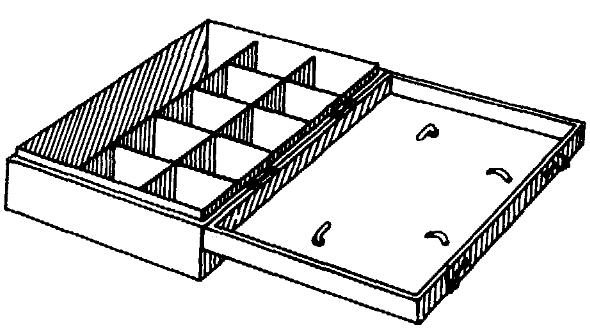
The workshop study conference is now a well-established and widely used device for the training of teachers in service. Such conferences have been held for science teachers in many parts of the world. It is only through them that teachers now teaching can be influenced to improve their practices and change their present conditions.

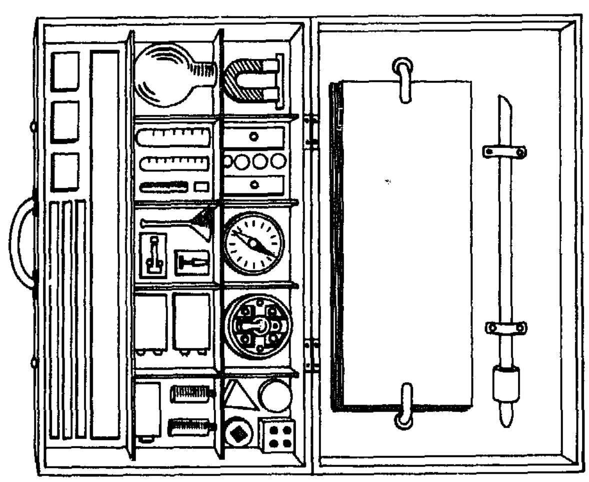
This book can serve as a useful basis both for instruction in methods of teaching science and for a laboratory practice where teachers are given instruction in the simple techniques of making improvised apparatus. They might then be encouraged to begin the training of other teachers in the area.

To provide the basis for assembling a loan library of simple science teaching kits

While the ideal situation would be for every school to assemble the simple equipment needed for teaching the various science units, this may not always be feasible because of lack of funds or time. Another scheme is to assemble kits of simple equipment for doing experiments. Each kit is assembled in a durable box with a hinged cover that latches securely. The kits are then stored in a central school and loaned out to teachers in the schools of the neighbourhood in much the same way as library books are loaned. Each kit also contains a list of the materials in the box as well as directions for doing the experiments.

The plan operates in this way. Assume that kits have been assembled and stored in a centrally located school. Perhaps the teachers in that school would take responsibility for keeping the kits in good order and making the necessary records. A card should be made out for each kit. Now let us suppose that a teacher in school X is planning to teach a unit on magnetism during the next week. She goes to the school where the kits are kept and fills out a card stating when she will need the kit on magnetism and when she will return it. The teacher in charge takes her card and then notes on the kit card, her name, the school and the dates. The kit is then issued to the teacher, and she takes it to her classroom for use. At the end of the unit the materials are carefully checked against the list and any breakage noted. The kit is then returned to the depository.





A project for assembling a library of simple equipment kits might be undertaken in several ways. One way would be to have the boxes made according to the pattern suggested above, by boys in a vocational school. The kits might be assembled at a central place or the project could be made co-operative by having each teacher, with her class, assume responsibility for assembling and making the necessary materials for one teaching kit.

Another plan might be worked out in which students in training at a teacher-training college could be assigned projects of assembling the kits for schools in a given locality.

As a source book for science club activities

Science club sponsors often find it a problem to provide worth-while projects and activities for club members. The many projects and experiments suggested in this book are appropriate for use by young people of all ages as science club projects.

To provide a model pattern of science materials and activities for many countries

The format of this book has been so planned, and the materials so selected as to make it adaptable to almost any local situation. The text materials and the simple line drawings can easily be reproduced.

TOOLS NEEDED FOR MAKING SIMPLE EQUIPMENT

Every school where elementary or general science is taught should be provided with some sort of work bench where simple equipment can be made. An old table can be used for this purpose. If no space is available for a work bench, a few rough boards cut to the right length may be placed on a school desk to prevent injury to the desk top. Such boards may be padded on the under side with cloth. A work bench will provide a place to hammer and saw. A good supply of old newspapers is always useful to put on the floor, especially if any painting is to be done.

Following is a basic list of tools that will be needed for the construction of simple equipment:

Hammers
Screwdrivers
Pliers
Small wood saw
Hack or metal saw
Small block plane
Wood chisel
Brace and bits
Gimlet
Metal shears
Round file
Triangle file
Flat file
Jack-knife
Metre stick
Glass cutter
Coping saw
Can opener (tin opener)
Cloth shears
Small table vice
Piece of heavy bench iron
Sandpaper
Paring knife
Steel wool
Leather punch
Soldering iron and solder
Wrenches

MATERIALS AND SUPPLIES

The materials needed for making simple equipment will vary from place to place and class to class. It is possible however to suggest a few basic materials and where they can be obtained.

From the home

Old pans of various sizes
Basins
Tablespoons and teaspoons
Cups and saucers
Dinner plates
Soup plates
Bottles, various shapes and sizes
Tin cans, various sizes with and without covers
Glass jars, various shapes and sizes

Garden tools
Hand tools
Ink bottles
Glass tumblers
Combs
Saltshakers
Soap
Old electric bulbs
Ink
Wire coat hangers
Fruit jars
Flower pots
Clothes pegs
Leather, soft, from old shoes
Milk bottles
Spools, wood
Old clocks
Razor blades
Old electrical appliances
Musical instruments
Cloth, various kinds
Fur
Newspapers
Paper bags
Used toothbrushes
Cork dinner-table mats
Plastic drinking cups
Aluminium and plastic tubes from old bird pens
Aluminium milk bottle caps

From the hardware shop

Nails—assorted sizes
Spikes—assorted sizes
Screws—assorted sizes
Bolts and nuts—assorted sizes
Screw eyes
Springs
Tape measure
Fishing-line
Staples—assorted sizes
Carpet tacks
Drawing pins
String and twine
Rope—small diameter
Mirrors
Glass jars—assorted sizes
Window glass
Washers
Hooks—assorted sizes
Torch batteries and bulbs
Sheet metal
Metal rods
Thermometers
Egg beater
Candles
Small wash-tub
Curtain rods
Magnetic compass
Kerosene lamps
Lamp chimneys
Lantern globes
Wire screening
Corks
Metal and plastic funnels
Rubber tubing
Metal tubing
Sewing, darning and knitting needles
Level
Sandpaper
Pulleys
Turnbuckles
Steel wool
Glue and household cement
Brass, copper and iron wire
Tools
Paint
Varnish
Flash lights
Hacksaw blades
Scissors
Shears
Metal and wooden balls
Dish pan
Oil cans
Oil
Tin and aluminium cups
Pyrex dishes and bottles
Small forceps
Tack puller
Sieve
Wicking for alcohol lamps
Asbestos mats
Battery jars
Pins
Block and tackle
Jack screw
Thermos bottles

From the automobile repair shop

Old rubber tyres
Old rubber inner tubes
Valves from inner tubes
Used storage batteries
Battery acid
Safety glass from old cars
Spark plug
Ammeter
Carburettor
Fuses
Curved reflectors from headlights
Fuel pump
Electric motor
Electric generator
Gears
Ball bearings
Springs from seats
Magnet from speedometer
Headlight lenses
Headlight bulbs
Tools
Metal tubing
Wire from old coils
Ignition coil
Engine
Rear view mirror
Wing mirror
Used oil

From the radio repair shop

Radio sets
Wire from old coils
Transformers
Old radio tubes
Electrical instruments
Coils
Transformer cores
Condensers
Rheostats
Solder
Metal plates
Plastic from old cabinets

From the food market

Ammonia
Baking powder
Baking soda
Bleaching powder
Blueing
Corn syrup
Epsom salts
Matches
Mineral oil
Paraffin
Beeswax
Sealing wax
Starch
String
Sugar
Paper bags
Table salt
Turpentine
Vinegar
Boards from boxes
Cardboard boxes
Wood boxes
Tin containers
Gelatine
Cooking oil
Lard
Seeds

From the lumber market

Asbestos sheets
Boards
Hardware
Insulating materials
Plywood
Press board
Rope
Paint
Varnish
Wire screening
Sawdust
Lime
Cement
Brick
Broken sewer pipes
Round dowel rod
Wood blocks and prisms

From the machine shop

Ball bearings
Gears
Sheet iron
Sheet brass
Sheet copper
Brass and iron rods
Iron filings
Scrap metal pieces

From the drugstore

Agar
Copper sulphate
Mineral oil
Saccharine
Hydrochloric acid
Nitric acid
Sodium hydroxide
Silver nitrate
First-aid kit
Cellophane
Beef extract
Drug capsule containers
Sheet rubber
Powdered sulphur
Boric acid
Manganese dioxide
Adhesive tape
Wood tongue depressors
Thermometers
Dyes
Ink
Iodine
Marble chips
Medicine droppers
Shaving mirrors
Glass tubes
Rubber stoppers
Medicine bottles and vials
Peptone
Sponges
Test tubes
Litmus paper
Potassium chlorate
Plaster of Paris

From the optical shop

Old cameras
Old eye-glass lenses
Lenses
Reading glass lenses

From the plumber and tinsmith

Scrap iron and lead pipe
Old taps
Sheet metal
Rubber suction cup

From the electrical shop

Dry batteries
Electric bulbs
Insulated wire
Switches
Lamp sockets
Insulation tape
Electric meters
Old electrical appliances
Miniature light sockets
Electric bell
Electric buzzer
Push buttons
Heating elements
Magnetic compass

From the toy market

Gyroscopes
Marbles
Small wagons
Ping pong balls
Mechanical toys

Coloured chalk
Steam engine
Steam turbine
Electrical toys
Rubber balloons

Toy musical instruments
Rubber balls
Plastic toys
Football pump adaptors

From the bicycle repair shop

Old bicycle wheels
Spokes from bicycle wheels
Inner tubes

Valves from tyres
A sprocket wheel
Bicycle pump

Rubber grips from handlebars
Bicycle lamp

From the textile market

Cloth—silk, cotton, woollen, and linen

Synthetic fabrics

Thread—cotton, silk, and linen

From the school

Cardboard
Blotters
Ink
Coloured chalk
Erasers
Burned-out electric bulbs

Paper
Oil
Chalk
Fuses
Paper towels
Pencils

Chalk boxes
Gummed labels
Rulers
Globes
Maps
Rubber bands

Miscellaneous materials

Mailing tubes
Cardboard
Blotting paper
Old watch and clock springs
Cigar boxes

Cigarette tins
Tin and aluminium foil
Old roller skates
Coal and charcoal
Telephone transmitters and receivers

Telephone magnetos
Magnetic iron ore (lodestone)
Tennis balls

Miscellaneous collections from the locality

Seeds and fruits
Leaves
Plants

Birds' nests
Rocks and minerals
Soils

Fossils
Insects

CHAPTER I

Some suggestions about the teaching of general science[1]

A. GENERAL SCIENCE

What is it?

In the primary school, children are seeking simple answers to their questions, which usually begin with: 'What is it?' First of all, science is *not* a lot of things it was once thought to be; not a series of object lessons about a piece of granite, an old wasp's nest, an acorn, or a tulip. It is not hit and miss like that, not learning the names of the parts of a grasshopper or a flower; not learning to identify 20 trees, 20 insects, 20 flowers or 20 anything else.

What is science, then? It is a study of the problems that are found wherever children live. More formally stated, it is a study of the natural environment—not merely pieces of chemistry and physics and biology and astronomy and geology. Its content is connected with those subjects but it is a study of problems that pop into curious children's minds as they live and grow from one day to the next, such as: What makes the wind blow? What's in a cloud? What's a stone made of? What does a bell do when it rings? How can a seed grow into a tree? What makes a rainbow? Anyone who has ever worked with primary school girls and boys knows that most of them are full of questions like this and like to know the answers to them. Well, finding the answers to such questions—that is science.

And it need not be too technical. The full explanation is not what the 10-year-old needs. He could not understand that. It is a foundation in simple terms of the how, the when, the where, and the what of the things that happen around him every day. That is his science. He doesn't need the technical terms, the formulas and the detailed explanations. Those will come later, but when he is 10 he chiefly needs to get satisfaction out of his tendency to be curious. He needs to have his curiosity broadened, his interests nurtured and his enthusiasms encouraged. That is the kind of science which fits him and with which he is able to deal.

Where is it?

Science in the primary school—where is it? It is everywhere that schoolchildren are: in the air they breathe, in the water they drink, in the food they eat. 'What's oxygen?', 'How do minerals get into water?', 'What's a vitamin?'

Science is in the things they see on their way to school: 'How does electricity make a street car move?', 'Why does my dog stick out his tongue when he pants in hot weather?', 'What makes the sky blue?'

Science is in their homes: 'What makes our doorbell work?', 'What makes lemons taste sour?', 'How does our furnace heat our house?'

Science is in the schoolhouse: 'How can the fire extinguisher put out a fire?', 'What made the rust in the drinking fountain?', 'Why did we all have to be vaccinated?'

Science, then, is all around the girls and boys we teach. They cannot help but see it. They will see more of it with a little help. They will get more interested in it with a little encouragement. They'll learn more about it with a teacher who sees the possibility of its use, and uses his teaching skill to help children learn about their environment.

What can it do?

It is generally true that a well-informed person is an interesting one, and some information regarding the environment is one of the pieces of equipment that go to make up an informed individual. That does not mean that you expect to pump your pupils full of facts that they can merely use to fill up blank spaces in

1. The materials for this chapter have been adapted with full permission of the authors and publishers from two booklets: *Teaching Elementary Science, Bulletin 1948, No. 4*, and *Science Teaching in Rural and Small Town Schools, Bulletin 1949, No. 5* of the Federal Security Agency, Office of Education, Washington, D.C. The authors were Dr. Glenn O. Blough and Dr. Paul Blackwood.

conversation. It means that you want to help them to come to learn generalizations or meanings which they can use in interpreting problems in their environment.

To illustrate: The members of the lily family have three sepals, three petals usually coloured alike, six stamens, one pistil, etc. A boy aged 10 can certainly live a full and well-rounded life without committing this to memory. But suppose he learns through an examination of many plants and many animals that 'Plants and animals are put into groups according to certain characteristics, and that knowing these characteristics helps you know the large group to which the living thing belongs'. This generalization can then be helpful in identifying animals and plants he sees, and make it possible for him to study their habits, to determine their helpfulness or harmfulness, and so on. He has become aware of this generalization through careful study and through observation, and by pressing together many small ideas into one large one. One aim in science, then, is to teach generalizations that can be used by pupils in interpreting the problems they come across in their daily living. The more nearly we can come to studying the problems that really make a difference in the lives of girls and boys the closer we are to having a science programme.

You don't want your girls and boys to grow up to be sloppy thinkers. The method by which science generalizations were originally discovered is the kind of thinking we hope they can be trained to achieve. We may call it a scientific way of getting the right answer. There is nothing brand-new about this idea. Probably you have been doing it for years in arithmetic and other subjects: defining the problem, suggesting several hypotheses, gathering evidence, drawing conclusions, checking conclusions. That does not mean that every time a problem comes up you get out these steps and make pupils climb them.

Actually, this scientific way of solving problems need not include these formal steps. For example: children want to know what makes a compass needle point north and south. You make sure that they state the problem as carefully as it needs to be stated, so that it asks exactly what children want to know. Then pupils say what they think makes the needle behave that way. Some explanations seem to make sense; some don't.

'How can we find out whose idea is right?' you ask. The pupils answer: 'Read our science books.' 'Ask Mr. Jackson, the physics teacher.' 'Do an experiment.' Then the pupils carry out their suggestions, discover an explanation, check it as carefully as they can by known authority, and they have solved the problem and can now make use of their knowledge. Simple, of course, and it is only the beginning of their introduction to a way of solving problems that, if properly used, is likely to produce good results. If they have intelligent guidance, pupils can make great strides in ability to solve problems in this manner.' Contact with this way of problem solving cannot come too early in a child's school experience. It takes a long time to become an accurate solver of problems.

You want girls and boys to develop certain scientific ways of thinking as they work. For example: Things don't just happen; they happen because of natural causes, so don't be superstitious. Be open-minded toward the opinions of others. Regard your conclusions as tentative until you are sure. Look for reliable sources for evidence. Be willing to change your mind if you discover that you were wrong. Don't jump to conclusions. Be curious about things and don't be satisfied with a vague explanation. These are a few of the safeguards of scientific thinking that a carefully directed study of science can help pupils to attain. Again, the earlier the contact with this kind of thinking, the better.

Then, too, you want to broaden the interests of the girls and boys. They seem to be naturally curious about many of the things around them, but there's half a world of things they know nothing about, so they can't be curious about the things in it. A study of the stars may open up a new field of interest in the sixth form and for a few it may turn out to be a lasting interest. A study of how plants grow may stir up an interest in plant culture that would otherwise have remained buried. Studies of children's interests seem to show that children are interested in all aspects of their environment, not just in animal and plant life as was once supposed. Some pupils, however, appear to have more or less narrow interests and need help in seeing other possibilities. Many life-long interests were born early in a child's school experience; scientists often say that their interest in science began when they were still very young. With better science teaching in the primary school more such results might be obtained.

You also want to have your pupils grow in appreciation of the things around them. How do young children come to appreciate things? Little sermons about the beauties of nature won't help much. Vague talk about the beautiful butterflies, bees, and flowers won't be of much help either. While we are learning new ways of helping pupils to grow in their appreciation, let's try to teach them to see, to look closely, to examine carefully, and to discover by themselves what wonders there are in the world about them. In the common green leaf a manufacturing process goes on that man himself has not duplicated. He has learned that the raw materials used in the process are water and carbon dioxide, that the green colouring matter in the leaf is indispensable to the process, and that it cannot happen without the help of light. He can analyse the resulting process to the last molecule, but he himself cannot duplicate the process nor is he able to understand it completely. Furthermore, without this process life itself could not exist. As a child learns these truths, as he is helped to realize their significance, his appreciation grows, especially if working with an enthusiastic, intelligent, appreciative teacher.

These, then, are a few of the things that the study of science can do for the children in our schools if teachers of science are fully aware that these are the purposes, and are intent on seeing that science is taught in such a way that they are accomplished. Aims that remain planted in teachers' manuals without being used do not help children. But aims that are in the teacher's mind and in the minds of children as well, will help them. Such aims colour the selection of the subject, the method of teaching it, the activities selected, the method of evaluation, and everything else that is done in the classroom. Here, then, is a point for all science teachers to remember —decide what it is you hope to accomplish by teaching science, keep it in mind, keep checking to see that you are staying on the track, and keep evaluating to find out how closely you are coming to your goal. And, above all, let these purposes be as nearly as possible those of the pupils, and let pupils help with the plans for accomplishing these objectives.

Elementary science and nature study

There has been and still is controversy over whether a programme in science in the primary school should be called elementary science or whether the term nature study should still be used. Some schools have so-called nature study programmes that are excellent. They are teaching science in the broadest sense and have the most modern objectives in mind although continuing to use nature study as the name for their programme. In some other schools, the programme is called elementary science, but the philosophy under which it operates is antiquated and holds to the original, narrower, view of nature study. From this it appears that the name is not so important as is the content and the procedure actually used in the programme. The science programmes that take the best from the nature study idea and build upon it the best that we have learned in recent years are those that are most useful today. While the difference does not lie entirely in the name, programmes in elementary science are likely to be broader in scope and conform more nearly to modern needs than those called nature study.

To illustrate this point: the nature study idea stresses the study of an object such as a rock or tree rather than a broad problem concerning rock formation or forestry. It is likely to lay stress on identification of rocks and trees rather than use this as a means to an end. It is not likely to be concerned with the study of the problems of real concern in the lives of children or the whole field of science, but to deal rather with the study of plants and animals. Experience with children shows that they are interested in all phases of their environment. From this brief sketch of nature study ideas it appears that the original idea of nature study is being supplanted by a programme more suited to the needs of modern children. The world in which these boys and girls live today has changed greatly during recent years; so, too, must their programme of studies change.

From the nature study idea, however, we realize the importance of first-hand experience in observing life around us, not just reading and hearing about it. A nature trail that points out kinds of plants and animals, homes of animals, spots that show interrelationships among living things, relationships between living things and their environments, and special adaptations of these living things, is useful learning equipment. A nature trail, then, although it has its origin in the nature study idea has, if properly used, much to contribute to a more up-to-date science programme. Schools that are near a wood, near a park, or in the country are fortunate if they avail themselves of the opportunity to establish such a nature trail, or in some other organized way make use of this resource.

Camping experience is another source of first-hand information and appreciation which a modern elementary science programme might well include. The experience of building a camp fire, preparing sleeping quarters, getting pure drinking water, procuring and preparing food, and many other necessary activities are packed full of science. Again, how much science and what kind of science is learned depends on the point of view of the individual in charge.

In deciding whether or not your point of view is in line with pupils' needs, measure it in relation to the objectives discussed earlier in this section. These, along with the purposes of the total elementary programme, are the guides that point the way. Don't think that you have a modern science programme if you spend half the time covering walnuts with tinfoil and hanging them on a Christmas tree, pressing leaves, colouring robin pictures, or cutting paper snowflakes. Such activities do not achieve the objectives of even the most elementary science programme.

Science and the primary school programme

An elementary science programme that tries to exist without consideration of its relationship to the general primary school programme is bound to be ineffective. A science programme's right to exist as a separate subject must be challenged on the basis of its contributions in accomplishing the general objectives of primary education.

The general purposes of the primary school have been variously stated. Perhaps the most important is to help children to achieve the ideals, understanding, and skills essential for becoming good citizens. This involves giving them the basic skills of reading, writing and arithmetic, as fundamental tools for gaining information. In addition, it means giving them an opportunity to identify and understand social procedures and problems, to participate both in suggesting solutions and carrying out their suggestions, to develop their social sensitivity to the needs of individuals and groups. The elementary school should help children to recognize and practise a number of human relationship skills—co-operation, selection of leaders, group planning—provide conditions conducive to physical and mental health, and give the children information and skills for developing these traits. It should help them to develop wholesome interests for their leisure time. These are the general aims of a good primary school programme and no science programme can be effective without keeping them in mind.

The objectives for teaching elementary science must be adapted to these broader concepts of the primary school's purpose. How we teach science, what activities are most useful to children, how we help them plan and evaluate, all must be shaped in accordance with these objectives.

For example, how shall we teach science so that it will help children to be better citizens? If the teacher himself selects all the content, organizes it, decides how it is to be learned, and makes all other decisions, how are children to grow in ability to organize, to plan and work together? If we agree that being able to plan and work together is one of the attributes of a good citizen, we must make plenty of provision for children to plan and work together. There is a distinct difference between exercising leadership as a teacher and dictating from behind the desk. The teacher, as a leader, may take initial steps to create interest, open possible avenues of procedure, and then be a helper. Because of his experience he is able to exercise some guidance—but praise be to the teacher who has learned to be silent at the proper time! Children learn to be responsible citizens through being just that—silent—in science as in other school activities. The subject matter exists in large part for the purpose of developing this potentiality. So, in teaching science let us give opportunities for children to plan together, make decisions, make mistakes, decide how to rectify them, recognize their successes, set up new procedures and evaluate the results.

Do not tell children the answers to every question they may ask, or tell them always to read the answer. How do we gain information on science? By experimenting, by observing, by asking people who know, by reading, by looking at films, and in other ways. Again, how do pupils learn when to use these ways and when to depend on their results? They learn through practice in deciding, then through trying out their proposed plans and evaluating the effectiveness of their efforts. With practice, pupils grow in their ability to use the tools available for gaining knowledge—but this is true only if we help them. Every subject has here a definite contribution to make—if we give it a chance.

B. THE SCIENCE TEACHER

If we wait until all elementary teachers feel fully equipped to handle science we shall never get started. The most successful teachers of science in the primary school have said to themselves: 'I believe in the importance of including some science in my work. I don't believe my programme is complete without it. I don't know much science, but I know how children learn. I don't mind being asked questions that I can't answer because I know how to help children find answers.'

These teachers have many problems. They need to build background in science, to learn how to teach it, to find the necessary apparatus and other materials. But they have two essential pieces of equipment: they realize the importance of including science, and they know how children learn.

The following suggestions have been found useful by many such teachers:

1. Approach the teaching of science with confidence, not with the awe usually reserved for the first sight of a man from the planet Mars. It is not as unusual as you think. It is not so much different from teaching social studies, language, arts or arithmetic, in which most teachers feel at ease. It is not harder to teach; in fact, in some ways it is easier because it deals with concrete things and reaches the real interests of many children.

2. Don't expect to know the answers to all the questions children ask you. If you wait until you do, you'll never begin teaching science. Teachers tell children too much anyway. If you know children, and know how to help them learn, half your teaching battle is won. Don't be afraid to learn with children. Let them set up plans for finding the answers to their problems and then you act as a guide and learn with them. Of course you need to know some subject matter, but you don't need to be a science specialist. The next few items of advice will help you build up some science background.

3. After a unit or area of science study has been decided on, read some basic science textbooks on the learning level of the pupils you teach. Then get some good general science or biology textbooks (the kind used in secondary schools) and read them. Here you will find most of the science subject matter background essential for teaching young children.

4. Do some of the experiments suggested in these books so that you get the feel of the material. These elementary science experiments are not half as complex as you may think.

5. Do some of the 'things to do' that the books suggest—trips, observations, experiments, collections. To see is both to believe and to feel and it is much easier to get your pupils interested in and excited about the town's filtration plant if you have yourself seen how wonderful it is.

6. Talk with a secondary school science teacher near your school and enlist his help. Secondary science teachers can often give you teaching ideas, suggest experiments, and help provide materials and books. Science is their special field, and they are usually full of helpful ideas.

Remember that it is the unfamiliar that is likely to make you timid, so give yourself as much first-hand experience as you can with the science material. Following the preceding suggestions is almost sure to make you confident enough to tackle a new science topic.

7. Don't feel too handicapped because you lack materials. Children can bring from home almost everything you actually need. What they cannot produce, you can get at the market or hardware store (ironmongery), borrow from the secondary school science department, find in the schoolyard, get from the school janitor, or let the children themselves make. Expensive, complicated apparatus is worse than useless in the elementary science class. It is likely to be confusing and to draw attention to itself rather than to the problem at hand.

8. Let pupils experiment. Children like to learn in this way. Use some of the abler pupils in your class to gather materials and prepare the instruments.

9. Start your science by teaching the topic with which you feel most at home. This may be contrary to the belief of some persons that pupils should initiate all problems for study. That theory is open to question anyway. If some of your college science training, a personal hobby, or an interest of your own has given you background in some special field, using that knowledge or interest to determine your choice of topic may be your springboard for science teaching. Later it will be easier for you to follow children's leads. They can always enter into the planning even if the original idea comes from you as the teacher.

10. Make good use of the teachers' manuals that accompany your textbook in science. They are full of teaching ideas that have been tested and found good. They are often helpful even if you are not following the text which they have been prepared to accompany.

11. Keep track of your science material, your notes on teaching, your plans, etc. so that you can use them at a future time and so that other teachers may borrow them. A topic is easier the second time, especially if you have access to the material you used before.

12. Talk to other teachers about what things they have found successful, and be ready to share your experience with them. Such an exchange is often a great help.

C. HOW CHILDREN LEARN SCIENCE

Children learn science in a variety of ways, just as they learn anything else. They learn it more readily when they are interested in it, when they can see that it makes some difference to them, when it is graphic, involves some manipulation on their part, is not too hard but hard enough to make them think, and when it gives them the satisfaction of having found out something they wanted to know. This is not peculiar to science. It is true for arithmetic, languages, the arts, or any other subject. The activities selected by and for children should take these things into account. Keeping them in mind, let us then examine some of the ways in which children learn science.

Experimenting

Experimenting is one of the chief ways of learning science principles and generalizations. Experiments should be kept simple; the commonest material is often sufficient and almost always desirable; pupils are capable of originating their own experiments—often bringing the necessary material from home—and are usually enthusiastic about performing them.

Certain points should be borne in mind:

1. Experiments should be conducted so that they will cause pupils to think. An experiment in which the teacher tells the pupils everything obviously gives no food to growing minds.
2. Children should be conscious of the purpose of an experiment. It is often desirable to write the purpose on the board in a simple, direct form. This is easy when the experiment is done to solve a problem which the pupils themselves have raised. For example: the children arrive at school on a slippery winter morning. The janitor has scattered salt on the school steps to clear the ice. The children want to know what happens to the ice and why that happens. They decide to set up an experiment to discover the reason. They get the point of why they are experimenting and are therefore more likely to press the performance to an ultimately satisfying conclusion. Other experiments may arise from the textbook, but the plan of action should as far as possible be worked out by the pupils.
3. Careful planning is essential to successful experimenting. Appropriate materials must be assembled—by the children, if possible. A plan of procedure must be drawn up. The plan must then be accurately followed, to ensure that the results can be depended upon.
4. As far as possible, children themselves should perform the experiments. They may work as individuals or as groups, depending on the type of experiments and the amount of material available. Experiments involving use of fire or other possible dangers, or experiments of a complicated nature, if used at all, should be performed by the teacher.
5. Children themselves can often originate experiments to answer their questions. These are the most satisfactory from every point of view. Contrary to the belief of some teachers, experiments need not always be complicated, nor need they have been previously described in a science book—sometimes they are; sometimes they are not.
6. Experiments should be performed carefully, and according to the directions, either those from books or those originated by the class.
7. Pupils should critically watch what is really happening when they perform an experiment, so that their results will be more dependable. For example: suppose they are attempting to discover whether or not leaves of plants give off water. They set up the usual experiment of covering a plant with a glass jar and shutting off the soil from contact with the air in the jar. The next morning droplets of water are found on the inside surface of the jar. The children immediately decide that they have discovered the answer to the problem. But how can they be sure that the water did not come out of the air in the jar? They can't. But suppose they assemble another set of apparatus exactly like the first—a plant pot, a glass jar, soil, etc., but without a plant. The jars are placed side by side and observed. This time if water appears on the inside surface of the jar with the plant in it and does not appear on the other jar's surface, the water must have come from the plant leaves. Such a procedure of controlled experimentation is essential if experiments are to assume their full meaning as activities for children. In this connexion it is essential that the experiment be tried more than once before conclusions are drawn. (See also item 9.)
8. Simple apparatus is more appropriate than complicated material for use in experiments in the primary school. As has been previously pointed out, intricate pieces of apparatus borrowed from high school laboratories often detract from the real point of the experiment.
9. Pupils should exercise caution in drawing conclusions from an experiment.

They cannot prove anything from having performed an experiment once. They must regard their finding as tentative until more evidence—either from additional experiments or from authentic books—has been found. Results should be accurately and completely stated.

10. As many applications as possible to everyday-life situations and problems should be made from an experiment. This is a difficult step, but it is one of the most important reasons for studying science. When an experiment has been performed, only the first step in its usefulness has been taken. For example, after pupils have experimented with rusting iron they may want to see how things may be kept from rusting. An experiment is performed involving a wet, unpainted nail and a similar nail covered with a layer of paint. The experimenters note that the unpainted nail rusts and that the other one does not. Now in a real life situation how is this principle applied? In school? At home? On the way to school and elsewhere? The experiment was done to make the idea real. The applications must be made to see how important this idea is and how useful.

Helping children to learn through doing their own experiments is not a difficult job. Pupils should realize that they are experimenting, not to discover information for the first time, as is the case with scientists, but for the purpose of understanding scientific ideas.

Reading

Reading ranks high in the list of ways in which children learn science. Unfortunately, some courses in science deteriorate into reading periods to the exclusion of all other activities. However, reading is one of the ways to learn science and as such deserves thoughtful planning if it is to be an effective tool. Accurate material on the reading level of the various class members must be available, and there must be guidance to help pupils read it. The following considerations are important:

1. The science class is the best place for children to learn to differentiate between fact and fancy in their reading. That is, they should come to know that some books are written for pure enjoyment; others as sources of knowledge. They should learn to challenge the authenticity of what they read. They should learn to exercise care in drawing such conclusions about material; i.e. to check one fact in a reference with an authentic source does not necessarily indicate that the book is accurate. Finding an error on a printed page may be an enlightening experience. The pupil may learn the valuable lesson that just because something appears in print does not necessarily mean that it is accurate.
2. Reading should be done with a definite purpose in mind, i.e. to check a pupil's own conclusion, to find information, to find out how to perform an experiment, to answer a question or to solve a problem.
3. A variety of sources of reading material on a given topic is desirable. More information is obtained and different points of view are seen.
4. It is often necessary for science pupils to do individual reading as a type of simple 'research'. Under such circumstances careful note-taking is essential so that an accurate report may be given to the class.
5. The reading material should be appropriate. This is largely the responsibility of the teacher, but the help of the children is also desirable. Material which is too difficult, or too easy, or which is inappropriate because it does not answer the children's questions, is discouraging. Slow-learning pupils or pupils with reading difficulties need special attention in the selection of their reading materials.

Developing skill in reading and learning in science can go hand in hand. But reading is only one of the ways to learn science. To overemphasize it is to ignore some of the fundamental purposes of teaching science.

Before science can be learned, enjoyed, and made to function in the lives of girls and boys, it must leave the pages of a book and get into their daily experience in a graphic way. The textbook will serve as an excellent guide. Problems will be raised by the pupils and teacher together. Ways to solve the problem will be decided on by the group. Then, reading may be, and almost always is, an extremely useful method. The textbook will supply much of the needed information, although that does not mean: 'We shall open our book to page 18 and read to 24 and then talk about what we have read.'

Observing

Observing is another essential activity in all science teaching. Through the use of their senses children can come to experience many things. Feeling the texture of material or the heat from an electric wire attached to a dry cell, seeing cloud formations, seeing the changes in lengths of shadows, listening to birds, and many other similar activities are an important part of their science work. They make learning more vivid.

Children observe to determine the characteristics of things, to see the changes in growing things, to learn the habits of animals, and to see the results of experiments, but they must learn to do so with ever-growing accuracy and to report their observations carefully.

This ability to observe accurately and to report observations correctly is essential. Experimenting is a total loss without it; field trips and visual aids cannot be effective without it. Much may be learned from our daily surroundings if we can train ourselves to be more careful in our observations. Pupils who have experience with this method of learning early in their school experience have a running start on those who do not.

Taking field trips

Making excursions to solve problems and to give information and appreciation are important activities in elementary science. Trips to the park, the zoo, the telephone exchange, the sawmill, the airport, the water purification plant, the rice field and similar places within reach of the school are commonly made by teachers and pupils. These can result in a headache for the teacher, a mere holiday for the children and bad public relations for the school unless the trip is well planned and motivated.

Children should make excursions with definite purposes in mind—to answer questions that are best settled by first-hand observation of the kind trips furnish. They should be aware of the purpose of the trip and the person who is to act as guide should know in advance what the children want to see and learn; the teacher should make a preliminary trip to see the place for himself and talk with the guide. He should assist the guide in keeping the group together, making sure that there is plenty of opportunity to see and to ask questions.

Excursions should be an integral part of a subject being studied and not just something to do. Field trips can be of inestimable value to a science programme, or they can be a waste of time. It is probably safe to say that more time should be spent getting ready for an excursion, and gathering deductions from it, than on the actual excursion itself.

Using visual aids

Another way in which pupils learn science is to see it pictured either in motion or otherwise. Much has been said about the desirability of using visual aids in connexion with primary school science teaching. Without the use of some of the aids now available a science course is incomplete, but much depends on how the aids are used. Motion pictures and filmstrips are but one of the many useful helps. There are others equally important.

If motion pictures or filmstrips are used, here are a few essentials to be considered.

1. The selection of a film is as important as the selection of a book. Films designed for use at higher levels are generally useless for elementary pupils. Films should be selected which deal directly with the problem under consideration and which are prepared specifically for the levels at which they are being used.
2. Films should be previewed by the teacher and a committee of pupils to determine fitness for showing and to make proper preparation for use. Previewing a film helps to determine the purpose for which the film may be wisely used and when it is to be shown—at the beginning, middle or end of a unit of study, or at more than one of these places as the case may be.
3. The class should be prepared before seeing the film. Pupils should know what to look for in the film and know why they are seeing it.
4. The follow-up discussion of a film is essential. During such discussions, questions are asked, ideas clarified, and further explanations are made.
5. Efforts should be made to help pupils realize that the films are not shown as entertainment but for the purpose of learning.

Motion pictures and filmstrips are but one of the types of visual aids useful in primary school science. The use of pictures from magazines and similar sources is often overlooked. In many schools, teachers, pupils and parents have, in co-operation, assembled an excellent teaching collection of pictures. Pictures that show how animals grow, how they are adapted to their environment, where they live, and what they eat, are examples of such picture collections. Pictures that show how we use electricity, machines, lenses, various kinds of power, are other examples. The important thing to remember is that these collections should be made to illustrate certain important ideas and not be just a collection of pictures.

Models are often useful in making ideas clear, and they should be used chiefly for that purpose. There are many instances of model-making in elementary science classes which are almost entirely a waste of time. For example, at the primary school level, making a wax model of the parts of a flower is not very useful, since a detailed knowledge of flower structure is not essential at this level. On the other hand, quite difficult concepts about the solar system can be more easily understood by use of a model of the solar system. It will give an idea of the relative sizes, and of distances between its members, and help pupils to gain better conceptions of other ideas of size and space concepts with which children can begin to deal. The purpose of model making, like the construction of any other instructional aid, should be carefully considered. Building model weather instruments and making balancing toys are other construction activities that contribute to understanding by children.

Thus there are many types of activities through which pupils learn science. The selection of an activity depends on what is to be accomplished. Let it be activity for promoting understanding, interest, and appreciation and not just activity for its own sake. An activity should make a science principle or idea more graphic, more interesting, and give pupils a chance to participate with their minds as well as with their hands.

D. RESOURCES FOR TEACHING SCIENCE

We are continually being urged to use resources at hand to make our curriculum more vital and meaningful to girls and boys. Very often subject matter and methods of instruction make things near at hand seem foreign and far away, because we try to teach without relating them to the children's experiences. A list of all the possible resources in a rural area would be endless and no two regions would contain the same possibilities.

Resources of the type suggested here are useful in at least three ways: they inspire observing pupils to ask more questions; they serve as sources for finding the answers to the questions; and they serve to make the science concepts more real.

The resources

The following pages include some typical examples of local resources as well as suggestions for their use.

1. *A gravel pit or stone quarry* may be instructive for: learning how the surface of the earth has changed over a period of years; seeing an example of how man uses materials from the earth; learning how observations of geological materials help scientists learn about the age of the earth and changes in climate; seeing how machines are designed and used to serve man; finding fossils to use in a study of animals of the past.

Possible use: take a field trip to observe and gather materials; hear a talk by the owner telling about the place, how the materials are marketed, what safety precautions are used, etc.

2. *A wood near the school* may be instructive for: discovering changes that animals and plants make as the seasons change; studying habits of plants and animals; finding out where animals live; seeing how animal and plant life depend on each other; seeing how physical surroundings, such as moisture, temperature and amount of sunlight affect living things; finding examples of useful and harmful animals and plants; appreciating the wonders of nature; studying various phases of conservation.

Possible use: take a field trip to observe and collect materials; bring selected materials into the classroom.

3. *A burned-over area* (roadside, field, wood-lot) may be instructive for: discovering the effect of burning on plants and animals; studying the causes of the fires; arousing interest in ways of preventing such fires if they are harmful; learning ways of stopping such fires; observing how life starts again in such areas; noting over a period of time how long it takes to rehabilitate such an area; seeing the effects burning has on erosion of such an area.

Possible use: visit the area to examine results of fire; collect and examine materials damaged by fire.

4. *A nearby field* may be instructive for: finding evidences of erosion to see how it starts and how it may be prevented; noting various adaptations which plants make to their environment, such as leaf arrangements, root length and arrangement, and leaf texture; observing various kinds of insects to see how they are adapted to the environment, how they are useful or harmful, and how the harmful ones are being destroyed; observing (if the field is being cultivated) how plants are cared for to provide moisture; noting different amounts of moisture in high

and low parts of the field; seeing how the vegetation differs where there is more moisture.

Possible use: visit field to observe plants; dig some up and bring them back for further study; collect insects for closer observation and study; ask qualified adult to discuss problems of weed and insect control with class.

5. *A new building being constructed* may be instructive for: Seeing how electrical wiring is installed; seeing how building is insulated; seeing what different materials are being used; examining samples of soil dug from the basement and comparing it with garden soil; learning how sewage is disposed of.

Possible use: collect examples of building materials for study—electrical wires showing different kinds of insulation, rock wool and other kinds of insulating materials, samples of soil, etc.; talk with workmen who are wiring the house, installing plumbing, or doing similar types of work; observe the procedure for locating and drilling well if there is to be one; examine plumbing, cesspool and location and installation if indoor plumbing is to be used; if outdoor toilet is used, find out where it is located in relation to the water supply and why this location was selected.

6. *A saw mill* may be instructive for: Learning how trees are selected for cutting; finding out how young timber is protected; learning which kinds of trees are considered most valuable and why; observing the use of machines; learning how lumber is made and cured; observing changes in animal and plant life when an area has been cut over.

Possible use: visit the saw mill to observe the procedures; bring back samples of wood to see growth rings; walk through woods to observe how trees are being cut; examine various machines being used to observe how they help workmen.

7. *A farm* may be instructive or: Observing various ways of preserving and storing food; caring for animals; growing garden vegetables and flowers; observing the use of machines in house, field, barn, garden, orchard; observing how buildings and grounds are made free from fires and how accidents are prevented.

Possible use: visit farm to observe science applications; let pupils report examples of scientific facts and applications they have observed at home.

8. *A vegetable and flower garden* may be instructive for: Studying how plants get enough light, moisture and other essentials for growth; learning how ground is prepared for planting, how plants are transplanted, and how seeds are dispersed; studying how flowers are self- and cross-pollinated and how seeds sprout and grow; learning what kinds of soil are suitable for the growth of different kinds of plants and how the soil is tested; observing how plants store food and how plants change with the seasons.

Possible use: visit the garden to observe plants and methods of growth; make collections of seeds and fruits that show methods of dispersal; sprout seeds in the schoolroom to learn more about how plants grow; perform experiments with plants to see the effects of light, temperature and moisture in growth; plant a school garden (if practical) to learn more about how plants grow.

9. *An apiary* may be instructive for: Observing how bees are cared for; learning how hives are constructed and how prepared for cold weather; learning what happens when bees swarm and how they are handled safely, and how bees are helpful to man; observing bees at work and learning how life inside a hive goes on; seeing an example of social insects and of insects that are useful to man.

Possible use: visit apiary to observe various activities; talk with beekeeper to learn about bees and how they live; observe dead bees under a reading glass or microscope.

10. *A tree on the schoolground* may be instructive for: Observing seasonal changes, leaf arrangements, bud formation and growth; seeing bird life and nests and learning of the usefulness of birds.

Possible use: observe tree at intervals and discuss observations; cut small branches and study them more closely.

11. *An orchard* may be instructive for: Learning how plants are transplanted, sprayed and pruned; seeing relationship of plants to useful (bees), harmful (scales, aphids) and other insects; seeing an example of man's use of plants to supply food; observing the effect of sudden changes of temperature or other weather phenomena on plant growth.

Possible use: visit orchard to observe trees at different times of year; mark certain flowers and observe what happens as season progresses; collect and study insects and fruit damaged by insects.

12. *A creek or pond* may be instructive for: Observing kinds of plant life and the adaptations of stems, roots, leaves, flowers and fruit to moist environment; learning how animals are adapted for life in or near water and contrasting this with land animals; observing how these animals and plants change as seasons change; observing the food-getting and home-building habits of the animal life.

Possible use: visit area to observe science applications indicated above; collect specimens of plants and animals for further study.

13. *The roadside* may be instructive for: Observing animal homes and animal methods of food-getting and of caring for young, observing various forms of plant life to see adaptations to environment, such as methods of seed dispersal and changes under conditions of drought or excess moisture; studying relationships between plants and animals (plants and insects, for example); studying examples of erosion and methods of preventing it. If the road cuts through a hill, pupils can observe the difference between topsoil and subsoil, see the depth of the topsoil and understand more clearly the importance of saving it from being washed away.

Possible use: visit area to observe examples given above; collect samples of topsoil and subsoil, try to grow plants in each and note results; collect seed-dispersal specimens.

14. *People in the community.* There are other people in the community who can be of help. For example, many parents have travelled extensively; some are experts in animal husbandry; some are expert homemakers; some can contribute experiences about hunting, trapping and fishing. There is an electrician and a mechanic in nearly every community. People are usually pleased to be asked to help schoolchildren with their problems, and the practice of using adults in the community to help in school may be a beneficial practice to all concerned.

Using these resources

The value of any of these resources depends on how skilfully it is used. Each should be used for a definite purpose or purposes: to help solve a problem, to make a scientific principle more graphic, to increase appreciation of the usefulness and wonder of science. In preparing for a trip, the teacher and children should have clearly in mind a definitely stated problem or problems. The teacher and perhaps a small committee of pupils should first go to the place to be visited by the class, to determine its suitability and accessibility.

Whenever the pupils plan to seek information from someone in the community, make sure that he or she understands the purpose of the visit, and keeps explanations easy enough for them to understand.

Follow-up discussions to make use of the material should be carefully planned. Appropriate data should be used in solving the problem, and written records made of the findings whenever it seems likely that the children will have a use for the records.

Most schools are not yet making full use of the community resources available. We are likely to overlook many common things about us even though we say 'science is a study of the environment'. The science in our rural school is not necessarily being best taught where there is costly equipment. It is being best taught where children and teachers are aware that they are living in a world of science and that the materials for its study are near at hand.

E. FACILITIES FOR TEACHING SCIENCE

Few schools either in towns or rural areas are fortunate enough to afford a separate room for science teaching. Where elementary general science is a part of the curriculum, it is usually taught in an ordinary classroom where other subjects must also be taught. Science, however, is somewhat different from most other subjects in that it is not effectively learned by children unless they experience it. It is not sufficient to hear about science or to read about it. Children must observe and experiment if their science learnings are to be permanent.

Thus, if children are to experiment and observe science in their regular classroom, there are some problems which must be solved. In this section a few suggestions will be given to help the busy teacher provide some facilities in his classroom which will make the teaching of science more interesting.

Making a science corner in the classroom

Set aside a corner in the classroom and call it the Science Corner. If possible, secure one or two tables which may be used for experimenting and display. Perhaps the school custodian will help you build shelves underneath the table for storage of materials, supplies and equipment, as described in later chapters of this book. Encourage the pupils to bring in materials to display in the science corner. Some teachers have a little competition each week to see which pupil can bring in the item which is voted the 'Science Item of the Week'.

The Science Corner should be a place of activity and change. The materials brought in by the children should never be allowed to remain on the table so long that their interest value is lost.

Providing aquaria

Aquaria are a source of constant interest and provide a place where many important science phenomena may be observed. Directions for making and caring for aquaria will be found on page 58.

Cages for animals

Several types of animals can be kept in the classroom for observation. Some animals adjust to being caged better than others. Children may be encouraged to bring their pets to school for short periods of observation and study. Suggestions for building cages for animals will be found on page 54.

Setting up a weather station

In Chapter VIII, simple weather instruments are described. These can be made from materials available almost anywhere. Observing the weather changes from day to day is a source of interest and can form the basis for useful science lessons.

A science bulletin board

If children are encouraged they will constantly bring to school interesting things they have clipped from newspapers or magazines. The science bulletin board provides a place to display such materials, as well as drawings and other things prepared in science classes. A good place for the science bulletin board is just above the tables in the science corner. The bulletin board can be made from soft wood or plaster board.

Growing things

Small flower pots placed along a window-sill where there is plenty of light will provide ample space for growing seeds and small plants. If more space is desired for some experiences, shallow wood boxes may be obtained or made from old orange crates.

A museum shelf

Once children become interested, they are insatiable collectors. Some of the things they collect are bound to find their way to school. Such activities should be encouraged. One way to do this is to provide a museum shelf where collections or individual science items may be displayed.

CHAPTER II

How to make some general pieces of equipment

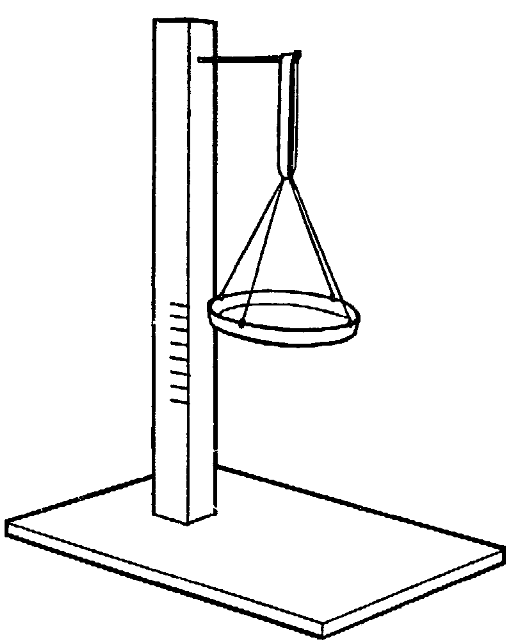
Wherever science teaching is based upon experiment and observation, there are certain pieces of apparatus that are used over and over again; such things as burners, tripods, flasks, aquaria, dip nets, etc. are almost indispensable in a science course. This chapter will be devoted to instructions for making pieces of equipment that are frequently used.

A. WEIGHING DEVICES

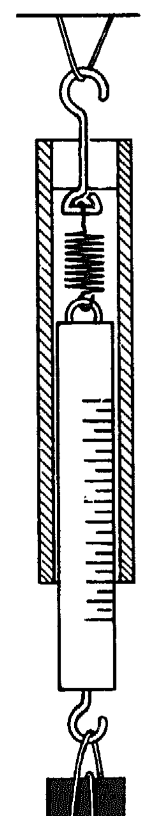
1 Simple 'spring' balance

Punch four holes in an old tin lid with a nail, spacing them equally round the circumference. Pass pieces of string through these holes and tie them together. Now attach this scale pan to a rubber band hung from a nail.

If weights are not available, it is possible to graduate the balance using known volumes of water poured from a measuring jar and by making marks on the supporting stick opposite the edge of the pan. Stones can then be found which will give the same extension and these should be marked for future use as weights. The use of coins for this purpose should also be investigated.



2 A serviceable spring balance



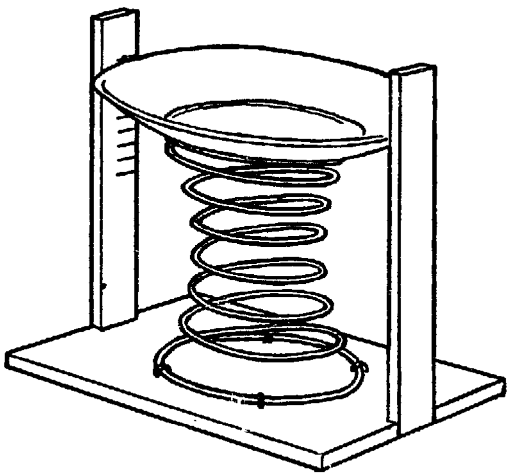
The quality of rubber deteriorates rather rapidly in unfavourable climatic conditions; a coiled steel spring is preferable. The pattern described has been found satisfactory. The coil is protected from damage by enclosing it in a tube. The reading is made at the bottom of the tube on a graduated wooden plunger.

First wind the spring (see Chapter XVIII, item 35), attach it by a screw eye to a piece of dowelling which will fit into the tube selected (bamboo or plastic). Fasten the other end of the spring by a wire staple to a wooden stick which will slide in the tube. Fix the dowelling to the top of the tube and insert into it a hook for suspending the balance. Screw another hook into the wooden plunger which can now be graduated.

3 Spring balance for heavier loads

Fasten a chair or automobile cushion spring to a flat piece of wood that will serve as base to the instrument. As scale pan, use a large tin lid or plate. Fix this to the top of the spring. If it is not possible to use solder for this purpose, the scale pan can be secured by fine wire passed through double holes punched through it in convenient positions.

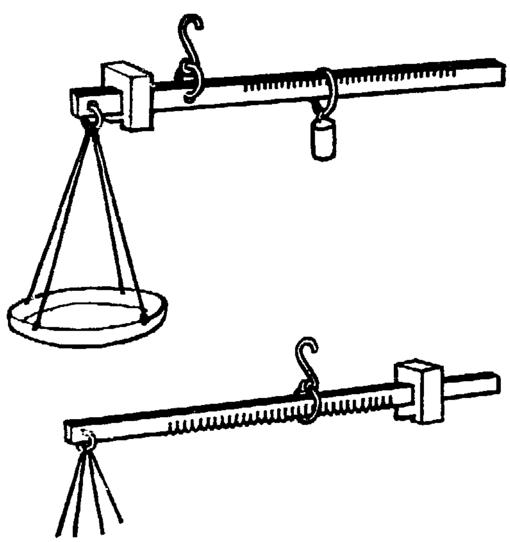
Attach two vertical laths to the base. These act as guides to the scale pan. Make graduations on these guides when loads of ½, 1, 2, etc., kilograms are placed on the scale pan. Wine bottles filled with water make suitable measures of litres, etc., and contain, of course, the equivalent weights in kilograms.



4 Steelyards

Either Roman or Danish steelyards can be improvised using short lengths of lead or iron water pipe as counter-weights and loops of wire as pivots.

The rod can be of either wood or metal; in the latter case notches can be filed on the underneath of the bar to indicate the balance points for various weights.



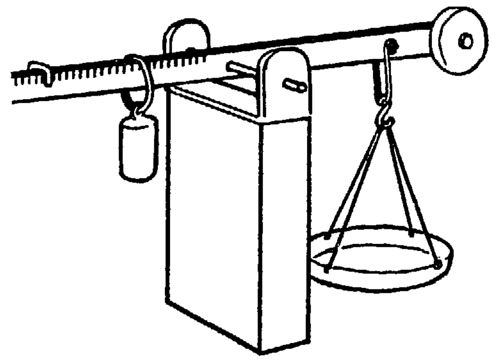
5 Laboratory steelyard

To make a steelyard weighing to 500 g use a wooden lath one metre long balanced on a strong sewing needle stuck through it 3 mm from its upper edge and 12 cm from one end. A disk of lead or anything suitably heavy can be used as counter-weight: if lead is used, a disk of it can be 'cast' in a tin lid.

A wire stirrup carrying a boot polish tin lid serves as scale pan and can be suspended 6 cm from the pivot.

A piece of U-shaped metal or two brass mirror plates separated by a wooden block will provide a suitable support.

Two sliders are needed, one weighing 50 g could be a piece of lead suspended by a copper wire: the other of 1 g weight could be in the form of a U resting on the top edge of the lath. The top edge can be calibrated in 6 cm divisions.

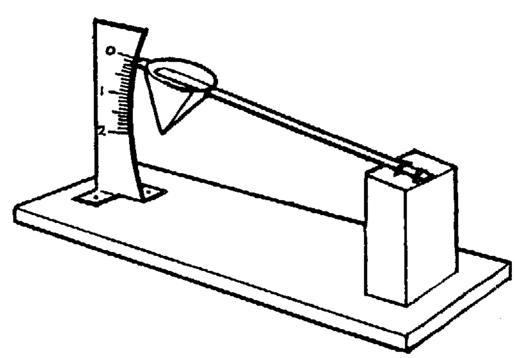


To use this apparatus, the nearest balance point is found by using the 50 g weight, and the final adjustment is made with the 1 g rider. No divisions are provided for this but the distance from the nearest mark can be quickly obtained by using a pair of dividers.

This balance is very quick in action and is satisfactory in use.

6 Clock spring balance

A sensitive balance for use between 0-1 g or 1-10 g is readily made using a piece of clock spring and a block of wood or cotton reel.



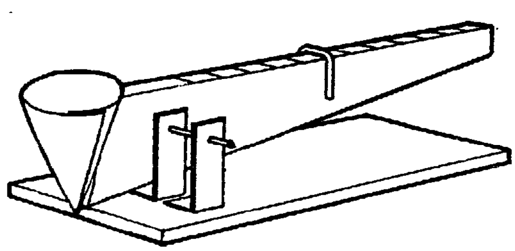
Fasten the wooden block or cotton reel down to a convenient base. Fix a piece of watch spring about 20 cm long to it and make a cardboard or paper conical pan. Fix the pan to the spring near the free end using sealing wax or cements suggested in Chapter XVIII. Use the free end as a pointer, and a postcard as a scale, and calibrate it by putting weights in the pan. The sensitivity depends on the spring used, but the scale is a reasonably open one.

7 **Simple steelyard** (reading to 100 g)

The pan is made from cardboard, and is shaped like a funnel. It is fixed to a beam made of a triangular-shaped lamina in plywood or 'perspex'.

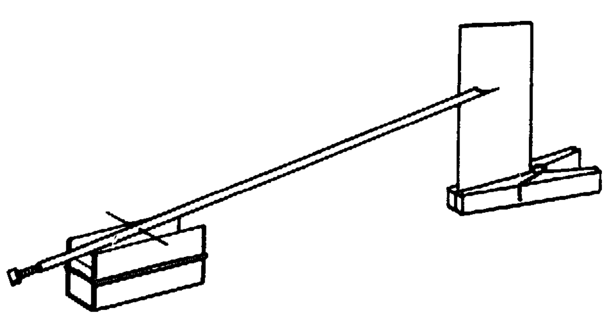
The beam tapers from 2 cm at the extreme end to 5 cm near the pan. The pivot, which can be a strong darning needle, is driven through the beam at a point about 5 cm from the pan and 2 cm from the top edge. Some part of the beam or pan can be cut away to make it balance.

The pivot is supported in holes through a metal stirrup, and an outer stirrup serves to prevent the beam from slipping sideways. The top of the beam carries a U-shaped rider; notches are made in the beam using standard weights to calibrate it. Powdered solids can be weighed using a filter paper or a piece of paper folded into a similar cone.



8 **Soda straw balance**

Obtain a small bolt (3 BA) which just fits inside the tube of a drinking straw, and screw it a few turns into one end. Determine roughly where this arrangement balances and punch a sewing needle through the straw to serve as a pivot. To ensure stability the hole should be made a little above the diameter of the straw.



Cut away the other end of the straw to form a small scoop. When the needle is in place set it across the edges of two microscope cover slips (or two razor blades) held parallel by a block of wood and a rubber band. Adjust the bolt until the straw balances at about 30 degrees to the horizontal. Support a piece of card vertically behind the scoop using a clothes peg or another piece of wood and a thumb tack; this will serve as a scale.

Hang a hair or a small piece of tissue paper from the scoop and notice the deflection. To obtain quantitative readings the scale must be calibrated. Aluminium foil from cigarette packets is suitable for making small weights. A common gauge of foil weighs 5 mg for 2 sq. cm of area. Cut the foil into areas weighing 1 mg, 2 mg, etc., and place them in the scoop using a piece of copper wire bent to form tweezers. Record the positions of rest of the beam by making marks on the card. The sensitivity of the balance can be varied by adjusting the position of the bolt.

9 **Zehnder's balance**

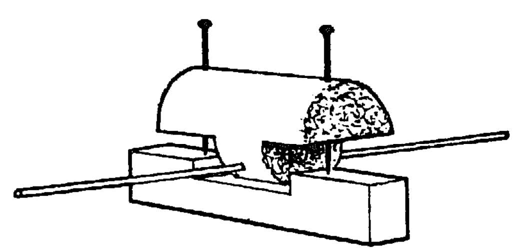
This ingenious balance, which is very useful for demonstration experiments, can be constructed in a few minutes using pins, razor blade, cork and knitting needle.

The knitting needle is first pushed through the cork as eccentrically as possible along a line parallel to a diameter of the end of the cork.

Half cylinders are cut away from each end of the cork to produce the balance beams as shown.

The supporting pins are now pushed through the cork, and can rest on slips of glass glued to a strip of wood.

The sensitivity of the balance can be varied by adjusting the supporting pins.



Experiments with the balance

1. A small rider of sewing thread or of the thinnest tissue paper, weighing about 2 mg and placed half-way along one arm, produces a turn of about 2 cm.
2. A slight formation of gas can be demonstrated by allowing the gas issuing from a small jet to impinge on the end of the beam.

3. Convection currents in air are shown by bringing a lighted match below the beam.

4. Since the balance-beam is an insulated conductor, it will show electrification. It can be charged by touching it with an electrified rod.

5. If the knitting needle is magnetized, it becomes a dip needle.

6. If the beam is magnetized and a wire spool is brought near to one of its poles, the balance becomes a galvanometer. For example, a thermocouple of iron-constantan can be connected to a coil of 22 turns of copper wire (1.5 mm thick). This, when warmed by a candle flame, produces a potential difference of only about 0.01 volt; nevertheless, the balance-beam detects the current flowing.

7. Projection. Small movements of the balance can be shown by using a beam of light reflected from a small strip of mirror attached to the beam. With this simple projection apparatus, thermo-electric currents can be demonstrated if the thermocouple mentioned above is merely warmed by the fingers.

10 A general utility equal-arm balance

Construct a base about 22 cm square from wood about 2 cm thick. Next make two uprights from wood 15 cm long by 6 cm wide by 2 cm thick and attach these near the centre of the base about 2.5 cm apart. They may be attached either with screws or by slotting the base and screwing the uprights to it. The top of each upright should be cut deeply enough with a thin saw to allow a razor blade to extend about 4 mm above the wood. The razor blades are wedged tightly in the slots.

The beam of the balance is made from a metrestick or similar length of wood with a thin finishing nail through its exact centre of balance. The nail rides on the razor blades.

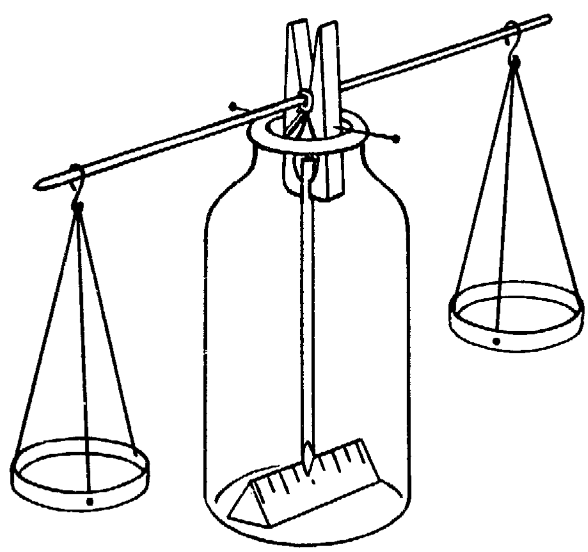
To give stability to the beam, the supporting nail should be positioned a little above the geometrical centre.

11 A sensitive beam balance

The materials needed for this balance include a clothes peg, a knitting needle about 12 in. long, two pins or needles and a support such as a milk bottle or preserving jar.

The beam of the balance is made by passing the knitting needle through the hole in the spring of the clothes peg. The pivots for the beam are the two needles or pins placed one on either side of the clothes peg, slightly below the hole through which the knitting needle passes. The latter must project equally on either side of the clothes peg, and can be wedged in this position inside the spring by a small splinter of wood. The lower end of the clothes peg grips a pencil which serves as the pointer of the balance. The pans of the balance are made from two tin lids pierced at the circumference by the equally spaced holes through which threads are passed and tied together to form a loop from which they can be suspended from the beam. Once the scales are balanced it is advisable to make a nick with a file to prevent the loops slipping off the knitting needle. Finally a graduated scale is placed inside the bottle in such a way that the pointer swings in front of it.

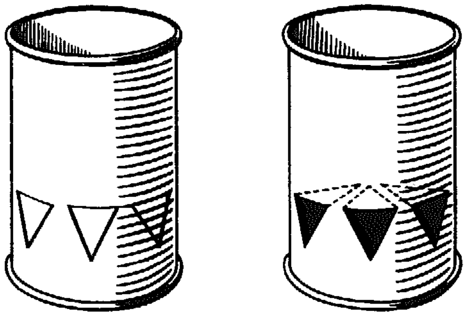
The weights may be coins, crown corks, matches, etc., correlated to standard weights. If none of the latter are available two similar small bottles may be used, one in each pan, and known amounts of water poured into one of them from some graduated vessel. Failing all else an old novocaine tube used by dentists for local anaesthetic is graduated in cubic centimetres and may serve as a very small measuring cylinder. Fractional weights may be improvised by hanging a loop of wire from the beam.



B. SOURCES OF HEAT

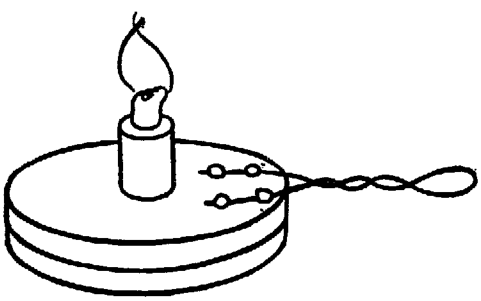
1 A tin can charcoal burner

A large tin can at least 10 cm in diameter should be used. About 4 cm from the bottom mark off triangular windows around the can, as shown in the diagram. With a pair of shears cut along the sloping sides of each triangle to make the windows. Do not cut along the base line. Bend the triangular parts inward to form a shelf for the charcoal.



2 Methylated spirits burner

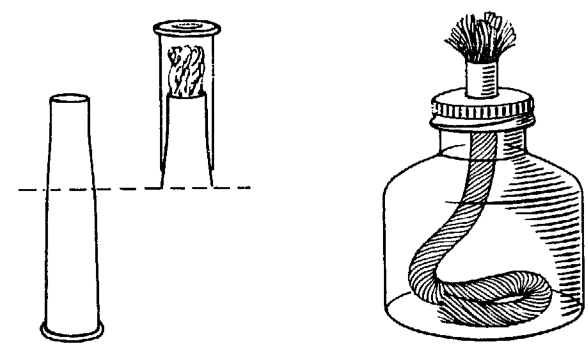
A simple burner can be made from an old boot polish tin. Though it is not essential, a metal tube can be soldered to the top and a twisted piece of wire makes a convenient handle. A piece of rag or cotton waste can be used for a wick.



3 An alcohol lamp from an ink bottle

Secure an ink bottle with a metal top which screws on. Punch a hole in the centre of the metal top with a nail. Enlarge the hole until it is about 8 to 10 mm in diameter by using a circular motion on a triangular file inserted in the hole. Smooth the opening by using some hard, round device. Cut a piece of metal about 2.5 cm wide and 4 cm long from a soft metal can or piece of sheet metal. Roll this into a tube on a piece of dowel rod or other round wood stick of suitable diameter to fit the opening in the top of the ink bottle. Insert the tube in the top and let it go about 1 cm into the bottle. The tube may be soldered around the joint with the top and along the seam. A wick may be made from cotton waste, a bit of cotton bath towel or from a bundle of strands of cotton string. Be sure to have enough wick to extend to the bottom of the bottle and cover it. Use denatured or wood alcohol.

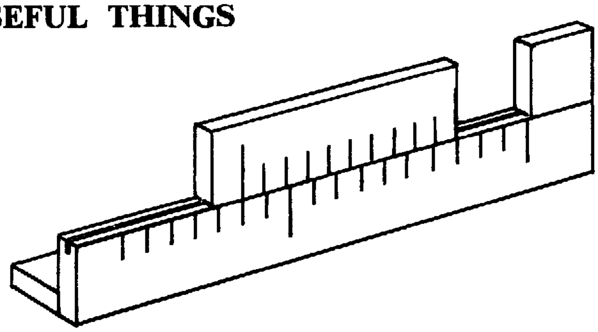
In hot countries a cap should be made to cover the wick when the lamp is not in use. An old fountain pen cap may serve the purpose. If a brass rifle cartridge is available it can be used to make both the tube and the cap by cutting it with a hacksaw at a suitable place.



C. OTHER USEFUL THINGS

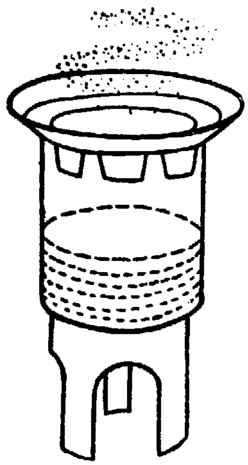
1 Demonstration vernier

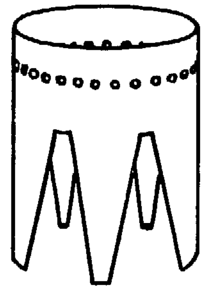
Two pieces of tongued and grooved floor board about 1 m long can be used to make this apparatus. Saw 7 cm off the tongued board and glue it into the groove to provide an end stop. With indian ink or sawcuts, mark off graduations 5 cm apart along the whole length of the longer board. Use about 50 cm of the tongued board to provide the vernier slide. Graduate it by measuring 45 cm from one end and dividing this into ten equal parts, i.e. 4.5 cm each. The remaining piece of board can be used to provide brackets so that the apparatus will stand vertically on the bench.



2 A simple tripod

A useful tripod can be made by cutting away the sides of a tin can. It is convenient to make two or three of these to suit different burners and for use as stands. Holes should be punched along the upper edge to let the products of combustion escape.



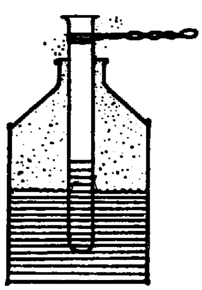


3 A steam bath

An evaporating dish and steam bath can be contrived from a saucer and a tin. Scallops are cut out of the top of the tin to allow the steam to escape.

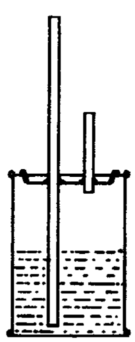
4 Heater

Another form of heater can be made from an old oil tin. Iron wire is wrapped round a test tube and twisted to form a handle.



5 Steam supply for experiments in heat

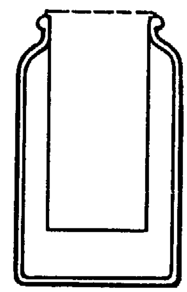
A tin with a press-on lid may be used to make a steam can. Punch two holes in the lid and solder through them one long and one short pipe as shown in the diagram. The long pipe serves as a safety valve and the short one supplies steam to the experiment (through a rubber tube attached). When the tin leaks or becomes rusty the same lid may be transferred to a similar tin.



6 A simple calorimeter

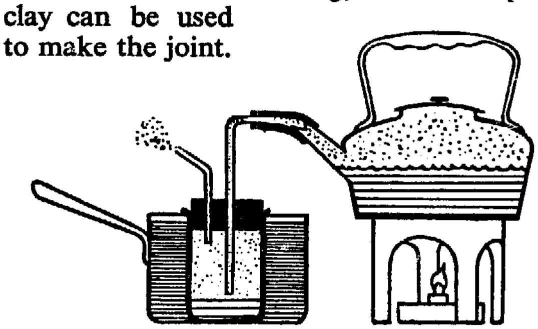
Small soup tins can be found which fit loosely into a 1 lb. jam jar. If the top of the tin is cut off cleanly with a rotary type opener it serves as an excellent calorimeter.

The tin can be prevented from slipping into the jar either by a stout rubber band round the edge, or by cutting nicks in the rim and bending it slightly outwards. This form of suspension, and the low conductivity of glass and air contribute to its efficiency.



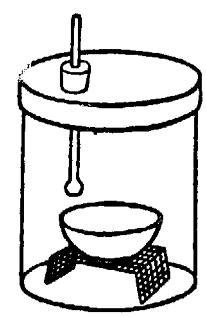
7 Distilled water

A kettle can be used to provide boiling water, which is then condensed in a jam jar fitted with a large cork and immersed in a pan of cold water. Rubber tubing, adhesive tape or clay can be used to make the joint.



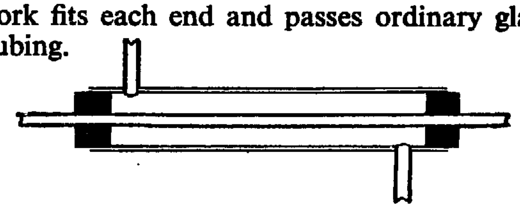
8 An air oven

A large tin can be used as an air oven. A hole through the lid fitted with a cork holds a thermometer, and the saucer or dish rests on a wire gauze bridge placed inside the tin.



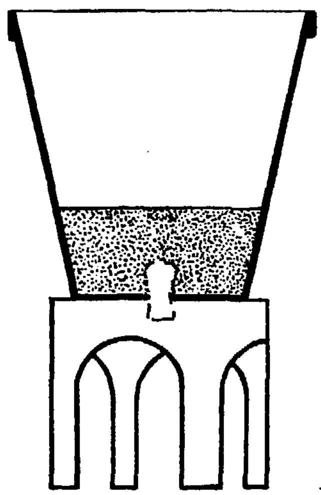
9 Liebig condenser (iron)

A piece of iron pipe such as is used for water or electric conduit can be used to make a metal condenser which is much more robust than a glass one. Inlet and outlet tubes are screwed or soldered to the sides. A one-hole cork fits each end and passes ordinary glass tubing.

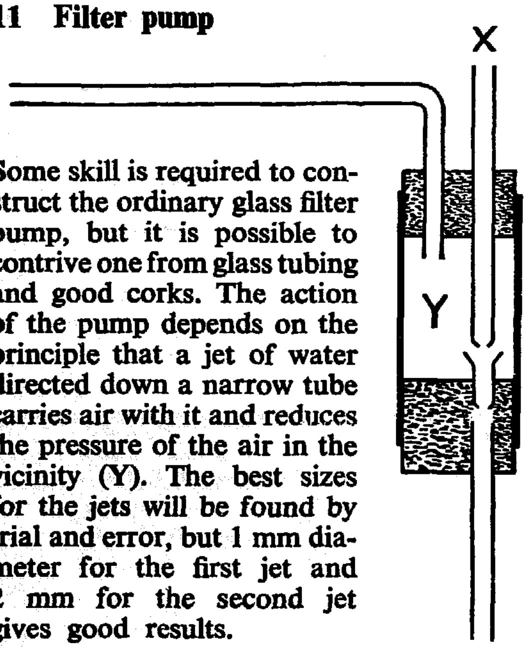


10 Filter

A plant pot with a plug of cotton wool in the bottom and a layer of sand a few inches deep makes a satisfactory filter for many purposes.

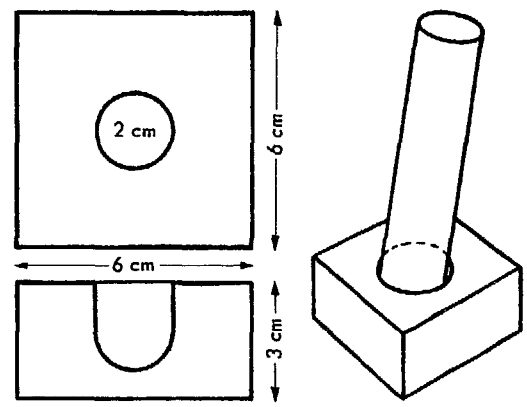


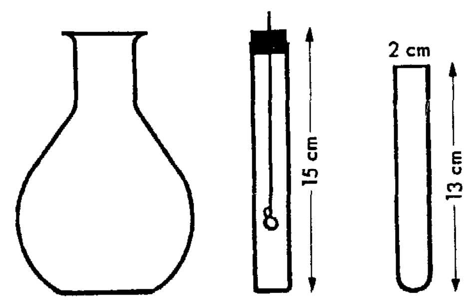
11 Filter pump

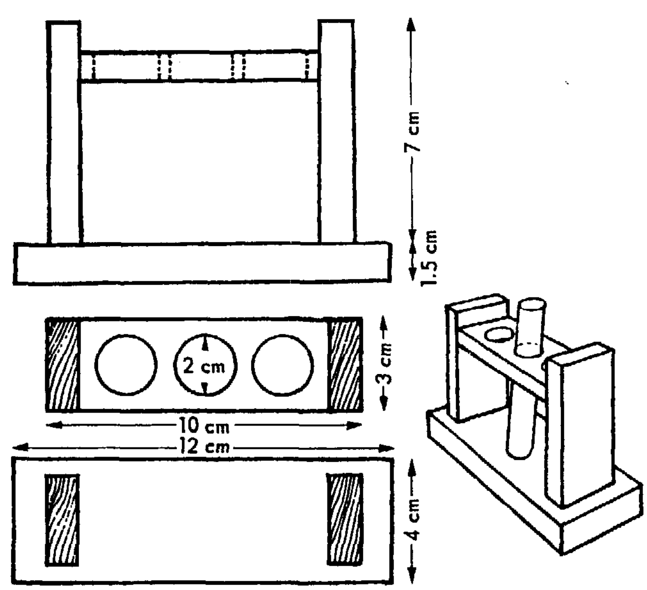


Some skill is required to construct the ordinary glass filter pump, but it is possible to contrive one from glass tubing and good corks. The action of the pump depends on the principle that a jet of water directed down a narrow tube carries air with it and reduces the pressure of the air in the vicinity (Y). The best sizes for the jets will be found by trial and error, but 1 mm diameter for the first jet and 2 mm for the second jet gives good results.

12 Apparatus for individual work in chemistry







Most of the experiments in elementary chemistry require some basic equipment such as beakers, test tubes, etc. The outfit described below will be found to include all that is usually required. The 150 cc Pyrex flask with a round neck can be used either as beaker, flask, or steam generator. An ordinary glass tube with a roll of wire gauze round it can be used as a combustion tube and does not break more often than the usual hard glass tube.

A specimen tube can be converted into a satisfactory small gas jar. Though not essential, a small test tube rack is convenient, and the small test tubes suggested have the advantage that they can be closed by the small fingers of children. A large tube with a wooden base is useful as a stock bottle for many other experiments. If running water is not available, a condenser is provided in the form of a large tin (500 cc) of water. The only difficult task is to make a water-tight joint for the outfall tube. This apparatus has been found very useful for junior class practical chemistry.

13 Containers from used electric bulbs

Used electric light bulbs can be made into containers that will substitute for flasks, beakers, test tubes and similar devices. With reasonable precautions these will stand considerable heat and handling. Any size electric bulb may be used. A variety of sizes will prove useful.

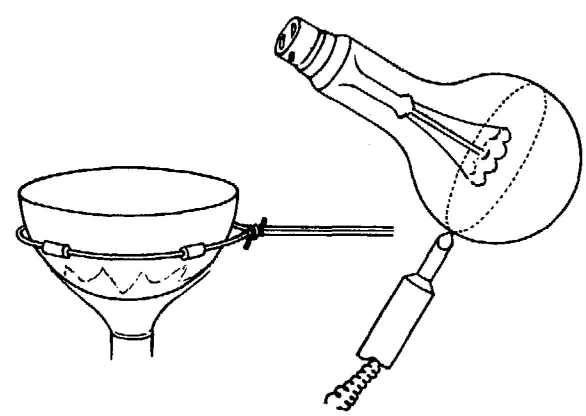
It is a wise precaution to wrap the bulb in an old towel or other piece of cloth while working with it. Begin by lifting the small metal button in the centre of the bulb top with a knife. Bend this up until it can be grasped with a pair of pliers. Raise this metal button by pulling upward on it with the pliers. This should expose the wire to which it is connected. Break the button away from the wire with a twisting motion. The hole in the centre of the black insulation should now be exposed. Carefully loosen and remove this insulation. It may be necessary to crack it into several pieces with the pliers. Be as careful as possible not to bend the brass shell. The next operation needs considerable care and you may break a few bulbs before developing enough skill. Hold the wrapped bulb firmly and use the top end of a file. With a quick motion puncture the bulb through the opening at the top. The glass rod which supports the bulb filament should drop into the bulb. Next use a round or rat-tail file to cut the jagged glass back at the neck. This can be done without cracking the bulb. The support rod and other material can be removed from inside the bulb which is now ready to use. If the brass shell which forms the top of the flask has been bent it can be re-shaped by inserting and rotating a piece of round wood of the proper diameter. The brass shell enables tight fits to be made with corks and rubber stoppers when needed in constructing a piece of apparatus.

14 Cutting a glass dish from a used electric bulb

The hemispherical bottom of an electric light bulb provides a useful glass dish; a soldering iron can be used to cut it off. Place the bulb on its side and make a scratch with a file somewhere along its line of greatest circumference. Support the soldering iron at an angle of 45° in a laboratory clamp so that the tip is the same height above the bench as the point of incision. Hold the bulb in both hands and, keeping it horizontal, bring the scratch into contact with the point of the soldering iron.

There will be a slight crack indicating the beginning of cleavage; the bulb, still held against the iron, should now be rotated on its axis to complete the cut. The sharp edge left by the cut can be removed by heating the rim in a gas flame.

In use these dishes are best supported on a wire ring with bearing points of asbestos fibre to prevent possible cracking along the wire. The remaining part of the bulb can be used to make a Voltameter.

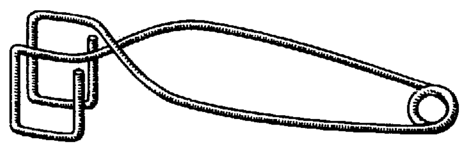


15 A measuring jar or graduate

Select several straight-sided glass jars of assorted sizes. Olive bottles are very useful for the making of graduated cylinders. Paste a strip of paper about 1 cm wide along the bottle to within about a centimetre of the top. Next secure a commercial graduated cylinder of about the same capacity as the bottle and measure out sufficient water to fill the bottle nearly to the top of the paper scale. Draw a line across the paper scale and mark under it the number of cubic centimetres of water poured in, say 50 cc or 100 cc. Next, if the bottle is of uniform diameter, divide the distance between the bottom of the bottle and the line into some convenient number of parts. Draw lines across the paper and label each division. For example, suppose that 50 cc of water were used: you might then divide the length of the bottle into five equal parts; the first line from the bottom would be marked 10 cc, then next 20 cc and so on. Each large scale division may next be sub-divided into smaller parts and lines placed across the paper scale. The graduated cylinder so constructed should be tested at several capacities by filling it to a certain level and then pouring the water into a commercial or standard vessel. Some of the lines may have to be moved slightly. When you have completed the test, you can make the scale permanent by covering it with a thin coat of melted paraffin, shellac, label varnish or plastic cement.

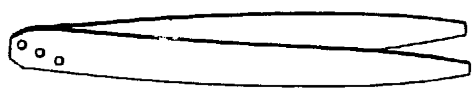
16 A test tube holder

A suitable test tube holder can be made by bending strong spring wire made of iron or brass into the shape shown in the diagram. Wire from a coat hanger works very well.

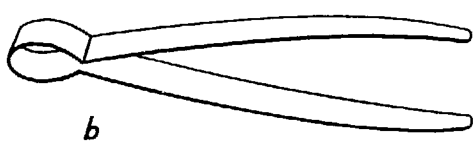


17 Laboratory tweezers

Very serviceable tweezers can be made from lengths of flexible strap iron used to put around boxes and crates for shipment.



a



b

The tweezers shown are about 12 cm in length. The pair shown in diagram *a* can be made by brazing or riveting two pieces of strap iron together and then bending and cutting to the proper shape. Those in diagram *b* were fashioned from a single 26 cm length of strap iron. The round head was made by pinning the centre of the strip around an iron rod of suitable diameter. The sides were then cut and shaped to size.

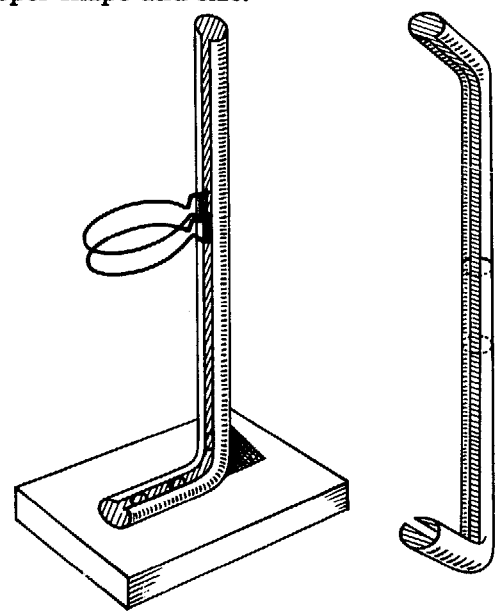
18 A metal ringstand and rings

A useful ringstand and rings can be made from a flat curtain rod and the fixtures which clamp over electric bulbs to hold lamp shades. These are usually obtainable in hardware stores. The curtain rod is shaped as shown in the diagram.

The curtain rod consists of two pieces fitted to slide together so that they are adjustable for curtains of different width.

Attach each part of such a curtain rod to a suitable wooden base either with nails or screws. A triangular brace secured against the rod and attached to the base will make the ringstand stronger. This is shown in the diagram. The lamp shade fixtures are squeezed together and the prongs fitted into the slot on the inside of the curtain rod. The spring pressure is sufficient to hold the fixture at any height, making a very useful ring for the ringstand.

Another type of ring may be made by bending wire from a coat hanger into the proper shape and size.

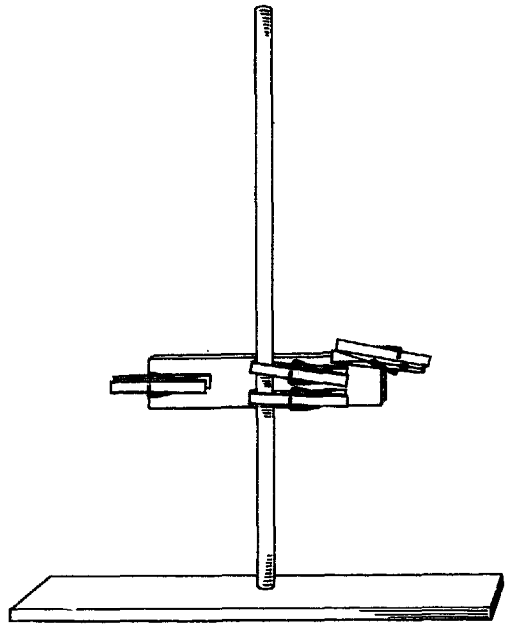


19 A wooden ringstand

The base for this ringstand is made from a piece of wood 40 cm long, 15 cm wide and 1 cm thick. A hole 1 cm in diameter is bored through the centre of the base. The upright is made from a piece of dowel rod 1 cm in diameter and 45 cm long. The dowel rod upright must fit very tightly in the hole made in the base. If dowel rod of this size is not available, another size may be used, but the hole in the base should be made accordingly.

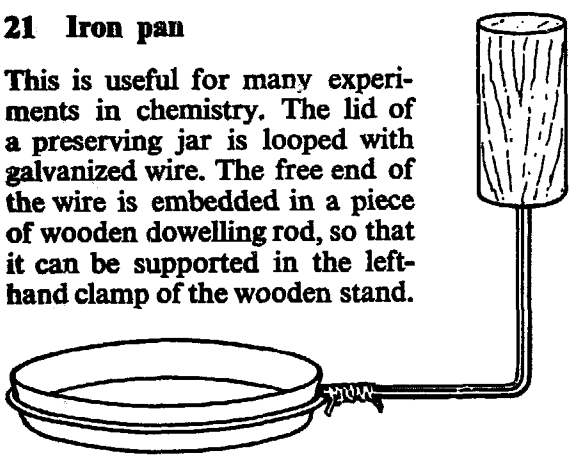
20 Equipment support bar for ringstand

A useful equipment support bar for the above ringstand can be made from a piece of wood 18 cm long, 4 cm wide and 1 cm thick, together with four clothes pegs of the spring pincer type. The clothes pegs are attached to the bar as shown in the diagram. The clothes pegs at either end support equipment such as test tubes, and the two placed parallel nearer the centre clamp to the upright of the ringstand. Observe that the clothes peg on the right-hand end of the bar is set at an angle, after a suitable place has been levelled, as shown in the diagram. This makes it possible to support the test tube at an angle so that it may be heated without setting the wooden clamp on fire.



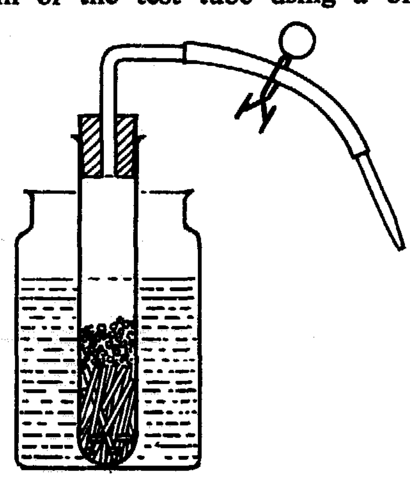
21 Iron pan

This is useful for many experiments in chemistry. The lid of a preserving jar is looped with galvanized wire. The free end of the wire is embedded in a piece of wooden dowelling rod, so that it can be supported in the left-hand clamp of the wooden stand.



22 Automatic gas generator

This is a semi-micro Kipps apparatus. The solid reagent (zinc, marble, iron sulphide, etc.) is placed in a large test tube with holes in it, and the acid is contained in a jar or other receptacle. A series of holes is made in the bottom of the test tube using a blowpipe and playing a fine jet, one shot at a time, until the glass is pierced. Glass beads, or short lengths of glass tube placed vertically, are put on the bottom of the test tube to serve as a platform for the solid reagent. A rubber stopper with a glass tube through it is then inserted in the test tube and connected by rubber tubing to a glass nozzle. The outlet is closed by a clip or by pinching the tube with the fingers.



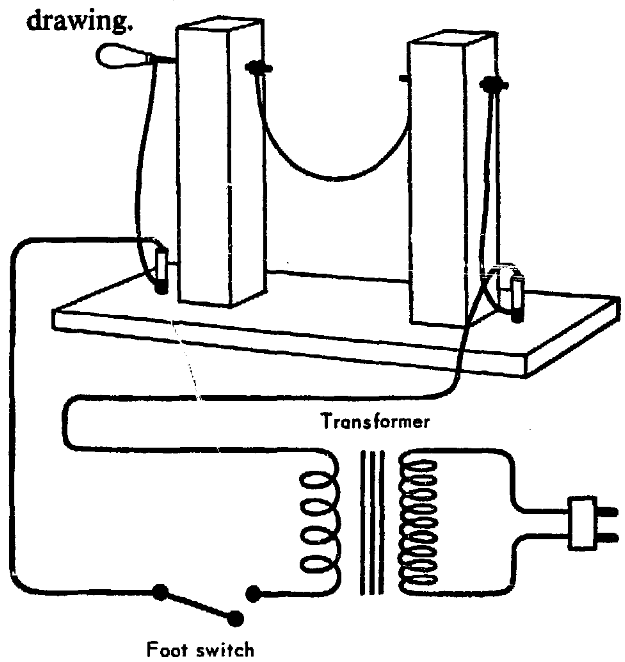
23 An electric device for cutting glass jars and bottles

A considerable number of pieces of useful equipment can be made from bottles, jugs, flasks, used electric bulbs and other things made of glass. It is often necessary to cut the top or bottom from such objects to adapt them to specific purposes. This piece of equipment will prove most useful for cutting such devices cleanly. After the cutting operation it is necessary to smooth sharp edges either with a file or by means of fire polishing.

Two wood uprights 20 × 7 × 4.5 cm are attached to a base of suitable size at a distance 15 cm apart.

Holes of suitable size to hold brass rods of 5 mm diameter are bored through the shorter dimension of each upright about 2 cm from the top. Through one upright a brass or iron bolt is put. Through the other a longer piece carrying a handle is placed. Notice that the drawing shows a set screw for the regulator.

A length of nichrome, or other wire of high electrical resistance suitable for the source of electricity (12 v, from a step-down transformer, 220-12 v, or 110-12 v) is attached to the ends of the rods by means of suitable nuts. The electrical circuit is shown in the drawing.



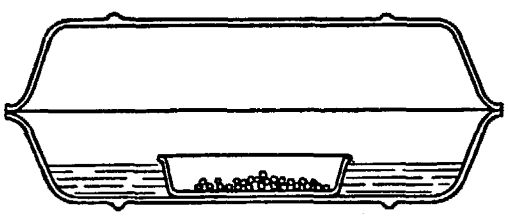
CHAPTER III

Experiments and materials for plant study

A. ROOTS

1 How to grow root hairs

Hairs can easily be seen on the roots of mustard seed grown on a damp flannel. Seeds placed on an earthenware dish standing in a soup plate containing water will produce very good specimens if covered by another plate to keep the air moist.

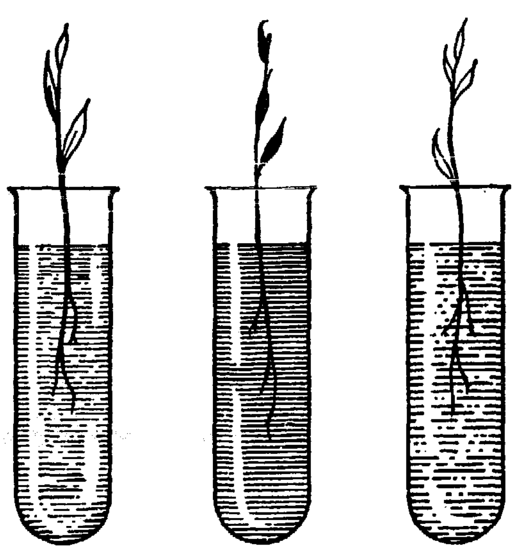


2 Observing root hairs

Study the root hairs with a hand lens and observe how they are constructed.

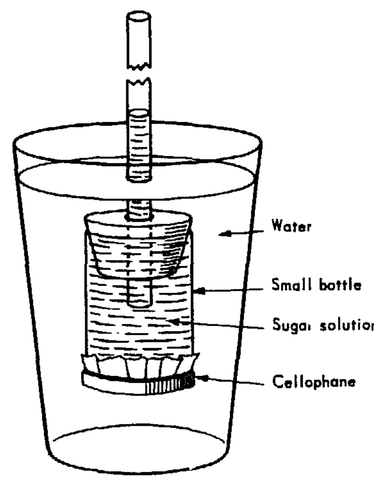
3 Testing whether roots absorb water and suspended solids

Three similar plants are inserted into test tubes containing 1, water; 2, red ink; 3, a suspension of congo red. After a few days 2 will be found to be coloured; 1 and 3 uncoloured, having absorbed only water.



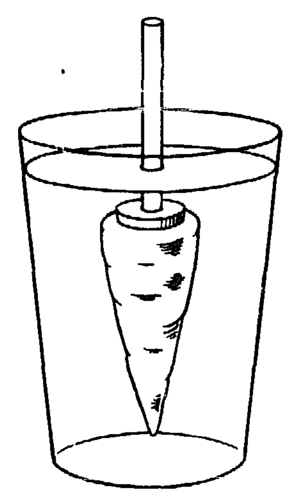
4 A simple osmometer

Remove the bottom from a small glass bottle about 2.5 cm in diameter. Fit a one-hole stopper tightly into the bottom and put a 50 cm length of glass tubing or a length of two soda straws through the hole.



Place a piece of cellophane or parchment paper over the other end of the bottle and fasten it securely by winding with several turns of string or strong thread. Fill the bottle with a very concentrated sugar solution and replace the one-hole stopper being sure that no air bubbles remain inside the bottle. Clamp the osmometer in a glass of water and allow to stand a few hours.

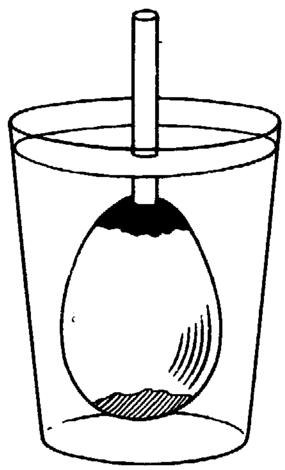
5 A carrot osmometer



Select a carrot which has a large top and which is free of breaks in its surface. With a sharp knife or an apple corer cut a hole in the top of the carrot about 2 or 2.5 cm in depth. Be careful not to split the top. Fill the cavity with a concentrated solution of sugar. Insert a tightly fitting one-hole cork or rubber stopper which carries two soda straws pushed together or a length of glass tubing. Place in a jar of water for a few hours. If your cut in the top of the carrot has not been even it may be necessary to seal the cork in with some wax dripped from a burning candle.

6 An egg osmometer

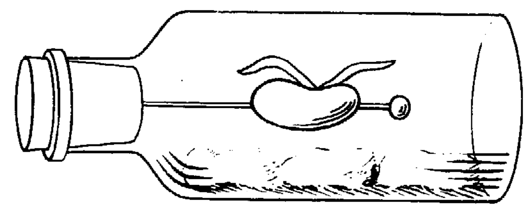
Place some dilute hydrochloric acid or strong vinegar in a shallow dish, such as a saucer, to a depth of about one centimetre. Hold the large end of an egg in the acid until the shell has been eaten away on the end leaving the thin membrane exposed. Rinse the acid from the egg. With a sharp instrument work a small hole through the shell at the other end. Insert a soda straw or a length of glass tubing through the hole into the interior of the egg. Seal the opening around the tube with household cement or sealing wax. This must be absolutely tight. Place the osmometer in a glass of water and let it stand for a few hours.



7 The effect of gravity on roots

Cut several pieces of blotting paper about 8 cm square. Place these between two squares of glass. Place several radish or mustard seeds between the blotting paper and glass on each side and secure with rubber bands. Wet the blotting paper and then stand the apparatus upright in a shallow saucer of water. When the seeds have sprouted and the rootlets are about 1.5 cm long, turn the squares through 90° and allow them to remain undisturbed. Repeat the turning and observe the effect on the roots.

Another way to study the effect of gravity on roots is to sprout some seeds and select one that is straight. Pierce the seed with a long pin or needle and stick this into a cork. Place some damp cotton or blotting paper in a bottle. Put the cork and seedling in the bottle. Place the bottle in a dark cupboard and look at it every hour or so.



8 How are roots affected by water?

Grow some seedlings in one end of a glass dish or pan. When they are about 5 cm tall begin watering them on one side only and a little distance away from the nearest plants. Continue the watering daily for about a week and then dig away the soil and see if the watering has had any influence on the direction of growth of the roots.

9 Growing roots from different parts of plants

Secure a box of sand and place it away from direct sunlight. Wet the sand thoroughly and keep it moist. Plant the following things in the sand:

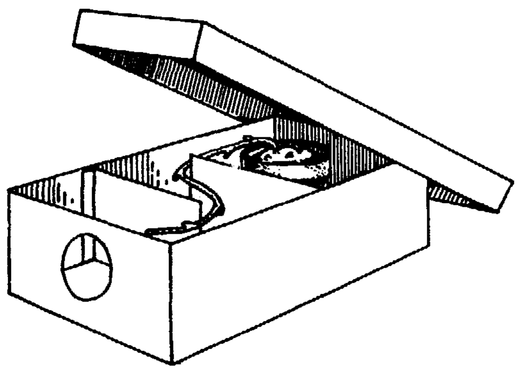
(a) Various bulbs.
(b) Cuttings of begonia and geranium stems.
(c) A section of sugar cane stem with a joint buried in the sand.
(d) A section of bamboo stem with a joint buried in the sand.
(e) Carrot, radish and beet tops each with a small piece of root attached.
(f) An onion.
(g) An iris stem.
(h) Pieces of potato containing eyes.
(i) A branch of willow.

B. STEMS

1 The effect of light on the growth of stems

(a) Plant some seeds that grow rapidly such as oats, radish, bean or mustard seeds in two flower pots. When the seedlings are about 2.5 cm high, cover one pot with a box that has a hole cut near the top. From time to time lift the box and observe the direction of growth. Turn the box so that light comes from a different direction and observe again after a few days.

(b) Put two light baffles in a long, narrow box as shown in the diagram, and cut a hole in the end. Plant a sprouting potato in a small pot that will fit in the box. Place the pot behind the farthest baffle from the hole. Cover the box and place in a window. Observe the direction of growth from time to time.



(c) Plant four flower pots with some fast-growing seeds as in (a) above. Keep the pots in a darkened room until the seedlings are about 2.5 cm high. Place one pot in a sunny window and observe the effect. Turn the plants away from the light and observe. Leave the pot in a place away from direct light for a few days and observe the results.

(d) Place each of the three remaining pots of seedlings in a different box. Cut a window in each box and cover each window with a different colour of cellophane such as red, yellow and blue. Place the three boxes containing the pots of seedlings in good light with the window facing the light. Observe any difference in the effect produced by different coloured light on the growth of stems.

2 Stems transport liquids

(a) Cut about 2 cm from the end of stems of celery and place them in cold water for about an hour to freshen. Next place the stems in dishes containing red ink and let them stand for several hours. Observe the stalks carefully. Cut them up into several short lengths and observe where the ink has moved upward in the stem. Try to pull some of the tubes out of the celery stems.

(b) Cut about 2 cm from the end of the flower stalks of white carnations. The cutting should be done with a sharp knife and under water. Place the stems with flowers in glasses containing different shades of food colouring or coloured ink. Observe after several hours.

(c) Split the stalk of a white carnation into three parts with a razor blade. Extend the split 8 or 10 cm up the stem and then wrap with tape to prevent further splitting. Spread the three sections out and place each in a vessel containing a different colour of ink or food dye. Observe the flower after a few hours.

(d) Put the cut ends of twigs or shoots of several kinds of trees in coloured ink and later cut them into short sections with a sharp knife. Observe the places where the colour has gone up in the stem.

(e) Plant seeds of common garden plants in flower pots. When the seedlings are 8 to 10 cm high and growing vigorously, cut the upper part of the stem off with a sharp knife. Soon drops of water will be seen where the cut was made.

3 Different types of stems

(a) *Monocots.* Secure stems of several plants such as bamboo, sugar cane and corn. Cut each of the stems crosswise with a very sharp knife or razor blade. Observe the similarities in the cut cross sections. Especially notice that the tubes or fibrovascular bundles are scattered throughout the pith on the inside of the stem.

(b) *Dicots.* Secure the stems of several plants or small trees such as willow, geranium, tomato, etc. Cut across each of these stems with a sharp knife or razor blade. Observe that just under the outside layer of the stem there is a bright green layer. This is the cambium layer. Also observe that the tubes or fibrovascular bundles are arranged in a ring about the central, or woody portion of the stem.

C. LEAVES

1 Types of leaves

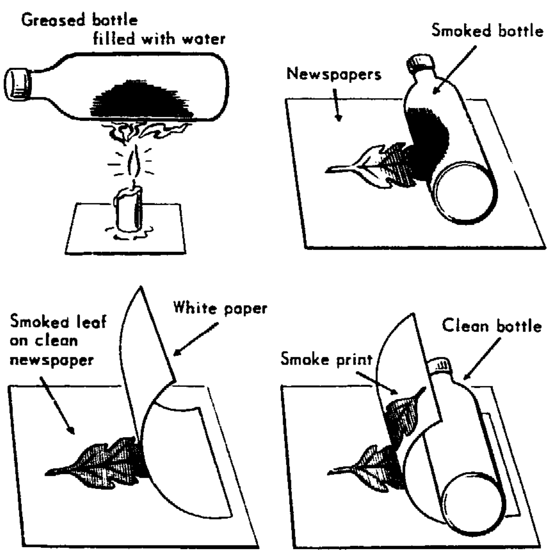
Collect leaves from such plants as lilies, bamboo, sugar cane, corn, willow and geraniums. Observe that the monocots (lily, bamboo, corn, sugar cane) have the veins running parallel. Observe that leaves from dicotyledrous plants (willow, geranium, etc.) have branching venation.

2 Making leaf collections

Collect young leaves of as many varieties of plants as possible. Place several layers of newspaper or blotting paper on a firm, smooth board. Next arrange the leaves so they do not touch. Cover the leaves with other layers of newspaper or blotting paper. Place another board on top and then place several heavy stones or weights on the board. Keep the leaves in the press until they are thoroughly dried. When the leaves are removed from the press they may be neatly arranged on note book pages and secured either with Scotch tape or small sections of gummed labels. The name of the leaf and any other interesting material can be recorded on the note book page.

3 Making smoke prints of leaves

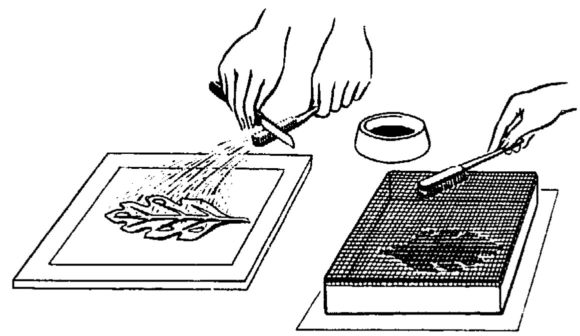
Smoke prints of leaves may be easily made by following the four steps shown in the diagrams.



Cover the side of a smooth, round bottle with a thin layer of grease or vaseline. Fill the bottle with cold water and cork it tightly. Hold the bottle over a candle flame until it is covered evenly with soot. Place a leaf, vein side up, on a layer of newspaper and roll the sooty bottle over the leaf. Remove the leaf and lay it vein side up on clean newspaper. Cover the leaf with a sheet of white paper. Next, roll over the white paper and leaf with a clean round bottle or other roller.

4 Making spatter prints of leaves

Place the leaf on a sheet of white paper and flatten it with pins, thumb tacks, or a few small pebbles. Dip an old tooth brush in poster colour or Indian ink. Hold the brush over the paper and spatter the material from the tooth brush evenly around the leaf by carefully drawing the blade of a knife over the bristles. Do not use too much colour or ink. When the colour has dried remove the leaf.



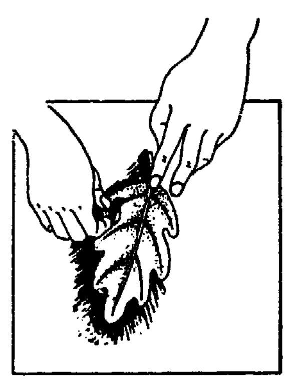
A leaf print spatter box can be made as shown above (right). A piece of window screening is placed over a shallow box or frame. The spatter is made by dipping a toothbrush in the colour and rubbing it over the leaf and paper which are secured to the bottom of the box. Try using white colour on various coloured papers.

5 Ink prints of leaves

Place a small quantity of printer's ink on a sheet of glass or a tile. Roll the ink into a thin even layer with a rubber roller. Place a leaf, vein side up, on several layers of newspaper and run the inked roller over it once. Carefully lift the leaf and place it, inked side down, on a sheet of white paper. After covering with a sheet of newspaper roll with a smooth, round bottle. Again remove the leaf carefully and the print is finished.

6 Leaf silhouettes

Place a leaf on a sheet of white paper and hold it securely with thumb or finger. Press a piece



of natural or artificial sponge against an ink pad. With short, firm strokes, rub outward around the entire edge of the leaf as shown in the diagram.

7 Carbon paper leaf prints

Cover the vein side of a leaf with a very thin layer of lard or vaseline. Place the greased leaf vein side up on several layers of newspaper and cover with a sheet of carbon paper. Cover the carbon paper with another sheet of paper and rub across it several times with the side of a smooth pencil, to coat the leaf with material from the carbon paper. To make the final print place the leaf between two sheets of white paper and again rub with the pencil.

8 Studying leaf arrangements

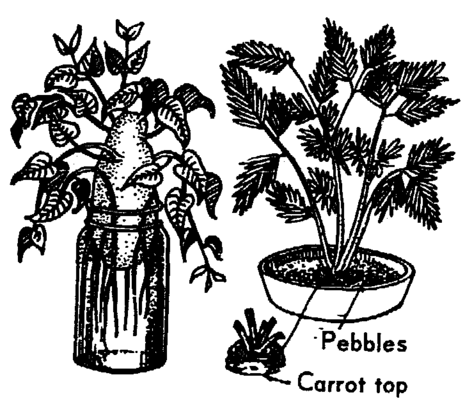
Observe as many growing plants as possible by looking down on them from above. Draw sketches of the different patterns of leaf arrangement.

9 Growing leaves in the classroom

A sweet potato will produce dense foliage in the classroom if it is placed in water. Set the potato, root end down, in a glass or jar and keep the lower third covered with water. The potato may be kept in position by pressing three toothpicks or matches into its side and resting them on the rim of the jar.

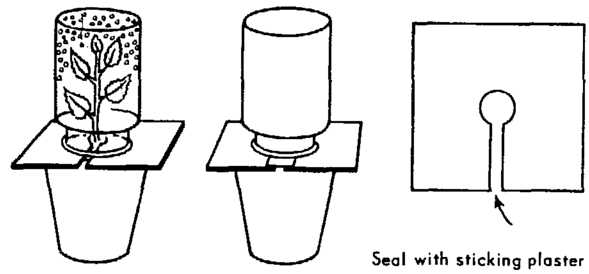
The roots of carrots, beets and turnips contain much stored food. They will produce foliage if grown in water but will not develop into new plants. Remove the old leaves from the top and then cut off all the root except 5 to 8 cm. Place this portion in a shallow dish of water. A few pebbles placed in the dish will hold it upright.

Cut off a pineapple 3 to 5 cm below the base of the leaves, and set this portion in a shallow dish of water. The leaves will continue to grow for several weeks.



10 Leaves give off water vapour

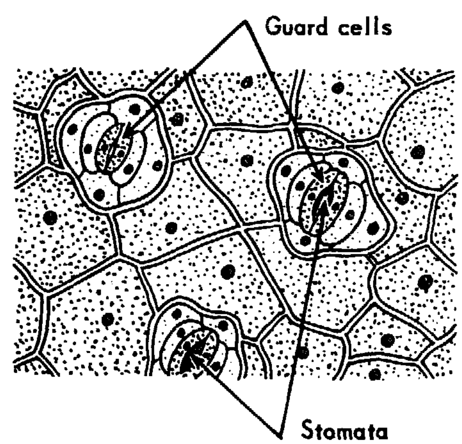
Use two similar pots of soil, one with a small plant and the other without. Cover the soil in each pot with cardboard as shown in the diagram after watering. Invert glass jars over each pot as shown. Place the pots side by side in the sun and examine from time to time during the day.



11 The structure of leaves

Borrow a microscope from another school, a doctor, or a hospital. Examine the underside of leaves and locate the breathing pores or stomata with the two little guard cells on either side.

Cut a very thin cross section of a leaf with a razor blade and look at the edge through the microscope. Locate the palisade layer, the epidermis and the spongy layer. You may be able to see a vein and a stomata opening into the spongy layer.

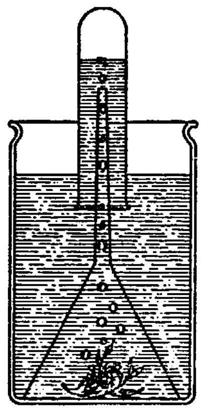


12 Green leaves make food for plants

Heat some alcohol in a jar over boiling water until it boils. Break several green leaves from a geranium or other plant which has been in the sun for several hours, and place them in the boiling alcohol until the chlorophyll has been removed. Quickly remove the leaves from the alcohol and put them in a basin of hot water. Remove a leaf from the water and spread it out on a piece of glass or tile. Cover the leaf with tincture of iodine and leave for several minutes. The deep blue colour is the test for starch which has been made by the leaf in the sunlight.

13 Green leaves give off oxygen in sunlight

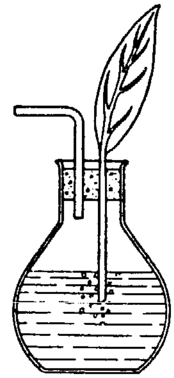
Place some water weed under a funnel in a beaker of water. Invert a test tube full of water over the tube of the funnel.



Leave the apparatus in strong sunlight. Bubbles of gas will be liberated from the weed and rise to the top of the test tube. In a short time the tube can be removed and the gas tested with a glowing splint.

14 Air can enter a plant through the leaf

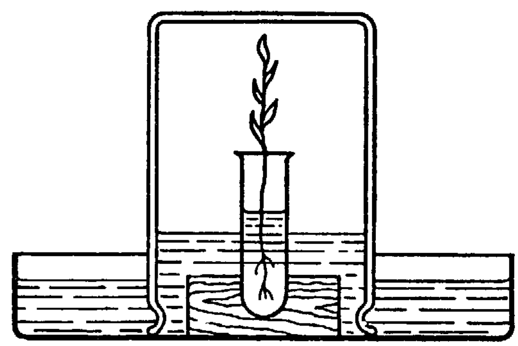
Procure a leaf with a long stalk to it and seal it into a hole through a cork. Fit this with a side tube, and seal the cork into a flask containing water. Suck air from the side tube. Air bubbles will be seen to issue from the end of the stalk.



15 To show the respiration of a plant

Place the plant in a test tube held in a weighted wooden block. Put this in a bowl containing lime water and cover the plant with a jar. Keep the plant in a dark place for several hours, or examine next day.

The lime water will be milky showing that CO_2 was given off, and the rise in the level shows that a considerable amount of oxygen was taken in.



D. FLOWERS

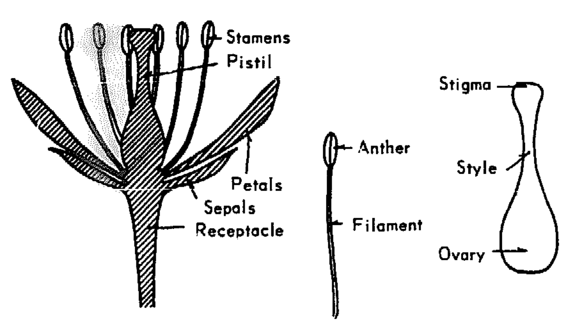
1 Collecting and preserving flowers

Use the same method as described for leaves on page 43.

2 Studying the main parts of a flower

Examine specimens of large simple flowers such as tulips or lilies. Count the stamens and observe how they are arranged about the central pistil. Make large diagrams of the essential organs. Label the parts of the pistil (stigma, style and ovary). Label the parts of the stamen (filament and anther).

The end of the stalk on which the flower grows is called the receptacle. At the base of the receptacle there are usually leaf-like structures that enclose the bud. These are called sepals. Above the sepals there is usually a ring of brightly coloured petals called the corolla.



3 Dissecting simple flowers

Label each of five cards or pieces of paper with one of the following words: stamens, pistil, petals, sepals, receptacle. Dissect a flower carefully and place the parts neatly on the appropriate cards.

Some flowers can be pulled apart quite easily but a knife or scissors may be needed for others. If a sufficient number of flowers are available this exercise is most valuable as an individual pupil activity. Simple flowers with a single row of petals should be selected.

Pick up one of the stamens and rub the anther lightly across a piece of black paper. Traces of pollen will usually be seen.

Cut the ovary crosswise with a sharp knife and count the ovules or 'seed pockets'. Look for traces of seeds in the ovules.

4 Observing pollen grains from different flowers

Secure several flowers in which the pollen has formed on the stamens. Shake pollen from each flower on different pieces of black or dark paper. Observe each type of pollen with a magnifying glass and note any differences.

5 Germinating pollen grains

Make a strong sugar solution and place it in a shallow dish like a saucer. Shake pollen from several kinds of flowers onto the surface of the sugar solution. Cover with a sheet of glass and let it stand in a warm place for several hours. If the experiment is successful you will be able to see little tubes growing from the pollen grains. Use a hand lens.

6 Making a model of a simple flower

Using modelling clay, coloured paper and toothpicks make three-dimensional models representing the parts of a typical flower. This exercise is most valuable as an individual pupil activity and should fix firmly in mind the parts of a flower.

To make the flower-stalk roll a piece of modelling clay into the form of a cylinder 2 cm in diameter and about 5 cm long. Press one end firmly against a desk or table and push half a toothpick into the centre of the opposite end as shown in the diagram at *a*.

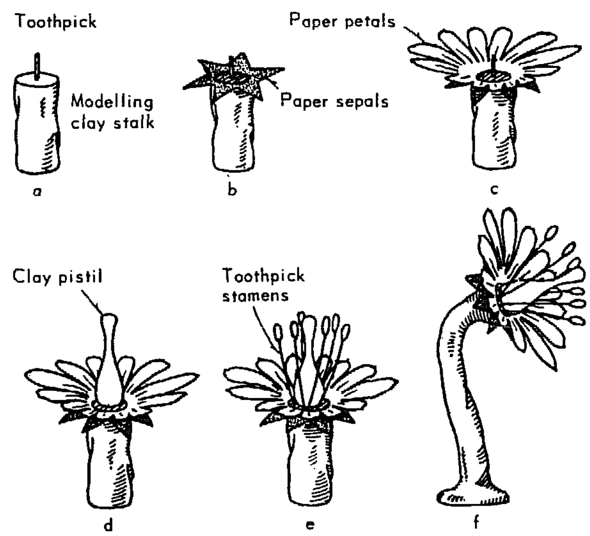
To make the sepals, cut a six-pointed star from green paper. Cut a hole in the centre at least 1 cm in diameter. Place the sepals in position on the stalk as shown at *b*.

From brightly-coloured paper, cut a corolla of petals. Cut a hole in the centre and set the corolla directly over the sepals as shown at *c*.

From modelling clay shape a pistil in the form of a small urn. Press this over the projecting toothpick to hold it in place, as shown at *d*.

Next, make stamens by putting bits of modelling clay on the ends of toothpicks. Push the toothpicks into the exposed circle of clay at the base of the pistil as shown at *e*.

When the flower model is finished, it can be made to look more realistic by stretching out the stalk with the fingers and bending over the flower head slightly.



7 A field trip to observe flowers

Plan a field trip to observe flowers in bloom. If no interesting wildflowers can be found growing near the school, the trip can be planned to a private garden or park. Collect some flowers.

8 Observing the development of flowers into fruit

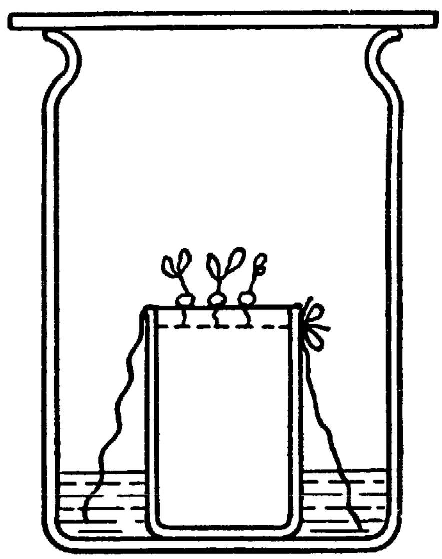
Collect specimens of flowers in different stages of maturity from newly opened buds to specimens in which the petals have fallen. Cut each ovary open and note the changes that take place during seed development.

Look over a quart of freshly picked peas or string beans and pick out the pods that are not completely filled. Open these and compare them with fully filled specimens. The abortive seeds are the remains of ovules that were not fertilized by pollen.

E. SEEDS

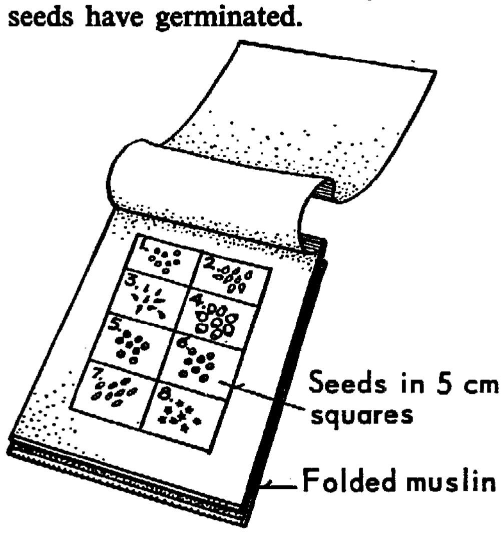
1 A useful way to grow seeds

Tie a piece of cloth over the mouth of an old potted meat jar. Allow extra cloth to hang down the sides and dip in about 2 cm of water contained in a jam jar. A sheet of glass placed over the top of the jar will keep the air moist. The seeds are placed on the cloth.



2 A 'rag doll' seed tester

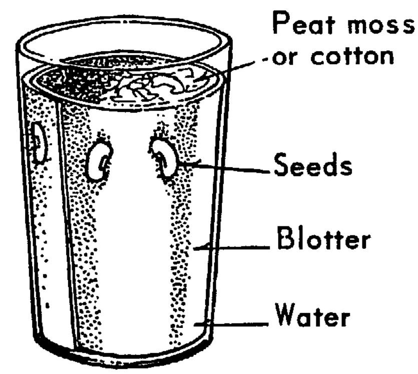
Fold a square metre of muslin twice in the same direction. Near one end mark out eight or ten squares about 5 cm by 5 cm with a pencil. Number the squares and place ten seeds from each packet on each square. Fold the opposite end of the muslin over the seeds. Roll up the tester and tie it loosely with string. Saturate the tester with water. Keep it moist and in a warm place for several days. Then unroll it and see how many of each kind of seeds have germinated.



3 A tumbler garden

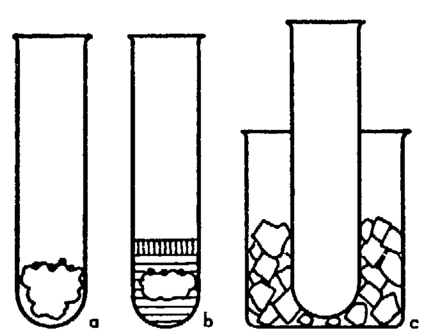
Grow various kinds of seeds in 'tumbler gardens'. Each pupil might grow a tumbler garden of his own and keep a day by day pictorial record of the development of the seedlings.

To make a tumbler garden cut a rectangular piece of blotter and slip it inside a drinking glass. Fill the centre of the glass with peat moss, cotton, excelsior, sawdust or some similar material. Push a few seeds between the outside of the glass and the blotter. Keep a little water in the bottom of the glass.



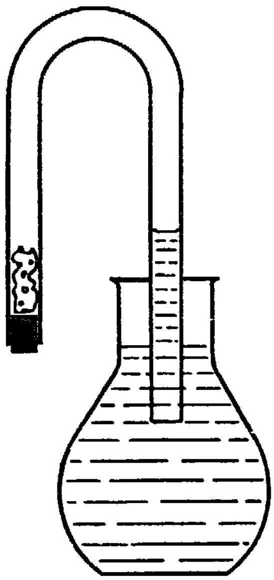
4 To study the conditions essential for the germination of seeds

In the diagram below *a* contains seeds on cotton wool with air, warmth, but no water; *b* has water, warmth, but no air, because a layer of boiled oil has been poured on top of the water; *c* has moistened cotton wool and air but is kept cool by having the test tube immersed in a freezing mixture.



5 To show that growing seeds take in oxygen

Cork up one end of a tube, having first placed inside some damp cotton wool and some mustard seeds. Immerse the open end in dilute caustic soda solution and leave for a few days. The solution will rise up the limb. Removing the cork, and testing with a glowing splint that shows little or no oxygen remains.

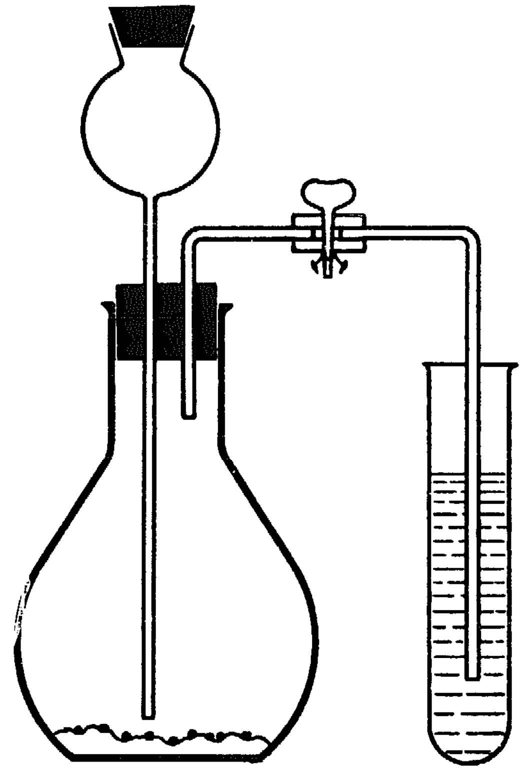


6 To study the structure of a seed

Soak seeds of bean, pea, pumpkin, sunflower, corn and other large forms. Remove the seedcoats and carefully cut the seeds open. Discover the parts that make up the seed. There is little point in teaching the botanical names of these parts though pupils may enjoy learning them. It is of more importance that pupils learn to recognize the part of a seed that is the young plant and the part that is stored food.

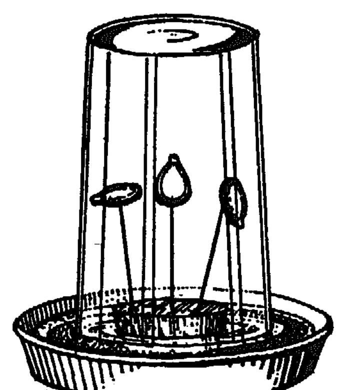
7 To test the gas given off when seeds germinate

Place some mustard seeds in a flask with some damp cotton wool, in the apparatus shown in the diagram, and allow them to germinate for a few days. Remove the cork carefully and pour water down the thistle funnel. Open the clip, and allow the displaced air to bubble through lime water. This becomes cloudy, showing the presence of carbon dioxide.



8 To show the direction of sprout growth in seeds

Soak pumpkin or other large seeds overnight and fasten three of them on needles as shown in the diagram. Fasten one with the tip pointing upward, one with the tip toward the side and the third with the tip pointing downward. Keep them in moist air and note the directions in which the sprouts grow.

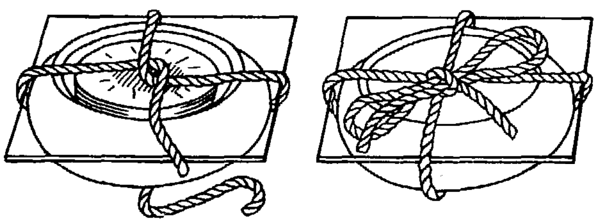


F. BACTERIA

1 Getting ready to grow bacteria

Secure two or three dozen shallow glass dishes. The glass coasters used to keep bed castors from marring floors will do. Cut 5 cm squares of window glass to make covers for the coaster dishes. These will serve very well for bacteria gardens. For beginning experiments slices of potato, carrot, or sweet potato will serve as soil upon which to grow the bacteria. Cut slices of these foods about 6 or 8 mm thick and large enough to fit easily into the dish.

In preparing gardens for bacteria care must be taken to keep everything clean. Wash the food slices thoroughly, wash and dry the dishes and their covers. Place dishes and covers on clean white paper. Be sure your hands are very clean. When all is ready lift the food slices into the dishes with toothpicks or wood splints. Tie the covers on as shown in the diagram. Place the dishes in a large pan and then bake them in an oven at about 110° to 120° C. for an hour. This should kill the bacteria inside the gardens.



2 Planting bacteria gardens

When the bacteria gardens have cooled place them out on the table but do not raise the glass covers until you are ready to plant them. Toothpicks or small wood splints make good garden tools for planting bacteria gardens. Place 30 or 40 toothpicks in a covered can and bake them in an oven for an hour. This will kill most of the bacteria. When you remove one from the can use tweezers and only touch one toothpick.

Secure bacteria from as many sources as possible. The following will be suggested: (a) a piece of decaying or rotten fruit; (b) a decayed tooth; (c) dirty money; (d) dirt from under finger nails.

Touch the toothpick to the source of bacteria and then quickly raise the cover of a sterile garden. Rub the end of the toothpick over the potato slice and then replace the cover. Be sure to raise the cover as little as possible when planting the garden to keep out bacteria and moulds that are in the air. Tie the covers on tightly again and set the dishes away in a dark, warm place for a few days. When they are examined the bacteria will show as spots on the potato slice. Each spot is a colony of thousands of bacteria.

3 Another type of soil for bacteria gardens

Boil some rice or potatoes in a dish until well cooked. Drain and save the water. Use the water to prepare some gelatin, or agar. Add a pinch of salt and a little beef broth or a bouillon cube to the gelatin. Use the same type of dish and cover as was used above. Pour sufficient of the hot gelatin mixture into each dish to cover the bottom to a depth of 3 or 4 mm. Quickly replace the covers and let the dishes stand until the gelatin has hardened. Tie the covers on and sterilize in an oven. Allow the dishes to cool and the gelatin to reharden before removing from the oven. These bacteria gardens are planted and grown in the same way as the ones described above.

4 Making a transfer needle

A transfer needle which can be sterilized by heating in a flame is useful in working with bacteria. Secure a piece of soft wood about the size of a pencil for a handle. Push the sharp end of the needle well into the wood and use the eye end for contact with bacteria sources.

5 To study whether bacteria grow best where it is moist or dry

Use two sterile dishes. Inoculate each one by touching a sterile transfer needle to a bacteria colony growing in another dish. Smear the material on the needle across the gelatin in each of the two dishes. Quickly replace the covers. Label one dish dry and the other moist. Dry the first dish by placing it on a radiator but covered with a box. Place the one marked 'moist' in a dark warm place but where it will not dry out. Examine the two dishes for several days.

6 To study if bacteria grow better where it is warm or cold

Again inoculate two sterile dishes. Label one 'warm' and the other 'cold'. Place the first dish in a dark warm place and the second in a dark cool place. Examine the dishes each day for several days.

7 To study if bacteria grow better where it is dark or light

Inoculate two sterile dishes as before. Label one 'dark' and the other 'light'. Place the first dish in a dark warm place and the second in bright sunlight or where an electric bulb can shine on it all the time. Examine the dishes daily for a period of several days.

8 Where may bacteria be found?

Expose sterile bacteria dishes to as many of the following conditions as you can. Label the dishes and set them away in a warm, dark place for a few days after which they should be examined.

1 Clean hands and dirty hands.
2 A dish cloth.
3 A garbage can.
4 Coughing.
5 Sneezing.
6 The bottom of your shoes.
7 A clean dinner plate.
8 A fly.
9 A cockroach.
10 Fur from a dog.
11 The air of the school room.
12 Souring milk.
13 A pencil point.
14 The air in a dirty street.
15 Stagnant water.
16 A rug or carpet.

9 Does sunlight kill bacteria?

Inoculate two sterile bacteria dishes from a dish where bacteria are growing. Place one dish in the open sunlight and the other in a warm dark place. After one dish has been in the sunlight for several hours place it in the dark warm place with the other dish. Examine the dishes each day for several days.

10 Do disinfectants kill bacteria?

Secure several types of commercial and household disinfectants. Inoculate as many culture dishes as you have samples of disinfectant and one dish in addition for a control. Rinse the soil in each inoculated dish with a different disinfectant. Pour off the excess. Label each dish. Replace the covers and set all the dishes including the control dish in a warm dark place and examine after a few days.

11 Observing where soil bacteria live

Dig up a clover, alfalfa or soy-bean plant. Carefully rinse all the soil from the roots and see if you can find the little white nodules on the roots. These are where the nitrogen fixing bacteria so important to soil fertility are found.

G. MOULDS

1 To secure different types of mould

(a) Secure an orange which has green mould on it and keep in a jar in a dark warm place.

(b) Place a piece of moist bread in a jar and expose it to the air. Leave for a few days in a dark warm place.

(c) Secure a piece of blue or Roquefort cheese in which there is mould. Place in a jar and keep in a dark warm place.

(d) Place a few dead flies in some stagnant water. In a few days they will become surrounded with a whitish growth of mould.

2 How to culture mould plants

Use either sterile dishes with potato slices or gelatin as those prepared for the experiments on bacteria. Transfer mould from each of the sources in Experiment 1 above to a sterile culture dish. Set the four dishes aside in a dark warm place. In a few days you should have pure cultures of each of the four types of moulds you have grown.

3 The structure of moulds

When the four pure cultures of mould have reached a vigorous state of growth examine each one with a hand lens. See if you can see the strands which make some moulds appear like spider webs. See if you can find little stalks with tiny black knobs on them. These are the spore cases. Thousands of spores are produced in each spore case which bursts when ripe. A new mould plant can develop from every spore if the conditions are right.

4 Do moulds need water for growth?

Place a spoonful of dry cereal such as rice or oatmeal in a sterile culture dish. Place a like amount of the same cereal cooked in another culture dish. Using a sterile transfer needle inoculate each sample with mould from a growing culture. Cover the dishes and label them. Set the dishes aside in a dark, warm place and observe each one after a few days.

5 Do moulds grow better where it is warm or cold?

Repeat Experiment 4. This time put one culture dish in a warm dark place and the other in a cold dark place. Examine the dishes after a few days.

6 Do moulds grow better where it is dark or light?

Repeat Experiment 4 above. This time leave one culture dish in a warm place where it receives light all the time. Place the other dish in a warm dark place. Examine the dishes after a few days.

H. YEAST

1 To show the effects of yeast on dough

Mix together some sugar, water and flour in the proportions to make a good bread dough. Divide the dough into two equal parts. Stir a half yeast cake in some water and mix this with one of the samples of dough. Put each sample of dough in a dish which has a label and set aside in a warm place. Observe after a few hours.

2 To test the effects of temperature on the activity of yeast

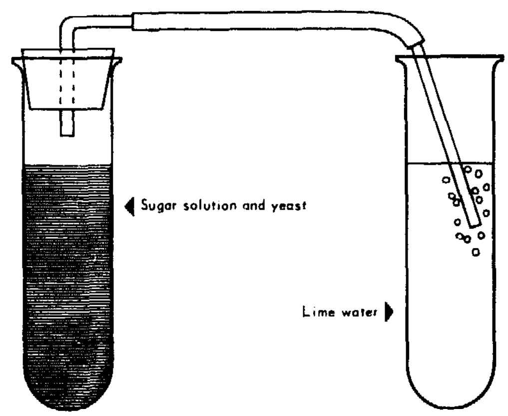
Make up a quantity of bread dough as in Experiment 1 above. Stir a yeast cake in water and thoroughly mix the yeast with the dough. Separate the dough into three equal parts and put in pans or jars. Label samples 1, 2, and 3. Place sample 1 in a refrigerator, sample 2 in a warm place, and sample 3 in a hot place. After a few hours examine each sample.

3 To show that yeast acts on sugar

Make a sugar solution in a jar either with brown or white sugar, molasses or honey. Thoroughly crumble a quarter of a yeast cake into a test tube of the sugar solution. Crumble another quarter yeast cake into a test tube containing the same amount of ordinary tap water. Keep both tubes warm. Observe the tubes from time to time and note any differences in them.

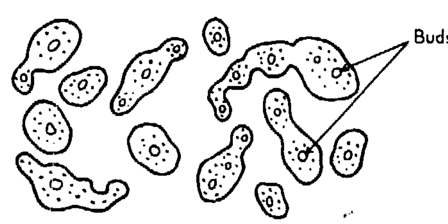
4 To study the gas produced when yeast acts on sugar

Place some clear lime water in a test tube and have a pupil exhale through a soda straw placed in the lime-water. Soon the lime-water will become milky which is a test for carbon dioxide gas. Next place some yeast in a solution of sugar water in a test tube. Fit a one-hole stopper to the tube and put a glass tube through the hole. Connect a rubber tube and another glass tube about 15 cm long to the stopper. Place the long glass tube in a solution of clear lime water. Let the tubes stand in a warm place for a while. Observe the lime water.



5 To observe yeast plants

Borrow a microscope from a college, a high school, a doctor or a hospital. Place a few drops of the sugar solution which contains yeast on a glass slide and observe it under the microscope. You will see many little oval-shaped cells each of which is a yeast plant. Perhaps you can see some that are carrying buds on them. This is the way that yeast plants reproduce.



I. GROWING PLANTS WITHOUT SOIL

Some children may be interested in growing plants indoors without soil. This can be done but requires special materials and chemicals. A kit for such experiments has been made up and may be secured from Science Service, 1719 N Street, N.W. Washington D.C., U.S.A. for about $5.

J. SIMPLE GARDENING

Many children are interested in making home or school gardens. Each child should be encouraged to select and clear a small garden plot. After the ground has been spaded and prepared it should be marked off in rows. Such small vegetables as lettuce and radishes may be planted in alternate rows. Each pupil should draw a plan of his garden and mark on it where he has planted various things.

Plants may be started either at home or at school for later transplanting. For this wooden boxes about 10 cm deep will be needed. The boxes are filled to a depth of about 8 cm with good soil. Such seeds as tomato, cabbage, cauliflower and sweet peppers may be started indoors. By the time the lettuce and radish plants have matured, the plants grown indoors will be ready for transplanting into the outdoor garden.

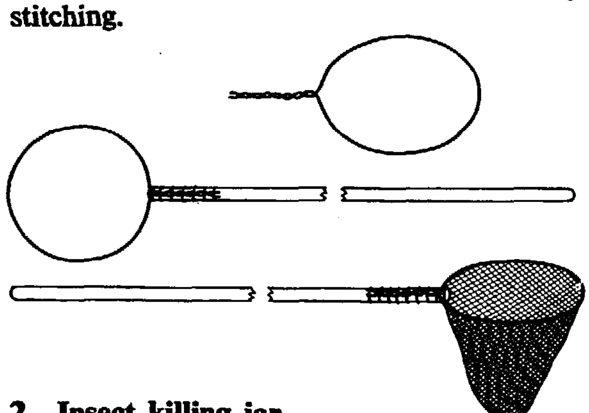
Gardening activities will lead to many worth-while lessons on the growth and care of plants. Later in the year an exhibit of vegetables grown may be planned.

CHAPTER IV

Methods and materials for animal study

1 An insect collecting net

A useful insect net can be made from a round stick such as a broom or mop handle, some heavy wire and mosquito netting or cheese cloth. Bend a heavy piece of wire into a circle about 38 to 45 cm in diameter and twist the ends together to form a straight section at least 15 cm in length. Fasten this to the end of a broom or mop handle by lashing with a wire wrap or by means of staples. Cut a piece of mosquito netting or cheese cloth to form a net about 75 cm deep. Fasten this to the circular wire frame by stitching.

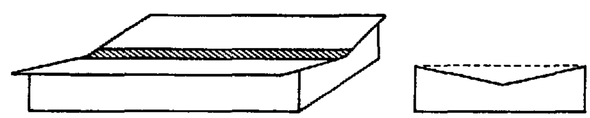


2 Insect killing jar

Secure a wide-mouth glass jar with a screw top or one which closes very tightly. Place a wad of cotton in the bottom and cover it with a round piece of cardboard or blotting paper which has several holes punched through it. When the jar is used saturate the cotton with carbon tetra-chloride (Carbona) or some available insecticide containing DDT. Place the piece of cardboard over the cotton and then put the insect in the jar. Close the jar tightly and leave until the insect has been killed. If moths or butterflies are being prepared be certain that the jar opening is large enough to prevent the tearing of the wings.

3 A stretching board for insects

A stretching board is essential when insects are being prepared for mounting. One can readily be made from a cigar box. Remove the cover from the cigar box and split it lengthwise into two equal parts. Attach these to the box again leaving a space about 1 cm wide between them. The body of the insect is placed in the slot and the wings are secured on the top by means of strips of paper held by pins into the soft wood but not through the wings. Sometimes a slight angle is desirable to the top pieces. This can be achieved by cutting the ends of the cigar box to a slight V form before attaching the sections cut from the cover. This is shown in diagram *b* below.



4 Mounting boxes for insect collections

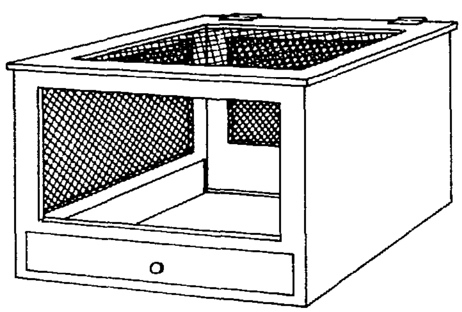
Wood or cardboard cigar boxes make very useful and convenient housings for insect collections. After the insect has been removed from the stretching board a pin is placed through the body and is then stuck into the bottom of the box to hold the insect. The pins are arranged in an orderly fashion and may carry, near the top end of the pin, a small card upon which data about the insect are entered.

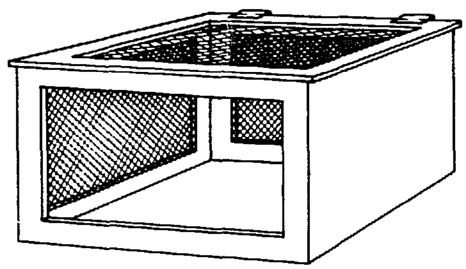
Cigar boxes may also be used to mount insects on cotton background. The cover is removed and the inside of the box filled with layers of cotton fluff. Next the insects are arranged on the fluff and then covered with glass or cellophane which is taped to the box making a permanent mounting. This type of mounting box is especially suitable for butterflies and moths or for displays in a school museum.

5 Cages for keeping animals in the science room

It is frequently desirable in elementary and general science to keep animals caged in the science room for short periods of observation. To carry out such activities effectively, suitable cages must be provided. These can be made from a variety of materials found in almost every locality.

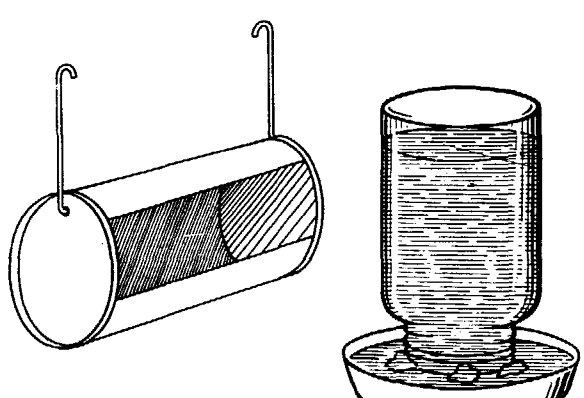
One such cage is made from a wood box provided with a hinged cover and having a window covered by wire screening. Windows are also cut in three sides of the box. The side and back windows are covered with wire screen and a glass plate is fitted in the front window. This type of cage can be improved by a drawer which is fitted under the front glass window and which covers the entire bottom of the cage. This enables the cleaning of the cage without disturbing the animals to any great extent.





In tropical areas very useful cages can be made using bamboo splints or other wood in place of wire screening.

Providing food and water for caged animals is often a problem. Generally food and water containers should be kept up away from the floor of the cage. A convenient feeding trough for small animals may be made by cutting a section from an ordinary tin can and then attaching this to the side of the cage by means of wires as shown in the diagram. A watering device for such animals as mice, guinea pigs and hamsters can be made from a preserving jar inverted in a heavy dish or soup plate.



Regular feeding and watering of animals and regular cleaning of the cages are important, not only for the health and comfort of the animals but also for disciplined habits and a sense of responsibility in the pupils. Food and water must be changed daily and cages must be cleaned once a week.

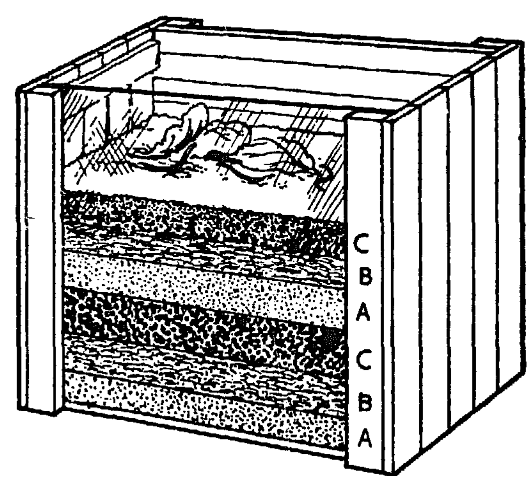
6 A home-made wormery

A wooden box 30 cm by 30 cm by 15 cm fitted with a glass front is useful for studying the habits of earth-worms.

Fill the box nearly to the top with layers of (a) sand; (b) leaf mould; and (c) loam, padding down each layer before adding the next.

Place lettuce leaves, dead leaves, carrot, etc. on the surface soil, together with some worms.

Keep the contents damp and study the behaviour of the worms.



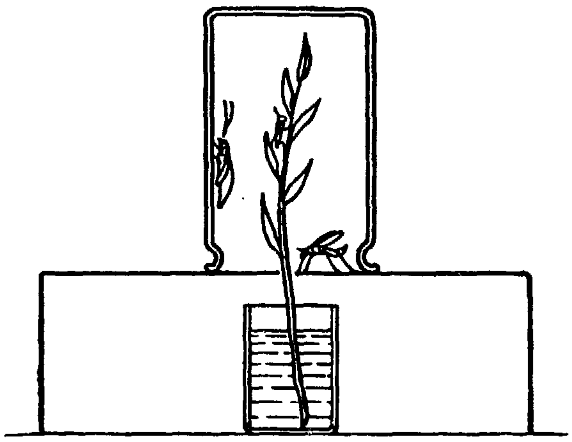
7 Studying life histories of insects

Cut large rectangular holes in the sides of a large cardboard container and cover them with muslin folded over at the edges and gummed or pasted into place. Make a large door by cutting along three sides of a rectangle and bending along the fourth side. Stick a tab of folded paper or cardboard to the front edge of the door to act as a handle. Leave the original bottom of the box intact, to give rigidity. (If cellophane is available a window can be made in the door or in one side of the box.) Put a loose piece of paper on the floor to facilitate cleaning out. Put moist soil into meat paste pots and put cut flowers into it, and stems and leaves of food plants. This is better than pots of water in which the insects may drown.

This cage is suitable for all stages of the life-histories of butterflies, and for moths if larger pots of soil are added, for pupation. The insects can be handled by means of a brush or small stick.

8 Providing for grasshoppers and stick insects

You can keep such insects in an inverted jam jar. They should be provided with a little foliage, which can be stood in a potted meat jar. To give the insect more room, and save it from drowning, the jar can rest on an inverted shoe box with the leaves projecting through what is now the top. Holes should be pierced in the shoe box to ensure a sufficient supply of fresh air.



9 A jam jar vivarium for flies

A jam jar can be used to hold a blow fly for studying its life and habits. After the eggs have been laid on a piece of refuse, transfer the fly to another jar and place the eggs in a warm place in the sun or on a radiator. After a week has passed they will hatch out into gentles. In another week's time they will have become chrysalids. A little damp earth or moss introduced now will prevent them from drying up and the complete life cycle can be followed in a few weeks. Later, problems can be investigated. Do they sleep? How do they eat? What are the differences between male and female?

10 Observing spiders

Make use of the fact that many spiders cannot travel over water or a polished surface. Stand a plant in a pot in a bowl of water, or on a polished table. Put two or three sticks or strips of cardboard together, tie them into some sort of polygonal shape and lean this structure against the plant. Put an orb spinner on the plant and it will make a web.

If a few shelves can be removed from a cupboard a large spider such as Epeira diademata (female) can be persuaded to spin a web in it. Put some plants in pots in the cupboards with the spider, and close the door. After a few hours open the door. This will probably break the web, but if the door is now left open the spider will show no desire to escape but will spin another web. If enough insects are not caught, give her daddy-long-legs, caterpillars, moths or flies.

The process of web spinning may be watched, and dated and timed observations made on feeding and other habits.

A 'cobweb spider' can be kept in a large jam jar. A gauze over the top serves to keep in a fly which can be introduced occasionally. Eggs which are laid can be easily observed, as well as the interesting feeding habits.

11 Caring for frogs and toads

Frogs and toads may be kept in an old bird cage. Put in plants and soil, and an empty dish or two for water. Then put a bottle of water through the small door of the cage and fill the dish from it. Feed the frogs and toads on small earth-worms and flies.

Accurate observations can be made on respiratory mechanisms and rates, and on feeding habits. By shading the cage, changes in skin pigmentation can be observed.

Both frogs and toads need continuous shade and must not be kept in bright sunlight. Frogs must have sufficient water in the cage to enable them to swim, but when desired they can be transferred temporarily to a large tank to enable their swimming habits to be observed.

Tadpoles can be kept in glass jars but when nearing metamorphosis should be transferred to a shallow dish with a pile of stones in the middle. The small frogs are not easy to keep and it is better to let them go and keep older frogs as above.

(Galvanized vessels are *not* suitable for amphibia.)

12 Caring for rats

Black and white rats may be kept in old galvanized baths with strong wire-netting covers. The young rats will climb through the wire netting and use the top of it as a playground. They cannot get down if the wire-netting overhangs the sides of the bath by several inches and there is no other support. Put clean sand in the bath to a depth of at least 3 cm. This must be changed daily. It can be washed thoroughly in running water, air-dried and used again. Give the rats clean rags for nesting purposes. These should be boiled or discarded. Alternatively torn up newspaper may be used and renewed when the cage is cleaned every week.

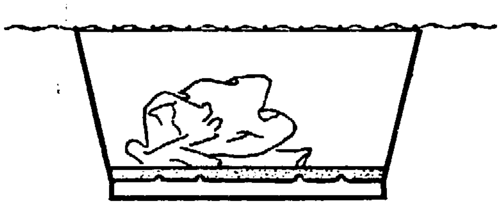
Although rats will eat almost anything, they need a balanced diet. In addition to wheat (or bread) and/or crushed oats they need seeds such as lentils and linseed (or mixed parrot seed), milk or milk powder (except for nursing mothers and young rats which do better on liquid milk). They must also have greenstuff and fruit or fresh vegetables daily, a little salt, and vitamin supplement which may be in the form of seedlings of sunflower, peas, beans or wheat. A little meat twice a week is desirable.

One pair of rats will be enough to begin with, as they breed rapidly.

If well fed and sympathetically handled, they will become quite tame, and will not bite unless they are frightened. They should always be handled by the same people.

Do not attempt to lift a rat by the tail: to pick him up with one hand, lay the palm of the hand across his back and put the thumb and forefinger under his chin, supporting with the other three fingers. Alternatively and preferably cup the two hands round his body.

Observations can be made on habits and breeding. Records of growth can also be kept. Keep a special box in which to weigh the rats. A cardboard box with a deep lid is suitable. Make a number of small holes in the top for aeration. Put a few Helianthus seeds into the



box, and when a rat enters put the lid on. Then weigh rat and box together and subtract the weight of the box. Simple experiments on diet can be done where weight can be used as a criterion. They should be weighed regularly; say, once a week.

Simple Mendelian experiments could be carried out with rats.

When a rat has to be killed for dissection this should preferably be done by enclosing it in a box or lethal chamber and passing in coal gas. Chloroform or ether may be used, but the liquid must not be allowed to cause pain by touching the animal, and there should be sufficient air to prevent suffocation.

Alternatively wrap the rat in a duster including both front legs, hold the head down and strike *very hard* behind the ears with a hammer or stout stick.

Drowning takes a long time and should not be used if it can be avoided. If it must be used, completely submerge a cage containing the rat and weigh it down.

No animal should be reckoned to be dead until stiffness (rigor mortis) has clearly supervened. Otherwise an animal which seems to be dead may later recover consciousness.

13 Making an observation nest for ants

An observation nest for the study of the life story of ants can easily be made as follows.

Make a wooden U from three 30 cm lengths of wood 1.5 cm square. Mount this vertically in a convenient wooden base. Now cut rectangles of glass 30 cm × 33 cm and clamp them on each side of the U with rubber bands or some sort of metal clip.

Make a well-fitting wooden lid to fit the top as shown in the diagram. Drill a 0.5 cm hole about 5 cm from the top of one of the sides and plug it with cotton wool.

The first thing to do in setting up the nest is to fill the space between the glass with soil. This should be taken from the field from which you get the ants themselves.

Pour sandy soil in the top and pat it down occasionally with a ruler until it is about level with the plugged hole.

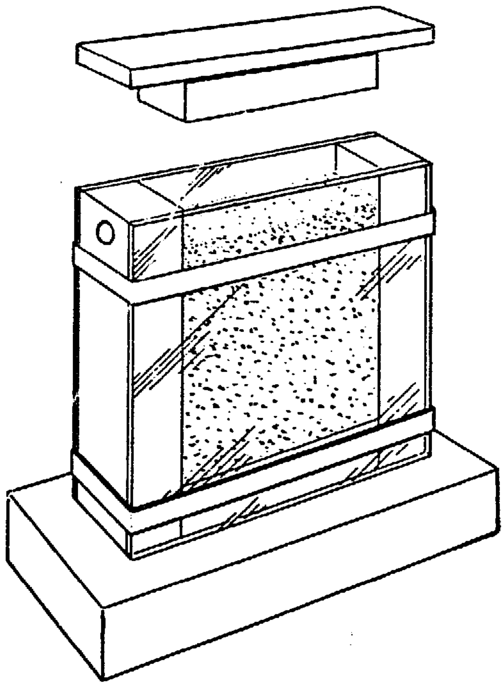
Now for the ants; small black or red ants are the best for this purpose. They prepare their colonies under flat stones nearly everywhere.

Raise the flat stone and you will see the ants scurrying away. You will need two narrow necked medicine bottles with cotton wool stoppers, a gardening trowel, and a white sheet or large piece of paper.

Lay one of the bottles on the ground and guide the ants to the mouth until you have collected about a hundred: then close the neck with the plug of cotton wool.

Next you must find a queen. To do this dig rather deeply with the trowel and put the earth on the white sheet laid flat on the ground. As you break up the earth with the fingers you will notice one ant much larger than the rest. This is the queen which must be guided to the second bottle: some patience is required here.

To get the ants into an observation nest, fill a large tray with water and place an upturned dinner plate in the middle to form an island from which the ants cannot escape. Place the observation nest on the plate and release the ants either on the plate or straight into the top of the formicarium: once the queen is inside the others will follow through the doorway.



As ants don't like daylight, plug up the hole, fit a brown paper envelope over the case and remove the nest to its permanent home.

A little honey smeared on the glass just inside the door will provide plenty of food, and an occasional sprinkle of water with a fountain pen filler will keep the soil moist.

The exciting happenings inside the nest, the laying of the eggs, the grubs and the way the ants have of talking to each other by tapping each other on the head with their antennae, can all be studied in artificial light which does not disturb them, and as the tunnels must run parallel to the glass these things are all quite easily seen.

Experiments such as the removal and subsequent return of a few ants; the introduction of foreign ants, green flies, spiders, etc., are all most fruitful.

Once the nest is settled and the queen begins laying eggs the cotton wool plug from the doorway can be removed. Place the observation nest near a slightly open window and the ants will come and go freely for a whole year.

14 Making a jam jar aquarium

If a large glass tank is not available, practically any glass vessel can be used as a simple aquarium if it is well stocked with submerged water plants such as Elodea or Myriophyllum, to aerate the water. A 1 kg jam jar is quite suitable for keeping caddis larvae, pond snails, small crustacea and plants such as Elodea and Lemna minor, and will keep in properly balanced condition for months if carefully stocked. It is as bad to understock as it is to overstock. The aquarium should require no attention, but if a Dytiscus or other predaceous larva is kept it should be fed regularly on tadpoles. Three centimetres of clean sand will provide hibernating quarters for the caddises at the bottom of the jar, and a muslin cover will ensure that the caddis flies do not escape unobserved.

A diary should be kept, to record egg laying and other changes, as well as habits.

Such an aquarium can be made the basis for a simple study of the interrelationship between plants and animals in pond life.

For collecting pond and stream specimens a strong net can be made from a soup strainer if one is available. Its handle should be firmly bound to a stick, the tape being threaded through the handle repeatedly. The tape must be liberally smeared with rubber solution if available, and then tied tightly and the knot smeared too.

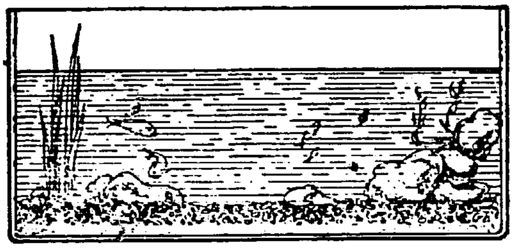
15 An aquarium for larger water animals

A glass aquarium 50 cm by 25 cm is of useful size. Old accumulator cells are suitable, but the glass is not very clear.

To prepare such an aquarium procure some fine silt from the bottom of a clear stream or pond and wash it carefully in running water. Cover the floor of the aquarium with it to a depth of about 2 cm. Plant a few reeds in this, weighting the roots with a stone or lead ring. Then put in a layer of coarse sand or gravel and some large stones to serve as hiding places for the water insects. Fill with a slow stream of water and allow to stand for a day or two until clear. Clean water plants should be introduced. There is no need for elaborate aerating arrangements if plenty of water weeds are present. If tap water is used some live food such as daphnia should preferably be added.

The animals can now be introduced with a few snails to keep the grass clean. Very little feeding will be necessary. Fish will eat the snails' eggs and enough small water organisms can be found in the average pond to supply other needs. If worms are used as food they should only be given once a week cut in pieces small enough to be eaten. Any unconsumed food should be removed immediately or fungi will grow and will infect the fish.

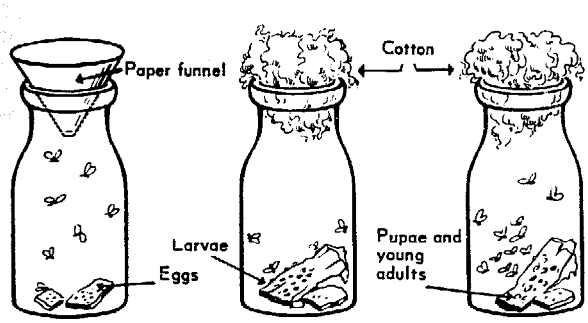
The aquarium must be covered with a glass plate or perforated zinc lid to keep out dust. If frogs or newts are kept, a floating piece of cork must be provided for them to sit on; the glass or zinc cover will then prevent their escape.



16 Observing the life cycle of fruit flies

Small glass jars make excellent habitats for fruit flies. Place a bit of ripe fruit in the bottom of the jar and make a paper funnel with a hole in the end to fit the mouth of the bottle. Place the bottle in the open; and when six or eight fruit flies have entered, remove the funnel and plug loosely with cotton wool. With this number of flies there should be both males and females. The females are larger with a broader abdomen. The males are smaller and have a black-tipped abdomen.

Soon eggs will be deposited, and in two or three days the larvae will hatch. A piece of paper may be placed in the jar for the larvae to crawl on when they are ready to pupate. The adult insects will come from the pupae. By adding newly hatched flies to another jar a new generation can be started.



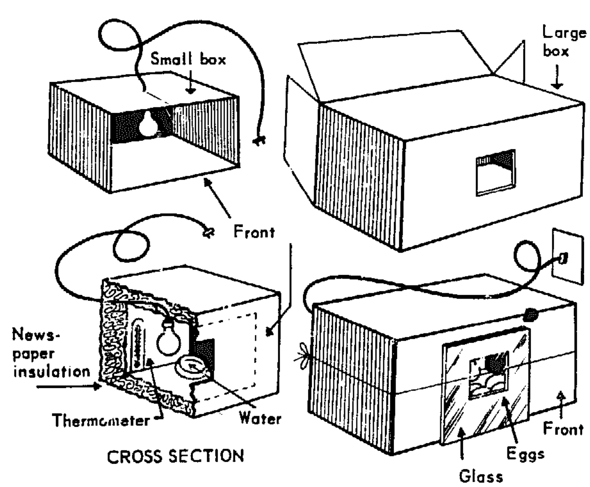
17 The incubation of chicken eggs

If electricity is available in your classroom a simple incubator can be made at a very low cost. Secure two cardboard boxes, one large and one small. Cut one end from the small box, and cut a 15 cm square window in a side of the large box. Next cut a slit in the top of the smaller box and suspend an electric lamp in it. There should be a long electric cord attached to the lamp.

Place the small box inside the larger one and pack crumpled newspaper between them on all sides. Be sure the open end of the small box fits against the side of the large box in which the window was cut. Place a thermometer in the box so that you can read it through the window. A glass plate is fitted over the window.

Now you are ready to begin to experiment. It is necessary to have a constant temperature of 103° F. (40° C.) night and day for 21 days. By using different bulbs and by changing the amount of newspaper you will be able after a few days to regulate your incubator to this temperature. A small dish of water should be placed in the incubator.

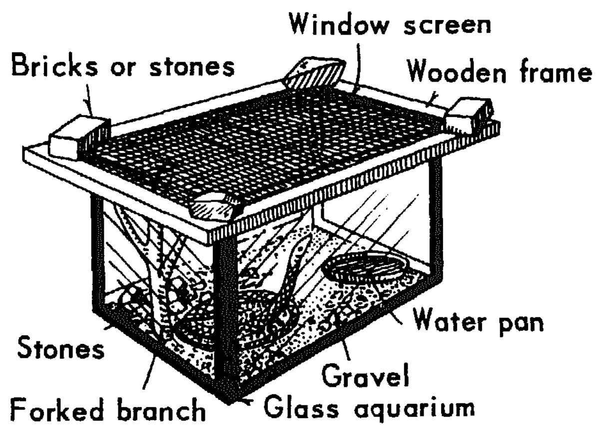
Now secure a dozen fertile eggs. Place the eggs in the incubator and leave them. At the end of three days remove one of the eggs and carefully crack it. Dump the contents into a shallow saucer. A three-day embryo will usually show the heart already beating. It may continue to beat for half an hour. Remove an egg every three days and observe the development of the embryo. Some of the eggs can be left for the full 21 days to see if any of them will hatch.



18 Snakes

Non-poisonous snakes can be brought into the classroom for observation. The diagram shows how a safe cage can be made for keeping a snake. The bottom should be covered with sand and gravel. A shallow pan of water should be placed in the cage. Some stones and a forked branch are also desirable. If snakes are kept in a glass tank, this must be protected from strong sunlight.

When a snake is observed outside it should be approached very quietly. If a snake is to be handled hold it securely just behind the head with one hand. Do not hold it too tightly. Support the rest of the body with the other hand. Snakes may be fed on earthworms, many kinds of insects, eggs or small bits of meat. A snake usually will not feed every day. Some will not eat at all in captivity. Often snakes do not eat for several weeks. If a snake does not eat it is best to let it go.



CHAPTER V

Experiments and materials for the study of rocks, soils, minerals and fossils

Rocks, soils, minerals and fossils are always of interest to children. Since samples are to be found in almost every environment, they can make a very important contribution to the teaching of science. The teacher should not feel it necessary to be able to name every specimen brought in by pupils; such classification and naming is the job of a trained geologist. Much can be learned about rocks and minerals without becoming involved with technical names. For additional information on rocks and minerals see Appendix C.

Some rocks are rough and gritty and appear to be composed of sand grains cemented together. *Sandstone* is a good name for such rocks. Another group of rocks appear to be made up of tiny flecks and crystals something like granite. These rocks may be called *granite-like* rocks. Other common rocks are *slate*, *limestone* and the soft, layered *shale* that often appears along the banks of streams. This simple vocabulary, while not technically complete, will serve very well for identifying and classifying most of the common rocks.

Rocks are generally classified into three great groups in accordance with the way in which they were formed.

1 *Sedimentary rocks* were formed under water from mud and silt deposited by rivers. These rocks often appear in layers. Examples are shale and limestone.
2 *Igneous rocks* were formed by the cooling of molten materials. Lava, quartz and mica are good examples of igneous rocks.
3 *Metamorphic rocks* were formed under great heat and pressure from both sedimentary and igneous rocks. Examples of this type are marble formed from limestone and slate formed from shale.

A. ROCKS AND MINERALS

1 Making a rock collection

A collection of the common rocks found in the community can be made by asking each pupil to bring in one piece of rock. Explain to the pupils that it will not be necessary to know the names of all the rocks. Similar specimens may be placed together on a table. Divide the collected rocks into groups based on differences of shape, colour and other characteristics. Try to find as many ways as possible of grouping the rocks.

2 Studying a single rock

Select a single rock and try to learn as much as possible about it from careful observation. If it is flat, it is probably a piece or layer from some sedimentary formation. Such rocks were formed by the hardening of sediments laid down millions of years ago. If the rock appears to be made of fine sand grains cemented together it is probably sandstone. If it is made up of larger pebbles cemented together, it is probably another sedimentary rock called *conglomerate*. If the rock appears to be rounded, it is probably the result of the stream action of water. Examine the rock with a magnifying glass. If it contains little flecks and crystals, it is a granite-like rock and was probably pushed up from deep in the earth long ago. Careful observation of several rocks in this manner will interest pupils in their further collection and study.

3 Making individual rock collections

Pupils should be encouraged to make their own collection of rocks. Small pasteboard or cigar boxes will serve to keep the collections. The specimens may be kept separate by putting partitions in the boxes. As a pupil identifies the rocks in his collection, he should cut small pieces of paper or adhesive tape and fasten one to each rock. Place a number on each and then paste a list on the cover of the box. It is a good idea to have the collections kept small. Pupils may be encouraged to fill out their collections by trading samples with other pupils.

4 A study of broken rock

Break open several rock specimens. Compare the appearance of freshly broken surfaces with the weather-worn outside of the rock. The rocks may be safely broken by wrapping in a cloth, placing on a large rock, and striking hard with a hammer. The cloth wrapping will prevent small chips from flying off.

5 The test for limestone

You can test the rock samples to see if any are limestone by dropping lemon juice, vinegar or some other dilute acid on them. If any are limestone they will effervesce or bubble where the acid is placed on them. The bubbling is caused by carbon dioxide gas which is given off by limestone when in contact with acid. Marble, a metamorphic rock made from limestone, will also respond to this test.

6 Studying broken rocks with a magnifying glass

Study freshly broken rocks with a magnifying glass and try to find crystals of different minerals. The crystals of different minerals will differ in size, shape and colour.

7 Examining sand with a magnifying glass

Examine a small amount of sand with a magnifying glass or under the low power of a microscope if there is one available. The nearly colourless crystals are those of a mineral called *quartz* which is the commonest mineral on earth. Crystals of other minerals can often be found in sand. See if you can find any others.

8 The meaning of 'rock' and 'mineral'

Develop the meaning of these two terms through a study of the specimens collected. A rock is usually regarded as mineral matter found in the earth in large quantities. Most rocks are mixtures of minerals although some kinds consist of a single mineral. A mineral is a substance found naturally in the earth which has a definite chemical composition and a set of specific and characteristic properties.

9 A field trip to a rock quarry

The quarry should be visited by the teacher in advance. Observe how the rock is removed. If the rock is sedimentary, observe the layers. Collect rock samples to take back to the classroom for study. Look for fossils of any plants or animals. A field trip may also be planned to an exposed rock cut or ledge and to a coal mine if there is one nearby.

10 Mounting rock and mineral samples

Samples of rocks and minerals can be mounted neatly for a collection by making a base from plaster of Paris. The white powder is mixed with water to form a thick paste. This paste is put in a tin can cover about 1 cm deep which has been lined with wax paper or greased. Before the plaster hardens the small rock or mineral sample is pressed far enough into the surface so that it is held firmly but so that it can be seen well. The name of the material can be printed on the white base and then the base can be coated with clear shellac or varnish.

B. ARTIFICIAL ROCKS

1 Cement and concrete

Secure a small bag of Portland cement. Have the pupils mix it with water and put it in tin can covers, paper cups, or small pasteboard boxes until it hardens. Study its appearance and its properties. Break a piece of cement and study it. Mix the dry cement with about twice as much sand or gravel. This will form concrete. After adding water and mixing thoroughly place it in moulds. Allow these to harden several days. Again study the appearance and the characteristics of these samples.

2 Plaster of Paris

Secure some plaster of Paris and mix a small amount with water. It must be worked rapidly or it will harden while being mixed. Place the mixture in moulds and let it set until very hard. Study the appearance and properties of the samples.

3 Collections of building materials

Collect samples of all the different types of rock or mineral building materials available in your locality such as marble, granite, slate, limestone, brick, cement, plaster, etc. These may be added to your collection after proper labels have been attached to the samples.

C. ELEMENTS AND COMPOUNDS

1 A collection of elements

Obtain a table of the elements and make a collection of samples of as many as you can. You should be able to obtain samples of the following: iron, aluminium, zinc, tin, copper, lead, gold, silver, mercury, sulphur. See Appendix C.

2 A collection of common chemical compounds

Collect samples of as many common chemical compounds as you can. The following are suggestions: salt, sugar, starch, soda, copper sulphate, bleaching powder, plaster of Paris, rubber, wool, cotton, etc.

D. MAKING A MODEL VOLCANO

Secure from a chemical supply house 500 g of ammonium bichromate, 125 g of magnesium powder and 30 g of magnesium ribbon. The total cost of these materials will be about $2.50 and will provide from 30 to 40 volcanic eruptions.

Have the children collect some ordinary clay. Use a board for a base and with the clay, build a volcanic cone about 30 cm high and 60 cm in diameter at the base. Push a piece of broomstick down into the tip of the cone to a depth of 5 to 7 cm.

On a piece of paper pour out enough of the ammonium bichromate to fill the hole in the cone about twice. Do not grind up the crystals. The lumps work better. Mix a little magnesium powder with the bichromate crystals and carefully stir with a pencil.

Pour about half of the mixture into the cone of the volcano. Cut a 7.5 cm length of magnesium ribbon and push one end into the mixture in the cone. Let the other end stick out the top for a fuse. Light the magnesium ribbon with a match and step back. If the eruption does not take place the first time wait a few moments, insert another fuse and try again. After the eruption has occurred, but while the material left in the cone is still hot, pour in the remainder of the mixture, and you will have a second eruption.

E. SOIL

1 Types of soils

Secure samples of soil from as many places as possible and place in glass jars. Try to get examples of a sandy soil, a loam soil, a clay soil, a soil rich in decayed matter or humus. Have the pupils study the samples and examine bits from each sample with a magnifying glass.

2 To show the differences in soil particles

Secure some glass jars that hold about a half gallon or two litres of water. Place several handfuls of soil in a jar. Fill the jar with water and then thoroughly shake up the soil in the water. Let the jar stand for several hours. The heaviest particles will settle out first and the lightest ones last. The layers in the jar after settling will be in the order of the weight of the soil particles. Siphon the water from the jar with a tube. Next examine a small sample from each of the layers with a magnifying glass.

3 To show that soil contains air

Place some soil in a glass jar or bottle and slowly pour water over it. Observe the air bubbles that rise through the water from the soil.

4 To show how soil is formed from rocks

Carefully heat a piece of glass in a flame and then plunge it into cold water. The sudden cooling of the glass causes it to contract unevenly, and it cracks. Heat some rocks very hot in a fire and then pour cold water on them. The rocks will often break up both when heated and when cooled. One of the stages in the formation of soil is the breaking up of rocks under differences of temperature.

5 What makes streams look muddy?

After a heavy rainfall have pupils take samples of running muddy water in glass jars. Let the water stand for several hours until the sediment has settled and may be observed by the pupils.

6 Making soil from rocks

Find some soft rocks in your locality such as shale or weathered limestone. Bring them into the classroom and have the pupils crush and grind them up into small-sized particles.

7 The effect of soil on growing things

Get samples of a fertile soil from a flower or vegetable garden, from a wood, from a place where a cellar is being dug, from a sandy place, from a clay bank, etc. Place the samples in separate flower pots or glass jars. Plant seeds in each type of soil and give each the same amount of water. Observe in which type of soil the seeds sprout first. After the plants have started to grow, observe the soil sample in which they grow best.

8 To show that soil may contain water

Place some soil in a thin glass dish and heat it cautiously over a small flame. Cover the jar and water will be observed to condense on the cool sides.

9 To study the difference in fertility between topsoil and subsoil

Secure a sample of good topsoil from a flower or truck garden. Secure another sample of soil from a depth of about 50 cm. Place the samples in separate flower pots and plant seeds in each. Keep the amount of water, the temperature and the light equal on each sample. See which soil produces healthier plants.

10 To show the presence of nodules of nitrogen-fixing bacteria on the roots of legumes

Carefully spade up some leguminous plant such as clover, alfalfa, soy-beans, cow peas, etc. Remove the soil from the roots by washing with water. Observe the little white bumps or nodules on the roots. Nitrogen-fixing bacteria are inside these nodules. These bacteria remove nitrogen from the air and fix it in a form that enables plants to get it from the soil.

11 To show how water rises by capillarity

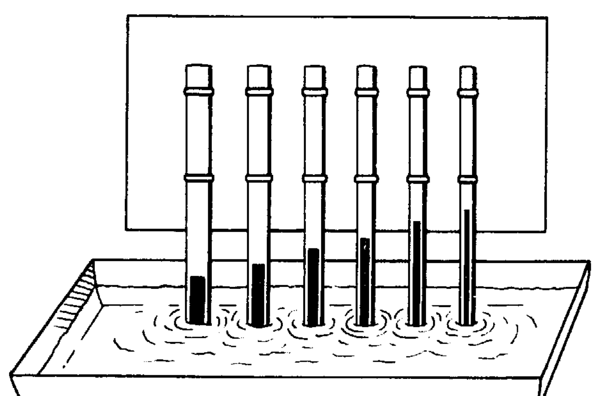
Colour some water in a shallow dish with ink and touch a blotter to the water surface. Observe how the water rises in the blotter.

Touch a lump of sugar to the water surface and observe how the water rises.

Place a lamp wick in the water and observe.

12 To show how water rises in fine tubes

Make some fine hair, or capillary tubes by heating glass tubing in a flame and drawing it out. Cut the tubes and glue them to a piece of cardboard with about 5 cm extending below the edge. Place the ends of these tubes in coloured water and observe how the force of capillary attraction causes the water to rise.



13 To show how water rises in different types of soil

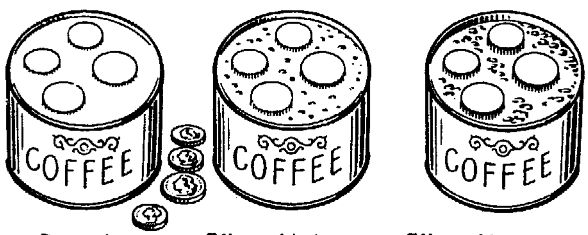
Place about 15 cm of different types of soil in a series of lamp chimneys after tying a piece of cloth over the end of each chimney. Such soil samples as sand, loam, gravel (fine), clay, etc. may be used. Next stand the lamp chimneys in a pan which contains about 3 cm of water. Observe the type of soil in which water rises highest due to capillarity. Clear plastic drinking straws can also be used for this experiment.

14 To show which types of soil hold water best

Tie cloth over the end of several lamp chimneys and then fill each one to within 8 cm of the top with different types of soil. Use sand, clay, loam and soil from the woods. Place dishes under each chimney to catch water which runs through. Next pour measured amounts of water into each chimney until the water begins to run through. Observe the soil type into which the most water can be poured without running through.

15 The effect of rain on loose soil

Make a sprinkling can by punching holes in the bottom of a tin can with a hammer and small nail. Fill several flower pots or cans with loose soil and press it down until it is even with the edges. Place some coins or bottle tops on the surface of the soil. Set each pan in a basin and sprinkle with water from your can to represent rain. First sprinkle lightly and note the effects of a light rain. Continue sprinkling to illustrate a heavy rain. Notice how the unprotected soil is splashed away leaving columns of soil under the bottle caps and coins.



Dry soil   Effect of light rain   Effect of heavy rain

16 The effect of rain on sloping soil

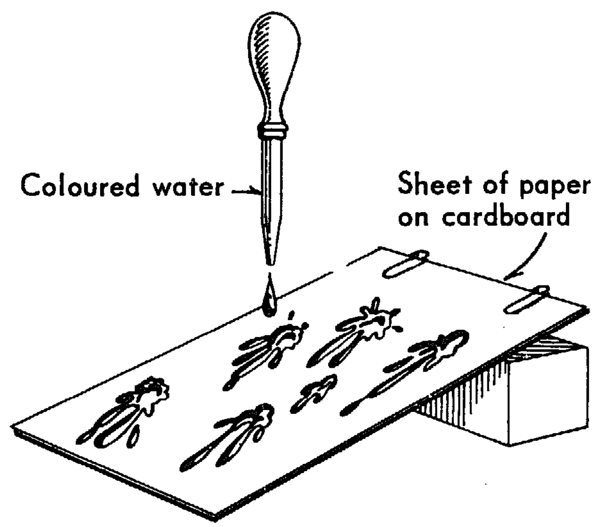
Fill a shallow pan or box with firmly packed soil. Set the pan outside in the rain with one end raised slightly. Observe how the raindrops splash the soil down toward the lowered end. This experiment can be done inside by using the sprinkling can for rain.

17 To show the impact of a raindrop on soil

Place a saucer or jar lid filled with soil on a piece of white paper. Fill a medicine dropper with water and hold it about a metre above the soil. Release water a drop at a time and observe how much soil is splashed out on the paper. Place a clean sheet of paper under the saucer. Again release drops but hold an obstacle such as a pencil in the path of the drop to break the force of the raindrop. Do plants prevent the wearing away of the soil in this way?

18 How the effect of raindrops on soil varies

Fasten a sheet of white paper to a piece of stiff cardboard with paper clips. Lay it flat on the floor. Drop coloured water on it with a medicine dropper. Note the size and shape of the splashes. Repeat but this time prop up one end of the cardboard. Study the effect on the splashes of varying the height from which the water is dropped, of varying the slope and the size of the drops. Try different combinations of the variables. A record of the results may be kept if a clean sheet of paper and different coloured water is used for each situation.



19 The effect of falling water on topsoil

Fill a flower pot with sandy soil or loam. Set the pot under a dripping tap for an hour or more. Observe how the clay and inorganic matter are removed from the surface by falling drops.

20 The effect of rain on unprotected surfaces

Build up a pile of sand and clay in a box or pan. Sprinkle gently near the top with water from the sprinkling can. Note the way the running water transports the rock particles and deposits them near the bottom of the pile.

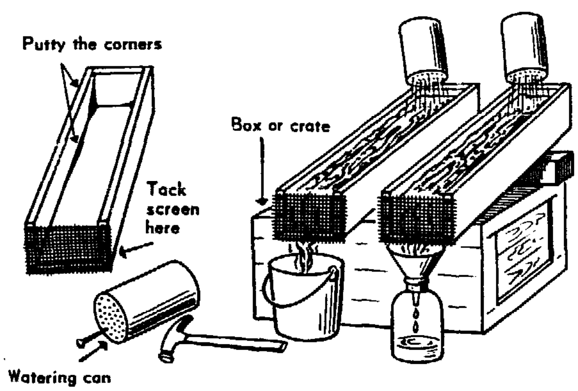
21 How running water wears away the soil

Construct the two trays as shown in the drawings below. Putty in the cracks will make them water-tight. Pails or glass jugs with funnels may be used to collect the run-off water.

(a) Fill one tray with loose soil and the other with firmly packed soil. With both trays slightly tilted, water each the same amount with a sprinkling can. Observe which soil is moved away faster and the nature of the run-off water.

(b) Fill both trays with soil but cover one with sod. Water equally as before and observe both the erosion and the run-off water.

(c) Fill both trays with soil but give one more slope than the other. Water and observe as before.



22 How to prevent the erosion of topsoil

Use the trays constructed for the experience above.

(a) Fill the trays with loose soil and tilt each one the same amount. Make furrows with a stick running up and down the hill in one box and across the hill in the other box. Sprinkle each the same amount. Observe the erosion in each case and the run-off water.

(b) Again fill the trays with loose soil. Water them until there are well-defined gulleys formed from the running water. Now block the gulleys at intervals with small stones and twigs. Again water and observe the effect of blocking the gulleys.

23 A field trip to study erosion

Find some place in the locality where running water has done damage by cutting gulleys. Take the class to study the erosion. Why was it caused? How could it have been prevented? What can still be done?

24 Conservation on the school grounds

Almost every school yard will have some place where running water has done damage. Enlist the class in a project to decide upon means for preventing the erosion and then let them carry out their project.

F. FOSSILS

1 Where to find fossils

In some localities fossils may be found in stone quarries or where there are rock outcrops. Try to find someone in the community who knows about fossils and then plan a field trip with the class to collect some of them.

Fossils can often be found by breaking lumps of soft or bituminous coal apart. Break the lumps carefully and examine the broken surfaces for imprints of leaves and ferns.

If there are no fossils in your community, you may have to depend on state or national museums to send you a few. A letter to the state or national museum may prove helpful.

2 How fossils were formed

Cover a leaf with vaseline and place it on a pane of glass or other smooth surface. Place a circular strip of paper or cardboard around the leaf. Press modelling clay against the strip to hold it firmly. Now mix up some plaster of Paris and pour it over the leaf. When the plaster has hardened, you can remove the leaf, and you will have an excellent leaf print. Some fossils were made this way—by having silt deposited over them, which later hardened into sedimentary rock. Repeat this experience using a greased clam or oyster shell to make the imprint.

3 How to mount fossils

If you happen to live in a locality where fossils are plentiful, it will be interesting to have the pupils make a fossil collection for the school museum.

Fossils can be neatly mounted in plaster of Paris by following the instructions given for mounting rocks and minerals in section A 10 of this chapter.

CHAPTER VI

Experiments and materials for astronomy

Astronomy is always an interesting topic for children in the elementary school as well as for young people studying general science. In many places the basic concepts of astronomy are taught descriptively—that is, the children merely read about them. In this chapter many experiments are suggested to enable the teacher to develop some of the concepts from observation and experiment.

No attempt has been made to grade the experiments. It is suggested rather that teachers select those experiments that seem most appropriate for the topics being taught.

A. OBSERVING THE STARS

1 Making a simple refracting telescope

To make a simple telescope, two cardboard tubes will be required, one fitting inside the other.

It is not possible to make a satisfactory telescope unless good lenses are available, a fact which was soon discovered by early experimenters.

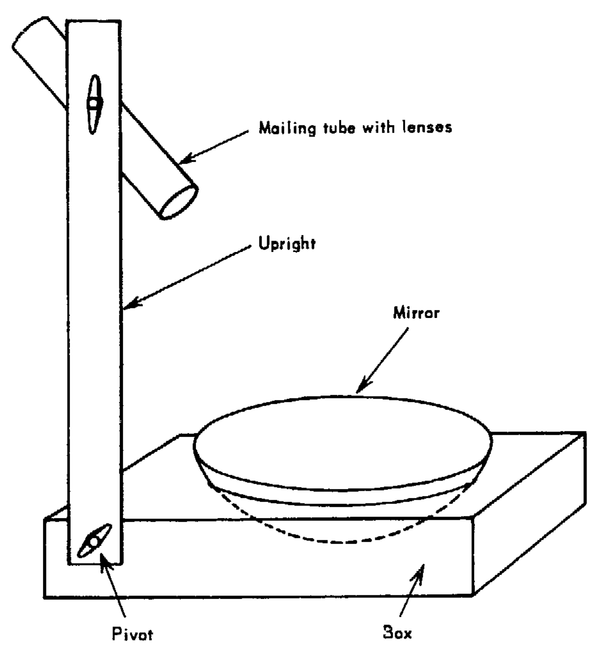
A linen tester (sometimes a stamp magnifier also) has lenses which are achromatic, that is corrected for colour distortion. Such a lens of focal length 2 or 3 cm will provide a suitable eye-piece when mounted in a cork with a hole in it.

It is equally important that the object glass should be achromatic for best results. If such a lens is available with a focal length of 25 to 30 cm it should be fixed in the wider cardboard tube by plasticine. A little adjustment is required to get both lenses on the same geometrical axis. When this has been achieved and the focusing done by sliding the tube, it is a superior instrument to the one with which Galileo made all his discoveries.

Jupiter's moons are readily observed with this apparatus, but not Saturn's rings.

2 Making a simple reflecting telescope

A simple reflecting telescope can be made from a concave mirror obtained from a shaving mirror. The mirror is arranged in a wooden box of suitable size in such a way that it can be tilted at different angles. An upright made of wood is attached to the box so that its angle may also be varied. Two short focus lenses are fixed in corks which are then placed in a short length of mailing tube as an eye-piece. Then attach this eye-piece attached to the wood upright exactly at the focal distance away from the mirror.



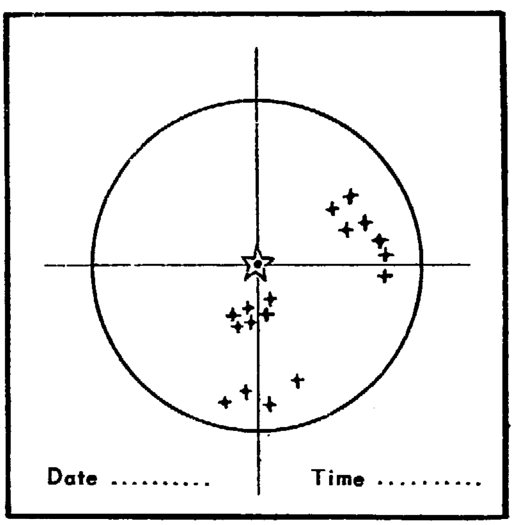
3 Making a precision reflecting telescope

It is quite beyond the scope of this book to include the intricate details for mirror grinding and testing. However, some teachers may wish to have able pupils engage in making a better telescope. Attention is therefore directed to the excellent book called *Amateur Telescope Making* published by the Scientific American Publishing Co., New York City, N.Y.

4 Learning to recognize the main constellations and making a star map

This is a convenient home task, and is best done about the time of a new moon. The moonlight does not then interfere with a good view of the stars. The Pole Star should be identified first, and it is helpful to take outside a piece of brown paper with pinholes pricked through it in the form of a few of the constellations. When the paper is held up to any light the pinholes become visible, and the paper can be rotated until a similar star pattern is recognized. A star map, with the Pole Star as centre, can soon be built up.

After a few constellations have been learnt in this way, it is instructive to make one map in the early evening, and one just before going to bed. Another interesting way of recognizing constellations is to take outside a blackboard and stick into it luminous (phosphorescent) buttons to represent the stars.



5 Photographing star 'trails'

A very interesting activity for pupils who have cameras is the photographing of star trails as the earth revolves. Select a clear moonless night for this and find a place where there is an unobstructed view of the horizon. The place selected should be away from extraneous light such as automobile headlights, etc. Face the camera as directly at the Pole Star as possible and secure it either with a tripod or with blocks of wood. If the camera is the focusing type, set the lens at infinity and open the diaphragm full. The shutter should be set for a time exposure. When all is ready open the shutter and leave it open any length of time from one to six hours. The longer it is open the longer will be the star trails. Try photographing stars in the Milky Way.

6 How to make a constellarium

A constellarium is a simple device used in teaching the shapes of various constellations. Get a cardboard or wood box and remove one end. Draw the shapes of various constellations on pieces of dark coloured cardboard large enough to cover the end of the box. Punch holes on the diagrams where the stars are located in the constellations. Place an electric lamp inside the box. When the lamp is turned on and various cards are placed over the end of the box, the constellations may be seen clearly.

Another way is to secure several tin cans into which an electric lamp will fit. Holes are punched in the bottoms of the cans to represent the stars in various constellations. When the lamp is placed inside a can and turned on, the light shows through the openings and the shape of the constellations may be observed. The cans may be painted to prevent rusting and kept from year to year.

7 How to make an umbrella planetarium

Since an umbrella has the shape of the inside of a sphere it can be used to illustrate portions of the heavens. Secure an old umbrella that is large. With chalk mark the North Star, or Polaris next to the centre on the inside of the umbrella. Use a star map and mark the star positions for various constellations with crosses. When you have filled in all the polar constellations you can paste white stars made from gummed labels where the crosses are; or you may paint the stars in with white paint. Later you can make dotted lines with white paint or chalk to join the stars in a given constellation.

B. THE SUN AND THE STARS

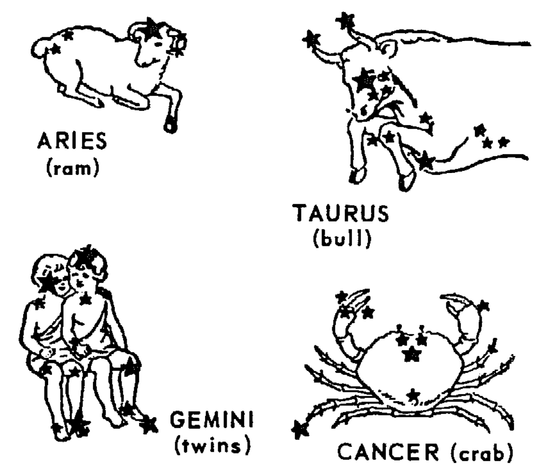
1 A chart of the constellations of the zodiac

The constellations of the zodiac are found along the ecliptic, in a belt 16 degrees wide. This belt can be subdivided into 12 sections each subtending 30 degrees, and including a constellation called a sign of the zodiac.

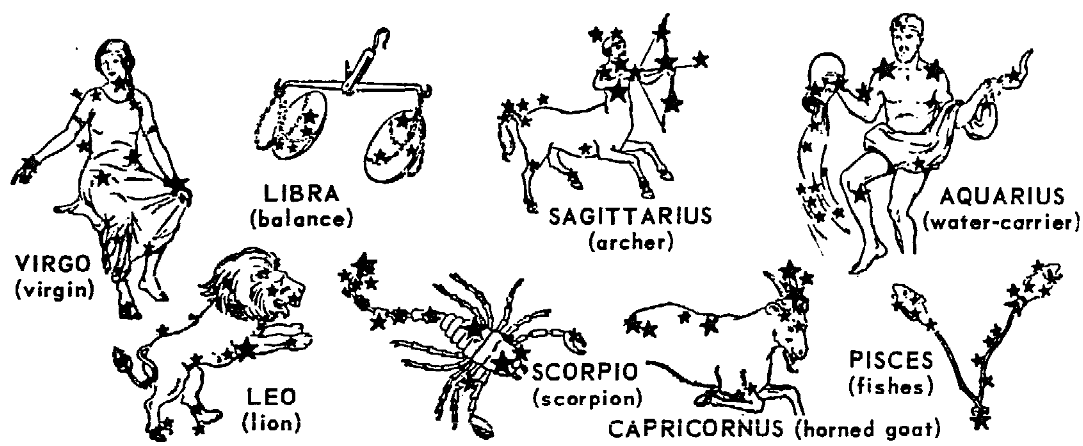
The sun has one of these behind it when it rises in each month of the year, e.g. about 21 March Aries is behind the sun at sunrise; a month later, the sun rises in Taurus, etc.

Spring signs	March	1 Aries.
	April	2 Taurus.
	May	3 Gemini.
Summer signs	June	4 Cancer.
	July	5 Leo.
	Aug.	6 Virgo.
Autumn signs	Sept.	7 Libra.
	Oct.	8 Scorpio.
	Nov.	9 Saggitarius.
Winter signs	Dec.	10 Capricorn.
	Jan.	11 Aquarius.
	Feb.	12 Pisces.

The charts display the whole of the constellations. The dates round its edge show when that part of the heavens is due north at midnight. The actual stars visible would be contained in a circle having a diameter slightly less than three-quarters of the whole chart, and so placed on the chart that it is on the opposite edge to the date required. The diameter of the chart being 11 cm, it is a good practice to cut an 8 cm circle of transparent paper, draw a diameter on it as a north to south



guide, and lay it on the chart to show what area is visible at midnight on a given date. The diameter should cross the Pole Star, and point to the date. There will be a gap between the edge of the paper and the edge of the chart, and it will be found that the Pole Star is always half-way between the centre of the transparent disc and its momentarily northern edge.



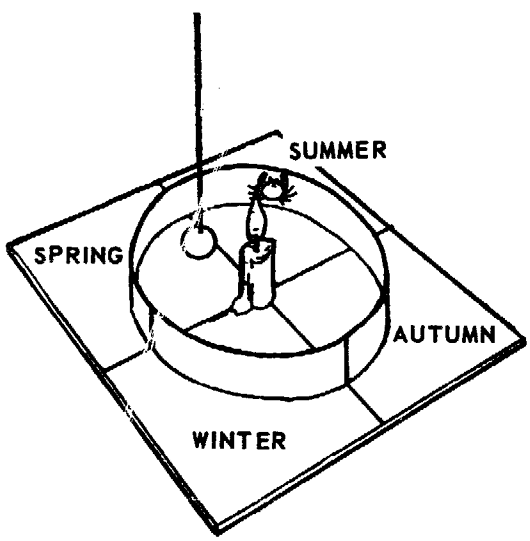
Northern hemisphere

Southern hemisphere

The above star charts are reproduced by kind permission of Messrs. George Philip and Son, Ltd., 98 Victoria Road, London, N.W.10.

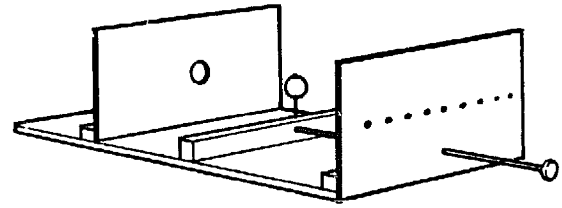
2 A model to show the apparent path of the sun among the stars

The signs of the zodiac are drawn in the correct order on a strip of paper about 60 cm long and 8 cm wide. The ends of the paper are then gummed together making a continuous loop with the zodiacal constellations inside. The loop is then stood edgewise and gummed in a circle about 18 cm diameter to a cardboard base. A short candle placed at the centre represents the sun. The seasons corresponding with the signs of the zodiac are marked on the baseboard outside. A chestnut or other object hung from a piece of cotton will rotate as the cotton unwinds and serve to represent the rotating earth.



3 A model illustrating how an eclipse appears

The sun is represented by an opal electric bulb shining through a circular hole 5 cm in diameter in a piece of blackened cardboard. The corona is drawn in red crayon around this hole. The moon is a wooden ball 2.5 cm diameter mounted on a knitting needle. The observer views the eclipse through any of several large pin holes in a screen on the front of the apparatus. The corona only becomes visible at the position of total eclipse. The moon's position is adjusted by a stout wire bicycle spoke attached to the front of the apparatus.



4 Illustrating an eclipse of the sun

Hold a small coin a few inches from one eye and close the other eye while looking at the lighted electric bulb on the ceiling of a room. The large bulb is far away and represents the sun. The small coin is close to your eye and represents the moon coming between the sun and the earth. You will observe that the small coin completely hides the light bulb on the ceiling and casts a shadow on your eye.

5 Observing sun spots

Use the telescope that you made in a previous experiment. Set it up so that it points directly at the sun and focus it so that a clear and bright image of the sun is formed on a piece of white cardboard placed a short distance from the eyepiece lens. If sun spots are present on the surface of the sun you may be able to observe them as small dark spaces of irregular outline on the image.

Caution. Do not look at the sun through the telescope, unless your eyes are protected by a dark glass filter.

6 Observing changes of position of the earth with respect to the sun

Mark a line on the floor or the wall where the sun shines in your room. Note the exact month, day and hour. At the end of each week make another line at exactly the same hour. Repeat this throughout the year and you will have some interesting observations. The variation in position of the line from week to week and from month to month is caused by the movement of the earth around the sun.

C. EXPERIMENTS RELATED TO THE SOLAR SYSTEM

1 Making a model of the solar system

The concepts of the relative size and distance of the planets from the sun can be illustrated by having pupils make a model of the solar system. This can be done by using various sized balls, for the sun and planets, by making clay models or simply by cutting circles of the proper size from cardboard. These can be arranged either on the wall, on the floor or on the blackboard where the orbits of the planets can be marked off with chalk. The table below gives the data necessary for making a model to scale.

Data on planets	*Mercury*	*Venus*	*Earth*	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*	*Pluto*
Average distance from the sun in millions of miles	36	67	93	141	489	886	1 782	2 793	3 670
Diameter in miles	3 000	7 600	7 900	4 200	87 000	72 000	31 000	33 000	?

2 Observing visible planets

By using a good star map the planets visible at different times of the year can be easily identified by the teacher. Pupils should be taught to identify the planets and to be able to tell them from the brighter stars. Children always enjoy an evening of observation. Make use of the telescope described on page 67 or a pair of field glasses.

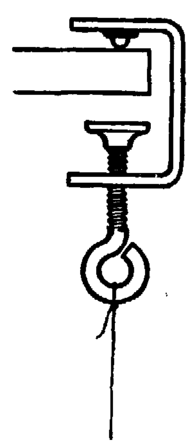
3 Watching for 'shooting stars'

A good time to watch for meteors or 'shooting stars' is in August or November. Have the children keep watch of the evening sky and report any observation they make.

D. EXPERIMENTS RELATED TO THE EARTH

1 A Foucault pendulum to show the rotation of the earth

A G-clamp with a ball bearing soldered to the inside of the jaw makes a good support for a Foucault Pendulum.



It is best hung indoors with the ball bearing resting on a stout razor blade or some other hard surface. When such a pendulum is set in motion, the plane of swing is altered after a few hours, as will be noticed if a mark is made on the ground at the time of release. It is, of course, the earth rotating underneath the 'bob' which gives this effect.

Unspun nylon fishing line should be used for suspending the bob, which can be a cricket ball. The length of the pendulum is not important; anything from 3 m to 30 m will do.

Care must be taken that the pointer, a short knitting needle driven into the ball, is continuous with the suspending thread.

A reference line drawn on a piece of white card can be fastened to the floor with drawing pins. This must be positioned accurately under the pointer when the ball is at rest.

To set the pendulum in motion, attach a long cotton thread to a tintack driven into the bob, and align it so that it lies along the direction of the reference line; then burn the thread near the tack.

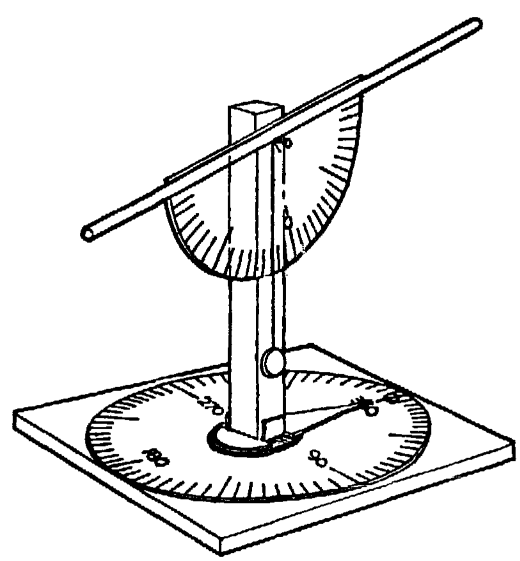
It is not easy to get good quantitative results without many refinements, but it is not difficult to observe the effect.

2 A simple theodolite or astrolabe

A simple theodolite or astrolabe is made by fixing a drinking straw to the base line of a protractor with sealing wax or glue.

A plumb line hung from the head of a fixing screw will ensure that the supporting pole is upright and will serve also to measure the angle of the star or any other object.

An improved model for finding latitude, and the bearing of a star from the N.S. meridian can be made by fixing the rod to a



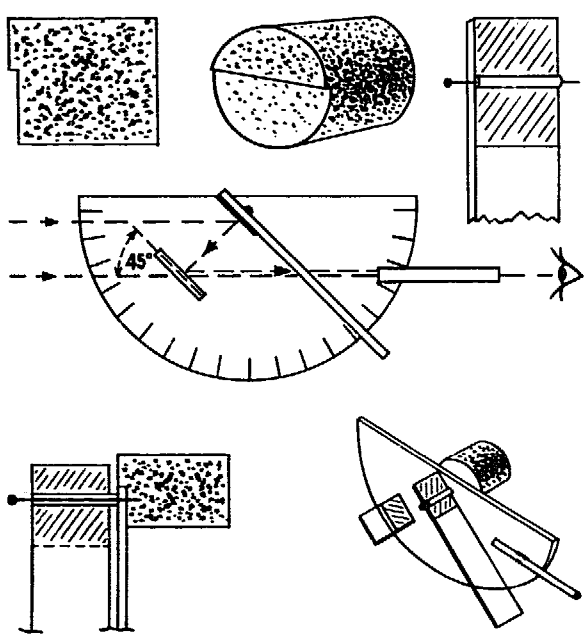
baseboard with a screw. Two coins with holes in the centre can be used as washers and a piece of tin fixed to the rod will indicate the angle on a horizontal scale. It is with such rough apparatus as this that many early discoveries were made.

3 A model sextant

A simple sextant can be devised using cork, glue, pins, glass tube, sealing wax, etc.

The cork is slightly cut away at one end so that the base line of the protractor is parallel to a diameter when in position. A stout pin stuck through the centre of the protractor serves as an axis on which the moving mirror can turn. A piece of glass tubing drawn out to fit the pin serves as a hinge when stuck to the mirror slip (7 cm by 1 cm). The silvering is removed from all except the first centimetre of the mirror slip, and the remaining clear glass acts as an arm to the instrument and indicates the angle on the protractor scale.

The fixed mirror is fastened by wax in a slot made in the protractor with a heated piece of wire or knitting needle. It is convenient to make this slot 45 degrees to the vertical. Half the silvering is scraped off this mirror so that the horizon can be observed through the straw or glass sighting tube which is fixed with wax parallel to the base line of the protractor.

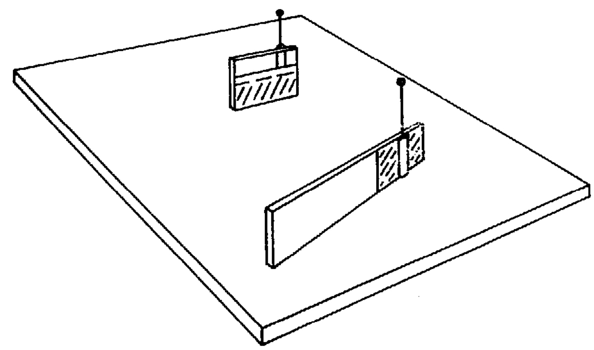


In use the instrument is held by the cork in the right hand, and the arm is adjusted until the two images of the horizon, seen in the clear and silvered half of the fixed mirror, are continuous. The angle indicated by the clear glass arm is then recorded.

The arm is now moved until the image of the sun or other object seen in the silvered half of the mirror rests on the horizon viewed directly through the clear half.

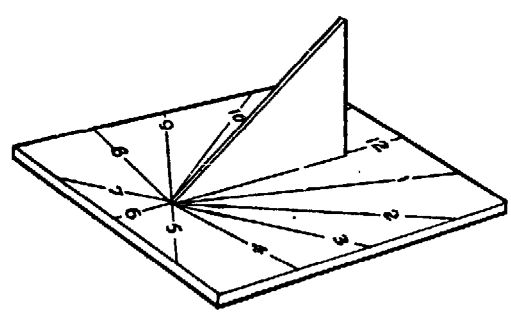
The angle moved through by the arm is half the altitude of the sun. A smoked eyeglass or a piece of gelatine filter may be needed if the sun is too bright.

Similar slips of glass mirror can be supported perpendicular to a drawing board by large pins stuck through the glass tubing. They are then useful for studying the paths of rays of light through the mirror system of a sextant, using beams of light or pins to track down the paths of particular rays.

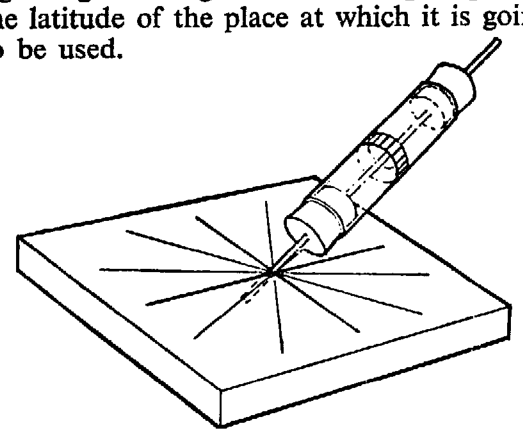


4 Making a sun-dial

To withstand all weather, a sun-dial should be made of metal or painted wood. A cardboard model can be made for simple experiments.



The gnomon which casts the shadow is a right-angled triangle with base angle equal to the latitude of the place at which it is going to be used.



This is glued in position so that the hypotenuse points to the North Star. The hours can then be marked off on the baseboard.

Another pattern can be made if glass tubing about 4 cm in diameter is available.

In this case the gnomon is a stout knitting needle fixed to the base at an appropriate angle. The scale, which is divided into 24 equal parts, is stuck round the circumference of the glass tubing and the shadow of the knitting needle indicates the hour. The glass tubing is held in position by corks.

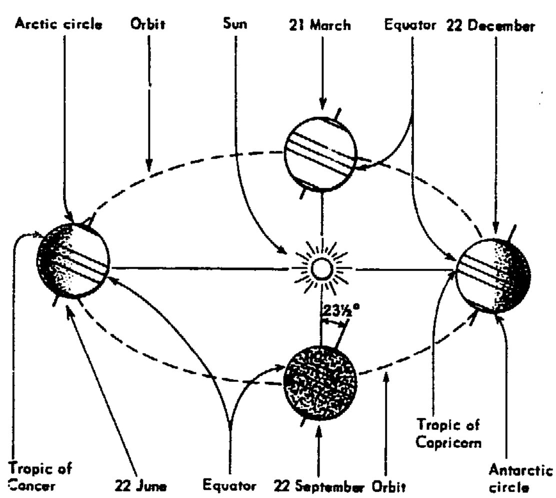
This type of sundial is not satisfactory in areas lying between latitudes 15° N. and 15° S. of the equator.

5 A simple model of the earth and moon

The earth can be represented by an orange or other round object stuck on a piece of bamboo or a meat skewer. A piece of bent wire or knitting needle stuck through the shaft will support a round chestnut or small nut to represent the moon. The phases of the moon, and the rotation of the earth round the sun, and also the formation of eclipses can be illustrated by holding it in the hand while walking in a circle round a lamp of some sort.

6 Demonstrating the cause of seasons

Use a hollow rubber ball such as a tennis ball to represent the earth. Push a 15-cm length of wire or a knitting needle through the ball to represent the earth's axis. Draw a circle about 40 cm in diameter on a piece of cardboard to represent the earth's orbit.



Mark the four quarter points north, south, east and west. Hang an electric lamp about 15 cm above the centre of the cardboard to represent the sun. A lighted candle may also be used. Place the ball representing the earth successively at the four positions with the axis slanted about 23.5 degrees. Observe the amount of the ball that is always illuminated. Observe where the direct rays of the sun strike. In each of the four positions observe which hemisphere receives the slanting rays of the sun.

Repeat the experiment with the needle perpendicular to the table top in each of the four positions and observe what would happen if the axis of the earth were not inclined.

7 Demonstrating the cause of difference in length of day and night in some places

Use the same apparatus as in 6 above. Mark a circle on the ball around its centre to represent the equator. Place dots on the ball to represent cities on the equator, in the northern hemisphere and in the southern hemisphere. Place the ball at each of the four positions again but this time rotate the earth on its axis in each position and observe how long the various city positions you have marked are in the light and how long in shadow. Can you observe when each pole has six months of day and six months of night?

8 Demonstrating the effects of the angle of the sun's rays on the amount of heat and light received by the earth

Bend a piece of cardboard and make a square tube 4 cm² in cross section and 32 cm in length. Secure a piece of very stiff cardboard and cut a strip 23 cm long and 2 cm wide. Paste this to one side of the tube with 15 cm extending. Rest the end of the stiff cardboard on the table and incline the tube at an angle of about 25 degrees. Hold a flashlight or lighted candle at the upper end of the tube and mark off the area on the table that is covered by the light through the tube. Repeat the experiment with the tube at an angle of about 15 degrees. Repeat again with the tube vertical. Compare the size of the three spots and determine the area of each. Is the amount of heat and light received from the sun greater when the rays are slanting or direct?

9 Making a shadow stick

In an open space on the school ground drive a 130 cm stick into the ground and let the children keep a record of the length of the shadow, measured two or three times a day at different seasons of the year.

10 Demonstrating how the angle of the sun's rays changes from day to day at the same hour

Cut a 1-cm round hole in a piece of paper or cardboard. Place this in a south window of your classroom where the sun's rays will shine through the hole and strike a piece of white paper on the floor, the table or window sill. Draw the outline of the spot where the beam of light strikes the paper. Write the date and hour inside the outline. Repeat this on succeeding days at exactly the same hour.

E. EXPERIMENTS RELATED TO THE MOON

1 Observing the surface of the moon

Use the small telescope described on page 67 or a pair of field glasses. Study the surface of the moon and see if you can see any of its craters and mountains.

2 Observing the phases of the moon

Over the period of a lunar month have the children make nightly observations and sketch drawings of the moon. Begin at new moon and continue through the four phases.

3 Demonstrating the cause of the phases of the moon

Place a lighted candle or electric lamp on a table in a darkened room. Paint an 8 cm rubber ball white. Hold the ball in your hand at arm's length with your back to the light. Raise the ball enough above your head to allow the light to strike the ball. Note the part of the ball illuminated by the candle. This represents the full moon. Now turn around slowly from right to left keeping the ball in front of you and above your head. Observe the change in shape of the illuminated part of the ball as you make one complete turn. Do you see the various phases of the moon? Now repeat the turning but stop at each one eighth turn and have someone else draw the shape of the moon (ball) that is illuminated.

4 Demonstrating an eclipse of the moon

Use a flash light or a lighted candle in a darkened room to represent the sun. Hold an 8 cm rubber ball in one hand to represent the earth. Hold a 2-cm ball in the other hand to represent the moon. Hold the ball representing the earth in the beam of light from the flash light and observe the shadow cast by the earth. Next pass the smaller ball or moon behind the earth into the shadow. The moon will be in eclipse while it passes through the earth's shadow.

CHAPTER VII

Experiments and materials for the study of air and air pressure

We live at the bottom of an ocean of air which is one of the essentials for life. Man also makes use of air pressure in many of his daily tasks. Air and air pressure should be a subject of study for every boy and girl.

A. TO SHOW WHERE AIR MAY BE FOUND

1 Plunge a narrow-necked bottle, mouth down into a jar of water. Slowly tip the mouth of the bottle toward the surface of the water. What do you observe? Was the bottle empty?

2 Place a lump of soil in a container of water and observe. Did you see anything that might indicate the presence of air in the soil?

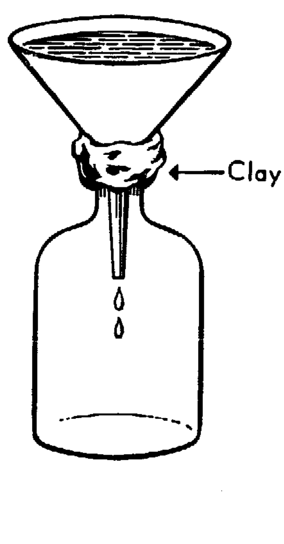
3 Secure a brick and place it in a container of water. Is there any evidence that air was inside the brick?

4 Fill a glass with water and observe it closely. Let the glass stand in a warm place for several hours. Observe again. What difference do you see? Is there any evidence that water contains air?

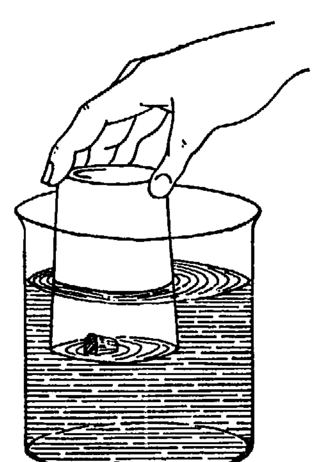
B. TO SHOW THAT AIR TAKES UP SPACE

1 Secure a bottle and a funnel. Place the funnel in the neck of the bottle. Fill the space around the funnel with modelling clay. Be sure to pack the moist clay tightly in the neck of the bottle. Pour water slowly into the funnel. What do you observe? What does this show about air?

2 Repeat experiment 1 above and pour water into the funnel until it comes nearly to the top. Carefully punch a hole through the modelling clay into the inside of the bottle with a nail. What did you observe? Why did it happen?

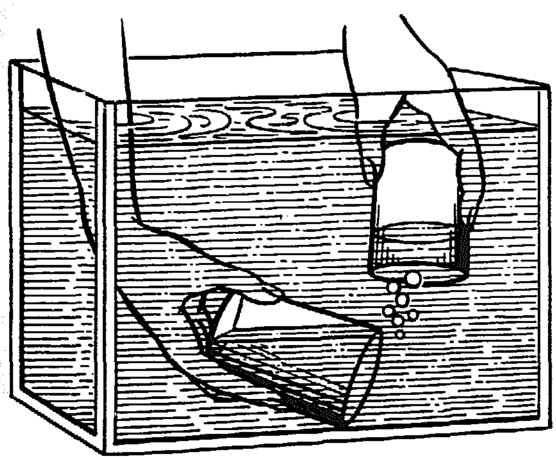


3 Float a cork on a large glass jar half full of water. Lower a drinking glass, mouth downward over the cork. What do you



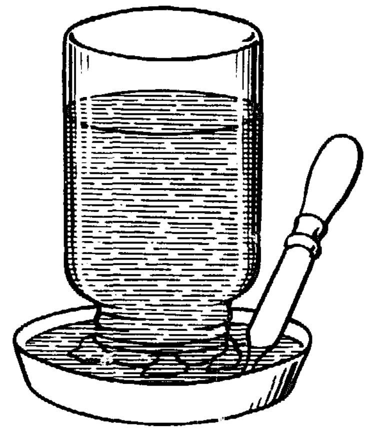
observe? Wedge a piece of paper tightly into the bottom of the glass and repeat. Does the paper get wet?

4 Secure an aquarium or a big water bowl and fill it nearly full of water. Lower a drinking glass, mouth downward into the aquarium. With your other hand lower another glass into the aquarium. Let this glass fill with water by tilting its mouth upward. Now hold the second glass above the first one mouth downward. Slowly tilt the first glass to let the air escape slowly. Fill the second glass with air from the first glass. What does this show about air?



5 Place a tall glass jar in the aquarium. Let it fill with water and stand, mouth down, on the bottom. Place a rubber tube or a soda straw under the edge of the bottle and gently blow into the tube. What does this show about air?

6 Invert a tall glass jar filled with water in a shallow pan of water. This may be done by first filling the jar, placing a piece of glass or cardboard over the mouth and then inverting it in the pan of water. Remove the cover under the water in the pan. Raise



the edge of the jar a little and place the end of a medicine dropper under it. Squeeze the bulb of the medicine dropper and observe what happens. This may be repeated several times. What does this show about air?

7 Secure a bottle with a tightly fitting cork or rubber stopper. Fill the bottle with water except for a small bubble of air. Turn the bottle on its side and try to make the bubble of air disappear by pressing on the cork. What do you observe? What does this show about air?

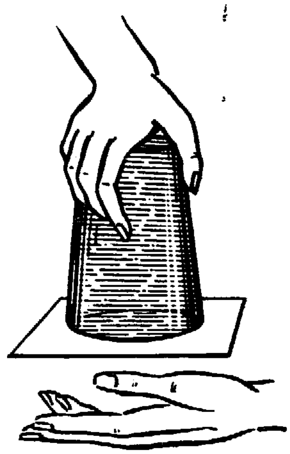
C. TO SHOW THAT AIR HAS WEIGHT

1 Drive a thin nail through the exact centre of a long rod such as a metre stick or a yard stick. Balance the stick by resting the nail on the rims of two drinking glasses. Make a rider out of a short length of wire and place it on the end of the stick which needs weight to balance. Move the rider until the stick balances perfectly. Hang a rubber balloon and a rubber band on one end of the stick. Now counterbalance the balloon exactly with some weight on the other end of the stick. Mark the place on the stick where the balloon and counter-weight were placed. Remove the balloon and inflate it, using a bicycle pump. Close with the rubber band. Next hang the balloon and counterweight exactly where they were before. What do you observe? What does this show about air? It must be remembered however, that the balloon increases in volume and so *displaces* more air. The resulting increased buoyancy complicates the experiment, but an increase in weight can be observed if the balloon is blown up hard. This difficulty can be avoided if a metal hot-water-bottle fitted with a cycle valve is used instead of the balloon.

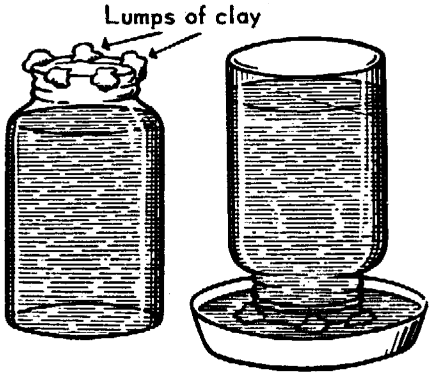
D. TO SHOW THAT AIR EXERTS PRESSURE

1 Fill a drinking glass to the brim with water. Place a piece of cardboard over it. Hold the cardboard against the glass and turn the glass upside down. Take away the hand holding the cardboard.

Place the inverted glass on a smooth table top and carefully slide it off the cardboard on to the table top. Move the glass slowly over the table top. Can you suggest a way to empty the glass without spilling the water on the table top? What does this experiment show about air?

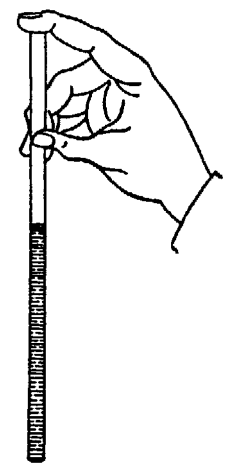


2 Select a tall glass jar and place a few lumps of clay on its rim. Fill the jar with water. Place a saucer on the clay and then invert the tall jar and saucer. This device can be used as a drinking fountain for chickens. Why does the water stay in the jar? Remove a little of the water from the saucer. What happens? Why?

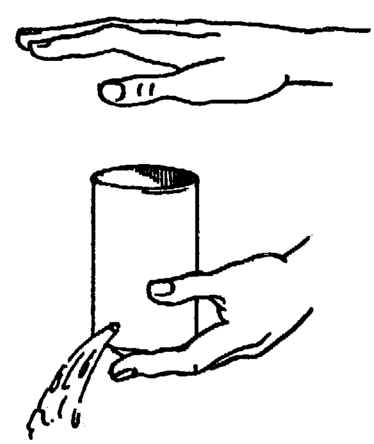


3 Secure a piece of thin board about 5 cm wide and 60 cm long. Place the board on a table with about 25 cm sticking over the edge. Now take a sheet of newspaper and spread it out so that the part of the board on the table is completely covered. Next carefully press all the air from under the paper by stroking with your hands from the centre of the paper toward the edges. The success of this experiment depends on how well you remove the air from under the paper. When this has been done have someone strike a sharp blow with a stick near the extended end of the board. What happens? What does this show about air?

4 Hold a finger over the end of a piece of straight glass tube or soda straw and lower it into a jar of coloured water. Remove the finger and observe what happens. Replace the finger on the top of the tube and then lift the tube from the jar. What happens? Why? What does this show about air?



5 Make a hole with a nail near the bottom of a tin can. Fill the can with water. Hold the palm of the hand tightly over the top and water will stop running from the hole. Remove the hand and water runs from the hole. What does this show?

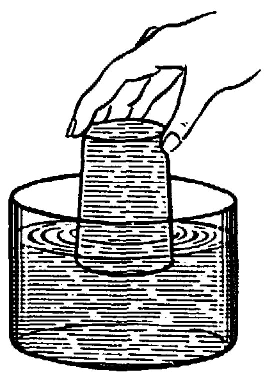


6 Select a tall glass jar or bottle. Screw up some paper, set fire to it and drop it in the container. Quickly stretch a rubber balloon over the mouth of the container or hold a piece of rubber tightly to the top. What do you observe? Can you explain why this happened?

7 Boil an egg for ten minutes or until it is very hard. Remove the shell. Select a bottle with a neck through which the egg can be forced without breaking the hard white of the egg. A quart or litre milk bottle will work very well. Screw up a piece of paper, set fire to it and drop it in the bottle. Quickly place the

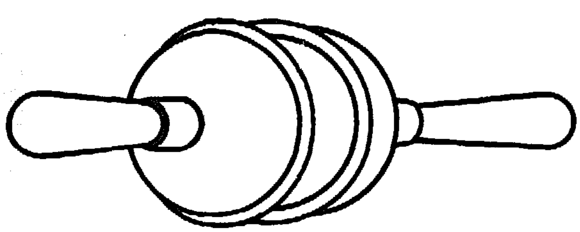
egg, pointed end down, in the mouth of the bottle. What happens? How do you explain this? To get the egg out, turn the bottle upside down. Let the egg rest, pointed end down, in the neck of the bottle. Now blow hard into the bottle and observe the results.

8 Submerge a drinking glass in a large container of water. Be sure the glass is filled with water. Lift the glass up with the mouth down, until the glass is nearly out of the water. Why does the water not run out of the glass?



9 Wet the bottom of a plumber's force cup and press it against some flat surface such as the top of a stool. Try to lift the stool with the stopper. Why is this possible?

10 Wet the rims of two plumber's force cups. Press the rubber cups tightly together and then try to separate them. Why is it so difficult to pull them apart? This experiment is similar to the classic Magdeburg Hemispheres experiment.



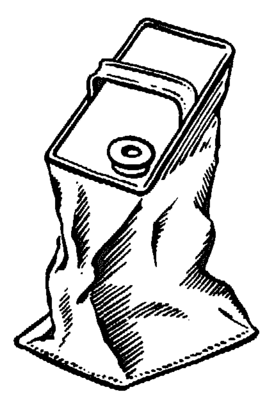
11 Blow a small amount of air into a balloon held in your mouth. Bring the balloon close to a table top and press two tea cups against the sides of the balloon. Blow a little more air into the balloon and then close the mouth of the balloon by pinching it. If the experiment has been carefully done you can lift the two cups with the balloon. What holds the cups to the balloon?

12 Select two thick drinking glasses and fit one of them with a collar of moist blotting paper. Screw up a piece of paper, light it and drop it into one glass standing on the table. Quickly press the other inverted glass tightly to the blotting paper. Can you pick up the bottom glass by lifting the top one? Why?

13 Select two thick drinking glasses. Fill each with water. Place a piece of paper over one and invert it over the other so that the rims fit closely together. Remove the paper. What happens? Why?

14 Place about 3 cm of water in a tin can which has a screw top. Place the can *open* on a stove and heat until the water boils and steam issues from the open stop. Quickly remove from the fire and screw the cap on very tightly. Allow the can to stand and observe the results. The effect can be hastened by running cold water over the can or by immersing it in a dish pan of cold water. Unless the tin has been perforated, it can be blown out for use again by heating it gently.

Plastic bottles or drums used in the home as containers for detergents can be used for a similar experiment. Remove the cap and place the bottle in hot water up to the neck for a few minutes. Replace the cap and plunge the bottle into cold water. Explain what happens.

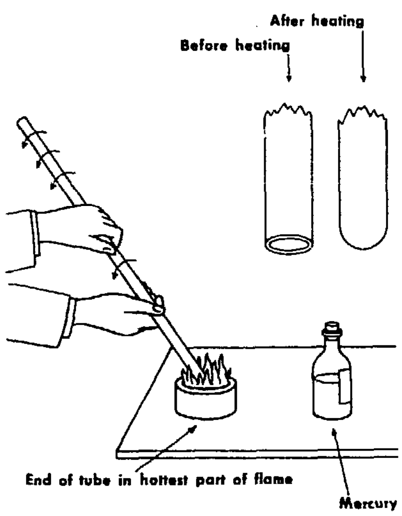


15 Remove the brass shell from a used electric bulb by gently heating it in a gas or alcohol flame. When the sealing wax begins to smoke, grasp the shell with a pair of pliers and twist it away from the glass bulb. Observe the end of the sealed tube, extending from the bulb, through which the air was removed. Place the bulb tube end down in a jar of coloured water. With a pair of pliers, snip the end of the tube (while under water). What happens? How do you explain this?

E. TO MEASURE AIR PRESSURE

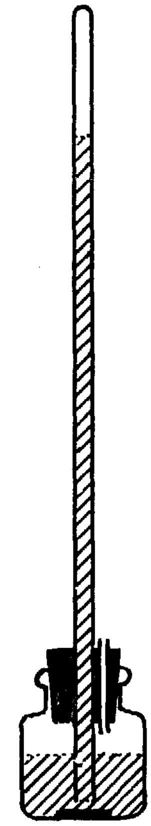
1 A simple mercury barometer

Seal one end of a glass tube about 80 cm in length by rotating it in a gas flame. The tube should be held as nearly vertical as possible. Attach a small funnel or thistle tube to the open end of your barometer tube with a short length of rubber tube. Pour mercury into the tube slowly. If air bubbles are trapped they may be removed by gently shaking the mercury in the tube up and down. Fill the tube to within 1 cm of the top. The last part is best filled by using a medicine dropper so that mercury will not be wasted. Fill the tube until a little mercury extends above the tube level. Pour about two centimetres of mercury into a bottle or dish. Place your finger over the end of the tube and place the tube open end down in the jar of mercury. Remove the finger from the tube when it is under the surface of the mercury. When this tube is properly supported it will serve as a mercury barometer. The height of the mercury between the levels in the jar and the tube measures the air pressure in centimetres or inches of mercury.



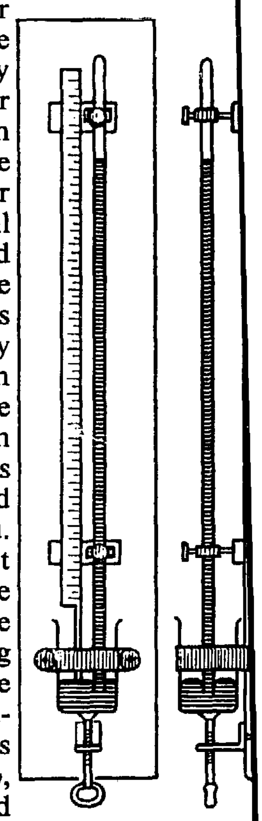
An ink bottle can be used as a container for the mercury in a permanent barometer and will help keep the surface clean. The following procedure may be used to set it up. Before filling the tube with mercury as described, find a cork which fits the barometer tube. Place the cork on the tube at about 15 cm from the open end and cut a small nick along one side. Now stick a rubber cycle patch onto the bottom of the bottle just opposite the mouth. Fill the barometer tube as described and place the bottle neck downwards over the open end, pressing the patch hard onto the top of the tube. Keeping the tube in contact with the patch, turn both over and stand the bottle on the bench. Still pressing on the tube, pour some mercury into the bottle. Now raise the tube a little to allow mercury to run from the tube, and push the cork into the neck of the bottle.

If desired, the barometer may now be supported in a bracket with a metre scale attached to it and hung on a wall. The top of the barometer tube should then be supported, and the ink bottle can be made to fit tightly in a tin fastened to the bracket. The effect of changing the pressure on the surface can be demonstrated by blowing or sucking through the nick in the cork of the mercury reservoir.



2 Fortin type barometer

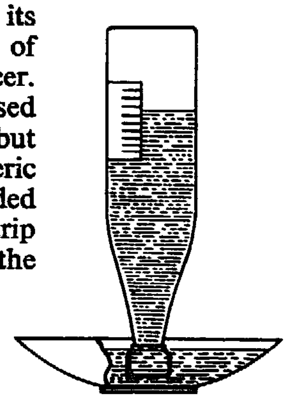
A simple Fortin type barometer can be improvised for the junior laboratory. The glass tube is held vertically with one end in the reservoir by two curtain-rod holders on wooden blocks, fixed to the back board. The reservoir is a potted meat jar or small beaker, which can be moved bodily up or down by the screw jaw of a G-clamp. This alters the level of the mercury and keeps it in contact with the bottom of the scale. The reservoir is prevented from slipping sideways by a brass collar, fitting loosely and attached to the back board. The scale is cut down so that the first 10 cm can reach the surface of the mercury in the reservoir, or an ivory knitting needle can be substituted. The scale is screwed to the wooden blocks holding the glass tube supports. For setting up, the reservoir should be filled



to the top, otherwise it is difficult to get the open end of the tube under the surface. Any excess can then be siphoned off. A carboard disc may be fitted to keep the mercury clean; it also serves to keep out little boys' fingers.

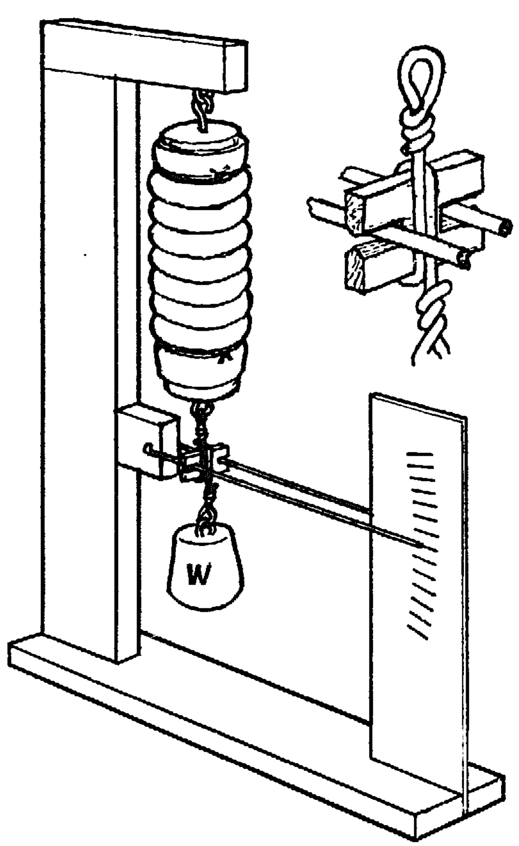
3 A bottle barometer

A bottle, partly filled with water, is inverted with its neck under the surface of more water in a saucer. This is the device used as a chicken feeder, but variations in atmospheric pressure can be recorded approximately on a strip of paper stuck on the outside.



4 An aneroid barometer

The corrugated rubber tube from a gas mask, or a cycle handle grip, can be used to make a model aneroid barometer. No great accuracy is to be expected because of the many possible errors.



Two good corks or pieces of non-porous wood are needed to close the ends of the tube, which serves as a vacuum box. They are fitted when the rubber is compressed and they should be made airtight with wax and by tying string round the outside of the rubber.

A weight hung from the lower cork will partially counteract the result of atmospheric pressure and extend the bellows.

Variations in atmospheric pressure can be indicated by a magnifying pointer.

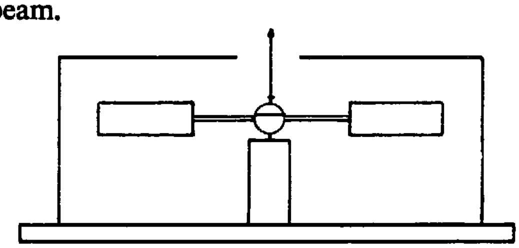
5 A balance barometer

This device depends on the fact that dry air is heavier than moist air at the same temperature.

Two equal cylinders (tin cans would do) are mounted, one at each end of the beam of a sensitive balance. Zehnder's arrangement (page 33) is quite satisfactory for this purpose.

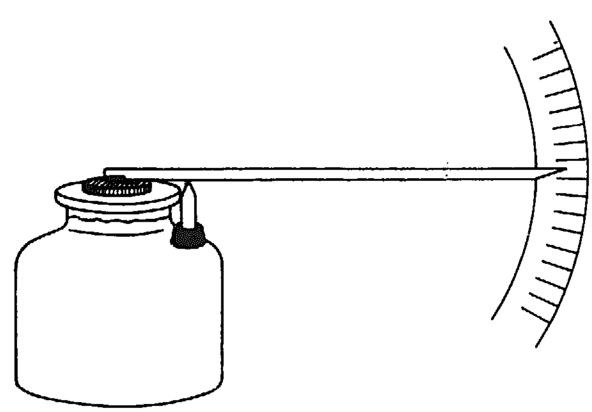
One of the cylinders is sealed as a standard specimen of air; the other has a hole in it so that air from the atmosphere can enter. The device would, of course, work on simple buoyancy with one cylinder only, but it is easier to balance it using two cylinders.

It must be mounted in a box to shield it from draughts, and an indicator projecting through the top indicates the position of the beam.



6 Another aneroid barometer

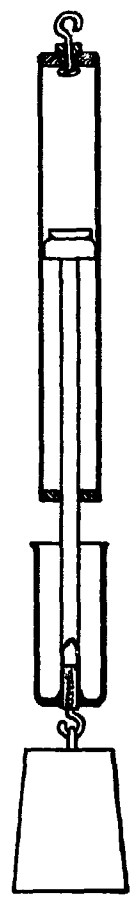
Stretch a piece of thin rubber over the mouth of a small glass jar. Wind thread or string over the rubber to secure it and then put a ring of household cement under the edges of the rubber sheet which have been trimmed off.



Cut a thin circle from the end of a cork and glue this to the centre of the rubber. Next glue a long broom splint or soda straw to the cork. Cut a little wooden triangle from a match stem and glue to the edge of the bottle so that the splint or soda straw rests on it. A scale can be made and placed behind the end of the splint.

7 Measuring atmospheric pressure with a bicycle pump

A bicycle pump with the washer reversed as shown can be used to measure atmospheric pressure. The piston can be made airtight by adding a little thick oil to the barrel. The area of cross section of the pump barrel can be calculated or measured with squared paper. The pressure of the air can then be calculated in kg/cm^2. The weight supported by the upthrust of atmospheric pressure is found by hanging various loads from a hook, screwed into a wooden plug fitted into the pump handle.

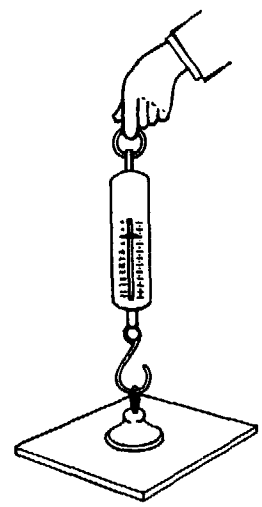


8 Measuring atmospheric pressure with a rubber sucker

The force required to pull the sucker away from a smooth surface can be found by using a spring balance. The area on which the atmospheric pressure is acting can be measured by pressing the sucker on a piece of squared paper.

Use a sucker which has a hook attached. If one is not available, tie some copper wire round the neck and form a loop.

If the laboratory bench is not smooth enough use a piece of plate glass, holding this down with one hand whilst pulling on the spring balance with the other. Make several trials and, if possible, use suckers of different sizes.



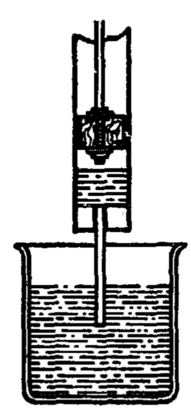
F. TO SHOW HOW PUMPS USE AIR PRESSURE

1 How different pressures of air force water from a container

Fit a test tube with a two-hole stopper. Through one hole place a length of glass tube which extends into the test tube nearly to the bottom. Put water in the test tube and suck on the upper end of the glass tube. Observe what happens. Next tightly close the open hole in the rubber stopper and again suck on the glass tube. Observe what happens. How do you account for the difference?

2 A simple syringe pump

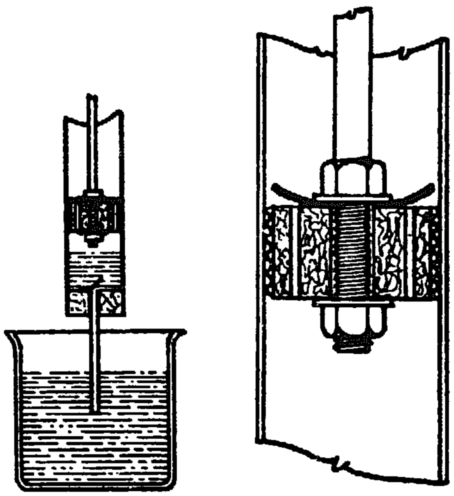
Assemble a simple syringe using glass or metal tubing (iron pipe or conduit tubing is suitable), two corks and a piece of metal rod. The cork which serves as the piston is made to fit tight by wrapping a string round it.



The other cork, with a piece of glass, bamboo or strong straw tubing, acts as an intake.

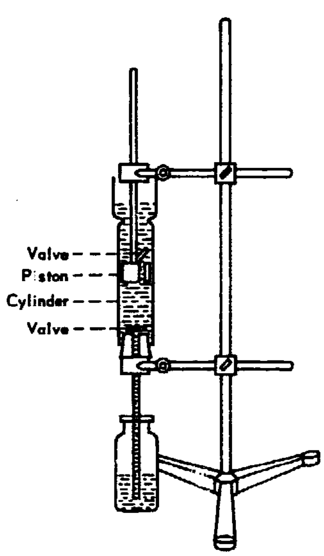
3 A lift pump

To modify the syringe and make a simple lift pump, burn two holes through the piston with a hot wire and fit a thin piece of leather or rubber above them to act as a valve which closes on the upstroke and yet allows liquid to pass through on the downstroke.



4 A lamp chimney lift pump

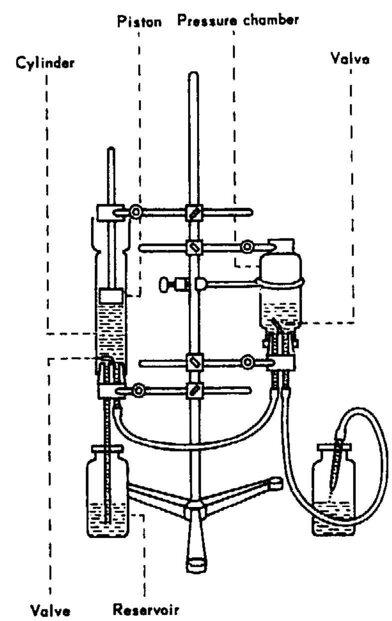
Use a straight-sided lamp chimney as a pump cylinder. Fit a two-hole stopper into the chimney for a piston. If the stopper is a little small wrap some string around it to make a tight fit. If it is a little large you can make it smaller with sand paper. Through one hole put an iron or brass rod for a piston rod. Cover the other hole on top of the stopper with a little flap of rubber or soft leather cut from an old shoe. This will be the piston valve. It can be held in place with a tack pushed into the stopper.



Fit a one-hole stopper carrying a 50-cm length of glass tube into the lower end of the lamp chimney. Over the hole in the stopper place another valve of rubber or soft leather. This is the foot valve. Put water in a pan. Prime the pump by pouring a little water on top of the piston. Observe the valves on the upstroke and on the downstroke of the piston. How does air pressure help the lift pump to work?

5 A lamp chimney force pump

Replace the piston in the lift pump described above with a one-hole stopper. Fit the piston rod through the hole. Fit the bottom of the chimney with a two-hole stopper. Through one hole place a 50-cm length of glass tube and put a valve over it. Through the other hole put a short length of glass tube. Next fit a glass bottle with a two-hole stopper. Put short lengths of glass tube through each hole flush with the underside of the stopper.



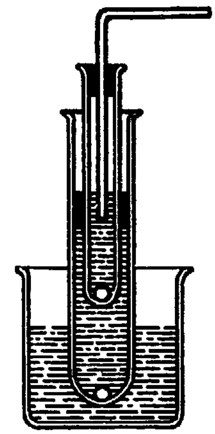
Place a valve over one of the holes. Clamp the pump firmly in a ringstand. Also clamp the bottle to the ringstand upside down. Place a clamp under the stopper and another on top of the bottle to hold it firmly in place. Now connect the outlet tube of the pump (the one without the valve) to the inlet tube of the bottle (the one with the valve). To the outlet tube of the bottle (pressure chamber) connect a length of rubber tube with a nozzle or jet tube (like a medicine dropper) in it. Prime your pump and see how far you can force the water. Observe the valves. How does air play a part in the operation of this pump? How does it differ from the lift pump? For what purpose could this pump be used?

F. *To show how pumps use air pressure*

6 A test tube force pump

To make this apparatus, heat the bottom of a test tube with a small flame and blow a hole. Now blow a hole in a larger test tube and fit both with ball bearings or small marbles to act as valves.

If the inner one is made to slide tightly in the outer one by wrapping string round it, and has a cork and tube as shown in the diagram, it will serve as the piston of a force pump.



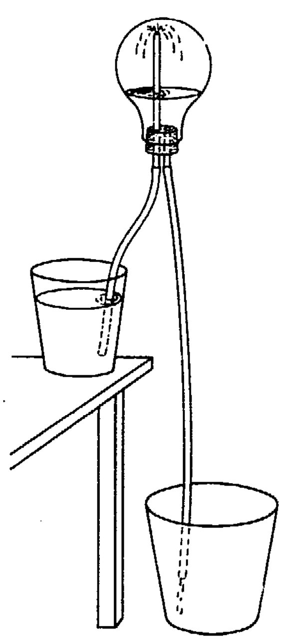
G. TO SHOW HOW SIPHONS USE AIR PRESSURE

1 A simple siphon

Secure two tall glass bottles and fill each about half full of water. Connect two 30-cm lengths of glass tube with a 30-cm length of rubber or plastic tubing. Fill the tube with water and pinch it. Put a glass tube in each bottle of water. Siphon the water back and forth by varying the height of the bottles. The experiment is more interesting if the water is coloured with a little ink. Place the two bottles on a table. Does the siphon flow? Can you explain how air pressure helps the siphon work?

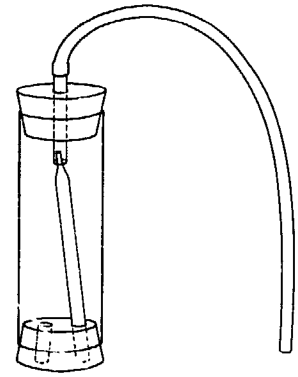
2 A siphon fountain

Fit a glass jar (a flask from a used electric bulb) with a two-hole rubber stopper. Through one hole place a jet tube which will extend about half way to the top of the flask and let about 2 cm extend beyond the stopper. Through the other hole push a short length of glass tube so that it is just flush with the bottom of the stopper. Let about 2 cm of tube extend outside the stopper. Connect a 20-cm length of rubber tube to the jet tube. Connect a 1-m length to the other glass tube. Place some water in the flask, insert the stopper and then invert the siphon. Put the short rubber tube in a container of water on the table and let the longer rubber tube go to a pail on the floor. The fountain can be seen better if the water in the jar on the table is coloured with a little ink. You can make a double siphon fountain by making another flask unit similar to the first one and connecting them together.



3 A self-starting siphon

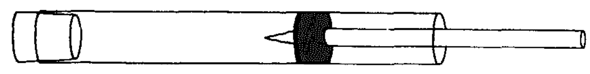
Secure a piece of glass or plastic tube about 2.5 cm in diameter and 8 to 10 cm in length. Fit one end with a one-hole stopper, carrying a short length of glass tube that extends about a centimetre below the stopper on the inner side. Fit the other end of the big tube with a two-hole stopper. Through one of the holes in the two-hole stopper place a jet tube which extends up through the larger tube and into the opening of the glass tube in the one-hole stopper. Connect a long rubber tube to the glass tube in the one-hole stopper. Plunge the assembled unit into a pail of water that is standing on a table and direct the longer end of the siphon tube to a container on the floor. The siphon may require some adjustment before it starts to flow.



H. TO SHOW SOME EFFECTS OF COMPRESSED AIR

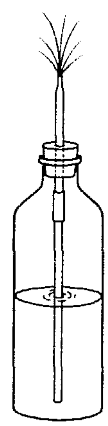
1 To feel the 'spring' of air

Secure a bicycle pump and place your thumb over the end of the outlet tube. Next push the piston in forcibly and quickly let go of it. What happens? How do you account for this?



2 Making a 'gusher' with compressed air

Secure a large narrow-necked bottle such as is used for soda water. Place a one-hole stopper in the bottle. Through the stopper put a 10-cm length of glass tube which has been drawn to a jet on the outside end. With a short length of rubber tube attach a length of glass tube that will extend nearly to the bottom of the bottle. Fill the bottle about half full of water. Insert the stopper firmly and hold it in with your fingers. Next blow hard into the bottle; and when you release the pressure, point the bottle away from you. What happens?



3 A compressed air pop-gun

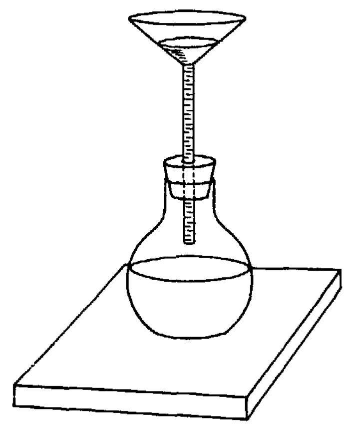
Use a straight piece of glass or plastic tubing of 1 or 2 cm in diameter and 15 or 20 cm in length. Make a piston by winding some string on a pencil till it fits tightly in the tube. Put a small cork in the end of the tube and push the piston in quickly.

4 Lifting things with compressed air

Remove the bladder from a soccer ball or basket ball and place it on a table. Pile some books on the bladder and then blow into it.

5 Making a 'burp' bottle

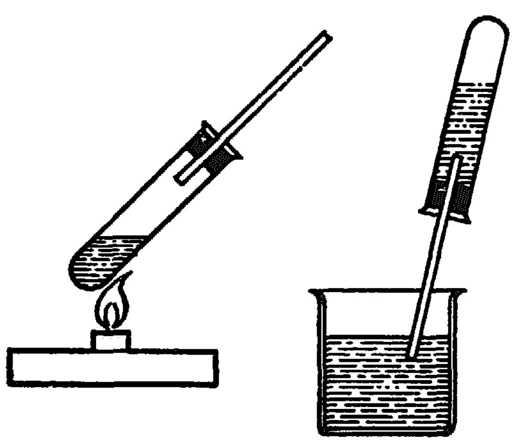
Fit a bottle or flask with a one-hole stopper which carries a funnel. Put the stopper firmly in the bottle and then pour water into the funnel. The bottle will 'burp' at regular intervals.



I. TO SHOW SOME RESULTS OF REDUCING AIR PRESSURE

1 Lifting water with air pressure

Fit a test tube with a one-hole cork and glass tube. Drive out the air by boiling a little water in it. Invert it with the open end under the surface of a jar of water. Atmospheric pressure will drive water upwards until it almost completely fills the test tube.

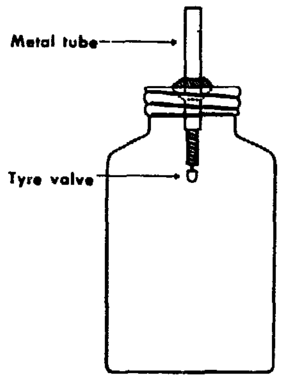


2 How to make a simple vacuum pump

Secure a bicycle or automobile hand pump. Open the pump and remove the piston. Unscrew the bolt that holds the leather washers. Reverse the washers by turning them over. Replace the washers on the piston and insert in the pump cylinder. A pump of this sort will serve to do many simple vacuum experiments.

3 How to make a receiver for vacuum experiments

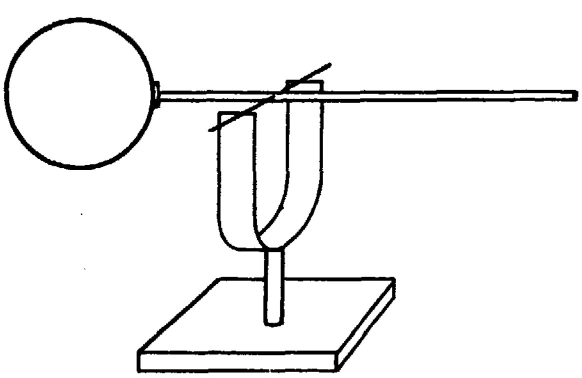
Secure a large jar with an air-tight screw cap, such as a fruit jar. Drill a hole through the top and have a short metal tube soldered in the hole so that it is air-tight. Solder a tyre valve upside down in the lower end of the tube.



The tyre valve mentioned in this experiment can be fitted into a good cork in the neck of a Winchester bottle with the bottom cut off (page 218). If the edges are ground smooth with carborundum stone or hard rock a sheet of rubber cut from a large tractor tube can be use as a base plate to make an air-tight seal. The baroscope described below can be introduced into this bell jar.

4 Model baroscope

Glue one end of a drinking straw (or better, a strip of balsa wood) so that it forms a beam perpendicular to the surface of a ping-pong ball. Find the point of balance and stick a fine needle through the beam to act as pivot. Rest this on a piece of metal bent into a U shape and supported on a base. Shave away the beam with a razor blade until the balance is perfect. Place this under the bell jar and pump out some of the air. Explain what happens.



5 An experiment with a balloon

Partially inflate a small rubber balloon and close it with a rubber band. Place the balloon in the receiver and remove some of the air with your pump.

6 An experiment with a bottle and cork

Tightly close a small bottle with a cork or rubber stopper. Place the bottle inside the receiver and remove some of the air with the pump. What happens? How do you account for this?

7 Moving water by reducing air pressure

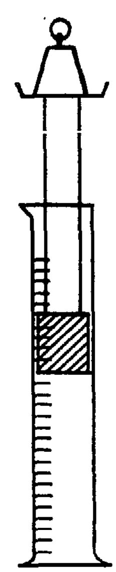
Secure two small bottles. Fill one about half full of water and close it with a one-hole stopper carrying a length of glass tube that reaches nearly to the bottom of the bottle. Attach a short length of rubber tube which empties into the other bottle. Place these in the receiver jar and remove some of the air with the pump. What happens? How do you account for this? If you wish, you may colour the water with ink.

8 Another balloon experiment

Stretch a rubber balloon over the neck of a small bottle. Place it in the receiver jar and remove some of the air with the pump. What happens? How do you account for this?

9 To study the relation between volume and pressure of air

Obtain a rubber bung or 'door stop' which just fits inside a narrow glass jar or measuring cylinder. Attach it to the lower end of a wooden rod. Fit a tin lid to the upper end of the rod to act as a scale pan. Lubricate the piston so formed with a little vaseline or heavy engine oil. Use the piston to trap air in the jar; put different weights on the pan and measure the volume of air inside the glass cylinder for each weight. Note that the volume is in inverse proportion to the pressure.



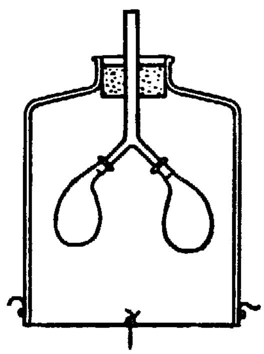
J. AIR IN THE HUMAN BODY

1 How the lungs work

Cut the bottom off a large bottle (see directions, page 218). Fit a cork to the neck with a Y tube in it. On each of the lower limbs of the Y tie a rubber balloon or some small bladder.

Tie a sheet of brown paper or sheet rubber round the bottom of the jar, with a piece of string knotted through a hole and sealed with wax. Pulling this string lowers the diaphragm and air enters the neck of the Y piece causing the balloons to dilate.

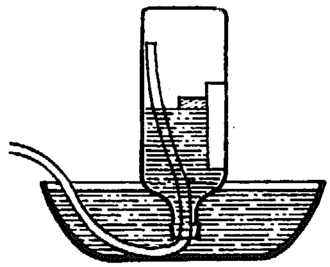
Pressing the diaphragm upwards has the opposite effect.



2 To measure the volume of air in the lungs

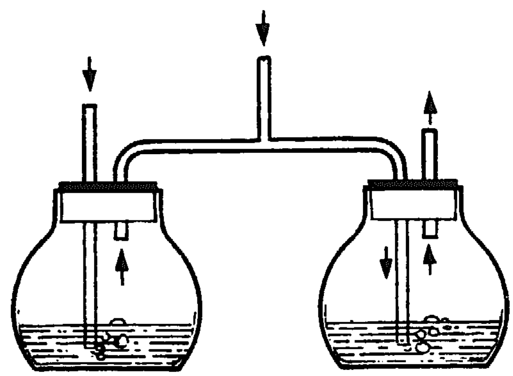
Invert a bottle full of water so that its neck is under the surface of water in a jar. Introduce a glass or rubber tube into the neck and blow one full breath of your lungs into the bottle.

Adjust the level of the water in the bowl so that the pressure of the air in the bottle is the same as that of the atmosphere, and stick a piece of gummed paper on the side of the bottle. Remove the bottle and measure the volume of water required to fill it to this mark.



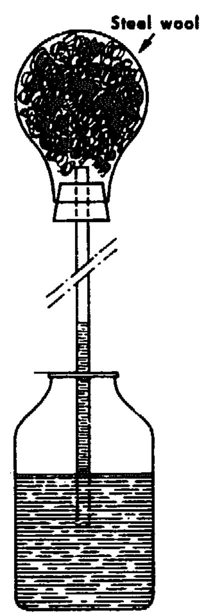
3 To show that expired air contains carbon dioxide

The two flasks are connected so that when you breathe through the T piece, all the air bubbles through the lime water in the flasks. One tube is closed with the finger while the air is drawn in; the other tube is closed when it is expelled.

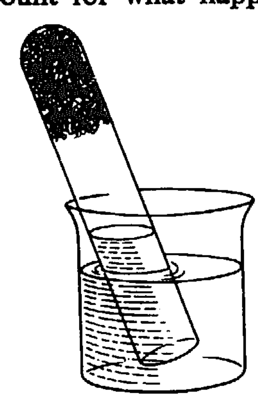


K. TO STUDY SOME CHEMICAL EFFECTS OF AIR

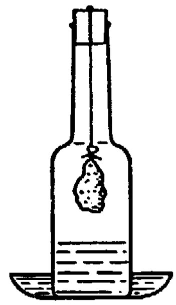
1 Wash a small wad of steel wool in gasoline, benzine or carbon tetrachloride (carbona) to remove any grease. Squeeze it out and then fluff it. As soon as it is dry, place the steel wool in a flask fitted with a one-hole stopper carrying a 40 cm length of glass tube. Stand the flask and tube in a jar of water with the end of the tube under water. Observe for a few hours. What happens? How do you account for it?



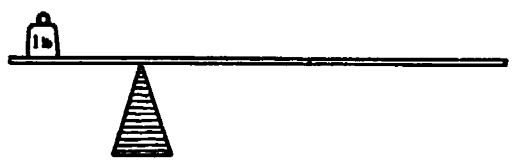
2 Repeat experiment 1, but this time place the steel wool in a small jar or test tube and place in water. Allow to stand for 24 hours. What do you observe? How much of the air in the jar has been replaced? How did the steel wool appear after the experiment? How do you account for what happened?



3 Hang a muslin bag of iron nails, or tin-tacks, from a cork in the top of a lamp chimney. Stand the chimney in a saucer of water. After a time the water will rise up the tube.



4 Counterpoise a steel rule or a piece of iron on a knife edge using a brass weight or a stone. Leave in moist air or on a window sill for a few days and notice the effect of the rust on the longer arm of the lever.

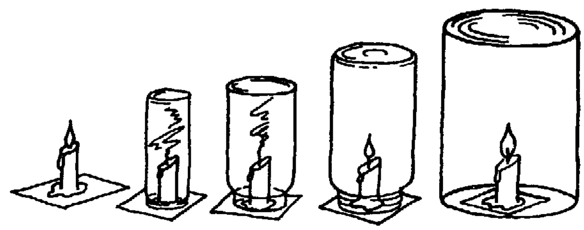


5 Without elaborate equipment it is almost impossible to prove that oxygen is necessary for burning. Yet there are many experiments which show the need for a continuous supply of fresh air to maintain combustion. These experiments will encourage the scientific attitude and help develop habits of critical thinking if carefully drawn conclusions and limited generalizations are made from them. After a suitable background has thus been established, the role of oxygen in burning can be explained.

Attach cardboard bases to several candles so that they stand upright. To do this cut new or used candles into pieces two or three inches long and chip off one end of each so that the wick projects about a quarter of an inch. Ignite a candle and hold it sideways so that melted wax drops off. Drip three or four drops on the centre of several pieces of cardboard. Hold the short candles against these until the wax hardens.

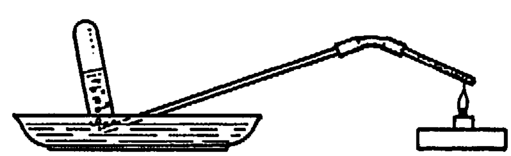
Invert a glass jar over a burning candle held upright by the cardboard candle holder. When the flame disappears, ask pupils for conclusions. Accept no conclusions that are not justified by the evidence. Now ask the class to propose conclusions which they can really justify. After several have been suggested, accept the conclusion that a candle will not continue to burn in a small closed space.

6 Direct four pupils to invert, at a given signal, four glass jars over four burning candles. Half-pint, pint, quart and gallon jars or some similar gradation of sizes may be used. Caution should be observed by the teacher as well as by the pupils in drawing conclusions from this experiment.



7 Fix a piece of candle to the bottom of a shallow pan with melted wax. Put water in the pan to a depth of 2.5 cm or 3 cm. Light the candle and invert a small, straight-sided jar over the candle. When the experiment is over, use a ruler and note the distance the water moved up the jar. Repeat the experiment using jars of different sizes. What do you observe? How do you account for this?

8 A small ignition tube (or a piece of ordinary tubing sealed off to make a 5-cm test tube) should be half filled with potassium permanganate. After connecting a delivery tube it should be heated strongly. The oxygen gas given off can be collected over water in a soup plate.

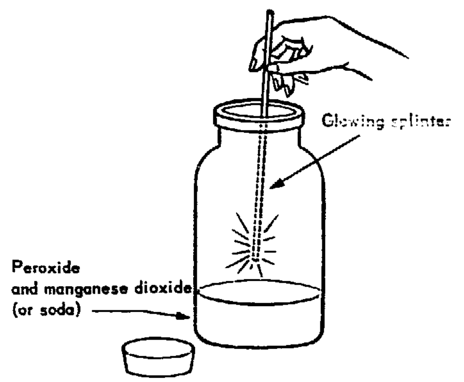


9 Oxygen may also be prepared by heating a mixture of five parts potassium chlorate to one part manganese dioxide in the same apparatus as is used in experiment 8.

10 Into a 100-ml bottle pour about 25 ml of hydrogen peroxide (ordinary drugstore or chain-store peroxide works very well but the kind used for bleaching hair gives off much more oxygen). Add a teaspoonful of manganese dioxide, cork the bottle loosely and leave it for a few minutes. The tiny bubbles that escape from the peroxide are bubbles of oxygen.

To test the gas in the bottle for oxygen, light a long wooden splinter and blow out the flame. Remove the cork from the bottle and insert the glowing splinter into the gas inside the bottle. The splinter should burst into flame.

Instead of manganese dioxide, ordinary baking soda may be used to drive off the oxygen from the hydrogen peroxide, but this reaction takes a little longer.

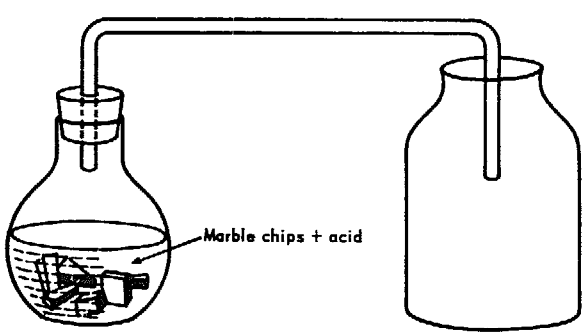


11 Hold the end of a piece of twisted picture wire in a hot flame until it begins to glow. Then quickly lower it into a bottle containing oxygen and watch the iron wire burn. A bit of powdered sulphur on the end of the wire will help.

12 Place a piece of fine steel wool in a metal tray. Ignite the steel wool with a match. The steel burns because it is in very thin strips; the oxygen of the air is in contact with much of the surface.

13 Fasten a strand of steel wool to the end of a wire. Ignite it by holding it in a flame and quickly lower it into a bottle containing oxygen. Notice that it burns more rapidly in oxygen than it does in air.

14 Carbon dioxide may be prepared either from baking soda or marble chips together with a diluted acid. It should be collected by allowing the gas to run into dry bottles or containers which should be covered with glass or cardboard plates.



15 Plunge a burning wood splint into a bottle of carbon dioxide. Does carbon dioxide support burning?

16 Fix a candle in the bottom of a wide glass jar with melted wax. Light the candle and pour carbon dioxide from another jar into the jar with the lighted candle. What does this show about the density of carbon dioxide?

17 Prepare clear lime water by stirring some slaked lime in water (see Chapter XVIII). Let the mixture stand for a day and then siphon the clear liquid into a bottle. This is lime water. Let some carbon dioxide from the generator used in experiment 14 bubble through clear lime water. What do you observe? This is a chemical test for the presence of carbon dioxide.

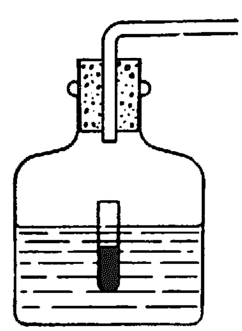
18 Burn a candle in a glass jar until it goes out. Remove the candle and pour in some clear lime water. Shake well and observe. What did you see? What is one of the products of burning from a candle? Repeat using burning wood and paper.

19 Let a burning candle, a piece of burning wood and some burning paper come into contact with a cool, shiny can. What do you observe? What do you believe this to be? Place a basin of cold water over a gas or kerosene flame. After a moment remove and look at the bottom. What other substance is a product of burning wax, wood and paper? Is the substance produced the same as before?

20 A model fire extinguisher can be made from an old ink bottle fitted with a cork and tube. Half fill it with sodium bicarbonate solution and float in it carefully a small pill bottle of sulphuric acid.

To operate the extinguisher shake the bottle so that the acid mixes with the bicarbonate, releasing CO_2.

Aluminium sulphate used instead of the acid provides a foam, especially if a little soap solution is added.

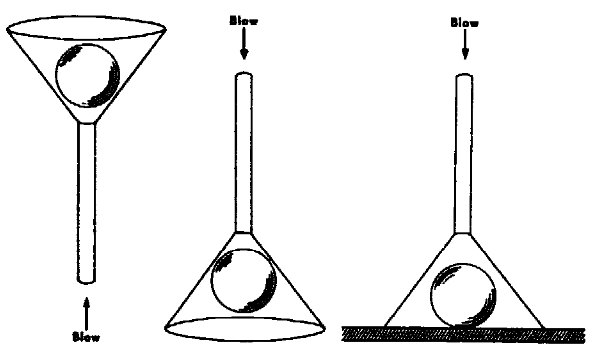


L. EXPERIMENTS WITH AIR STREAMS

When air is moving, air pressure is less where the velocity of the stream is high and greater where the velocity is low. The following experiments apply this principle.

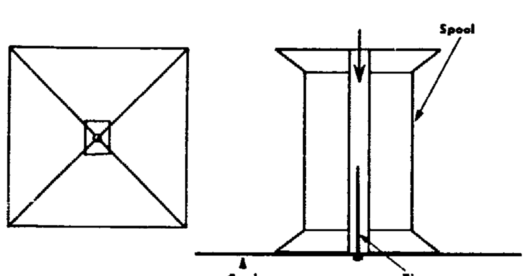
1 Suspend two apples, oranges or ping pong balls on threads at least one metre in length. The suspended objects should be on the same level and should hang about 10 or 15 cm apart. Blow a steady stream of air between the objects and observe what happens. Where was the air stream moving fastest? Where was the pressure reduced? How do you account for what happened?

2 Place a ping pong ball inside a funnel. Blow hard through the stem of the funnel and see if you can blow the ball out of the funnel. Invert the funnel and hold the ping pong ball in the end. Blow hard through the stem and see what happens as you remove your hand holding the ball. Place the ball on a table. Cover it with the funnel. Blow through the stem and see if you pick the ball up from the table. How do you explain your observations?

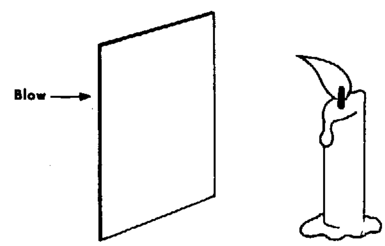


3 Make a bridge from a piece of thin cardboard, 20 cm × 10 cm. Bend down about 2 cm on each end. Place the bridge on the table and try to blow through the arch. The harder you blow the greater the force holding it to the table top.

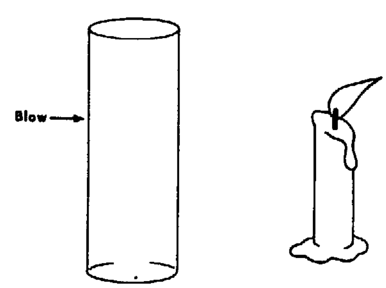
4 Cut a piece of thin cardboard about 7 cm square. Draw diagonals from each corner and put a common pin through the card where the lines cross at the centre. Secure the head of the pin by covering it with a bit of Scotch tape. Place the pin in the hole of an empty thread spool and try to blow the card from spool by blowing through the hole. Turn the spool and card upside down. Hold the card against the spool lightly with a finger. Blow through the spool, then remove the finger. How do you account for this?

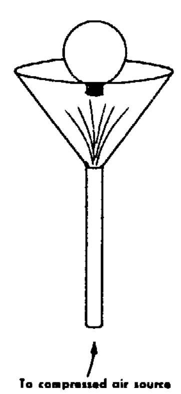


5 Light a candle and hold it behind a card about 5 cm wide. Blow hard toward the card and observe the movement of the flame. How do you account for your observations?



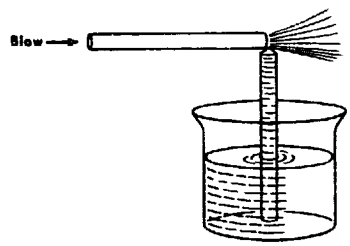
6 Place a lighted candle on a table. Place a bottle in front of the candle. Blow hard against the bottle and observe the flame.





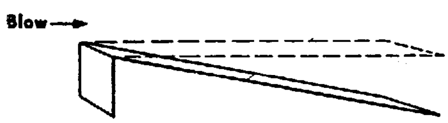
7 Attach a funnel to a source of compressed air such as a vacuum sweeper. Blow up a balloon and place a piece of copper wire around the neck for a weight. Turn on the compressed air and balance the balloon in the air stream. Try also to balance a ping pong ball between the balloon and the funnel.

8 Obtain two glass tubes or two transparent soda straws. Place one tube in a half glass of coloured water. Place the second tube at a



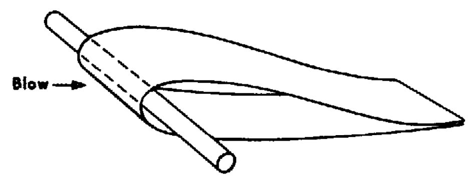
right angle with the first one so that the ends of the two tubes are close together. Blow through the horizontal tube and observe the water level in the second tube. How do you account for the result? Note that the same principle is applied for an atomizer, a DDT or paint sprayer.

9 Take a strip of paper about 30 cm long and 4 cm wide. Fold the paper about 4 cm from one end. Crease the fold well. Now hold the short end of the fold against your chin with the crease about level with your lips. Blow hard across the top surface of the paper and observe what happens. How do you account for this?

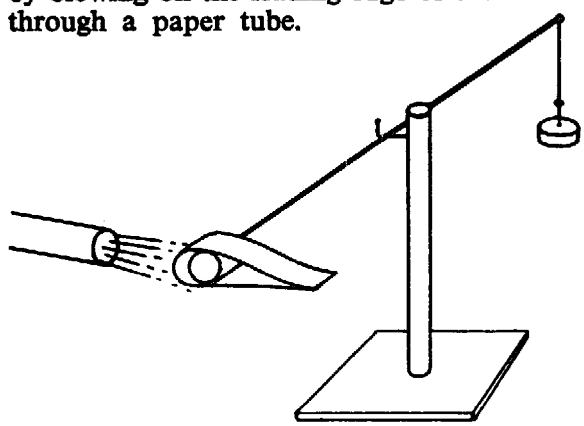


10 Hold your hand flat outside the window of a moving automobile. Then slightly raise the front edge of your hand and notice the lifting effect of the air stream.

11 Make an airfoil section (section of an airplane wing) by folding and glueing a piece of paper as shown in the diagram. Suspend the airfoil section on a pencil or smooth, round rod. Blow a stream of air so that it strikes the leading edge. What do you observe? Can you explain the lift?



A similar airfoil section can be made from sheet metal. It can be attached to one end of a large knitting needle with a cork or piece of dowelling. A notch cut with a file in the middle of the needle can be used as a balancing point, with a bent pin or nail as its pivot. If the beam is balanced with a counterweight, the lift is very easily shown by blowing on the leading edge of the airfoil through a paper tube.



CHAPTER VIII

Experiments and materials for the study of weather

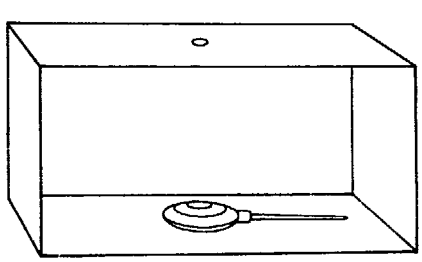
A. MAKING WEATHER INSTRUMENTS AND A WEATHER STATION

Weather is a topic that is close to the life of every child. Even at the lowest levels of primary instruction, observations of the weather may be made from day to day. At the intermediate levels a simple weather station may be set up in the classroom. At the level of general science and later, a more detailed study of the causes of weather phenomena may be made. At all stages of the work it is an advantage to represent readings and observations in graphical form whenever this is possible.

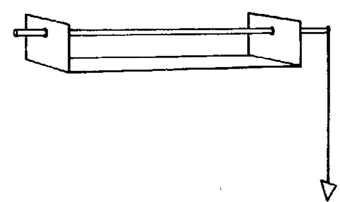
1 An aneroid barometer

A small wooden box such as a cigar box serves well to contain a simple aneroid barometer. Bore a 1-cm hole in the middle of the side to which the cover is hinged. For the pressure mechanism you may use a glass jar with a piece of thin rubber stretched over it and secured as instructed in experiment E 6, page 81. A somewhat better mechanism can be made from a plastic or tin oil-can of the type shown below.

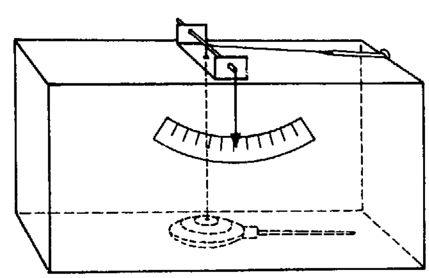
Squeeze the oil-can to force out a little of the air and then seal the end, with plastic cement if a plastic oil-can is used, or solder if it is metal. This pressure mechanism must be absolutely air-tight; so, after the cement or solder has set, try it under water to see if there are any air leaks. If you find some, squeeze out some air and then seal the leaks. Cement the pressure mechanism to the inside of the box so that the centre of the round part falls exactly under the hole you have made in the other side.



Tie a 30-cm length of thread to a short length of match stem and cement to the centre of the pressure mechanism. Cut a piece of metal from a tin can about 1 cm wide and 9 or 10 cm long. Bend at right angles about 1.5 cm from each end of the piece.



With a nail, punch a small hole in the ends of the piece a little way from the top and in the centre. Enlarge the holes so that they will let a small nail or knitting needle turn easily in them. Glue a broom bristle to one end of the needle to serve as a pointer. Securely fasten the metal piece on top of the box so that the needle-axle is across the centre of the hole. Have the broom splint move over the back of the cigar box but not touch it.



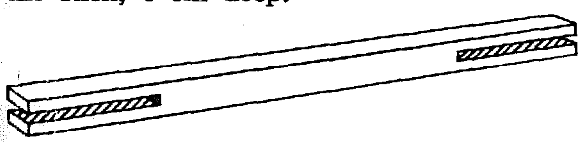
Next put the end of the thread from the pressure mechanism up through the hole. Wind it about the needle axle several times and then tie it to a rubber band. Be sure that the thread from the axle to the pressure mechanism is tight. Stretch the rubber band just enough to place a slight tension on the thread and fasten it to the end of the cigar box with a thumb tack. You may have to change the tension.

Mark off a scale like the one shown and fasten it under the pointer to the back of the cigar box. Arrange the pointer so that it is at the centre of the scale. Set your barometer where you can observe it. As the pointer changes, you can adjust the tension in the rubber band so that it moves properly over the scale. Place the words 'rising' and 'falling' on the proper side of the scale. This is a very sensitive barometer and will clearly indicate changes in air pressure.

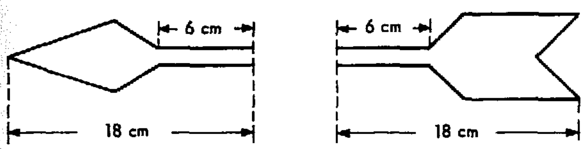
Note reference to other types of barometer in Chapter VII, page 80.

2 A wind vane

A wind vane is used to tell the direction of the wind. Secure a piece of wood about 25 cm in length and 1 cm square. With a saw, cut a slot in the centre of each end of the stick, 6 cm deep.



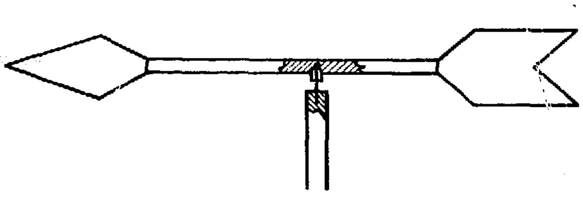
Next select a thin piece of wood about 10 cm wide which will fit tightly in the slots. From this cut two sections, one the head of an arrow and the other the tail, as shown below.



Push the head and tail of the wind vane into the slots and fasten them either with glue or with small nails.

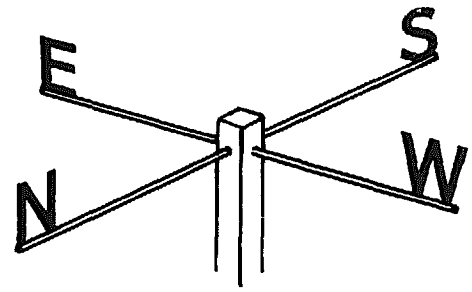
Next balance the wind vane on the blade of a knife and mark the place on the stick where it balances. Secure the glass part of a medicine dropper and close the small end by rotating it in a gas or alcohol flame. At the place where the vane balanced, drill a hole just slightly larger than the medicine-dropper tube about three-quarters of the way through the stick. Put the small end of the tube up in the hole and fasten it securely with glue or putty.

To make a supporting rod for your wind vane select a piece of soft wood about a metre in length and drive a small nail in the top. With a file, sharpen the end of the nail to a point. Place the medicine dropper over



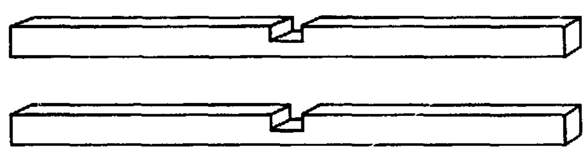
the nail and mount your wind vane on top of a building or on a pole where it is exposed to the wind from all directions.

Fix stout wire arms to the pole and bend the symbols N, E, S, W at the ends, or solder to each free end large letters cut from sheet metal.

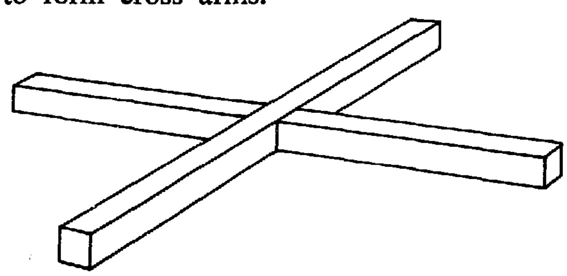


3 A wind speed indicator

Select two pieces of light wood about 50 cm long and 1 cm square. Cut a notch 1 cm wide and about 0.5 cm deep at the exact centre of each piece.



Next fit the sticks together at the notches to form cross arms.



Obtain the glass tube from a medicine dropper and close the small end by rotating in a gas or alcohol flame. At the exact centre of the cross arms drill a hole about three-quarters through the wood and set the medicine-dropper tube securely in the hole with cement or putty. Secure four cigarette tins or small plastic dishes and fasten them to the ends of the cross arms with small nails or screws. Be sure the cups are all facing in the same direction. Prepare a mounting stick for the wind indicator in exactly the same way as you did for the wind vane. Drive a nail in the end of the stick and sharpen it to a point with a file.

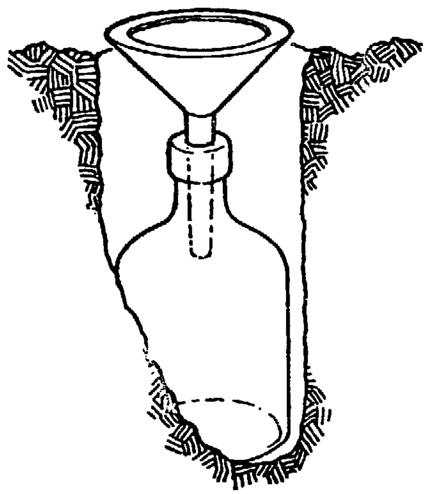
Your wind speed indicator will spin in the wind. You can get a rough idea of the speed of the wind in miles per hour by counting the number of turns made in 30 seconds and dividing by 5. If you wish the result in kilometres per hour you divide again by 0.62.

Another way to determine the wind velocity is to have some one drive you in a car on a calm day. Hold your speed indicator out of the front window and have the driver go steadily at five miles per hour. Count the number of turns in 30 seconds for this speed. Repeat with the driver going at 10, 15, 20, 25, 30, 40, etc. miles per hour.

Mount your wind speed indicator in a place that is exposed to the wind from all directions.

4 A rain gauge

It is easy to make a simple rain gauge using a funnel and bottle, with a measuring cylinder to measure the volume of water.



The funnel should have either a very sharp vertical edge, or a horizontal lip to prevent raindrops bouncing out again. The whole apparatus should be buried so that the funnel is a few centimetres above ground level.

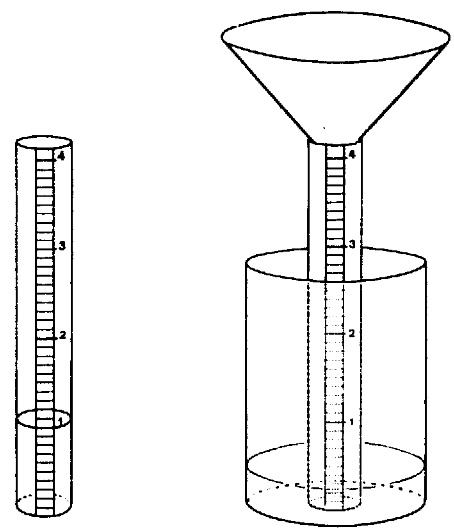
5 Another rain gauge

Procure a large tin can about 10 cm in diameter and 14 cm in height. Almost any can will do. Next secure a straight-sided bottle, such as an olive oil bottle about 3 cm in diameter and at least 25 cm high, that will stand inside the larger can. Place the larger can on a level table and pour water into it until the water is exactly 1 cm deep on a ruler. Paste a strip of paper about 1 cm wide the length of the tall straight-sided jar. Next pour the water from the larger can into the tall jar and make a mark on the paper strip at the level where the 1 cm of water from the larger can comes. Measure the distance from the inside bottom of the tall jar to this mark and mark off equal spaces to the top. Divide the distances between the marks into 10 equal parts to measure millimetres. The small jar will measure small amounts of rainfall.

To assemble the rain gauge place a funnel in the tall jar and then place these in the larger can. Set the rain gauge in an open spot where it will not be easily upset. If the rainfall is light it can be measured by the small jar alone. If it is heavy, excess water will overflow into the larger can and may then be measured by pouring it into the bottle. If the rainfall is to be measured in inches, pour 1 in. of water in the large can and then pour this into the tall jar. Mark the depth to which the 1 in. of water reaches and then divide the scale accordingly.

A better way to determine the rainfall in centimetres or inches is to graduate the smaller measuring bottle in terms of its radius and the radius of the collecting funnel by use of the formula:

$$\left.\begin{array}{l}\text{Height in bottle}\\ \text{for cm or inch of}\\ \text{rainfall}\end{array}\right\} = \frac{(\text{Radius of funnel})^2}{(\text{Radius of bottle})^2}$$



6 A wet and dry bulb hygrometer

Obtain two inexpensive thermometers, and check them in warm water at different temperatures to see that they agree. Attach the two thermometers to a piece of board, about 10 cm apart, with their bulbs projecting and exposed to the air.

Place a small bottle just under the thermometer on the right-hand side. Fasten a wick made from linen cloth or muslin around the exposed bulb and let it dip into the bottle. The bottle should be filled with rain water. This device will help you measure the relative amount of water in the air at any given time.

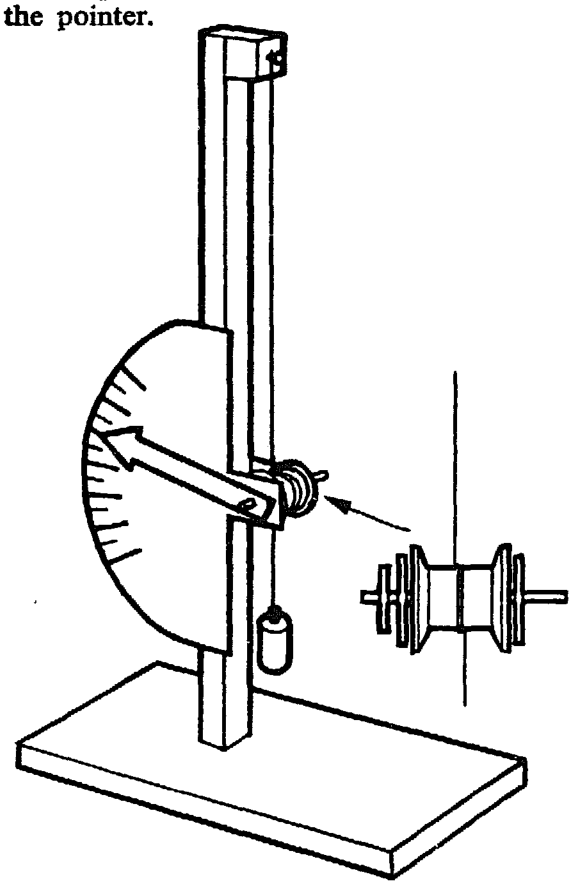
Hang the instrument where it has free access to the air. Fan the wet bulb until the temperature will go no lower. Make a reading of both the wet bulb and the dry bulb. Subtract the wet bulb reading from the dry bulb reading and then look up Table VI (page 245) to find the relative humidity. If your reading from the table is 40 it means that the air at that time holds only 40 per cent of the water vapour it could hold at the dry bulb temperature.

7 A hair hygrometer

This device will enable you to read the relative humidity directly without the use of tables.

Procure a few human hairs about 30 cm long. Free them from grease with dilute caustic soda solution. Fix one to the upper end of a stand and stretch it with a 50 gm weight. The hair should pass two or three times round a spool fixed to an axle which is free to rotate in bearings made from a piece of tin and fastened two-thirds of the way down the stand. Fix a light pointer of balsa wood to the axle, and arrange a postcard to act as a scale. For greatest sensitivity the diameter of the spool should be small.

Changes in atmospheric humidity will affect the length of the hair and the position of the pointer.

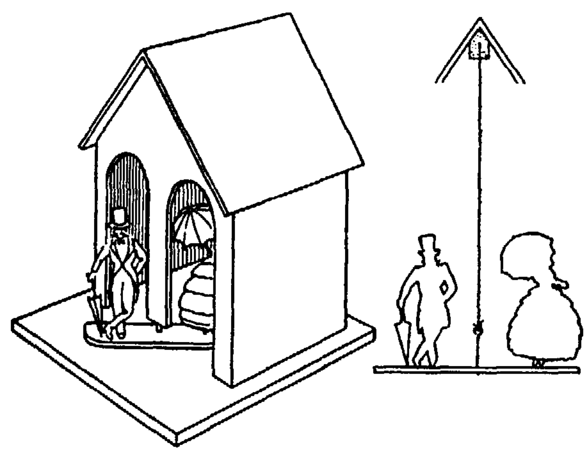


To mark off the scale it is best to compare your hygrometer with a standard one. If one of these is not available place the instrument above some warm water in a pail and cover with a wet towel. When the pointer has moved as far as it will, mark this point 100 on your scale for the air in the pail will be 100 per cent saturated. Other points can be marked by taking readings on your wet and dry bulb hygrometer. Find the relative humidity from Table VI (page 245) and mark the position of the pointer on your scale accordingly. When you have established about three points on your scale you can then divide the rest into equal divisions and mark them off at 5 interval markings from 5 to 100.

8 A weather house

Changes in the amount of water vapour present in the atmosphere can be indicated by variation in tension in a few strands of human hair or by using the hygroscopic properties of a piece of catgut.

The familiar weather house can be constructed from cardboard. One end of the gut is glued to a piece of cork on the roof angle, the other end carries a horizontal platform on which figures can be mounted. The direction of twist of the gut can be found by trial. Two sides of the house should be open to prevent heat accumulation, and the outside should be painted white.



9 A weather picture

A piece of white blotting paper is immersed in a solution containing two parts cobalt chloride to one part common salt. While wet the paper will remain pink, but when dried in the sun or near a bunsen burner it turns blue.

This is the basis of the weather pictures sold in the shops. A home-made one works just as well. A picture containing sky or water can be cut from a book and an inset of this prepared blotting paper made to replace say, the sky. The picture should then be mounted on a card and hung near a window where it will quickly respond to changes in the hygrometric state of the atmosphere.

10 Keeping a weather record

Some kind of scale of intensity is necessary when keeping a record of the weather.

The date, hour, temperature, sky, and wind can all be recorded in a table.

It is better to take the readings at the same time each day.

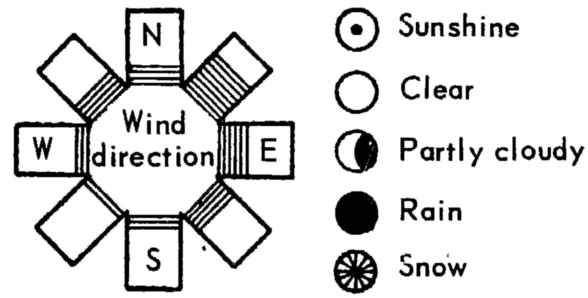
If no thermometer is available, a suitable temperature scale is: hot, warm, moderate, cool, cold, very cold.

There are international weather symbols, but abbreviated scales can be used unless the records are for some official purpose.

The velocity of the wind can also be recorded.

Light—moves smoke, but not wind vanes.
Moderate—raises dust and just moves twigs.
Strong—large branches move.
High—blows dust, papers and moves whole trees.
Gale—breaks off twigs from trees.

Date	*Time*	*Temperature*	*Sky*	*Wind*	*Rain*

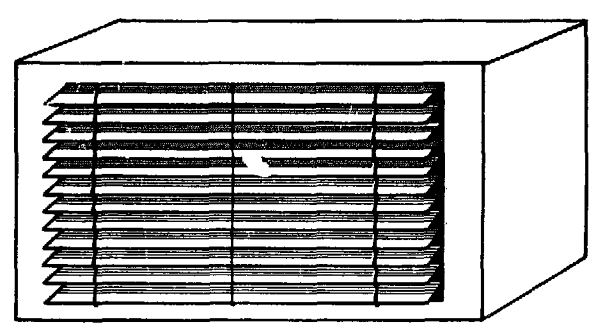


The direction of the wind can be indicated by an arrow in the column, but it is interesting to construct a paper star as shown in the diagram and to draw a line each day along the arm which most nearly coincides with the direction of the wind.

11 Making a housing box for weather instruments

Some of your weather instruments must be exposed to the weather. Among these are the wind vane, the wind speed indicator and the rain gauge. It is wise to protect metal parts of these instruments with either grease or paint. Aluminium paint works very well for this purpose.

Other instruments such as the barometer, the thermometer, and the hygrometer, need to be shielded from rain and wind. These may be placed in a wooden box which has no top. Place the instruments in the box so that one of the closed sides forms a roof and another a floor for your house. The open side should be fitted with louvres, such as are found in a window blind, for best results. This will provide a free access of air but will protect the instruments from wind and precipitation.



B. WINDS AND WEATHER

1 Air expands when heated

To show that air expands when heated, fit an electric light bulb flask or a bottle with a one-hole stopper or cork which has a 30-cm length of glass tubing or a soda straw through it. Place the end of the tube in a small bottle of water. Heat the flask and observe what happens. Heat the flask until a considerable amount of air has been removed and then cool the flask by pouring cold water over it or by rubbing it with a piece of ice. What do you observe? How do you account for this?

2 Another way to show that air expands when heated

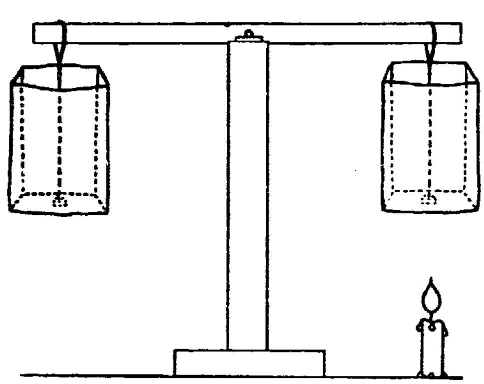
Snap a toy balloon over the neck of a small bottle and place the bottle in a pan of warm water. What do you observe? How do you account for this?

3 Expansion of air

Connect a one-hole rubber stopper carrying a short length of glass tube into a 2 or 3 litre can with a narrow opening. Attach a rubber tube to the glass tube. Invert a bottle of water in a basin of water and put the end of the rubber tube under the edge of the bottle. Heat the can. What do you observe? How do you explain this?

4 Cold air is heavier than warm air

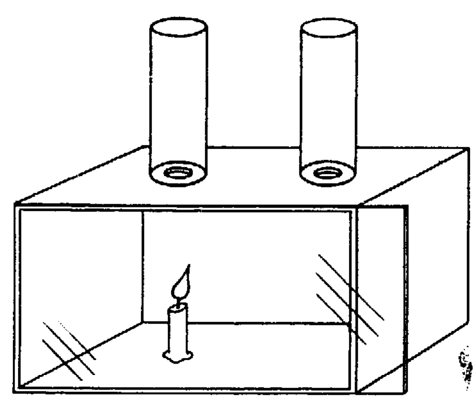
(a) Make a simple balance as you did in experiment C 1, page 77, for showing the weight of air. Secure two paper bags that are the same size. Open the bags and attach a 20 cm thread to the bottom of each one with a piece of Scotch tape or by making a hole in the bottom of the bag, inserting the thread and then tying a knot in the end. Make a loop on the other end of each thread that will go over the ends of the balance rod. Place a bag near each end of the rod. Move the bags in or out until they are in exact balance. With a candle heat the air well below one of the bags. What do you observe? Let the balance stand for several minutes. What happens? Now heat the air under the other bag. Observe what happens. How do you account for this?



(b) Another way to study the difference in weight between warm and cool air is to use flasks on the balance rather than paper bags. Attach the flasks with loops of string. Move them until they are in perfect balance and then heat one flask gently. Observe the effect. Allow to cool to room temperature. Observe and then heat the other flask. Flasks made from old light bulbs work very well for this experiment.

5 A convection box

A box to show why winds blow may be made easily. Use a wood or pasteboard box for which you can secure a pane of glass, the correct size to make a tight window. A wood chalk box which has grooves for a cover works very well. Cut the glass so that it will slide in the grooves. Next bore two holes in one of the long sides of the box, one near each end. The holes should be from 2.5 to 3 cm in diameter. The box must lie with this side up. Secure two lamp chimneys to place over the holes. If lamp chimneys are not available you can use pieces of mailing tube about 15 cm in length. Place a short piece of candle on the floor of the box just under one of the chimneys. Light the candle. This represents a land area that has been heated by the sun. Close the window and, with a piece of smoking paper, trace the air current in each chimney. Observe the movement of air inside the box. Move the candle under the other chimney and repeat. What do you observe? How do you account for this? This is called a convection current.



6 Tracing convection currents

(a) Shield a burning candle to protect it from stray air currents. Trace the air currents about it with smoking paper.

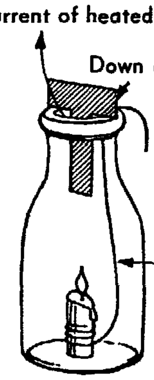
(b) Open a door a little way between a warm and a cool room. With a piece of smoking paper explore the air currents about the opening at various levels above the floor.

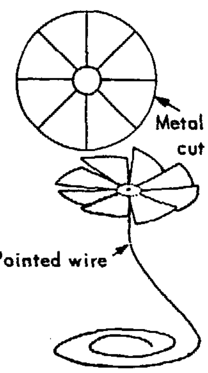
(c) If you can, explore the air currents in a room that is heated with a radiator or a stove.

(d) Explore the air currents in a room that is ventilated with windows open at the top and at the bottom.

(e) Lower a lighted candle into a milk bottle by means of a wire. Observe what happens. Ventilate the bottle with fresh air. Again place the lighted candle in the bottle but this time separate the warm and cold air currents by a piece of cardboard cut in the shape of the letter T as shown in the diagram. Explore the air currents on each side of the cardboard with smoking paper.

(f) Cut out a metal can top with a rotary opener so as to have a metal disk. Punch a depression in the exact centre. Cut along radial lines almost to the centre and give each of the blades thus formed a twist in the same direction. Mount the wheel on a pointed wire and hold it over a candle or other source of heat. A carefully made wheel of this kind will also turn over a radiator or a lighted electric lamp.



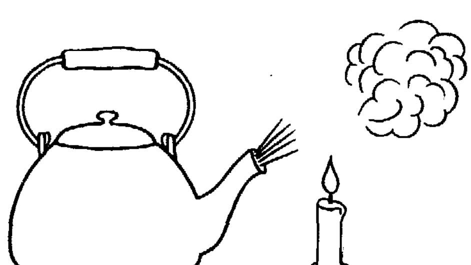


Place a metal foil top from a milk bottle on a piece of blotting paper with the flat side down. Press the point of a ball pen into the middle to make a dent. Cut 'petals' in the turned-up edge to form the vanes of a turbine. Pivot it on a pointed wire or on a needle stuck eye downwards into a cork. This is more sensitive to convection currents than the apparatus described above.

C. HOW MOISTURE GETS INTO THE AIR

1 You cannot see atmospheric moisture

Place some water over a fire in a vessel that has a spout such as a tea kettle or copper pot. If these are not available, fit a flask with a one-hole stopper and place a right-angle bend of glass tubing in it. Place some water in the flask and put it over a flame. When the water is boiling and steam issues from the spout, observe the cloud that is formed. This is not steam, but condensed water. Observe the space next to the spout when the steam comes out. Can you see it? Now hold a candle or a burner in the cloud of condensed steam. What do you observe? Where does the moisture go?



2 The mop weighs less

Put a floor mop in water. Wring it out and then balance it on a triangular file placed on the corner of a table. Be sure you have it carefully balanced. Look at the mop an hour later. What has happened? How do you account for this? Where has the water gone?

3 Weighing moisture again

The same experiment can be done with a bath towel. Wet the towel and wring it out. Hang it on a coat hanger. Hang the coat hanger on one end of a long stick balanced over the corner of a table on a triangular file.

4 Moisture evaporates from soil

Fill a flower pot with moist soil and place it on a pair of scales. Either balance the pot of soil with weights or observe its weight. Observe its weight again after 24 hours.

5 Moisture comes from house plants

Place a cellophane bag over a leaf of some house plant or garden plant and close the end about the stem with a rubber band. Make an observation after one hour. What do you observe? Where did it come from?

6 Moisture comes from other plants

Secure a flower pot which has some bean or pea seedlings that are 10 or 15 cm in height. Cover the top of the pot with cellophane or sheet rubber, pinning it closely around the stems of the plants so no soil is uncovered. Invert a clean, dry glass jar over the plants and observe after an hour. What do you see? Where did it come from?

7 Moisture from breathing

Moisture coming from breathing may be shown by blowing on a cool mirror or into a cool glass or bottle.

8 Moisture from a gas flame

Moisture coming from a flame may be shown by placing a pan of cold water over a gas stove for a few moments. Remove the pan from the fire and observe the bottom.

9 Moisture from other flames

Bring the flame of a candle near a cool blackboard. Repeat using the flame of a gas burner, the flame from an alcohol lamp, the flame from a piece of burning paper, and the flame from a piece of burning wood. What do you observe? Where did it come from?

10 Area affects the rate of evaporation

Measure 50 ml of water and pour it out into a container of much larger diameter than the graduate. Again measure 50 ml in the graduate. Place them side by side where the temperature and air movements will be the same. On the following day measure the amount of water in each container. What causes the difference in evaporation?

11 Temperature affects the rate of evaporation

Warm a spot on a blackboard or slate by using a candle or by placing in the sun. Place water spots of equal size on this warm area and on a cool area. Observe the spots and see what happens.

12 Moving air affects the rate of evaporation

With a moist sponge or cloth, make spots of equal size on a cool blackboard surface at some distance apart. Fan one spot with a piece of cardboard and leave the other to evaporate without fanning.

What causes the difference in rate of evaporation?

13 Moisture in the air affects the rate of evaporation

Fasten some cloth over a wooden hoop or frame that is about 30 cm square and about 3 cm thick. Wet the cloth. Next make two wet spots on a cool blackboard surface with a sponge or cloth. Cover one with the frame carrying the wet cloth and leave the other one open. After a few moments observe both spots. Which has evaporated the faster? How does moist air (under the frame) affect the rate of evaporation?

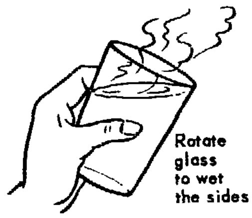
D. HOW MOISTURE COMES OUT OF THE AIR

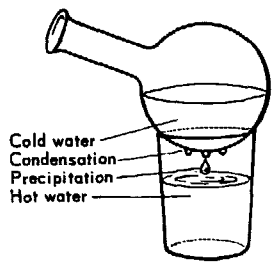
1 Moisture condenses on cool surfaces

Place some ice in a shiny tin can. After a little while observe the outside of the can. What do you observe? Where did it come from?

2 The water cycle

Heat some water until it is near the boiling point. Place it in a drinking glass and rotate the glass so as to moisten the sides right to the top. Place some very cold water in a round flask, such as one made from an electric bulb or a Florence flask. Place the flask on the glass at an angle as shown. Water will evaporate from the hot water, condense on the cool surface of the flask and fall back in droplets into the glass. Here





you have evaporation, condensation and precipitation. You have seen the water cycle as it goes on in nature.

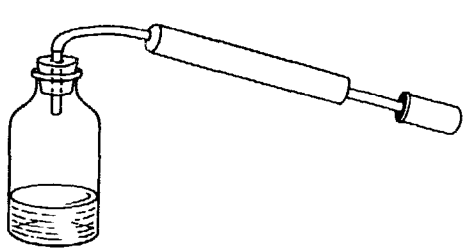
3 Dew-point temperature

You can measure the dew-point temperature with a shiny can containing some water, a thermometer and some ice. The dew-point temperature is an important weather observation. It is the temperature at which the moisture in the air begins to condense. The dew-point temperature changes from day to day.

Be sure that the outside of the can is dry and shiny. Place some water inside the can and then stand the can on a page of printing so that the printing is clearly reflected from the can. Place the thermometer in the can. Now add ice, a little at a time, to the water and carefully stir with the thermometer. Keep close watch of the temperature and read the thermometer at the temperature where dew begins to form on the outside of the can. This will be near the dew-point temperature.

4 A cloud in a bottle

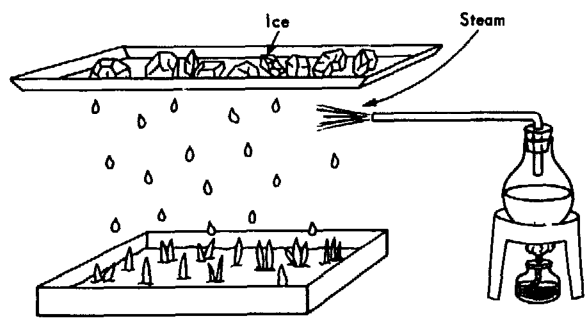
You can make a cloud form in a bottle. Obtain a large glass bottle and fit with a rubber stopper carrying a 10-cm length of glass tubing. Place about 2.5 cm of warm water in the bottle and dust a little chalk dust into the air inside. Connect the glass tube to a bicycle pump with a piece of rubber tubing. Hold the stopper in the bottle and have a pupil pump air in. When the air has been compressed inside the bottle let the stopper blow out and observe what happens. If you do not get a good cloud, introduce a little smoke from a smouldering match or cigarette.



When the air expands it cools, thus reducing the temperature in the bottle below the dew point. The moisture condenses as a cloud. When warm air rises above the earth the air pressure is reduced. The air expands, cools and clouds form when the cooling goes below the dew point.

5 The rain cycle

You can reproduce the rain cycle in miniature in your classroom. Place a box of plant seedlings on the table. Place a metal tray about 35 to 40 cm above the box of seedlings and support it. Strew the top of the tray with pieces of cracked ice. Place a tea kettle or flask containing water over a source of heat so that steam will issue between the seedlings and the tray. You are now ready to study the rain cycle. The tea kettle or flask serves as the earth source of water. This evaporates and rises up to the cool tray which represents the upper layers of air above the earth which have been cooled by expansion. Here the moisture condenses on the tray and drips back on to the seedlings as rain.



6 Frost in the classroom

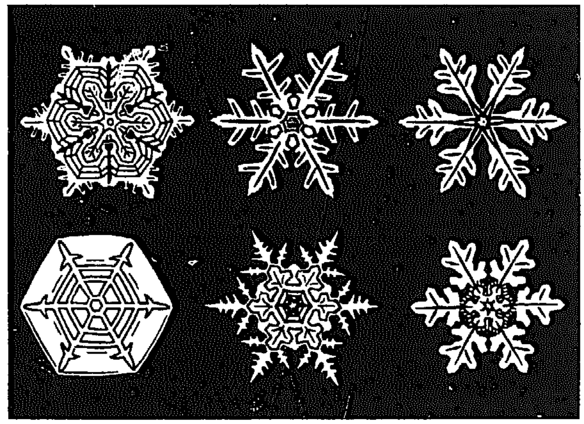
Frost can be made in the classroom by using a tall metal container such as a tin can. Pack the can with alternate layers of ice and salt, using about twice as much ice as salt. Tamp the mixture with a stick as you pack it. When it is full, watch the outside of the can. Some dew will form and may freeze, but you should also be able to observe the delicate white frost which forms. When the can has stood for a while it will be covered with a beautiful white frost.

7 To study a hailstone

When it hails, collect some of the hailstones. Cut them in half and observe how the ice of the hailstone has been built up in layers.

8 To study snow-flakes

If you live in a region where snow falls, collect some snow-flakes on a piece of dark wool cloth and look at them with a magnifying glass. You will find them of many, many shapes, but always six-sided. Snow-flakes are among the most beautiful sights in nature.



CHAPTER IX

Experiments and materials for the study of water

A. THE COMPOSITION OF WATER

1 How water can be decomposed

You will need a six-volt storage battery or accumulator or a battery of six dry cells for this interesting experiment.

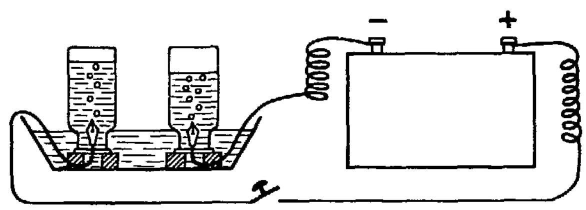
Remove the insulation from about 6 cm at each end of two lengths of copper wire each at least 30 cm long. Next secure the gold points from two old fountain pens and wrap the uninsulated end of one of the copper wires securely around each one. Cover the joint with sealing wax so that no copper is exposed. Connect one wire to each terminal of the battery. Fill a shallow glass cooking dish about half full of water. Fill two small bottles with water, place a piece of cardboard over the mouth and invert them in the dish of water. Stand each bottle on two thin strips of wood so that the mouth is raised from the bottom of the dish. Now carefully place one of the pen points up in each bottle.

Place about two tablespoonfuls of sulphuric acid in the water and give it a few moments to mix thoroughly. Be very careful in handling the sulphuric acid, as it will burn if it touches your skin, and it will make holes in your clothing if you spill it. You can obtain sulphuric acid at a drug store, a battery service station or from a chemical laboratory.

When all is ready turn on the current. This experiment may take some time to complete. Observe what happens in each bottle. If the bottles are the same size you can measure the results with a ruler. How do these compare?

When the bottles are filled with gas place a glass plate over the mouth of each one. Leave the one which filled more quickly mouth downward on the glass plate. Set the one which filled less quickly mouth upward with the glass plate still covering. Place a glowing splint in the bottle which you placed mouth upward. What happens? This gas is oxygen.

Bring a lighted splint to the mouth of the bottle you left inverted. What happens? This gas is hydrogen. Have you ever heard water called H_2O? Can you explain this from your experiment?



2 How oxygen can be prepared

Directions for preparing oxygen are given in Chapter VII, page 88.

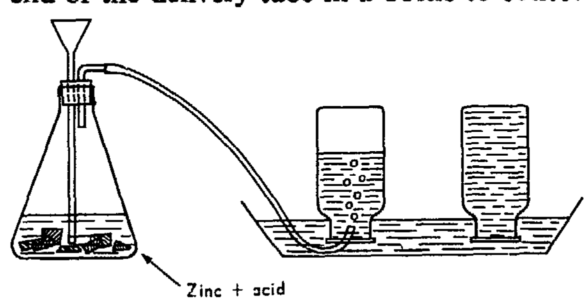
3 Some experiments with oxygen

Directions for experiments with oxygen are given in Chapter VII, page 89.

4 How to prepare hydrogen

Hydrogen can be prepared from a dilute acid, such as hydrochloric or sulphuric, when it is chemically reacted with a metal such as zinc. The acid may be secured from a drug store. It should be handled carefully to avoid spilling acid on hands or clothing. Zinc can be secured from the outside container of an old dry cell. Clean the zinc thoroughly and cut into pieces about 2.5 cm square.

To make the hydrogen place the zinc in a flask or bottle fitted with a two-hole rubber stopper. Through one hole place a funnel tube that reaches nearly to the bottom. In the other hole place a tube with a right-angle bend and attach to it a 30 or 40 cm length of rubber tubing. Fill a pan about half full of water and invert bottles of water in the pan. Place the end of the delivery tube in a bottle to collect



the hydrogen. Pour the dilute acid on the zinc through the funnel tube. Be sure to keep flames away from the generator; hydrogen mixed with air is very explosive. When the bottles are filled with hydrogen, put a glass plate over the mouth and stand them on the table, mouth down.

5 Does hydrogen burn?

Light a wood splint and bring it near one of the bottles of hydrogen as you lift it from the table. Push the wood splint up in the bottle. Now slowly remove the splint. What happens? Does hydrogen burn? Does it support burning like oxygen does?

6 What is produced when hydrogen burns?

Place a short length of glass tubing on the end of the rubber delivery tube and get a good action with zinc and acid in the flask. Bring a smouldering wood splint to the tube. The hydrogen should burn quietly with a pale blue flame. Bring a cold dish or metal plate into contact with the flame. What is formed when hydrogen burns (unites with oxygen)?

7 Blowing soap bubbles with hydrogen

Mix up a strong soap solution that will make good soap bubbles. Place a small funnel tube or a clay pipe on the delivery tube. When you have a good action of acid and zinc in the flask, blow bubbles with the hydrogen. When each bubble has been formed a slight jerk will detach it from the funnel and it will rise to the ceiling. You can have a lot of fun trying to light the bubbles by placing a lighted candle on the end of a stick to reach them near the ceiling.

B. HOW WATER CAN BE PURIFIED

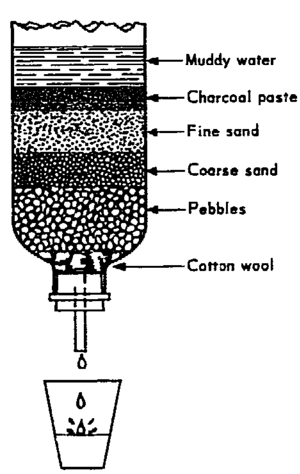
1 How to make a filter

A plant pot with a plug of cotton wool in the bottom and a layer of sand a few inches deep makes a satisfactory filter for many purposes as shown in Chapter II, experiment C 10.

Make some muddy water by stirring earth in a dish of water. Pour the water into the filter and catch it in a clear glass as it drips out. See if you can improve the filter by building it up with alternate layers of sand and powdered charcoal. Such a filter will work very well for clarifying water before it is boiled for drinking purposes.

2 How to make an experimental filter

Fit a one-hole stopper carrying a short length of glass tube into the small end of a lamp chimney. Put a little cotton wool in the bottom and then a layer of small clean pebbles. Wash some coarse sand well and place a layer above the pebbles. Next wash some fine sand and make a thicker layer in the filter. Grind up some wood charcoal and make into a paste with water. Pour the charcoal paste evenly over the surface of the sand. Secure some very muddy water and pour in the top of the filter. Collect the filtrate in a clean glass placed below the filter.



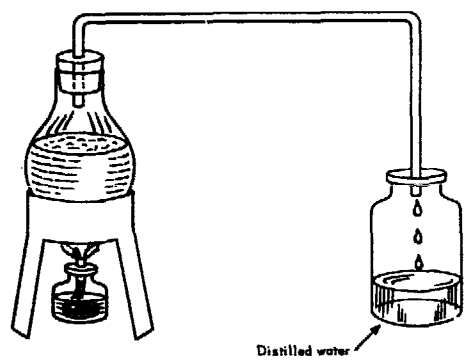
3 Sterilizing water by boiling

The presence of tiny living plants and animals makes water unsuitable for drinking. Such forms of life can only be seen through a microscope. We can study how boiling affects living things in a simple way. White of egg is known to be chemically very similar to the substance that makes up the bodies of living bacteria.

Fill a test tube or flask about half full of water and heat it to boiling. With a medicine dropper put a few drops of egg white in the boiling water. Observe that the egg white is changed completely. It becomes like egg white in a boiled or fried egg. We say it has coagulated. This is probably what happens to the living tissue of harmful bacteria when water containing them is boiled.

4 How to make a simple apparatus for distilling water

You can make a simple water-distilling apparatus from a flask, and a length of glass or rubber tubing. Fit the flask with a one-hole stopper or cork which has a short length of glass tube through it. Either bend a 60 cm length of glass tube as shown in the diagram or use a piece of rubber tube. Attach this tube to the tube in the flask. Use a flask, or drinking glass or jam jar to collect the distilled water. Fill the boiling flask about half full with muddy water containing some ink or other colouring material. Boil the water over a suitable flame.



5 How to make a larger distiller

See Chapter II, item C 7, page 36.

6 How to make a Liebig condenser

See Chapter II, item C 9, page 36.

C. HARD WATER AND SOFT WATER

Hard water contains minerals which are dissolved from the rocks as the water runs over and through the earth. Soft water is water that contains little or no dissolved minerals, such as rain water or distilled water.

1 The difference between hard and soft water

Collect some hard water from a stream (or make some as described in the next experiment). Also secure some soft water such as rain water or distilled water. Make some soap solution by dissolving soap shavings or powdered soap in a little warm water. Place equal amounts of hard and soft water in each of two bottles. Add soap solution to the soft water with a dropper, a few drops at a time. Shake the bottle well after each addition. Count the number of drops of soap solution needed to produce suds about 1 cm thick on the top.

Next add the same amount of soap solution to the hard water and shake well for about the same length of time. Observe any differences. Continue to add soap solution to the hard water until you get good suds. How do the amounts of soap used compare?

2 How to make hard water

There are two kinds of hard water, one called temporary and the other called permanent. Temporary hard water can be made as follows: Start with some clear lime water (see Chapter XVIII, item 12, page 214, for directions). Bubble carbon dioxide (see K 14, page 89) through the lime water until the cloudiness first formed disappears and you will have some temporary hard water. Permanen hard water can be prepared by stirring some calcium sulphate or plaster of Paris with water and letting it stand for several hours. After this has been filtered the clear filtrate will be permanently hard. You can also prepare this type of hard water by dissolving magnesium sulphate (Epsom salts) in water.

3 Softening hard water by boiling

Temporary hardness can be removed from water by boiling. Shake a little temporary hard water with a few drops of soap solution and see if you can make suds. Next boil a similar amount of the water that contains temporary hardness. Try making suds with this sample after adding the same amount of soap solution.

4 Softening water with chemicals

Try making suds with a half test tube of hard water and a few drops of soap solution. Next boil a similar sample and again try to make suds by using the same amount of soap solution.

Add some washing soda (sodium carbonate) to a sample of permanent hard water. Try making suds with soap solution. Has the water been softened? Add some borax (sodium pyroborate) to a sample of permanent hard water and test to see if it has been softened.

5 How soap helps water in cleaning

Prepare two greasy cloths by smearing kitchen fat or vaseline on cloths. Wash one sample in warm water without soap. Wash the other sample in warm water with heavy soap suds. Hang the samples to dry and observe which one was made cleaner by washing.

6 How water acts towards fat

Half-fill a tall glass jar with warm water. Add some olive oil or other oil to a depth of about 1 cm. Shake this mixture hard. Observe how the fat is broken up into tiny droplets or globules. Allow this to stand and observe that the globules all finally come together and collect on the surface. Set this aside to compare with the next experiment.

7 How soap acts towards fat

Prepare another jar with warm water and oil just as you did in the experiment above. This time add about half a cup of either liquid soap or strong soap solution made by dissolving soap chips in water. Shake this mixture vigorously, allow to stand and compare with the sample from the previous experiment. You should observe that the soap has broken up the globules of fat and they are now distributed so that the mixture looks like milk.

8 Hard and soft water in cleaning

Prepare two samples of dirty cloth. Wash one in soft water with soap until it is clean. Wash the other cloth in hard water for the same length of time and with the same amount of soap. Hang the samples to dry and observe the difference.

9 How to make soap

Soap can be made from waste fat. Secure some waste fats and melt in a dish. Strain the fat through several layers of cloth. Weigh the fat and then weigh out about one third as much commercial lye (sodium hydroxide). Dissolve the lye in water. Heat the fat in an iron kettle or dish. When it is melted, pour the lye solution in slowly and stir continuously. Keep the flame low to avoid boiling over. Let the fat and lye boil for 30 minutes with frequent stirring. After boiling add common salt—about twice the weight of lye used. Stir well. When this mixture has cooled the soap will appear as a layer at the top. Take only the soap, melt and pour it into match boxes to make little cakes of soap. Is it a good soap?

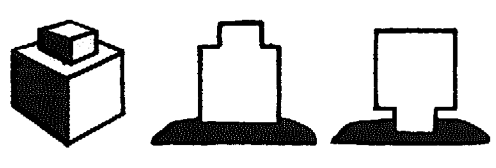
D. WATER AT REST AND IN MOTION

1 The meaning of pressure

Stand with muddy feet or boots on a piece of paper and draw an outline of the footprints. Measure the area using squared paper, and calculate the force per square centimetre. Standing on one foot will distribute your weight over about half the area, with a corresponding increase in pressure which can also be calculated.

2 The difference between weight and pressure

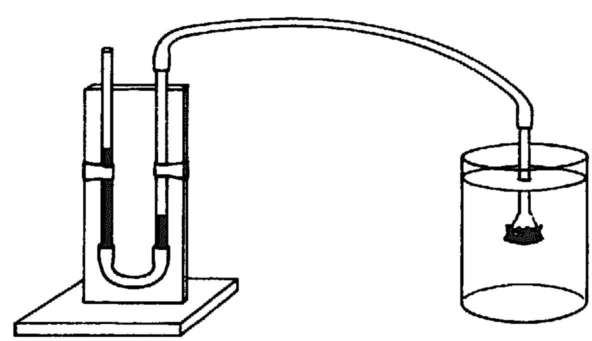
Make two square blocks of wood, one much smaller than the other, and join them together as shown in the diagram. Press each of these faces consecutively into a slab of clay or plasticine using the same force in each case.



The difference in pressure is seen by the different depths of the indentations.

3 To show that liquids exert pressure

Connect two 15 cm lengths of glass tubing or two transparent plastic soda straws with a short length of rubber tubing and attach them to an upright as shown in the diagram.



Put some coloured water in the tubes to a depth of about 6 or 8 cm. This is your pressure gauge or manometer. Cover a small funnel with thin rubber stretched tightly and tie it securely with thread or string. Attach the funnel to the manometer with a 30 cm length of rubber tubing. Push the funnel into a pail of water and watch the manometer.

4 Water pressure changes with depth

Use the funnel and manometer which you made in the previous experiment. Fill a tall glass jar or pail with water. Measure the pressure just below the surface with your manometer. Measure the pressure at the bottom. How does pressure change with depth?

5 Pressure depends upon the liquid

Obtain two glass jars into which the funnel will fit. Fill one with water and the other, to the same depth, with a less dense liquid such as alcohol. Measure the pressure at the bottom of the jar of water. Measure the pressure at the bottom of the jar of alcohol. How do they compare for the same depth?

6 Water pressure in a large vessel is the same as in a small one, at the same depth

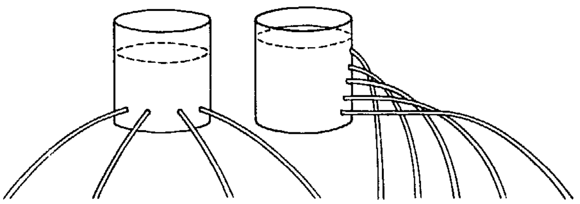
Use the funnel and manometer from the above experiments. Secure a tall glass jar of small diameter and a glass jar of larger diameter. Fill both jars to the same depth with water. Measure the pressure at the bottom of each jar. How do they compare?

7 Another way to show that water pressure increases with depth

Find a tall tin can. Punch holes up the side of the can about 3 cm apart. Put a strip of adhesive or plastic tape over the row of holes and fill the can with water above the top hole. Hold the can over a sink and strip the tape from the holes beginning at the bottom. Observe the streams and note the distances travelled outwards from the can.

8 Water pressure is the same in all directions

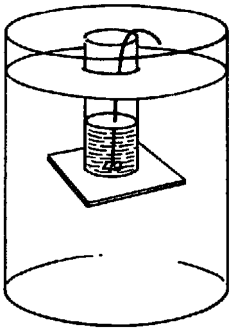
Punch holes around the base of a tall tin can with a nail. Cover the holes as above with a strip of tape. Fill the can with water and strip off the tape while holding it over a sink. Observe and compare the distance the streams shoot out from the holes all around the can.



9 Upward and downward pressure are the same at any given depth

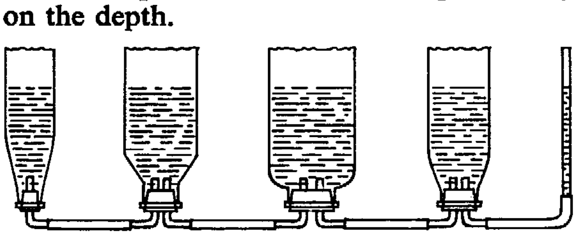
Obtain a glass cylinder at least 15 cm long and 4 cm in diameter. Such a length of tube can be made from a straight-sided bottle like an olive oil bottle by removing the bottom (see page 218). A clear plastic tube will do or even a cardboard mailing tube that has been coated with paraffin wax or shellac.

Cut a square of cardboard about 5 cm on one side. Coat it with paraffin or shellac. Attach a length of thread or string to the centre with tape. Put the thread through the tube and hold the cardboard to the bottom with the thread. Plunge the tube, card-end down into a jar of water. Let go of the thread. Now pour coloured water into the tube. Note the depth of water inside the tube when the card falls away.



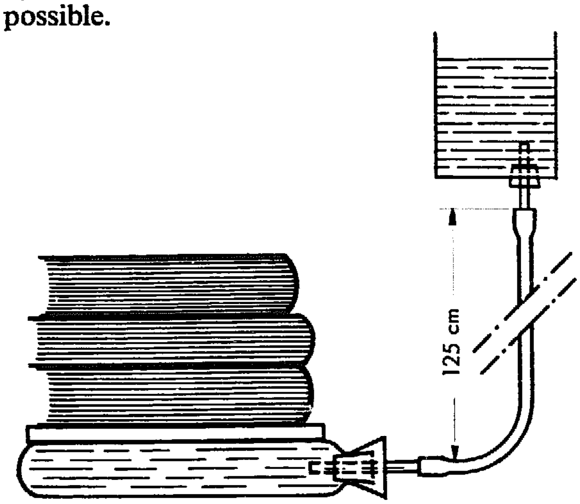
10 Balancing water columns

Remove the bottoms from several glass bottles of different shapes but of about the same height (see page 218 for directions). Fit the bottles with stoppers or corks carrying glass tubes as shown in the diagram. Connect the bottles together as shown. Pour coloured water into the bottles until they are nearly full. This experience again shows that in a given liquid, pressure is independent of the size or shape of the vessel and depends only on the depth.



11 Raising heavy weights by water pressure

Obtain a rubber hot-water bottle. Put a one-hole stopper carrying a short glass tube tightly in the neck. Punch a hole in the bottom of a tin can and make it large enough to take a one-hole stopper. Put a short length of glass tube through the stopper. Connect the water bottle and the can with a length of rubber tube at least 1.25 metres in length—it will be wise to wind wire around the connexion at the bottle. Fill the bottle, tube and can with water. Place the bottle on the floor and put a length of board on it. Place books or other heavy objects on the board. Now raise the can above the level of the floor and observe the weights. See how heavy a weight you can lift by raising the can as high above the floor as possible.



12 Water will not compress

Fit a soda water bottle with a one-hole stopper. Through the stopper place the glass tube from a medicine dropper, narrow end up. Fill the bottle to the top with water. Insert the stopper tightly until the water rises a little way in the medicine dropper. Now grasp the bottle in your hands and squeeze as hard as you can. The water will rise in the tube because you cannot compress it. Can you make the water run over the top of the tube?

Fill a medicine bottle with water. Force in a good cork. Strike the cork sharply with a hammer; the bottle will burst.

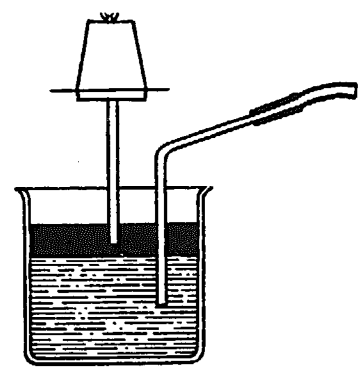
13 Making a model hydraulic elevator

Some freight and passenger elevators are raised by water pressure. You can make a model of one of these with an automobile hand pump. Connect the tube from the pump to a length of rubber tube. Bind the connexions with wire so they will not blow out. Now connect the tube to a water tap with a one-hole rubber stopper. Again bind the connexion of the tube and stopper. Steady one of your pupils as he sits on the handle. Turn the water on slowly and see if the water pressure will lift him. You may have to hold the stopper in the tap.

14 Simple hydraulic press

The principle of the hydraulic press is illustrated by the following model.

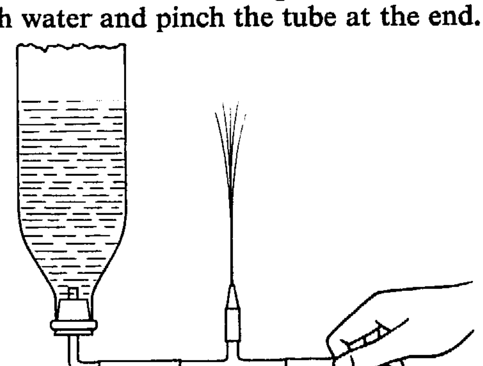
Half fill a cylindrical jar with water. Pour melted paraffin wax on the surface to form a piston, holding a piece of glass tubing in the wax as it cools. When the wax is solidified it forms a watertight piston. Gently blow down the tube, and the plug will be raised. Considerable weights placed on the piston can be lifted in this way.



15 A model hydraulic ram

Hydraulic rams are sometimes used to raise water from a low level to a higher level. They are operated by a flowing stream of water.

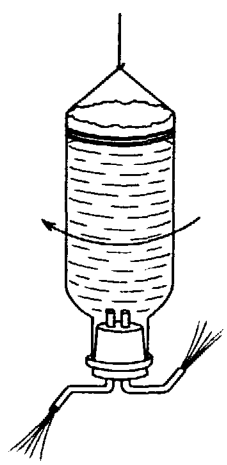
You can make a model hydraulic ram. Secure a soda water bottle from which the bottom has been removed (see page 218 for directions). Fit the bottle with a one-hole rubber stopper carrying a short length of glass tubing. Connect this to a glass or metal T-tube which has a piece of rubber tubing on one end and a jet tube connected to it with a rubber tube as shown in the diagram. Fill the bottle with water and pinch the tube at the end. Let



the water run from the end of the tube. Stop the flow suddenly by quickly pinching the tube, and note the height to which the water squirts from the jet tube. Let the water flow and stop alternately, and you have a working model of the hydraulic ram.

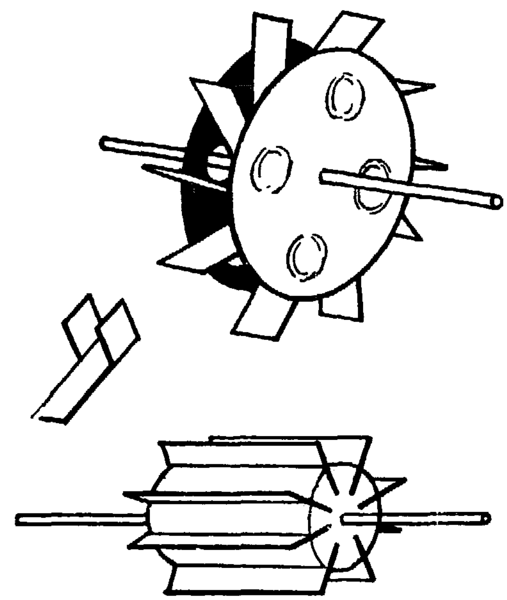
16 A model reaction water turbine

Use a soda water bottle from which the bottom has been removed. Wind string around it near the bottom end and suspend it as shown in the diagram. Fit a two-hole stopper to the neck of the bottle. Through the holes place glass tubes that have been bent as shown and have their ends drawn out to jet tubes. Fill the bottle with water and watch the turbine rotate as the water runs from the jets.



17 Model water wheels

A meat skewer or a knitting needle can be used as an axle. An old typewriter ribbon-spool or a sticking plaster reel is useful as a basis for these improvisations. A stream of water from a tap, or guided from a tank along a piece of rainwater spouting is a suitable source of water power.



A cotton reel or cork can also be used as the 'nave' of the wheel. Cut slots down the sides, perpendicular to the ends. Slide pieces of wood or tin into these slots to act as paddles.

E. SINKING AND FLOATING

1 What determines sinking and floating?

Shape a piece of lead, tin or aluminium foil into the form of a little boat and float it on the water in a pan; now wad the metal foil from the boat into a small ball and try to float it on the water. What do you observe? What is your best explanation for this?

2 The buoyancy of water

Find a metal can like a coffee can or a cigarette tin which has a tightly fitting cover. With the cover on, push the can into a pail of water, cover end down, and quickly let go of it. Repeat this having the can in different positions. What do you observe? Can you observe the upthrust on the can? Put a little water in the can and repeat the experiment. Keep adding water a little at a time and repeating until the can no longer floats.

3 You can observe the buoyancy of water

Make an equal arm balance (see page 34 for directions). Secure two soda water bottles and suspend them with loops of string from either side of the arm until they balance exactly. Bring a pail of water up under one of the bottles until the bottle sinks in the water a little way. Observe what happens.

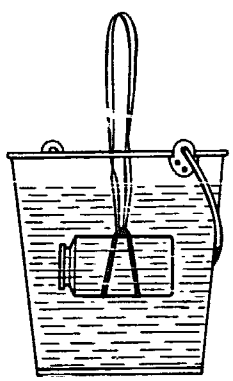
4 Another way to observe the buoyancy of water

Push a large cork to the bottom of a pail of water. Notice the amount of force you have to apply to hold the cork at the bottom. Repeat the experiment using a fairly large empty bottle stopped with a cork. Is there any difference in the force required?

Blow up a toy balloon and push it to the bottom of the pail. How does the force to hold it down compare with the force required for the cork and bottle?

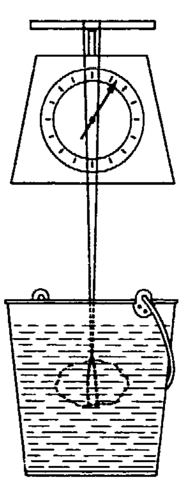
5 Still another way to observe the buoyancy of water

Obtain a can with a tightly fitting cover such as a cigarette tin or a coffee can. Fill the can with water and put the cover on. Put a double loop of string around the side of the can and then attach a large rubber band to the other end of the cord. Lift the can by holding the rubber band and observe how much the band stretches. Now lower the can in a pail of water and observe the stretch in the rubber band. How do you account for the difference?



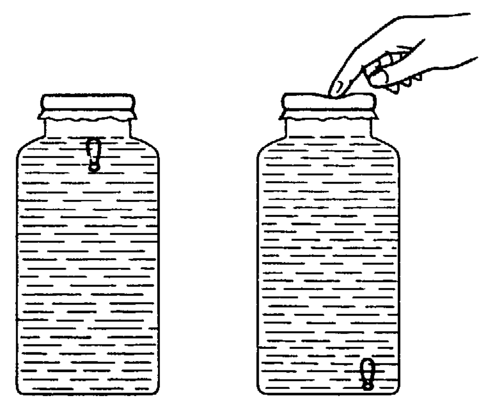
6 A stone seems to weigh less in water

Weigh a large stone on a pair of kitchen scales. Put a loop of heavy string around the stone and weigh it again suspended in a pail of water. How do you explain the difference?



7 How to make a devil diver (cartesian diver)

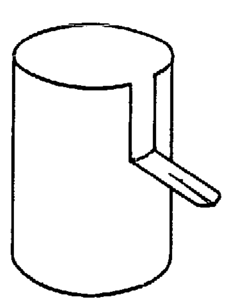
Find a tall glass jar with a fairly wide mouth. Wrap a few turns of copper wire about the narrow part of the rubber bulb from a medicine dropper. Fill the jar brim full of water. Put a little water in the bulb and float it in the jar of water. The bulb should contain enough water to bring it nearly to the point of sinking. At this point almost all the rubber will be under water. Considerable adjustment will be required. Remove air from the bulb a bubble at a time by pinching the bulb. When you have adjusted the diver, put a solid stopper in the bottle or tie a piece of rubber cut from an old inner tube over it. By pressing on the stopper or rubber, the diver will sink. When the pressure is released it will rise to the surface. If you make the floater from a small glass test tube or a medicine vial you can explain the action of the devil by observing the level of water inside the float when it sinks and when it floats.

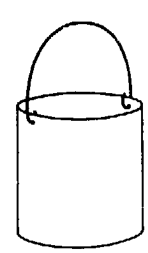


8 How to make an overflow can and catch bucket

These are useful for the study of Archimedes' principle, which controls floating and sinking. To make an overflow can secure a tin can 10 or 12 cm high and 7 or 8 cm in diameter. Make two vertical cuts 2 cm apart and 4 cm down from the top edge. Bend out the tongue so formed into a V-shaped spout.

The catch bucket can be made from a smaller tin can. Punch two holes near the top of the can and on opposite sides. Make a wire bale for the catch bucket.

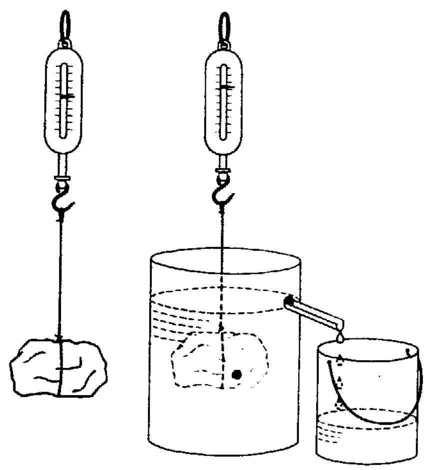




9 Sinking bodies

Fill the overflow can with water to the level of the spout. Select a stone that will go inside the overflow can. Attach a string to the stone and weigh it with a spring balance. Weigh the catch bucket. Place the catch bucket underneath the spout. Immerse the stone in the water and record its weight. Does it weigh the same as in air? Collect the displaced water and determine its weight by subtracting the weight of the bucket from the weight of the catch bucket and water.

How does the apparent loss of weight of the stone from air to water compare with the weight of the displaced water? Try this experiment with other sinking bodies.



10 Floating bodies

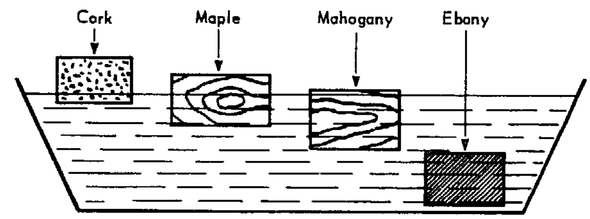
Fill the overflow can with water and let it run out until the surface is level with the spout. Select a piece of wood that floats half or more submerged in the overflow can. Weigh the piece of wood on a spring balance. Weigh the catch bucket. Place the catch bucket under the spout. Put the wood block in the overflow can and note the balance reading. Find the weight of the displaced water by subtracting the weight of the catch bucket from the total weight of catch bucket and water. How does the weight of the floating piece of wood compare with that of the water it displaces? Repeat the experiment with other floating bodies.

11 An experiment with a floating candle

Put a nail in the lower end of a candle. The nail should be just the right weight to make the candle float with its top a little above the surface of the water. Float the candle and nail in a tall glass of water. Light the candle and watch it until it is nearly burned up. The candle constantly loses weight as it burns. Why does it continue to float?

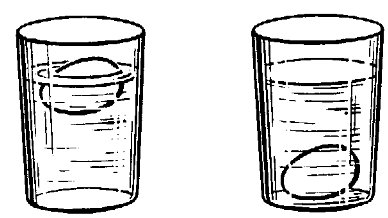
12 A floating experiment with different kinds of wood

Secure a cork, and pieces of wood such as maple, mahogany and ebony. Place them in a pan of water and notice how each one behaves. Can you explain this?



13 An experiment with a floating egg

Place an egg in a glass of fresh water and observe it. Next add salt to the water and see if you can float the egg. Can you explain this? How does this relate to the fact that ships ride higher in ocean water than they do in fresh water?

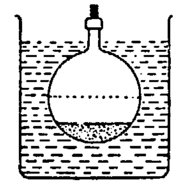


Egg in salt water   Egg in fresh water

14 Experiment on Archimedes' principle

Solder a cycle valve to one half of a copper ball tap float. Load inside the other half with lead or lead shot until the whole just floats in water. A small quantity of plasticine can be used to make a temporary joint.

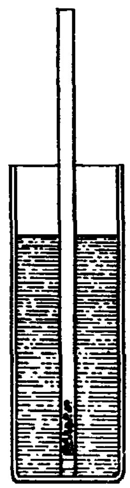
After these adjustments solder the two halves of the ball together and make any final changes by winding copper wire round the neck of the valve holder.



In a discussion on 'why things float', the inevitable answer offered by a class is 'because they have air in them'. Granted this argument, things should float 'better' the more air they have 'in' them. Twenty pumpfuls of air forced into this apparatus causes it to sink.

Try the same experiment with a football or metal water bottle.

15 Drinking straw hydrometer



Procure a drinking straw or a stout natural straw about 20 cm long. If it is not 'water-proof' dip it in melted candle wax and allow it to dry. Seal one end with wax, and introduce some lead shot or fine sand until it floats in a vertical position. Then drop in melted wax to keep the shots or sand in place. Have a thin rubber band or a piece of black cotton tied round the stem so that it can be slid up and down as a marker.

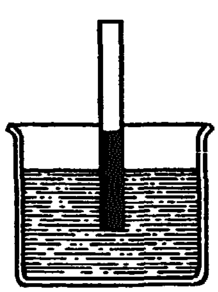
Put a mark on the straw at the water level. Then take the straw out of the water, and measure the length of the straw from the bottom to the water level mark. Let it be x cm. Now let us assume that water has a specific gravity of unity and that the straw has a uniform area of cross-section. Thus we may put a set of markings on the straw for measuring specific gravities of different liquids with ranges, say, from 0.6 to 1.2 by using the formula:

$$\text{length of straw from the bottom to the mark} = \frac{x}{\text{specific gravity of liquid}}$$

16 Specific gravity of a liquid not mixing with water

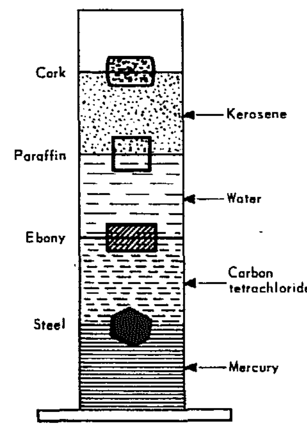
Pour oil into an open glass tube partially immersed in water until it forces water as far as the lower end. The relative lengths of the total oil column, and of the immersed tube is a measure of the specific gravity of the oil.

For a liquid heavier than water, reverse the procedure, i.e., pour the water into the tube.



17 Floating in different liquids

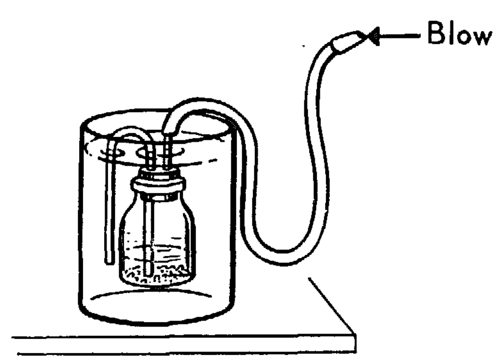
Obtain a tall, slender glass jar, test tube or bottle, and the following liquids: mercury, carbon tetrachloride, water and kerosene. You will also need a small iron or steel ball such as a ball bearing, or iron nut or bolt; a small piece of ebony or some other wood that sinks in water; a piece of paraffin wax; and a piece of cork. First pour some mercury into the glass jar, then some carbon tetrachloride, some water and some kerosene. Drop the four solid substances in and you will observe that the iron sinks in the three top liquids but floats on the mercury. The ebony sinks in the two top liquids but floats on the carbon tetrachloride. The paraffin sinks in the kerosene but floats on the water and the cork floats on the kerosene.



18 How a submarine is raised and lowered

Place pieces of iron or rocks in the bottom of a small wide-mouth bottle and pour a little melted paraffin on them to fasten them down so that the bottle will float in an upright position. Insert a two-hole stopper. In one hole place a U-shaped length of glass tubing which extends to the bottom of the bottle. In the other hole put a short length of glass tube and a rubber tube. Set the bottle in a large vessel of water.

Withdraw some air by sucking on the rubber tube and water will siphon into the



bottle until the bottle sinks. The bottle may be made to rise by blowing out part of the water.

Actually, submarine engineers adjust the buoyancy of the submarine to that of the water and then use the elevators to dive or climb. To remain at the surface they will 'blow' the tanks with surface air after rising. The use of compressed air to empty the tanks is not practical while the submarine is submerged.

The device also illustrates the principle of the tanks or pontoons used to lift sunken ships. Fasten a weight to the bottle, sink both in water and lift the weight by blowing air into the bottle.

F. LIQUID SURFACES

Water and other liquids have a thin film which covers their surfaces. The surface film is pulled tightly over the liquid and this is often spoken of as *surface tension.* Many interesting experiments can be done with liquid surfaces.

1 Floating a needle on water

Thoroughly dry a steel needle. Place it on the tines of a dinner fork and gently break the surface of the water in a dish with the fork. If you are careful the needle will float as you take the fork away. Look at the water surface closely. Can you see how the surface film seems to bend under the weight of the needle?

2 Floating a razor blade

Secure a used razor blade of the double edge type. Try floating it on the surface of water. Again observe the surface and see if the surface film dips under the razor blade.

3 Lifting the water surface

Bend the pointed end of a pin or use a piece of fine wire to make a hook. File the point of the hook until it is very sharp. Put your eye on a level with the surface of the water in a drinking glass. Put the hook under the surface of the water and gently raise the point to the surface. If you are careful the point will not penetrate the surface film but will lift it slightly upwards.

4 Holding water in a sieve

Pour some oil over the wire mesh of a kitchen sieve and shake out the excess so that the holes are open. Carefully pour water into the sieve from a pitcher, letting the water run down the side of the sieve. When the sieve is about half full, hold it over a sink or pail and observe the bottom. You will see the water pushing through the openings but the surface tension keeps it from running through. Touch the bottom of the sieve with your finger and the water should run through.

5 An experiment with a can lid

Punch many holes in a tin can lid with a hammer and very fine nail. Float the lid on the water in a pan. Does water come through the holes? Fill the lid with water from a pitcher. Does water run out of it?

6 Heaping water up in a glass

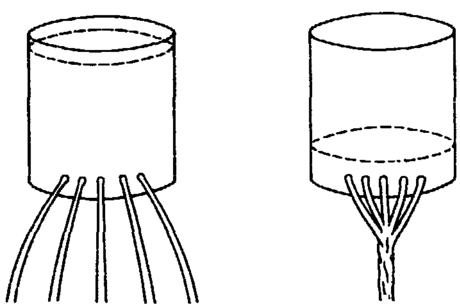
Place a drinking glass in a shallow pan or on a saucer. Rub the top edge of the glass with a dry cloth. Pour water into the glass until it is full to the brim. You will observe that you can fill the glass several millimetres above the top. Now drop coins or thin metal washers into the water edgewise. See how far you can heap the water up by dropping these in before it runs over.

7 Putting a point on a brush

Secure a paint brush of some sort and observe the bristles. Now dip the brush in water and you will observe that surface tension has drawn the bristles together. An artist's paint brush or a shaving brush will work very well for this experiment.

8 A trick with surface tension

Obtain a used tin can and make five holes in it with a nail. The holes should be very near the bottom of the can and about five millimetres apart. Now fill the can with water and observe that the water comes from the can in five streams. Pinch the jets of water together with your thumb and forefinger and you can make one stream from five. If you brush your hand across the holes in the can the water will again flow in five separate streams.



9 The water will not run through the cloth

Select a glass jar and a piece of cloth from an old sheet or handkerchief. Fill the jar with water. Wet the cloth well, stretch it over the mouth of the jar and fasten with a piece of string or thread. Invert the jar over a pail of water and observe that the surface tension keeps the water from coming through the cloth.

10 The effect of soap on surface tension

Select a large plate and rinse it until you are sure that it is very clean. Fill the plate with cold water and let it stand for a time on a table until the water is still. Sprinkle some talcum powder lightly over the surface of the water. Wet a piece of soap in water and touch it to the water near the edge of the plate. The talcum powder will be drawn to the opposite side of the plate at once. The soap reduced the surface tension at one point and the increased surface tension on the other side contracts the surface and pulls the talcum with it.

11 The effect of petrol on surface tension

Repeat the above experiment, being sure that the plate is very clean. It is wise to rinse the plate in cold water for a time before filling it. Instead of soap, place one drop of petrol on the water near the edge of the plate. How does petrol affect the surface tension of water?

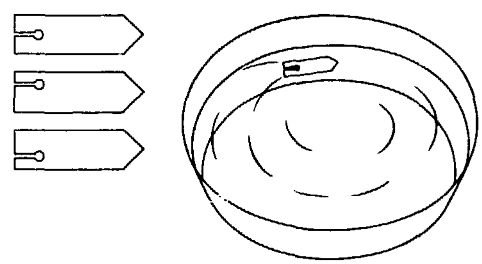
12 An experiment with a loop of thread

Rinse a dinner plate thoroughly and then fill it with water. Make a loop with thread, open it a little and float it on the water. Touch the surface inside the loop with a bit of soap and observe the results.

13 Driving a boat by surface tension

Secure some gum camphor at the drug store. Cut two or three boats from stiff paper, each about 2.5 cm in length. Cut a notch in the stern large enough to hold a small lump of gum camphor in contact with the water without letting it fall out. Float your boats in a large pan of water.

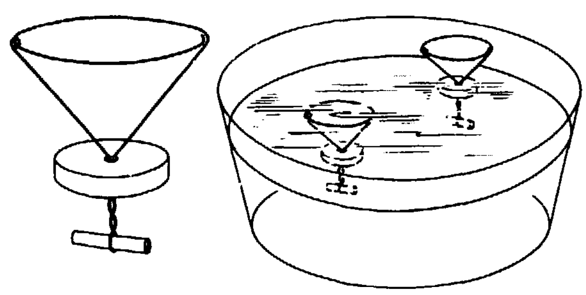
You can make an interesting variation by placing the notch in the stern on the right or on the left.



14 A floater to show surface tension

Bend a piece of small copper wire into a ring about 8 cm in diameter. Attach two other pieces of wire rigidly to opposite sides of the ring and join these pieces by twisting them together about 8 cm below. Make the twist about 5 cm long. Attach a flat cork as shown in the diagram and then a wad of tinfoil to keep the floater upright in water.

Now set the floater in a pan of water and press it beneath the surface. When it floats upwards, it does not break through the surface film. Observe how it stretches the surface film.



15 Making spheres with surface tension

Find a glass jar and fill it about two-thirds full of commercial alcohol. With a medicine dropper place some drops of oil in the alcohol and then fill the jar with water. If you get the correct mixture, the oil spheres will float down to about the middle of the jar. The oil droplets are pulled into perfect spheres by surface tension.

16 Blowing soap bubbles

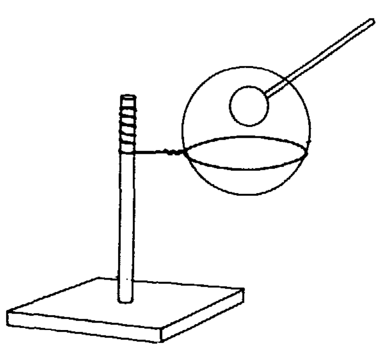
Soap films and bubbles serve very well for observations on surface tension. You can make a good soap bubble solution by placing three level tablespoonfuls of soap powder or soap flakes into four cups of hot water. Let the solution stand for three days before using. Try blowing bubbles with a bubble blower, a soda straw, a clay pipe and an old tin horn about 4 cm in diameter.

Another good bubble blower can be made by slitting the end of a soda straw into four parts extending about 1 cm from the end. Bend these pieces outward. A razor blade works well for slitting the end.

17 Making a soap bubble support

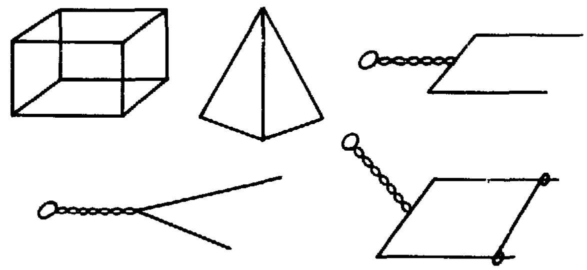
Put a round dowel rod about 15 cm long into a wooden spool or a piece of wood suitable for a base. Wind copper or iron wire about the dowel rod and make a loop about 10 cm in diameter. Dip the loop in soap solution.

Blow a large soap bubble and detach it in the loop. Now wet a soda straw in the soap solution and carefully put it through the large bubble. Try to blow a smaller bubble inside the large one. This will take a little practice.



18 Some experiments with soap films

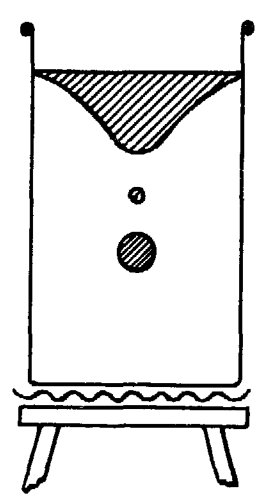
Make the following forms from wire. Dip the various forms in the thick soap solution and observe the films.



Dip the wire form with the slider in the soap solution. Pull out the slide slightly and watch the film stretch. Release the slider, and it will be pulled back by the contraction of the film.

19 To study the formation of a drop of liquid

Gently pour aniline into a large beaker of cold water until a layer about half an inch deep accumulates at the bottom. Place the beaker on a gauze and tripod and warm it using a small bunsen flame. Aniline expands more than water and after a while it will float to the top. Remove the bunsen and wait for results. As the aniline cools it will sink again to the bottom, but in so doing exhibits the form taken by all drops of liquid when falling. The effects of surface tension are seen in slow motion because the densities of the aniline and water are nearly the same.



CHAPTER X

Experiments and materials for the study of machines

A. LEVER, WHEEL AND AXLE, PULLEY

1 A simple equal-arm lever

Make a wooden base 15 cm square and 2 cm thick. In the centre of the base fasten another block of wood 4 cm square and 3 cm thick. Fasten to two sides of this block two uprights 15 cm long, 3.5 cm wide and 1 cm thick. These may be fastened to the small block by means of screws. In the top end of each upright cut a narrow slot with a thin blade saw. The slot should be a little less than 2 cm deep or just deep enough to hold a used razor blade with 2 or 3 mm extending above the top of the upright.

For the lever arm use a uniform bar about 1 m in length, 4 cm in width and about 5 mm thick. Balance the bar on a knife edge and locate its exact centre of balance. Put a slender nail through the centre of balance of the bar. The nail should be long enough to rest on the two razor blades at the ends of the uprights and permit the bar to swing freely between them.

Balance the bar on the razor blades, and if it does not balance perfectly cut off a little of the heavy end with a knife or saw.

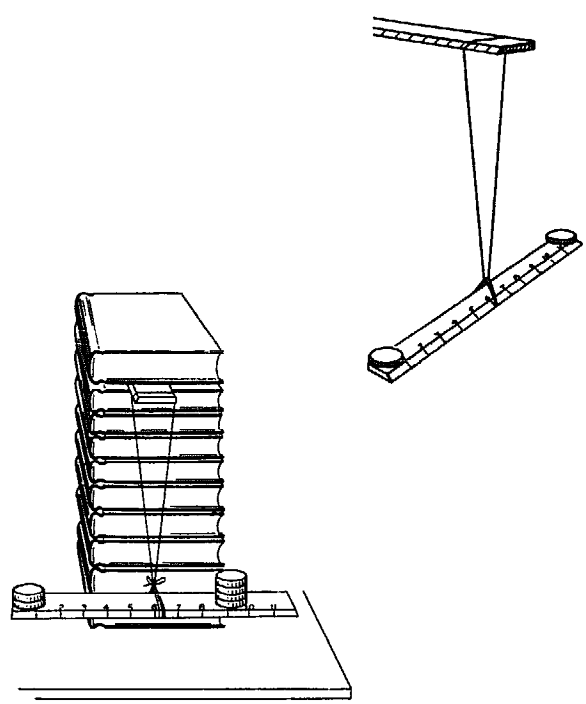
Mark the bar off in centimetres beginning at the nail (fulcrum) and numbering from 1 in each direction to the end of the bar.

Suspend weights by loops of thread from the balance bar.

1 Hang a 10 g weight 20 cm from the fulcrum and then balance with another 10 g weight on the other side. Observe the distance of this weight when the lever is in balance. Repeat placing the weight nearer the fulcrum; farther from the fulcrum.
2 Repeat 1 above with 100 g weights.
3 Place two weights on one side and balance with one weight on the other side. Can you find the condition for balance here? Suggestion: multiply each weight on one side of the fulcrum by its distance from the fulcrum and add the products. Compare this with the product of weight and distance on the other side.

2 A simple balance

Suspend a ruler by loops of cord a short distance above a table top, as shown in the diagram. When the ruler is in balance, place identical coins in different positions on each side of the fulcrum so that the ruler balances again. Using the simpler combinations of numbers of coins and distances from the fulcrum, develop an elementary understanding of the principle of moments. For instance, two coins placed at one end of the ruler will balance four coins placed halfway between the fulcrum and the opposite end.



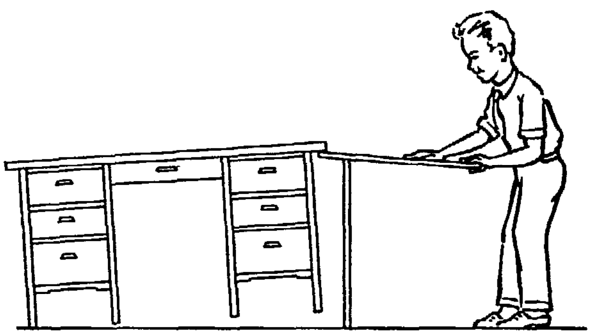
3 A simple beam balance

The beam of a platform balance on which pupils are weighed is really a lever with the fulcrum very close to one end. To show the principle of this type of balance place a stack of eight or ten coins near the fulcrum of the suspended ruler used in 2. Slide a single coin along the opposite end of the ruler until it balances.

4 A lever of the first class

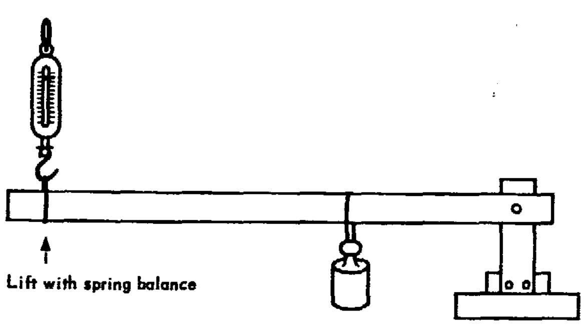
Saw off a stick or board so that it is the same height as a heavy desk or table in the classroom. Place another stick about the same length on this. Place the end of this stick under the edge and use it as a lever to lift the desk or table.

Note that in lifting a heavy object with a lever the longer end travels farther than the shorter end. No energy is really gained but the force exerted by the shorter end of the lever is much greater than the force used to move the longer end.



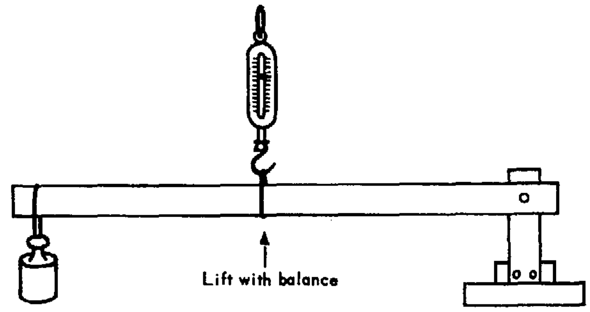
5 A lever of the second class

Use a uniform wooden bar about 1 m long, 4 cm wide and 5 mm thick. Drill a hole near one end, in the centre of the width dimension. Also drill a hole through both uprights used in experiment 1 above, about 12 cm from the base. Put a nail through the holes in the uprights and the hole in the end of the lever bar so that the lever bar is between the uprights. Place weights along the bar and use a spring balance to lift the end of the bar.



6 A lever of the third class

To make a lever of the third class for simple experiments use the materials which were used in experiment 5 above, but interchange the weight and balance.

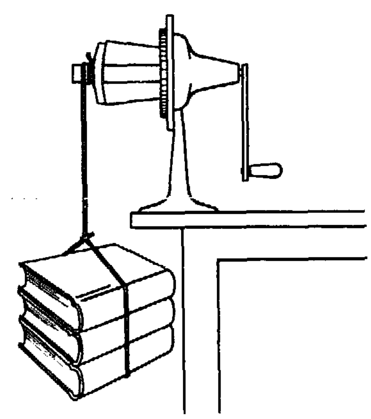


7 A see-saw lever

Obtain a thick plank about 3 m long and bring it into the class room. Balance it over a box or some other convenient device and let the pupils experiment with the see-saw; place different numbers of children on either side of the balance point.

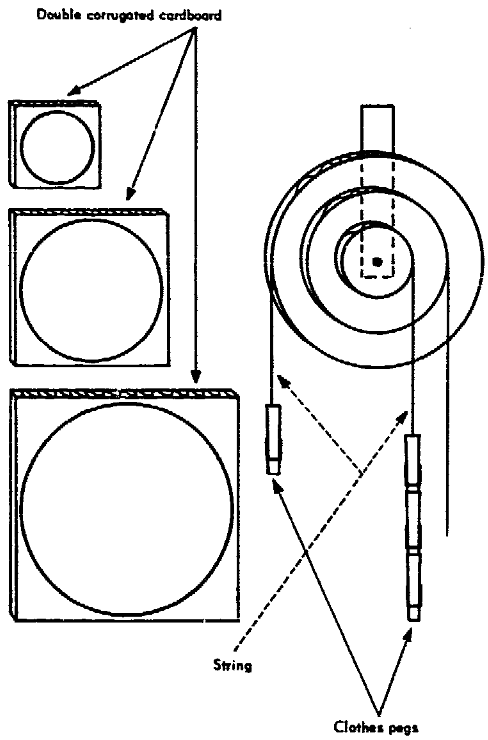
8 A simple wheel and axle

Remove the cover from a pencil sharpener and tie a string tightly around the end of the shaft. Tie a weight of several kilograms to the end of the string and turn the handle. Note that the force needed to turn the handle is much less than the force of gravity on the weight. Point out that the pencil sharpener is used as a wheel and axle in this demonstration.



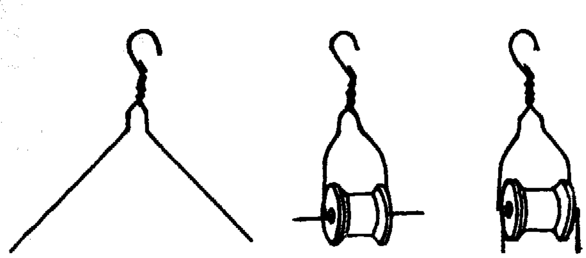
9 Another wheel and axle

Secure some double corrugated cardboard and draw circles of 15, 10 and 5 cm in diameter on it with a compass. Punch through the cardboard with the compass and draw each wheel or circle on the other side. Cut out each of the wheels, cutting cleanly from either side of the cardboard. Punch a nail through the centre of each wheel and then glue or staple the wheels together—with the largest and smallest wheels on the outside—so that they will turn easily on a common axis. Mount them as shown in the diagram. Press gently into the rim of each wheel with a blunt instrument to make a groove. Wind a thread or string over each pulley and attach one end to the groove with a pin. Put a loop in the other end of the thread so that weights may be suspended from it. Use some light weights such as clothes pegs, and you will discover that you can lift weights many times greater, just as you can with a lever. The wheel and axle is a type of lever.



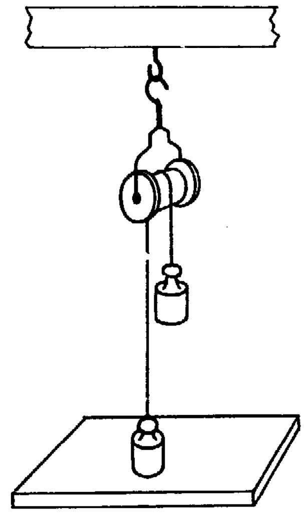
10 How to make a simple pulley

A reasonably satisfactory pulley can be made from a wire clothes hanger and a cotton reel. Cut off both wires of the hanger at a distance of about 20 cm from the hook. Bend the ends at right angles and slip both through a spool. Adjust the wires so that the spool turns easily and then bend the ends down to keep the wires from spreading.



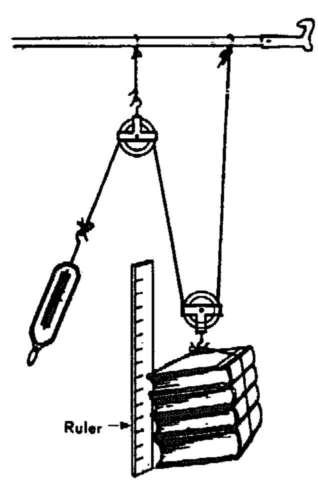
11 A single fixed pulley

Set up a single fixed pulley as shown in the diagram below. By means of weights see how much force is required to lift weights of 25, 50, 75, 100 and 200 g. Measure the distance moved by the effort force when the resistance force (the weight) is moved through 20 cm.



12 A single movable pulley

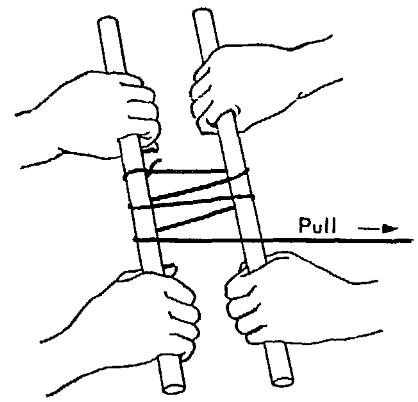
Suspend two pulleys on a cord from a horizontal support, and load them as shown. If there is no adjustable support on the demonstration desk, a window stick laid across the back of two chairs will serve. Attach a spring balance to the end of the cord and compare the weight of the object with the force required to lift it with the pulley system. Compare also the distances through which the force and the weight are moved.



13 The block and tackle

Let two pupils each grasp a round stick, such as a broomstick, and stand several feet apart. Tie a length of clothes line cord to one of the sticks and wrap it several times around both sticks so as to form a combination of pulleys. Ask a third pupil, smaller than the other two to pull on the rope. He can easily pull the two sticks together despite the efforts of the pupils holding the sticks.

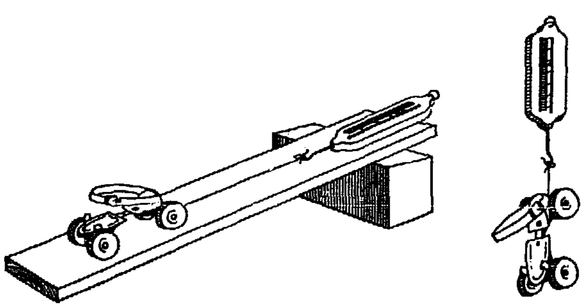
Make a list of devices in which pulley combinations are used to increase forces. Tow cars and power shovels are examples. List other devices and machines used to increase forces.



B. INCLINED PLANE, SCREW AND WEDGE

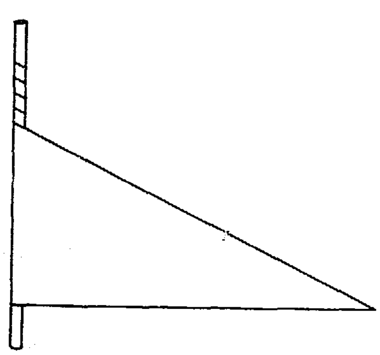
1 A simple inclined plane

Attach a spring balance to a toy car or roller skate and pull it up a slanting board (inclined plane). Note the force required to move the car and compare it with the force needed to lift it vertically. Note also that in moving up the inclined plane, the force is exerted over a greater distance than when the car is lifted vertically to the same height above the table. Neglecting friction, the work required is the same in both cases. Point out that this is also true for other simple machines.



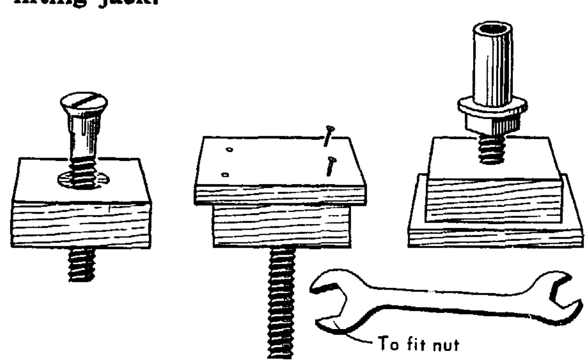
2 The screw is an inclined plane

Mark off and cut out a right angle triangle on a piece of white paper or a piece of wrapping paper. The triangle should be about 30 cm long on its base and about 15 cm long on its shortest side. Secure a round rod about 20 cm long and roll the triangular piece of paper on the rod beginning at the short side and rolling toward the point of the triangle. Keep the base line of the triangle even as it rolls. Observe that the inclined plane (the hypotenuse) spirals up the rod as a thread.



3 A simple jack screw

Bore a hole through a block of wood to fit a carriage bolt. Select a bolt that is threaded nearly its entire length. Sink the head of the bolt in the wood, so that it is flush with the surface and nail a piece of board over it. Over the projecting threads place a nut, then a washer and short piece of metal pipe. The inside diameter of the pipe must be slightly larger than the bolt. By turning the nut with a wrench the device will act as a powerful lifting jack.



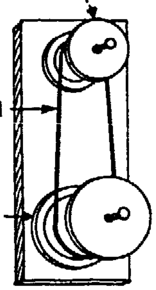
4 The wedge

Make a wedge from a piece of wood and drive it under a table leg or some other heavy object. Observe that the wedge is a double inclined plane.

C. HOW SPEED IS INCREASED BY THE USE OF MACHINES

1 A small spool and a large spool

Using nails for axles fasten a large spool and a smaller spool to a block of wood. Slip a rubber band over both spools. Turn the larger spool one turn and note whether the smaller spool makes more or less than one full turn. Make a list of devices that are driven by belts.



2 Using a bicycle

Turn a bicycle upside down so that it rests on the seat and handlebars. Turn the pedal wheel exactly one turn and note the number of turns made by the rear wheel.

3 An egg beater

Examine an egg beater, hand drill or some other device in which an increase of speed is obtained by means of gears.

4 Using a lever

Show that the longer end of a lever travels farther and faster than the shorter end when the fulcrum is not in the centre. A baseball or cricket bat makes use of this advantage. List other examples of the use of levers and other simple machines to increase speed.

5 Using a pulley

Use the pulley set-up shown in experiment A 12. Apply the force on the movable pulley and observe how rapidly the weight on the other end of the string rises.

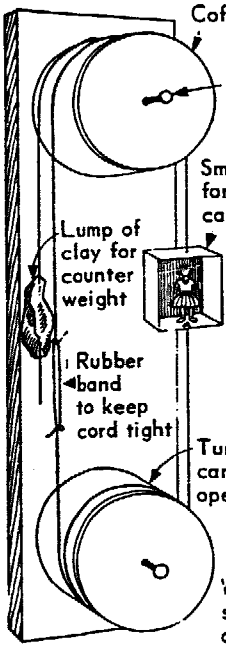
6 Using a wheel and axle

Use the pencil sharpener that you used in experiment A 8. Pull on the end of the string that held the books and observe how rapidly the crank turns.

D. HOW MACHINES ARE USED TO CHANGE THE DIRECTION OF FORCES

1 A model elevator

A working model of an elevator can easily be made from simple materials. For the



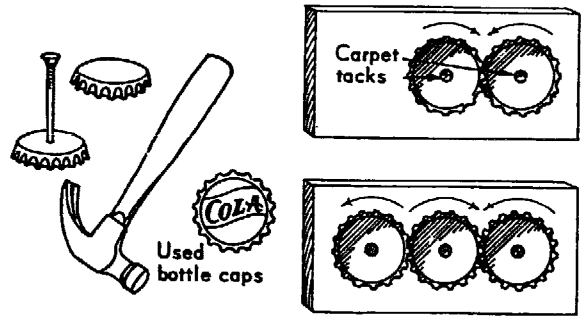
rotating drums or sheaves, metal coffee tins will do. With a hammer and a large nail punch holes in the exact centre of the bottoms and lids. Replace the lids and mount the tins on opposite ends of a board, taking care that they both turn easily.

For the elevator car use a small cardboard or wooden box. Attach pieces of string to both ends of the box and wind them round the sheaves as shown. A piece of modelling clay can be used for a counterweight and should just balance the weight of the car. Operate the elevator by turning the sheave that has the double turn of cord. A model of this kind is very similar to real elevators, but the sheave of a real elevator is turned by an electric motor.

2 Simple gears

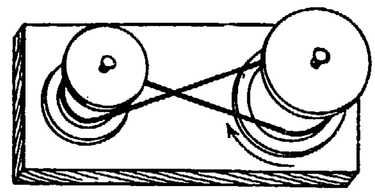
With a hammer and a medium-sized nail, make holes in the exact centres of several used bottle caps. Straighten the edges of the caps to make them as round as possible.

Lay two of the caps on a block of wood so that the toothlike projections mesh together. Fasten them down with carpet tacks, but make sure that they still turn easily. Turn one of the caps and note the direction that the other turns. Add a third cap and note the direction that each turns.



3 Using cross belts

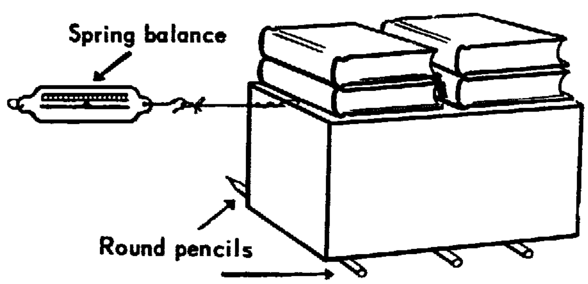
Cross the belt on the spool pulleys used in C 1 above and turn one of the pulleys. Note that they now turn in opposite directions.



E. USING AND OVERCOMING FRICTION

1 Reducing friction with pencils

Place round pencils under a heavy box. Attach a string to the box and find the force needed to move it across a table. Find the force needed to move the box without the rollers. Summarize the data obtained and suggest explanations for the results.

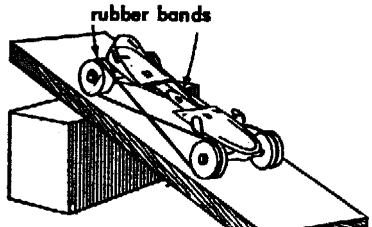


2 Using wheels

Repeat the previous experiment but use a wheeled device such as a roller skate (or several roller skates) instead of rollers. State some advantages that wheels have over rollers for moving things.

3 Sliding friction

Lock the rollers of a roller skate by crisscrossing rubber bands over them on both sides. Place the roller skate on a sloping board and note how the friction of the rubber keeps it from sliding.



4 Places where friction occurs

Locate the places on various mechanical devices where parts rub together. Roller skates, pulleys and the wheels of toys often need oil. Try to find two similar bearings that need oil, such as those on a roller skate. Oil one and compare the ease with which it turns with the bearing that has not been oiled.

5 Reducing friction with oil

Lay two panes of glass side by side and place a few drops of oil on one. Ask pupils first to rub a finger back and forth on the unoiled pane and then on the oiled pane. Feel the difference.

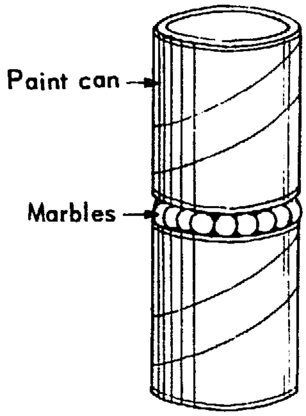
6 Friction of rough surfaces

Place two pieces of sandpaper together. Notice the friction that is created when one is rubbed against the other. Now put some grease between the pieces of sandpaper. The friction is much reduced because the grease fills up the irregularities on the surface of the sandpaper. Applying grease to the moving parts of a machine acts in a similar way.

7 Reducing friction with ball bearings

Find two tin cans that have a deep groove around the top, such as paint cans. Lay marbles in one groove and invert the other can over the marbles to form a ball bearing.

Place a book on top and note how easily the demonstration bearing turns. Oil the marbles and it will turn still more easily.



8 Real ball bearings

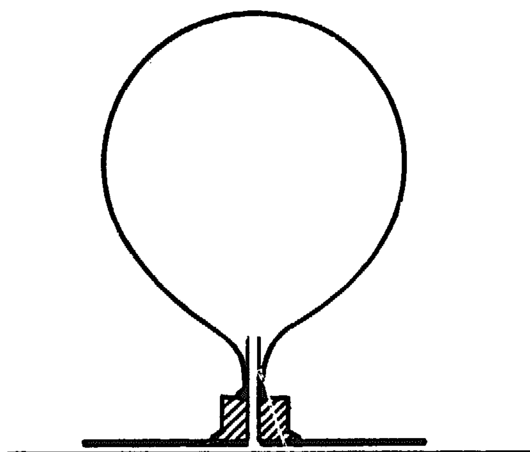
Examine real ball bearings and roller bearings. Make a list of devices that contain ball bearings or roller bearings.

9 Ball bearings again

Place some marbles in the lid of a tin on the floor. Put one foot on the marbles and notice how easily you can spin round.

10 Reducing friction by an air stream

Cut out a disc of cardboard about 10 cm in diameter. With a red-hot pin, burn a hole through the centre. Saw a small cotton reel in half and glue the original end of one half over the middle of the disc. Find a piece of bamboo or some other tube which just fits the hole in the reel. Push this into the neck of a small balloon, using cotton or a rubber band to secure the joint. Blow up the balloon, pinch the neck, and insert the tube into the hole in the cotton reel. Place the disc on the table and release the air. The expanding air, escaping through the hole in the disc, will lift the card so that, given a flick, it will shoot across the table with practically no friction. This experiment illustrates the principle of the Hovercraft.



CHAPTER XI

Experiments and materials for the study of forces and inertia

A. BALANCE

1 Making a device for the study of balanced forces

See Chapter X, experiment A 1.

2 Balance with a see-saw

Secure a strong board about 3 m long and a saw horse or box over which the board may be balanced to make a see-saw or teeter-totter. If possible set this up in the classroom. The playground of your school may have a see-saw for the children (see also Chapter X, experiment A 7).

Select two children of equal weight and place them at either end of the board so that they balance. Measure the distance from the balance point to each child.

Next have a heavier child balance himself with a lighter child and observe the changes that have to be made. Next have one child balance two others on the opposite side. Observe the changes. If you measure the distance each time from the balance point to the child and multiply the distance by the child's weight you will discover an interesting thing about balance.

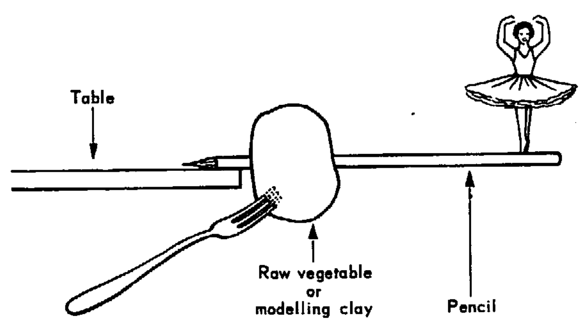
Note: When two children are on the same side, measure the distance of each from the balance point, multiply by the weight of each child and add the products.

3 A balance trick

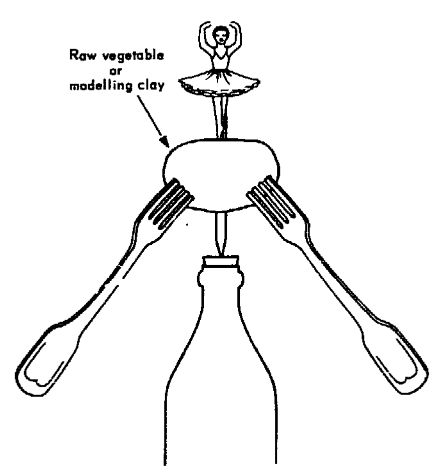
Obtain a smooth metre stick and let it rest lightly on your two forefingers. Place your fingers near the ends of the stick and then move them toward the centre. Where do your fingers meet on the metre stick? Place the finger of your right hand near the end of the metre stick and the other about half way to the centre on the other side and repeat. Where do your fingers meet this time? Reverse and put the finger of your left hand at the end while the finger of the right hand is about half way to the end on the other side. Where do your fingers meet now? Try other distances. Can you explain this interesting trick?

4 Some simple balance experiments

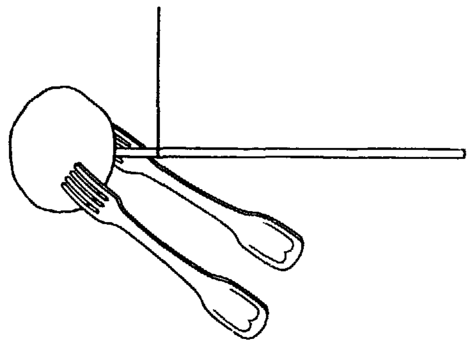
(a) With a sharp knife cut a slice of some raw vegetable or modelling clay about 2.5 cm thick. Punch the point of a lead pencil through the slice until it protrudes about 2.5 cm on the other side. Insert a dinner fork in the slice of vegetable as shown in the diagram. Now place the pencil point on the edge of a table and adjust the parts until balance is obtained; then give the long end of the pencil a little tap.



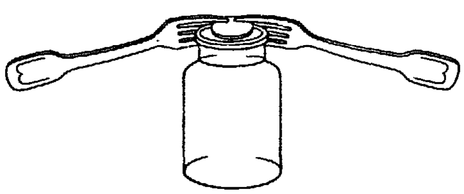
(b) Assemble a slice of raw vegetable or modelling clay, two dinner forks and a pencil as shown in the diagram and balance them on the top of a soda water bottle.



(c) Assemble a slice of raw vegetable or modelling clay, a pencil and two forks as shown in the diagram. This time suspend them with a thread or string. A little experimenting will be required to find the exact point where the string must be placed for balance.



(d) Assemble a coin and two dinner forks as shown in the diagram. Balance on the edge of a bottle or glass.



(e) Try to devise some other simple experiments with balance using common things found about the house or school.

5 Can you straighten the cord?

Obtain a strong cord or small rope about one and a half metres in length. Wrap another cord around a heavy book or other suitable weight. Tie the cord with the weight securely to the centre of the other cord so that it hangs about 15 cm below. Grasp the long end and try to straighten it by pulling your arms apart. Have a pupil pull on one end while you pull on the other. Can you straighten the cord?

6 Finding the centre of gravity of objects

Secure a triangular file and place it on a table as a balancing point. Any sharp-edged device with a flat side may be used. Balance various sticks, rods and devices such as brooms, bats, brushes, etc., on the knife edge and mark the place where they balance with a piece of chalk. Is the centre of gravity of every device you tested at the exact centre of the body? Which objects seem to have the centre of gravity at the centre? Where is the centre of gravity of the others usually found?

B. EXPERIMENTS WITH GRAVITY

1 Falling bodies

If you can find a building that is about 20 m high in your locality you can study how gravity makes bodies fall faster the longer it acts on them. Get a piece of string long enough to reach from a point at least 20 m high to the ground. Fasten the cord so that it forms a straight vertical line. Opposite a window 20 m from the ground tie a piece of coloured cloth or yarn to the string. At about 5 m below this point tie another piece of coloured yarn. Have someone stand on the ground with a watch and call out the seconds. A good way is to beat seconds with the arm and call out 'A thousand and one—a thousand and two—a thousand and three'. This will beat seconds approximately.

Now station someone at the 5 m mark below the starting point and someone on the ground. Drop heavy stones and light stones. Drop small objects and large objects and see how far they have fallen at the end of one second and how far at the end of two seconds.

2 The coins fall together

Place a ruler obliquely on the edge of a table so that one end just projects over the edge and the other end is about 3 cm from the edge. Now place one coin on the projecting end and another on the table, between the other end of the ruler and the edge of the table. With another ruler strike a sharp blow, hitting the projecting end horizontally. One coin falls straight to the floor while the other travels a longer path. Carefully observe when each coin reaches the floor. You will have to repeat this experiment several times. What conclusions do you reach?

3 A simple pendulum

Tie a cord at least 2 m long to some object like a stone or a small metal ball. Suspend this in a doorway or from a hook in the ceiling and start it swinging through a large arc. Count the number of swings it makes in 10 seconds and then multiply by 6 to see how many swings it makes per minute.

Next swing the pendulum through a short arc and determine the number of swings per minute. Repeat each of the above manipulations several times and take the average in each case. Does the length of the arc affect the time of vibration of a pendulum?

Keep the length of the pendulum the same but change the material used for a weight. Repeat the manipulations suggested above.

Does the material in the bob affect the time of vibration of a pendulum?

Repeat each of the above experiments, but use a pendulum that is only half as long. Does the length of the pendulum affect its rate of vibration? How does it affect it?

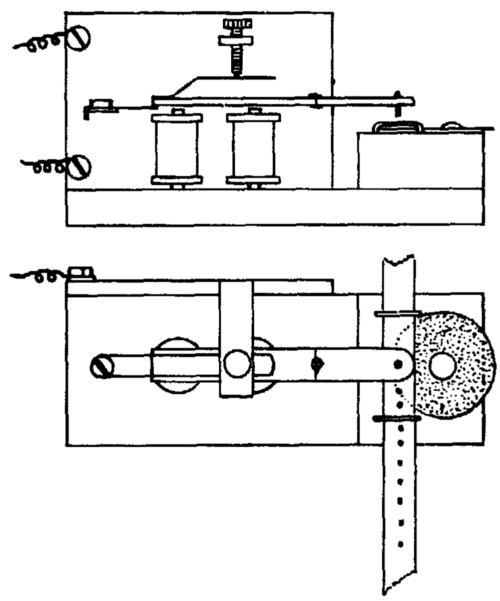
4 Timing a falling body

The motion of a freely falling body can be examined by attaching it to a strip of paper tape on which marks are made at equal time intervals. This may be done by passing the tape between the armature of an electric bell and a pad of carbon paper. To modify an electric bell mechanism for this purpose, remove the clapper, and extend the armature by soldering to it a strip of metal about 5 cm long. Near the end of this extension, drill a hole to fit a small round-headed screw, and fix it in with the head downwards to act as a marking hammer.

Fasten the mechanism to a piece of wood measuring approximately $5 \times 2.5 \times 18$ cm which will serve as a base. Fix another piece of wood, $5 \times 5 \times 2.5$ cm under the striker to support the disc of carbon paper, and staples to guide the path of the ticker tape. The carbon paper disc should be about 3 cm diameter, held loosely at the centre by a drawing pin so that it can rotate to expose a new surface as the tape passes over it. The staples are easily made from wire paper fasteners pressed into the wood.

The extension to the armature may have to be bent a little so that it does not strike the paper too hard and cause bouncing, which may result in uneven timing. The paper strip is now passed through the staples with the carbon paper underneath and the armature is set in motion. As the strip is released and the body falls, it drags the paper after it. Marks are thus made on the paper at equal time intervals and measurements can be made of the distances travelled from the start.

This timing device can be used for other experiments, e.g., the acceleration of a cyclist can be measured by attaching the tape to the saddle of the machine. For absolute measurements an A.C. bell can be modified, when the time interval is that of the frequency of the mains.



5 Study of a rolling ball

A large ball bearing or 'bagatelle ball' rolling down a smooth track can be timed by a pendulum. To make the track, fasten together two 120 cm lengths of glass tubing (or other smooth rods) with rubber bands. Place them on a length of wood resting on a table, with a matchbox under one end. Set up a simple pendulum to give about quarter second time intervals. A metal nut supported by cotton is suitable. Start the ball rolling down the track and observe its position after successive swings of the pendulum. Make marks along the wood opposite the position of the ball at equal time intervals. Taking the average of several trials, measure the distance travelled from the start. The curve obtained by representing these on a distance-time graph will reveal that the relationship is parabolic, i.e.,

$$s = \tfrac{1}{2}.a.t^2$$

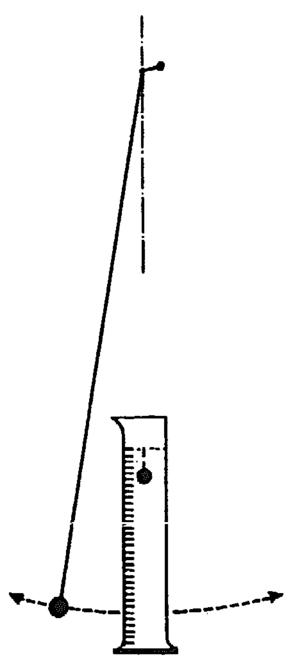
where s is the distance travelled, a the acceleration, and t the time taken.

6 Uniform motion

When a body falls through a fluid, the pull of gravity is soon balanced by the frictional forces set up, and it continues to move at a constant velocity. If this is the case the distances then travelled are proportional to the time taken. The effect can be investigated by the following experiment in which a wax pellet falls in water.

Make a small pear-shaped float out of softened wax and weight it at the tip with lead shot so that it maintains its balance without sinking to the bottom or floating on the surface of water contained in a measuring cylinder or large graduated test tube. Take a length of thread measuring exactly 98 cm and attach a small weight to one end, thus making a pendulum which takes exactly one second to swing from side to side. Support this so that it swings near to, and behind, the measuring cylinder. Carefully place the lump of wax on the surface of the water (where it will remain motionless, owing to the resistance of the water at the surface). Push the wax gently with your finger so that it begins to sink through the water and at the same time set the pendulum swinging. Observe the divisions which the wax is opposite each time the pendulum passes the vertical.

Repeat the experiment once or twice, and from the observations find how many divisions the wax falls through per second.



7 The acceleration of a falling ball

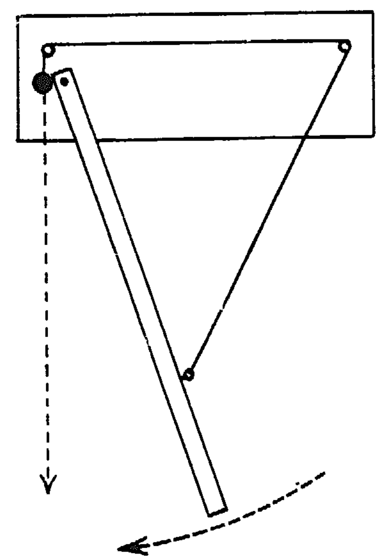
The change in speed per second of a moving body is called the acceleration. When it is constant as in the case of a ball falling under the action of the earth's gravity, it can easily be measured. In this particular case it is generally represented by the symbol g. In the following experiment, the fall of a metal ball is intercepted by a lath about 120 cm long swinging from a nail fitting loosely onto a hole near one end.

The period of swing of the pendulum is first found, using a clock to time, say, 100 swings. The ball, which has a small hook attached, is then blackened and hung from a thread which passes over smooth nails and also pulls aside the lath from the vertical position, as shown in the diagram. On burning the thread, the ball and lath are released simultaneously and the ball will hit the lath. From the position of impact, the distance fallen vertically by the ball in one quarter of the period of the lath can be found.

Using the relationship

$$\text{distance fallen} = \tfrac{1}{2}\, g\, (\text{time of fall})^2$$

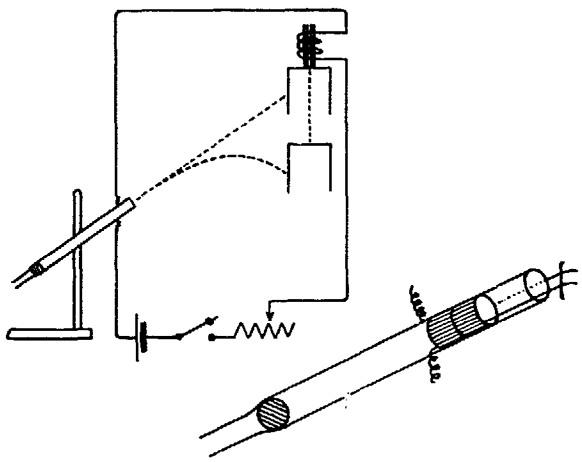
g can be calculated.



8 Path of a projectile[1]

The apparatus below can be used to show that there is no relation between the vertical and the horizontal velocities of a projectile. The projectile is a metal ball, and the target is a small tin can hanging from an electromagnet. The circuit of the electromagnet includes two bared wires which are fixed parallel to and each side of the axis of a cardboard tube, projecting about 2.5 cm beyond the end. An old thermometer case is suitable for this part of the apparatus. A large ball bearing is placed inside the tube, being prevented from falling through by the narrow end. The electrical circuit is completed by a short length of copper wire resting on the projecting wires. Fix the tube in a stand so that it points at the target. Blow up the tube; as the ball passes the muzzle it will displace the copper wire and release the tin can. The ball and target will meet in mid-air. The experiment can be repeated using different angles and distances.

1. Reproduced from *Demonstration Experiments in Physics* by permission of McGraw-Hill Book Co.



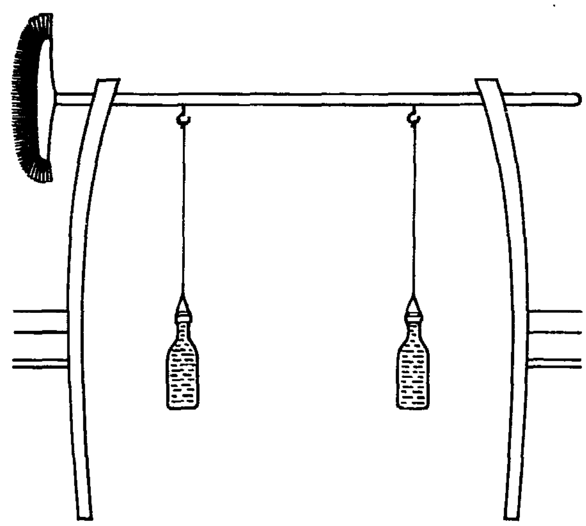
9 Fun with a pendulum

Suspend a hard ball about 8 cm in diameter on a cord over a table. The cord should be at least 1.5 m in length and should be just high enough off the table to hit the top of a pencil which has been placed in a cotton reel and rests on the table. Pull the pendulum and release it in such a way that it misses the pencil on the outward swing and knocks it over on the backward swing. You will find that it requires a great deal of practice to become skilful at this.

10 Shifting pendulums

Obtain two soda water bottles that are exactly the same size. Fill them with water and cork tightly. Place a rod across the back of two chairs. Suspend bottles as pendulums from the rod. Be sure that they are the same length.

Hold one pendulum and start the other swinging; then release the first one to hang at its zero point. Soon the swinging pendulum will slow down, and the one that was quiet will take up the swing.



C. CENTRIFUGAL FORCE

1 Feeling centrifugal force

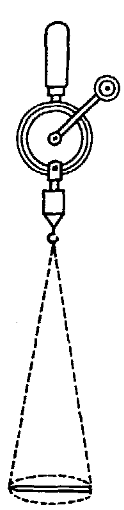
Tie a weight to a string about a metre in length and then whirl the weight around at arm's length. Observe the outward pull on the string. This is centrifugal force.

Replace the string with a strong rubber band. Cautiously whirl the weight on the rubber band. Observe the stretch in the rubber. This is caused by centrifugal force.

2 A simple rotation machine

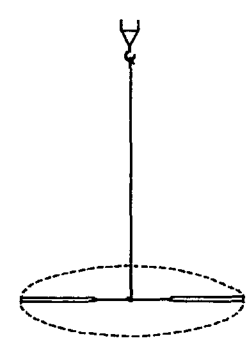
Secure a breast-drill or hand-drill such as the one shown in the diagram. Clamp a small screw eye or cup hook in the chuck of the drill. Attach a 30 cm length of light string near the point end of a spike. Make a loop in the other end of the string and attach it to the screw eye in the chuck of the drill.

Now rotate the drill steadily by crank. Observe how the centrifugal force affects the suspended spike.



3 An experiment with two spikes

Use the drill for a rotation machine as in the above experiment. Join two spikes by attaching the point end of each to the end of a 15 cm length of cord. Grasp the cord joining the spikes at its centre and attach it to the cord from the drill chuck at this point. Rotate the drill crank steadily and observe the effect of the centrifugal force on the two spikes.



4 Centrifugal force with a ring

Secure an iron ring about 6 cm in diameter and attach it to the cord on the drill. Observe the effects.

5 Centrifugal force with a tin can lid

Punch a hole near the edge of a tin can lid.

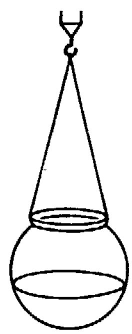
Attach it to the cord from the drill and observe the effects of rotation.

6 Centrifugal force with a beaded chain

Secure a length of beaded chain like that frequently used for pull cord on electric light switches or for key chains. Fasten the ends together to make a ring. Attach this to the string from the drill and observe the effects of centrifugal force.

7 Centrifugal force with a liquid

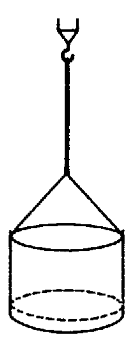
Obtain a small goldfish bowl or glass jar. Fasten a wire securely about the neck. To this wire attach a bale. Attach the cord from the drill chuck to the exact centre of the bale.



Place about 3 cm of water coloured with ink in the bowl. Turn the drill handle to spin the bowl and water. Observe the effects of centrifugal force on the water.

8 Another experiment with water

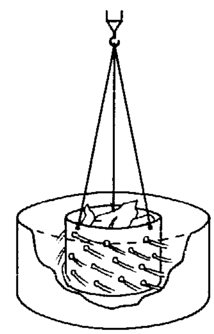
Suspend a tin can about 8 cm deep and 12 cm



in diameter as shown in the diagram. Pour about 3 cm of water into the can and spin the drill. Observe what happens to the water.

9 How a centrifugal clothes dryer works

Use a can similar to the one used in the last experiment. Punch the sides full of holes with a nail. Punch three holes equidistant from each other around the top of the can. Suspend with three cords and attach these to the screw eye in the drill chuck. Make a cylinder out of cardboard or find a pail a little deeper than the can and considerably wider. Place a bit of wet cloth in the can attached to



the drill. Lower the can into the cylinder or pail and spin it rapidly with the drill. The water is thrown out of the cloth and can by the centrifugal force.

10 The water will not spill

Obtain a small pail and fill it nearly full with water. Swing it around rapidly at arms' length and the water will not spill because of centrifugal force.

11 Fun with centrifugal force

Find a wire coat hanger and place the hook over the first finger of your hand with the base resting on the table. Carefully balance a small coin on the straight wire at the bottom and directly under the hook. This requires some skill. If you need to, you can flatten a small space on the bar with a file or hammer.

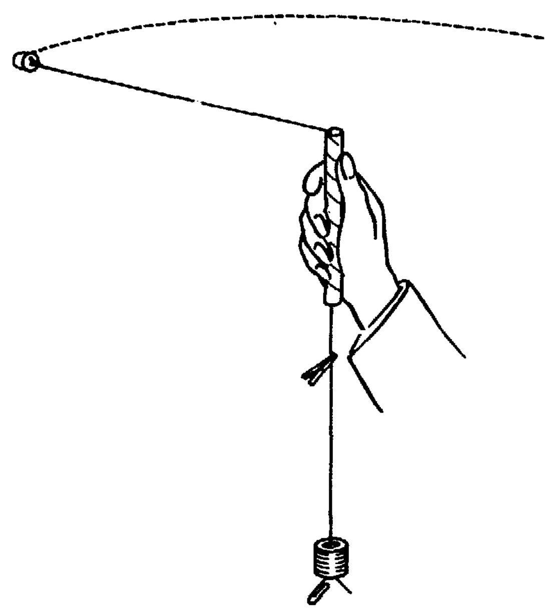
Gently start to swing the hanger and coin on your finger. When it has gained a little motion, and with practice, you can swing the hanger around in a circle, the coin will be held to the wire by centrifugal force.

12 Centripetal force

Sir Isaac Newton first looked at the above effects in another way. He suggested that motion in a straight line is most natural, and that deviations from this type of motion are caused by a force pulling the body out of line. When the force acts on the body from a fixed point, such a body moves in a circle, and the force towards the centre is called a centripetal force.

c. *Centrifugal force*

Circular motion can be studied by the apparatus shown in the diagram. The force producing circular motion with different radii and frequency can be measured. Cut a piece of glass tubing 15 cm long and about 1 cm external diameter. Heat one end in a bunsen flame until the walls of the tube are smoothly rounded. Wrap two layers of adhesive tape round the outside of the tube to provide a grip. Tie a two-holed rubber stopper to the end of about 1.5 m of nylon braided fishing line. Pass the other end of the line down the axis of the tube, and hang half a dozen 1 cm iron washers from it. A wire paper fastener can be used as weight carrier.



Pull up the line so that the distance from the top of the tube to the cork is 1 m. Grip the glass tube and swing it in a small circle above your head so that the rubber stopper moves in a horizontal circle; the force of gravity on the washers provides the horizontal force needed to keep the stopper moving in a circle. Use a small alligator clip on the vertical fishing line to check that the motion is steady, and record the frequency of revolution required to keep the body moving in a path radius 1 m when different numbers of washers are hung from the carrier.

The relation $F = m\,4\pi^2 f^2 R$ can also be examined, keeping the frequency f constant. This presents a little more experimental difficulty, but a suitable simple pendulum is helpful as a reference in both experiments.

D. EXPERIMENTS ON INERTIA

1 A bottle and marble

Pour some sand into a wide-mouthed bottle. Place a piece of cardboard about 5 cm square over the mouth of the bottle. Set the marble on the cardboard and then tap the edge of the cardboard. If the experiment is successful, and it may require practice, the cardboard will be set in motion and will go flying off while the inertia of the marble causes it to drop into the bottle.

2 Driving nails with the help of inertia

Extend a thin board over the edge of a table and support it well by having someone stand on the part over the table. Try to drive a nail into the board near the end which is not supported by the table. Next have someone hold a heavy hammer or stone under the board. Observe that it is now easy to drive the nail because of the inertia of the weight.

3 Cut an apple in two parts with inertia

Secure a long sharp knife such as a carving knife. Cut into the apple with the knife until you can pick them up together. Be sure to have enough of the end of the knife sticking out to enable you to strike it. Now hold knife and apple securely in one hand and strike the end of the knife a sharp blow with a stick. The knife will move through the apple because of the inertia of the apple.

4 Inertia with a handkerchief and tumbler

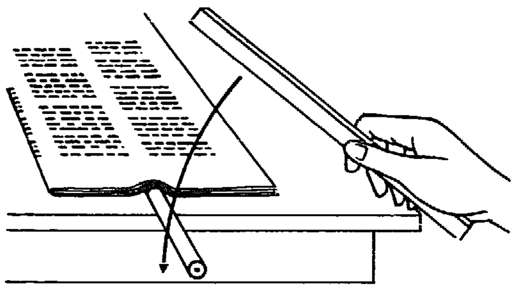
Spread a handkerchief out on a smooth table-top. Place a tumbler filled with water near one corner of the handkerchief. Raise the opposite corner and give the handkerchief a sharp jerk. The tumbler will stand still, and no water will spill.

5 Inertia in a pile of books

Stack up a pile of books. Grasp hold of the one at the bottom of the pile and give it a quick jerk. Can you remove it without upsetting the whole pile on top?

6 Break a stick with inertia

Secure a small stick 18 to 20 cm in length. If no other stick is available a lead pencil will do. Fold a newspaper and place it near the edge of a table. Place the stick under the newspaper on the table and let about half the stick extend over the edge. Strike the stick a sharp blow with another. Inertia should cause the one on the table to break in two parts.



7 Inertia with a spade

Scoop up a spadeful of dry earth. Now pitch the earth away from you. Observe that when the spade stops the earth flies on because of inertia.

8 Inertia on a bicycle

Get your bicycle going and then apply the brakes quickly. Observe the tendency of your body to stay in motion and pitch you over the handlebars. This is the result of the inertia of your body.

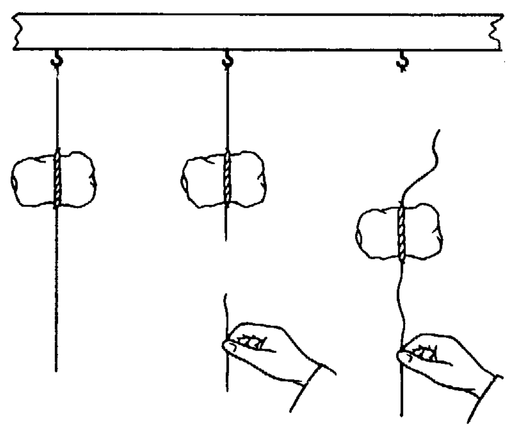
9 Inertia in an automobile

You can observe the same effect as in experiment 8 when you are riding in a car that is suddenly stopped. You have to brace yourself to keep from sliding off the seat. Your body is in motion with the car and tends to stay in motion after the car is stopped.

When you are sitting in a car that is at rest and the car is suddenly started, observe that you are thrown backward because of inertia. Your body is at rest and it tends to stay at rest when the car is started.

10 Inertia with a stone

You will need a stone weighing about 1 kg for this experiment. Wrap a length of heavy string about the stone. Now, on opposite sides of the stone, attach half-metre lengths of lighter cord to the heavier cord. The lighter cord should be barely strong enough to support the stone when it is suspended. Next carefully suspend the stone above a table top. Place a length of board on the table under the stone so that the table top will not be dented when the rock strikes it. Grasp the lower end of the string firmly and give it a quick jerk. If you are successful, the lower string will break and leave the stone suspended. The inertia of the stone caused this. Now take hold of the remaining length of the lower string and pull steadily on it. This time the upper string breaks and the stone falls to the table because the steady application of force (rather than the quick jerk) set the stone in motion.



11 How to identify a hard-boiled egg

Secure a fresh egg and a hard-boiled egg. Give each of them a spinning motion in a soup dish or a plate. Observe that the hard-boiled one spins longer. The inertia of the fluid contents of the fresh one brings it to rest sooner.

E. FORCE AND MOTION

1 A light object moves faster

Mark off a half-metre on a table top with chalk. Divide this equally into centimetres. Secure a long rubber band and two spring clothes pegs. Attach a clothes peg to each end of the rubber band. Now grasp the clothes pegs while they rest on the table top. Place them along the marked-off place on the table top. Stretch the rubber band to a distance of about 15 cm and release each clothes peg at the same instant. Observe that they meet half way.

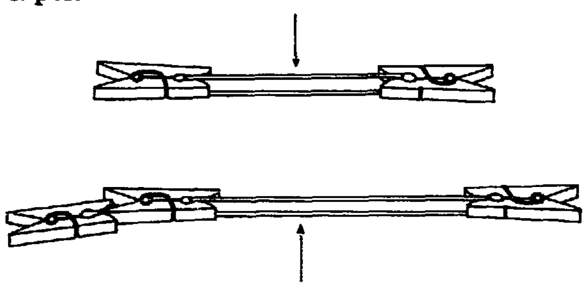
Next, clamp two clothes pegs on one side of the band and one on the other side. Stretch the band to a distance of about

24 cm and release. Where do they meet this time?

Repeat, attaching two clothes pegs on each end of the band. Where do they meet?

Again repeat with two on one side and three on the other. Where do they meet this time?

Can you draw a conclusion from this experiment?



2 An experiment with force and motion

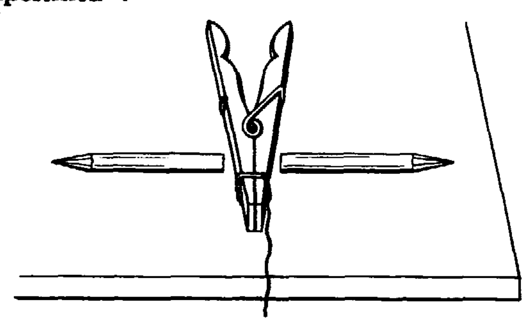
Tie a spring clothes peg open by placing one winding of thread about the long ends. Place the clothes peg in the centre of a long table and put two pencils of about equal size and weight one on either side of, and against the tied end of the clothes peg. Carefully burn the thread and observe the pencils. They are given speeds in opposite directions.

Repeat the experiment, using two larger pencils of about equal weight and size. What do you observe? Compare with the first results.

Repeat, using a large and heavier pencil on one side and a small, lighter pencil on the other side. What do you observe?

If you can secure some metal balls and marbles, repeat, using different combinations of metal balls and marbles.

Can you draw a conclusion from this experiment?



3 Action and reaction in pushing forces

Forces work in pairs. If you push against a wall, the wall pushes with equal force back against you. Secure two kitchen spring balances with square platform tops. Put the tops together with the dial faces up. Have a pupil push on one while you push on the other. Observe that when you push together each balance reads the same.

4 Action and reaction in pulling forces

Secure two spring balances. Make a loop in each end of a short piece of strong cord. Attach a spring balance to each end and have two pupils pull in opposite directions. Make a reading on each balance and compare them.

5 Action and reaction with a roller skate

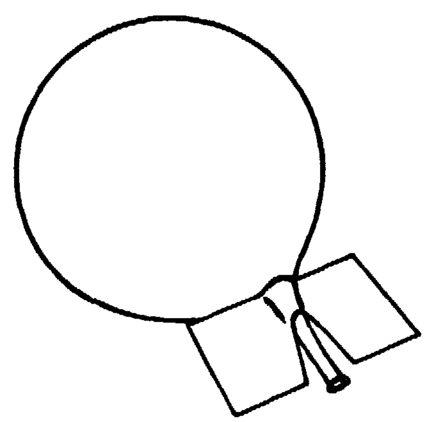
Place a roller skate on a smooth floor. Step on the roller skate with one foot and take a step forward with the other. Observe that the skate moves backward in the opposite direction.

6 Action and reaction in a boat

Step from a free row boat to land and observe that the boat moves in the opposite direction.

7 Jet propulsion is made possible by action and reaction

Fit a small cardboard stabilizer to the neck of a balloon by means of adhesive tape. Inflate the balloon, and close the mouth with your fingers. When the air contained under pressure in the balloon is allowed to escape, the balloon will be propelled forward by the force of the escaping air. This is the principle used in rockets and jet engines.



CHAPTER XII

Experiments and materials for the study of sound

Children will find fundamental principles and elementary experiments in this chapter on sound interesting and closely related to everyday experiences.

A. HOW SOUND IS PRODUCED AND TRANSMITTED

1 Different sounds

Exercise on naming different sounds from experiments, if possible, such as crash (dish falls and breaks), thud (falling weight), clang (beating sheet of iron with hammer), clatter (falling tin cans), crackle (damp wood on fire), tick (clock), crunch (stepping on gravel), splash (stone falls into water), pop (toy gun), boom (drum), bang (door), patter (rain drops on pavement), tramp (feet), rustle (leaves), rattle (thunder, snake), rumble (far-off thunder; thunder rattles, crashes and rumbles) buzz (bee), tinkle (hitting spoon against drinking glass), neigh (horse), bleat (sheep), cackle or cluck (hen), low (cattle), chirp (bird), hiss (airplane), whistle, moan, etc.

Children will have fun imitating these sounds. Help them to find the exact definitions in dictionaries.

2 Vibrating bodies produce sound

Tie a loop of stout string in a hole near one end of a ruler. Hold the loop with the fingers. Swing the ruler in a vertical circle. Whirl it faster. What sound is produced? Repeat the same experiment with different sizes of rulers and loops. To make it easier, use another ruler or a wood rod instead of your fingers.

3 Say 'Ah'. Prolong it and feel your windpipe. What causes the vibrations? Again feel it when you are speaking, singing and whistling.

4 Place a ruler on a table so that about three-quarters of it juts out from the table edge. Now hold down the end on the table with your hand. Bend the other end and let go quickly. The ruler vibrates up and down. Note what sound you hear. Again place the ruler so that half juts out from the table edge. Repeat the experiment. Note the sound you hear again. Is it different from the last one? Repeat the experiment with different lengths of the ruler jutting out from the table edge.

From these experiences one may conclude that sound is produced by vibrations. The vibrating bodies set up vibrations in the air which strike your ear, and you hear a sound.

5 Meaning of a vibrating object

Secure a small, heavy object, such as a piece of lead or iron or a small ink bottle. Tie the object with one end of a string about 1m in length. Now set up a pendulum by hanging the object from the top of a doorway with the other end of the string. Let the object swing freely like a pendulum. How many swings will it make in one minute? Take many more counts with shorter lengths of string. You will note that shortening the string makes the object swing faster.

Also observe the vibration of a children's swing.

Secure a pendulum clock and a metronome, or a musician's time-piece. Make a study of rates of vibrations with these instruments. Imagine that an object vibrates faster and faster; beyond 16 times per second the surrounding air will be set into vibration, and a very low note will be heard. Higher notes are produced from faster vibrations, up to about 20,000 times per second, which is the highest note man can hear.

Also see Chapter XI, experiments B 3-5, page 123.

6 Run a toy car with a siren. The faster it runs, the higher the note it produces.

7 Blow across the mouth of an empty bottle. Try the same experiment with different-sized bottles.

8 Now replace the vibrating human lips in the last experiment by the wing top of a burner. Air blown through the wing top will pass the opening with great speed and spread out flat like a broad flame. The resonating sounds produced depend on the vibrating air columns in bottles or tubes. Adjust the position of the wing top so that the air stream produces the loudest sound. You will hear the lowest note from a fairly big bottle or a paper mailing tube, up to the highest audible note from the end hole of a very small key.

9 Sympathetic bottles

Have a pupil hold the mouth of one bottle close to his ear without obstructing the opening. Now blow strongly across the mouth of another similar bottle until you produce a strong, clear note. Every time you do this, resonant vibrations are set up in the second bottle. These produce a weaker, though similar, note which your pupil can hear distinctly.

10 Secure a tuning fork and a used petroleum tin can, a violin or any wood box as a sound box. Set the fork into vibration by hitting it against a block of wood. Then press its handle against the sound box. You will hear a very loud humming sound from the box. Repeat the experiment with a dinner fork.

11 Air carries sound

Let one person whistle; other persons in the same room will hear the sound distinctly. Now send the first person into another room, and let him whistle again; it will no longer be possible to hear him distinctly.

12 Sound cannot travel through a vacuum

Make a vacuum pump and receiver (Chapter VII, experiment I 3, page 85).

Tie two small bells inside the vacuum receiver. Start the experiment by shaking the receiver with air inside; you will hear the bells ringing. Then screw in the cap tightly, suck the air out of the receiver with the pump. Shake the receiver again; you will not hear the ringing of the bells as clearly as before. What does this mean?

Repeat the experiment, but create the vacuum by burning pieces of paper in the receiver.

13 Take a long garden hose, open at both ends. Use it as a telephone line for talking and listening to another person. Air inside the hose is the carrier of sound. The principle is still applied within a ship for speaking from one quarter to another.

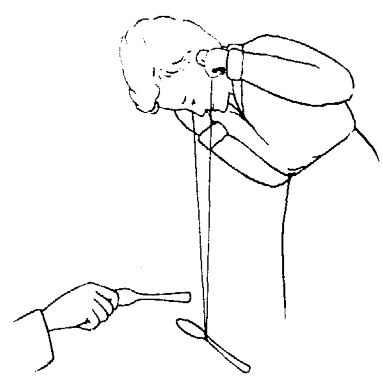
14 Solids carry sound

Secure two used tin cans with lids neatly cut out. Now punch a small hole in the centre of the bottom of each tin can. Thread several metres of a thin cotton string through the holes. Attach a matchstick at each end of the string so that the matchsticks cannot go through the holes. Now use the cans as telephones: get the string taut and talk and listen to your pupil. Sound travels through the string and through the air inside the tin cans. The bottom part of the tin acts as a diaphragm.

This experiment can also be performed with two empty matchboxes, one side of each being covered tightly with thin pieces of transparent cigarette wrapper paper. The holes may be punched in the paper.

15 Church bell from a spoon

Cut one metre of a cotton cord. With both ends together, balance a teaspoon in the loop. Now hold each end with your fingertips. Press both ends to your ears and bend down so that the string and spoon hang freely. Let someone hit the spoon lightly with a nail or another spoon. You will hear a chime like that of a church bell. Again sound travels right up the string, ending in your ears.



16 Tapping codes through water pipes

Send a code message made up by a pupil and yourself through a water pipe that goes from one room to another on the same floor or on different floors. By striking the water pipe with a piece of iron in one room the sound reaches your pupil in the other. Then interchange messages. Sound travels through the water pipe this time.

17 Hear through your teeth

Set a fork or a tuning fork into vibration. Wait until you cannot hear any sound from the fork, then place the handle between your teeth. The sound will still be heard. Repeat the experiment by placing the handle on the bone at the back of your ear.

18 Liquids carry sound

Place your head under a pool of water so that your ears are immersed. (It may be in a swimming pool, the sea, a river or even a bath tub.) Let somebody else strike a gong or a bell under the water away from you, while your ears are still under water. You will hear the sound coming through the water clearly. It is a fact that sound travels about four times as fast under water as through air.

19 Gas balloon acts as a sound lens

Fill a rubber balloon with air by blowing into it with your mouth until it expands to normal size. Hold the balloon with your fingers. Now the balloon is partly filled with carbon dioxide gas. Hold the balloon between your ear and a watch. You will hear the sound of ticking more clearly than without the balloon. This is because sound waves travel more slowly through heavy carbon dioxide gas than they do through air. The balloon acts as a converging lens to sound waves. Repeat the experiment with a balloon full of hydrogen gas.

20 How waves travel

The way in which energy is carried by waves can be studied by observing how they travel along the surface of water. They can often be seen in lakes, ponds and harbours, and the patterns produced help to explain many of the phenomena of light and radio, as well as of sound.

A more detailed examination of this behaviour can be made in the laboratory by producing ripples on the surface of a shallow dish of water. One way of making the patterns more visible is to place a source of light underneath a shallow tank with a glass bottom. Ripples produced in such a tank behave as cylindrical lenses, and shadows are seen on the ceiling or a screen placed above.

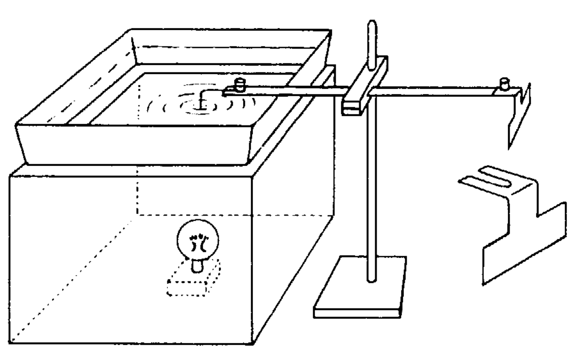
21 Making a ripple tank

Cut a rectangular aperture in the bottom of a photographic developing dish of full plate size, leaving a rim about 2.5 cm wide all round. Fit a sheet of clear glass to the tank and stick it down to the rim using a waterproof glue. Set it aside to dry. Obtain a cardboard box about 30 × 30 × 45 cm in size. Cut a circular hole 15 cm in diameter in the middle of one of the smaller faces, and make a small door in the middle of one of the rectangular sides. Paint the inside of this box a dull black. As a point source of light fit a car bulb and holder to a cube of wood of 7.5 cm side.

Stand the tank over the circular aperture in the box, and pour in water to a depth of about 1 cm. Darken the room and switch on the bulb. Observe the circular pattern produced on the ceiling when a drop of water falls into the water from a pen filler or pipette. If the pattern is distorted by the action of waves reflected from the sides of the tank, fit sloping beaches of picture frame moulding in the water all round the edges. Should there be patterns parallel to the sides caused by vibration of the tank as a whole, stand it on strips of 'sorbo' rubber or felt.

Continuous trains of waves can be produced by a vibrator with one end dipping into the water. Clamp a 30 cm hacksaw blade in the middle and attach a single piece of stout copper wire to one end, using an electrical terminal or a small bolt. Bend the wire at right angles to the plane of the blade and cut it off about 2.5 cm long. Support the blade in a firm retort stand so that the end of the copper wire dips into the water in the tank. Pluck the free end of the blade, and notice the generation of continuous waves.

Cut a T-shaped piece of tin to form a dipper for plane waves and attach it to the free end of the blade as before. Stick a piece of plasticine to the blade near the copper wire so that both ends of the blade carry the same load; in this way the vibration will be maintained for a considerable time.



22 To study reflection of waves

Cut strips of tin slightly wider than the depth of the water in the tank and about 8 cm long.

Bend the end of one of them at right angles and stand it in the water near one end of the tank. Adjust the position of the vibrator so that circular waves are reflected from this obstacle. Use both single pulses and continuous waves. Notice that the reflected waves appear to diverge from a spot as far behind the 'mirror' as the vibrating wire is in front. Now replace the point dipper by the flat piece of tin which generates 'plane' waves. Observe the form of the reflected waves when the obstacle makes different angles with the incoming waves. Clearer patterns are obtained with plane waves if the lamp is turned on its side and so placed that the filament is parallel to the dipper. Repeat these experiments using a curved strip of tin which represents a convex or concave reflector when different sides face the waves.

As ripples have a lower velocity in shallow water than in deep water, it is possible to study the transmission of waves as they pass into an apparently 'different' medium. To study, for instance, the action of the 'sound lens' of experiment 19 above, use a circular disc of glass or perspex to form a circular 'shallow' in the tank. Place such a slab in the middle of the tank and use a pipette to adjust the level of the water so that the slab is just covered. Allow a train of plane waves to pass over it and notice that the waves passing over the diameter of the slab are held back and there is a resultant focusing effect. Slabs of different shape can be used to study refraction at a single surface, and the action of prisms and lenses.

B. SOUND AND MUSIC

1 Vibrating box

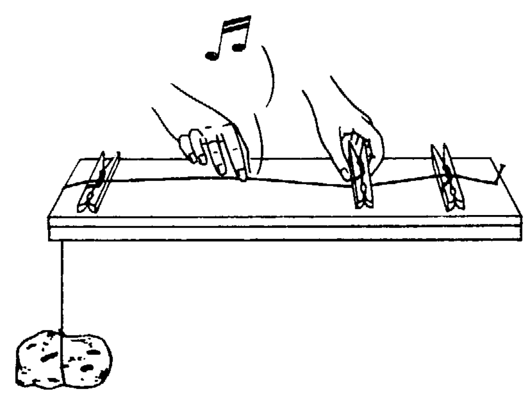
Cut a hole in the bottom of a used tin can. Put a stout string or a fishing line through it with its end tied tightly to a pencil inside the can. Rub resin on the string. Hold the can with one hand and keep the string taut with two fingers. Now draw your fingers along the line. Sound will come from the can. Repeat the experiment of drawing your fingers along the line at different speeds. Note the different pitches of sound. Can you make music out of the can? Try again with different sizes of tin cans and candy boxes. Will wood boxes give similar sounds?

2 Rubber band harpsichord

Stretch several rubber bands about a cake tin, cigar box, photographic developing dish or wash basin. Arrange them to different tensions with correspondingly different keynotes. Now play on them as on a harpsichord. The principle of this instrument is vibrating strings and a sound box. Repeat the experiment with various sizes of rubber bands on the same box.

3 One-string guitar

Secure a steel wire about 1 m long, a nail, three clothes pegs, a sound box made of thin plywood or of some other material (size about 60 × 15 × 3 cm) and a weight to hold the wire taut. Assemble these parts as shown in the diagram. Can you get music out of this home-made guitar? Repeat the experiment with more strings.



4 Music box with pins

Arrange several pins in a row on the sound box used in the above experiment or on a cigar box. Play music on this music box by plucking the pins with a letter opener. You will get lower notes out of longer pins and higher notes out of shorter ones.

Make another observation using a hair comb having different lengths of teeth.

5 Drinking straw orchestra

Secure 10 drinking straws for five players and a pair of scissors. Flatten one end of a straw and cut both corners of this flat end. Now this flat end acts as the reed of a wind instrument. Blow into it and adjust the reed until you get the best vibrations.

Next, set up an orchestra by making similar reeds out of other drinking straws. Cut off the other ends of the straws bit by bit to tune with different musical notes until you get a complete scale. Each of the five players is responsible for two notes, holding a straw in each hand. To begin with, try to play your National Anthem.

The principle is that the air column inside the straw vibrates because of the vibrating reed.

6 Bottle and glass tube trombone

Secure a glass or metal tube about 1 cm in diameter and 20 cm in length, and a bottle nearly full of water. Hold the bottle in one hand and the glass tube in the other, with the end of the tube dipping in the water. Now blow across the other end of the tube for a note. Next, as you blow, move the bottle up and down. You will hear various notes as you change the length of the column of air vibrating in the tube.

7 Musical bottles

Prepare a set of musical bottles so that each contains an air column tuned to one of the notes of the scale. Select eight similar bottles. Let the first one be empty. If water is added to the others to the proper heights, when they are tapped with a ruler or chopstick they will sound out a complete musical scale. You can do the same experiment with tall drinking glasses. The air columns inside the bottles or glasses take up vibrations from the outsides.

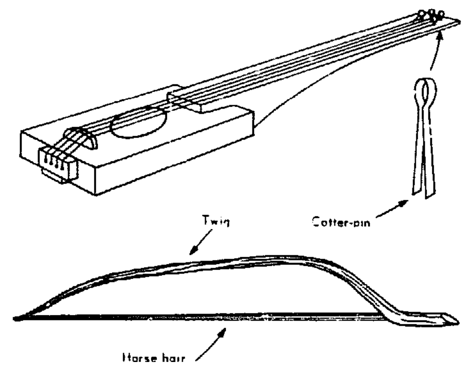
It is fun also, if you happen to possess china vases or bells of many sizes. Pick out those which are tuned to notes of the scale. Arrange them in a row. Hold a chopstick or a fork in each hand and carefully beat out a tune on them.

8 A set of dinner chimes

Secure a straight steel pipe about 3 cm in diameter and about 3.5 m in length. Cut it into four parts, 100 cm, 90 cm, 80 cm and 70 cm. Drill holes through both sides of each pipe near one end, and suspend them. Let them hang freely. Strike each pipe in turn with a rubber hammer and compose a sort of signature chime for your class.

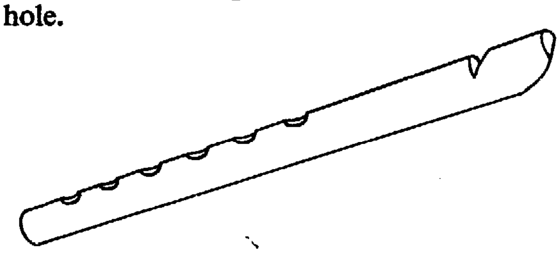
9 Cigar box violin

Procure a cigar box or any similar box, regular strings from a music supply store, bits of wood, a piece of resin and cotter pins. Try to assemble these parts yourself so as to make the cigar box violin shown in the figure. The bow may be made from horsehair and a twig about 70 cm in length.



10 Shepherd's pipe

A section of bamboo is suitable for the pipe. Secure a straight bamboo about 1.5 cm in diameter and 30 cm in length, open at both ends and all through its length. Dry it by roasting on a small fire until its skin turns a yellowish brown all over. When it cools, make the mouthpiece and row of holes as shown in the figure. The pipe is similar to a tin whistle but the sound obtained is sweeter. The air column vibrated is measured from the exit hole in the mouthpiece to the first uncovered hole.



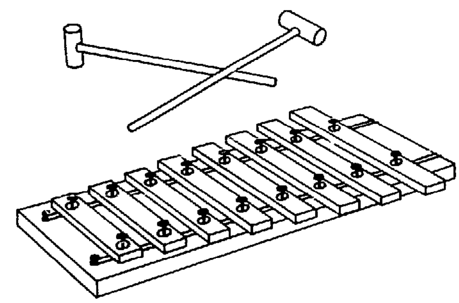
11 Xylophone and marimba

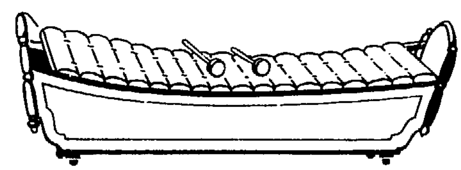
What you need here are strips of hard wood, bamboo, or iron, and a board; 8, 12 or 16 of these strips, cut to the proper lengths to sound out the scale when tapped, are required. For pieces of hardwood 2.5 cm wide and 1 cm thick, lengths of 20.0, 22.8, 24.2, 25.8, 27.2, 28.3, 29.5, 30.5 cm will give the diatonic scale. For the flat board of the xylophone, drill a hole about 2 mm in diameter near the end of each strip. Lay strips of felt on the board and drive small nails through each hole to hold the strips loosely. The strips will vibrate when tapped with a rubber hammer. This can be made from a pencil and a piece of eraser.

For the marimba, pieces of wood are shaped, as shown in the figure, to form the base and act as a sound box. Drill two holes near the end of each strip. Put a stout string through all the holes as shown and suspend the strips over the box.

Now procure two rubber hammers with rather long handles. Tap the strips lightly to obtain music.

Other simple musical instruments can be constructed, e.g., a variety of drums, scale of small gongs, flutes and many string instruments. Try to devise them yourself.



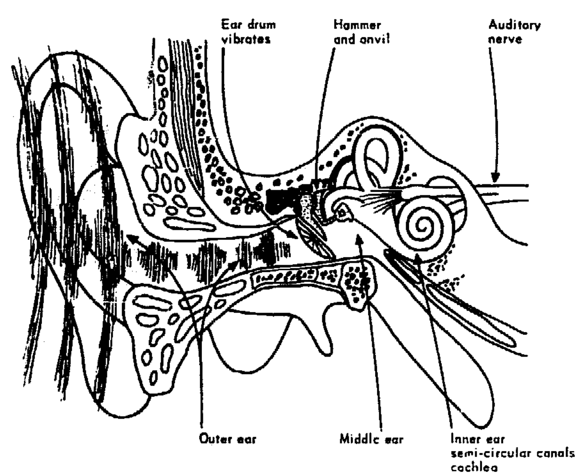


C. RECORDING AND REPRODUCING SOUND

1 How the ear works

Air vibrations enter the ear by the auditory passage formed at the base of the ear by the ear-drum membrane. They set the ear-drum in motion and, in doing so, set in motion the system of three little bones attached to it; by this means they reach a cavity in the bone called the inner ear.

One part of the ear is shaped like a snail shell. Here is found the organ which receives the sound vibrations and is connected with the brain by the auditory nerve. Another part of the inner ear which includes three small semicircular canals and serves to maintain equilibrium plays no part in hearing.

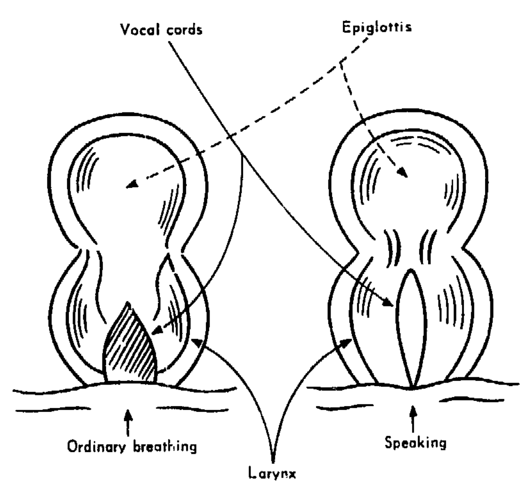


Sound vibrations are normally transmitted to the snail-shell-shaped cochlea by the ear-drum and the small bones (this gives rise to a nerve message which is carried to the brain); but they can also be transmitted by the bones of the skull, and we hear a sound if the waves reach the cochlea by either route.

When a sound reaches our two ears, we can distinguish the direction from which it comes; if it comes from straight ahead, the vibrations reach both ears at the same time and with the same strength; but if the source of the sound is on one side of us, one of our ears is farther away from it and receives the waves less strongly and with a slight delay.

2 How the voice is produced

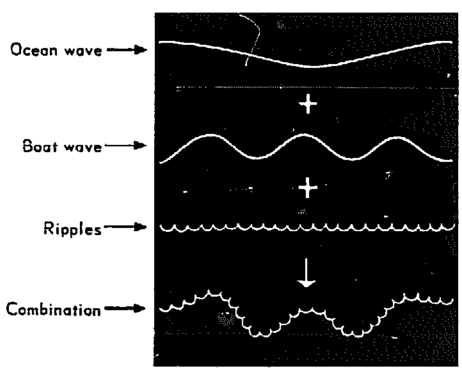
Mouth, teeth, tongue, throat and lungs are all used in the production of the voice. The sound is produced by vibrations of two thin sheets of membrane called the vocal cords, which are stretched across the sound chamber called the larynx. The larynx is the upper end of the windpipe and is located well back, at the base of the tongue. Here a trap door of cartilage called the epiglottis automatically drops



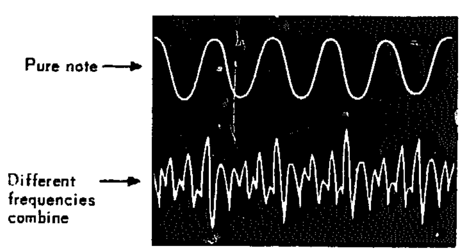
down over the larynx when you swallow, so that no food will go through the windpipe. When the cords are stretched by the contraction of certain muscles in the throat, a narrow slit tends to form between them. It is when the air is forced through this narrow slit that the cords are forced to vibrate. This sets the air vibrating in the windpipe, lungs, mouth and nasal cavities.

3 Sound wave patterns

The number of complete vibrations in one second is the frequency of a particular vibration. The way in which different sound frequencies combine is analogous to water waves. Ocean waves are longest, i.e. of low frequency. Let a small motor-boat pass over these waves. The boat sends out its own waves, which have a shorter frequency than ocean waves. Next, if there is a breeze, it will send tiny ripples across the surface of the motor-boat waves. The ripples usually have an even shorter frequency than the other two. Now these three vibrations combine to form a pattern shown in the figure.



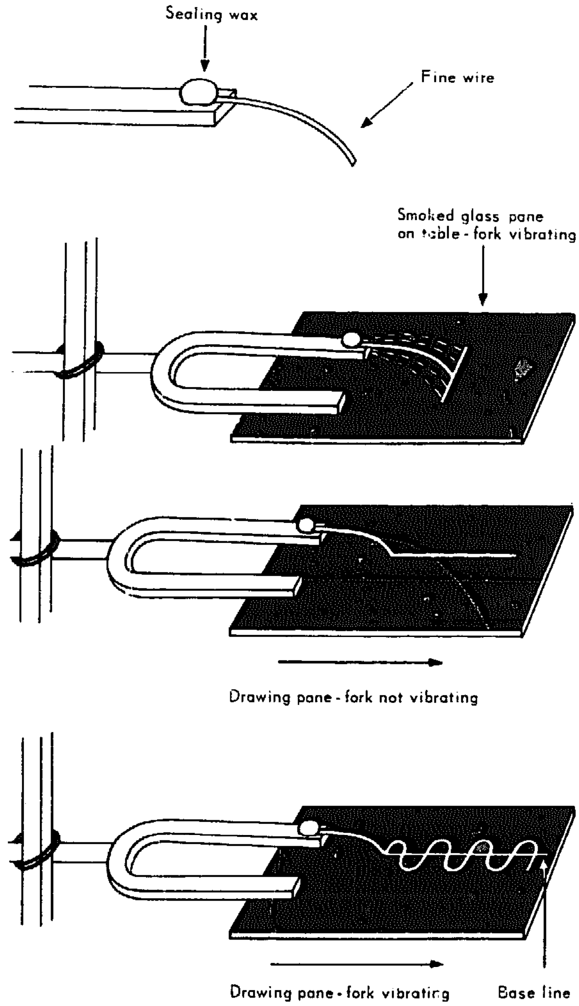
In a similar way, sound waves of different frequencies from various instruments combine and form sound wave patterns.



4 Wave pattern of a tuning fork

With a few drops of hot sealing wax attach a piece of fine wire to the prong of a tuning fork. The fork is held rigidly by the handle and placed horizontally just above the table top. Smoke a small pane of glass from the flame of an oil lamp or a candle. Now lay the smoked glass pane under the prong with the fine wire which is bent to touch the glass pane. Start the vibrations with the finger and draw the pane along the table fast enough to make a wavy line on the pane.

Repeat this experiment drawing the pane away at different speeds and using different tuning forks.

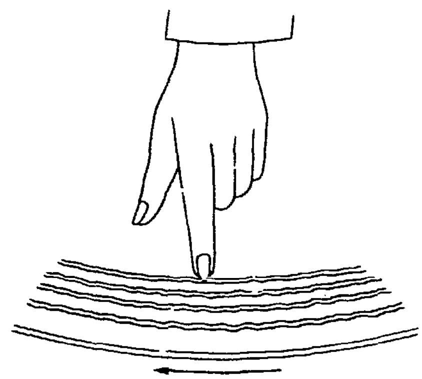


The higher the top of the wave from the base line the louder the sound.

5 A gramophone reproduces sound

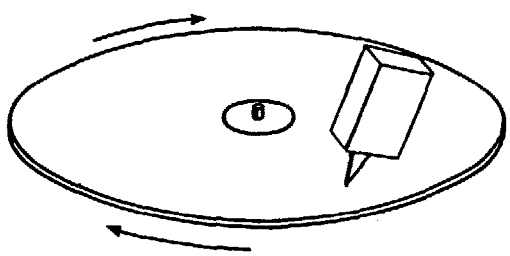
Secure a 78 r.p.m. gramophone record and a hand magnifier. Through the magnifier you will notice a great number of wavy lines on the record. If possible, compare the wavy lines of records of different speeds.

Next, set the record turning at its usual speed of rotation. Place the edge of your finger-nail in the groove and listen carefully. Do you hear music coming from your nail? Do you feel your nail vibrate? It is clear that your nail is forced to vibrate as it follows the grooves, and produce the recorded sounds.



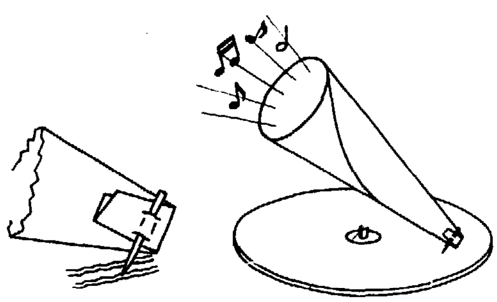
6 A simple reproducer

Thrust a record needle through the corner of a card or an empty matchbox. Now repeat the last experiment. Let the needle replace your fingernail. Has the sound been amplified?



7 Another simple reproducer

For a more effective home-made reproducer you can copy the early phonographs by using a horn. Substitute for the card or the matchbox a horn made out of a square sheet of heavy wrapping paper, about 40 × 40 cm.

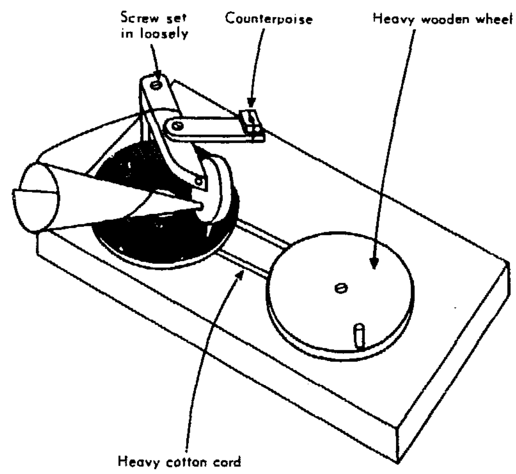


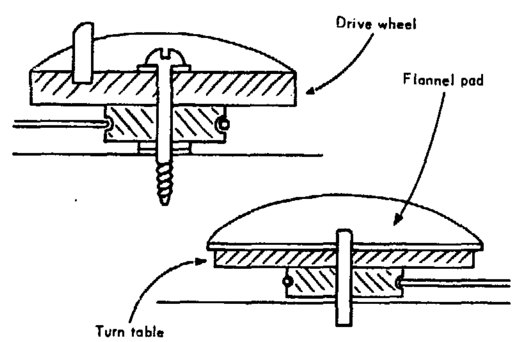
Shape the paper into a cone and fold the small end. Force a needle into all thicknesses as indicated in the diagram. Hold the horn so that the needle will rest lightly in the groove as the record rotates. Now, everybody in the room should hear the music from your simple reproducer.

8 A gramophone for everyone

What you need are two circular pieces of wood about 2.5 cm thick, and 30 cm in diameter, a base board about 80 × 40 × 2.5 cm, a sheet of flannel, 30 cm in diameter, as base, a piece of mica sheet 10 × 10 cm, a tube of Duco cement, gramophone needles, pins, a metal flange as frame of the reproducer, and an adaptor for the needle.

Your gramophone will look roughly like the first figure. Mount the two circular pieces of wood on the base board as illustrated, with the drive wheel and turn-table connected by a suitable length of heavy cotton cord. The flannel or felt pad is glued to the turn-table as the base for the record.



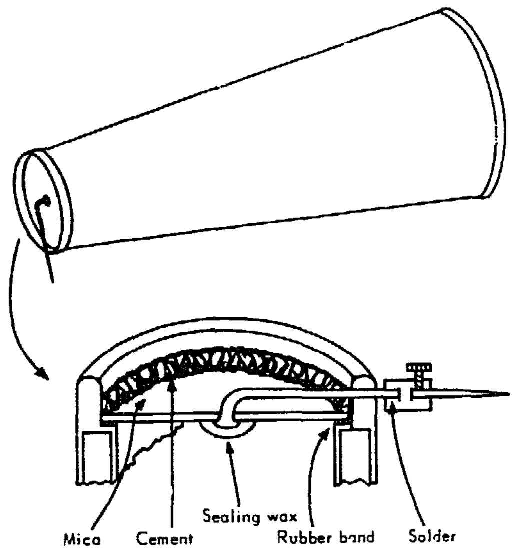


The important part of the machine, i.e., the reproducer and horn, may be made in one of two ways. The paper milk container method is the simpler one. Follow the illustration.

(a) Cement a rubber band neatly around the edge of the metal flange upon which the cap normally rests.

(b) Cut a disk from the mica sheet to fit the milk container opening.

(c) Drill a small hole at the centre and, after bending an oversize pin sharply near the



head, insert it into the hole and then through another hole in the metal flange.

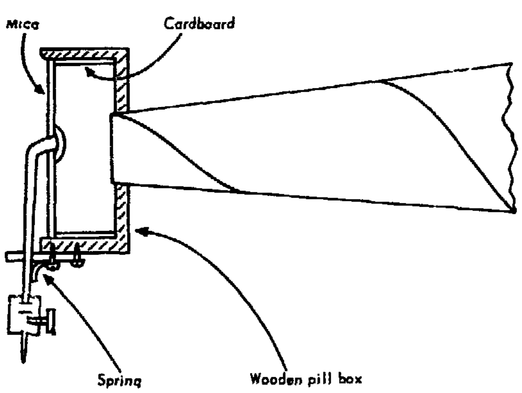
(d) Cement the diaphragm in place with Duco or a quick-drying cement.

(e) For the adaptor, cut a 6 mm length of small brass rod, drill a small hole all the way through and solder it to the cut-off end of the pin; secure a little set screw and drill a hole in the side a bit smaller than the threaded part of the screw and then force the screw in by turning it strongly so that it is well secured.

(f) Instead of making the adaptor in (e) you can use a brass electric wire fixer in any old lamp socket as the adaptor.

(g) For the horn, remove the bottom of a wax paper ice-cream cup or a paper milk container, and fix it in the hole of the metal flange.

(h) Attach the whole unit to the carrier arm with adhesive tape, and the rest will be up to you.



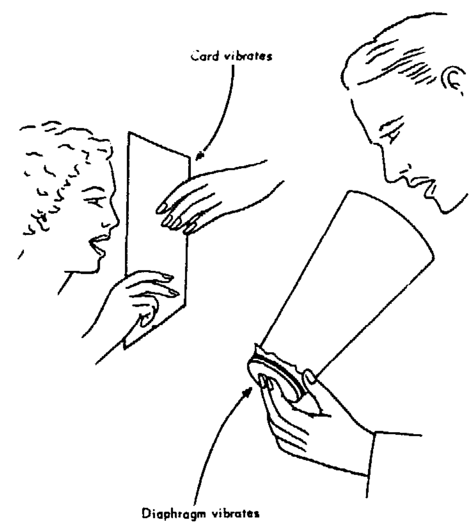
The second way of making the reproducer is illustrated above. This will give you an instrument more on the lines of a regular gramophone.

9 Recording of sound by gramophone

Recording is just the reverse process of reproducing. We have learnt that the voice or any other sound can be used to cause an object to vibrate and to form wavy lines on a smoked glass pane in motion.

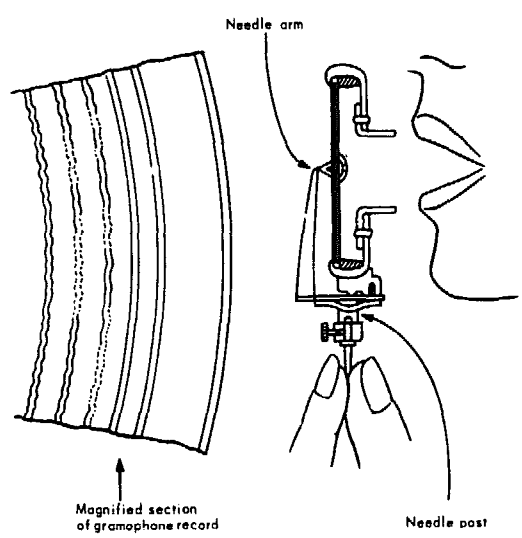
Hold a card in front of your mouth and utter sounds against it. Feel the vibrations with your finger tips.

Remove the bottom of an ice-cream cup or a paper milk container and bind a diaphragm of thin paper or rubber over the small end. Hum into it and feel the vibrations again.



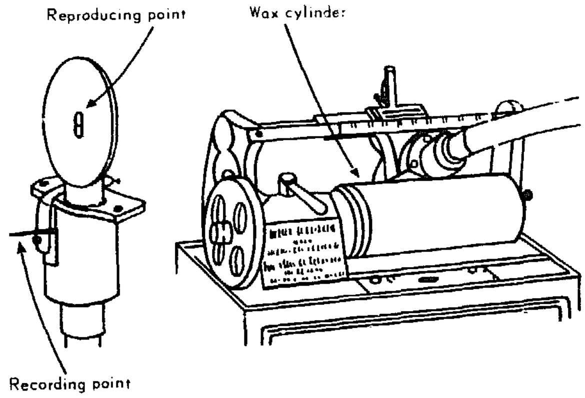
Detach the reproducer you made in the last experiment. Speak into the opening and, while doing so, feel the tip of the needle vibrating.

Now replace the reproducer and put a smoked glass disk of about the same diameter as the usual record on the turn-table. Speak into the horn and at the same time rotate



the turn-table. The vibrating needle point will draw wavy lines, a record of your voice. A hard-wax circular sheet might be used in place of a smoked glass disk.

Thomas A. Edison devised the first talking machine, which was a recorder as well as a reproducer. He first recorded the sounds and then played them back. If you are able to visit a science museum, have a look at the old-fashioned type of dictaphone. The parts are shown more clearly than in the newer types.



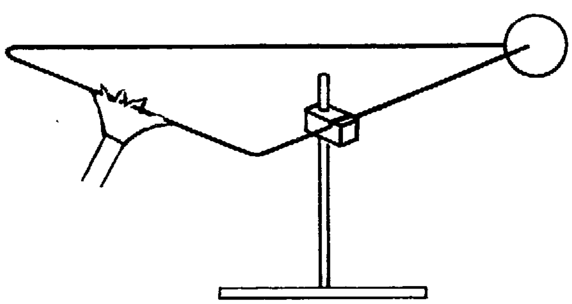
CHAPTER XIII

Experiments and materials for the study of heat

A. THE EXPANSION EFFECT OF HEAT

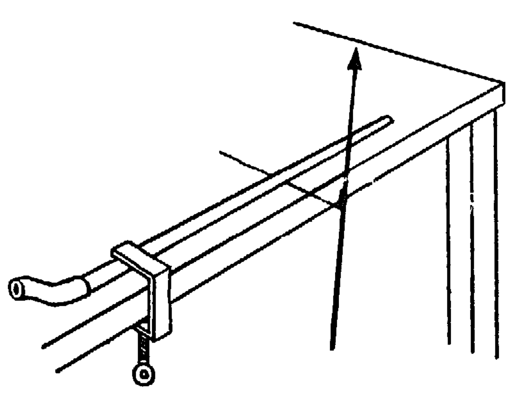
1 Triangle to show expansion on heating

Bend a piece of stiff metal wire into a triangle. Support it in a horizontal plane and suspend a coin between the two free ends forming one corner. Heat the opposite side of the triangle and the coin will fall out.



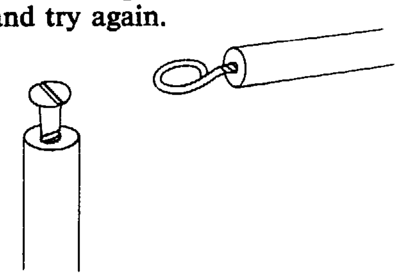
2 To show the expansion of a solid when heated

Get a piece of stout copper tubing about 2 m long. Lay it on a table and fix one end by a clamp. Underneath the other end put a piece of bent knitting needle or bicycle spoke to act as a roller. A thin strip of balsa wood about 1 m long fixed to the roller by sealing wax will show any movement of the rod resting on it. Blow steadily down the tube at the fixed end, and the expansion of the tube caused by the hot breath will be detected by this arrangement. Now pass steam through, and the pointer will make a complete revolution or more, depending on the diameter of the roller. Repeat the experiment after the roller and pointer have been moved nearer to the loose end of the rod. Compare the results.



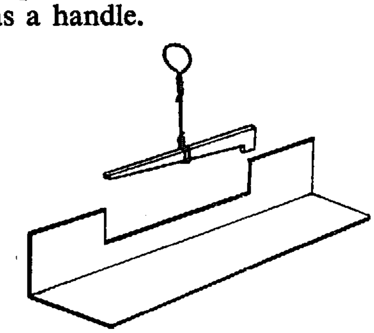
3 The ring and plug experiment

Secure a large wood screw and a screw eye; the head of the screw must just go through the screw eye. Screw each one into the end of a stick, letting at least 2.5 cm of metal protrude. Heat the head of the screw in a flame for a while and then try to put it through the screw eye. Keep the screw hot and heat the screw eye in the flame at the same time. Now try to put the screw head through the screw eye. Keep the screw head in the flame. Cool the screw eye in cold water. Again try to put them together. Next cool the screw head and try again.



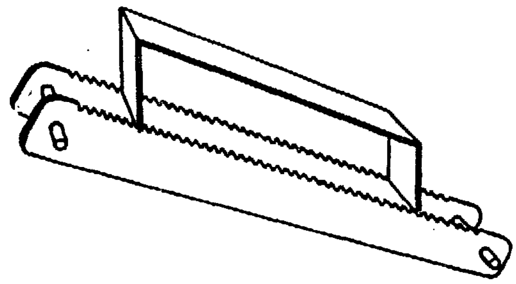
4 A bar and gauge

To construct this traditional apparatus use a cut nail as the bar and a piece of tin as the gauge. Cut the gap in the tin with shears and bend it into an angle girder so that it will stand on the bench with the gap upwards. Wind a piece of iron wire round the nail to serve as a handle.



5 Thermal creeper

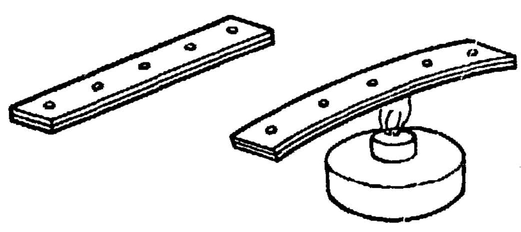
This model illustrates the creeping of lead roofs etc., under the action of heat. Push a cork onto each end of a knitting needle. Stick two pins through each cork so that the apparatus has four legs. These legs are slanting so that the front pair slide forward as the



needle expands, but stick in the ground and drag the back 'legs' after them as it contracts. A bridge of brass set on a pair of hacksaw blades will behave in the same way and will, in fact, climb uphill.

6 A bimetallic strip

A pair of iron and brass strips, riveted together, will bend when heated because of the difference of expansion. Make the holes with a nail and use small tacks as rivets.

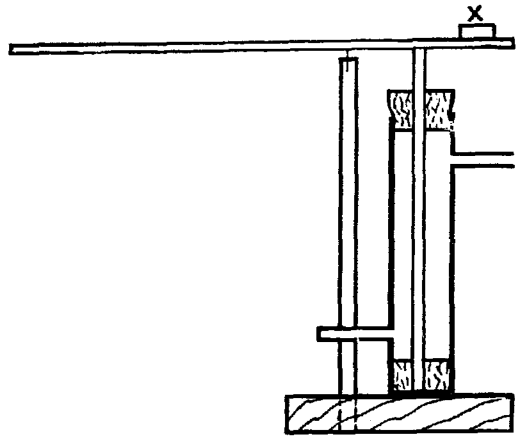


Another way of fastening the strips together is to cut them with projections at equal intervals and bend them over to interlock.

7 A device to measure the rate of expansion

The Liebig's condenser described on page 36 is used as a steam jacket for this experiment. The expansion of the test rod is magnified by a wooden lath acting as a lever. A piece of dowelling rod with a razor blade stuck into the top makes a satisfactory pivot, and X is a counterweight.

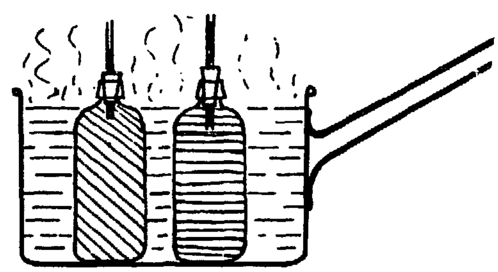
First cold water and then steam should be passed through the outer tube. The expansion



of the rod is calculated from the dimensions of the lever and the movement of the free end.

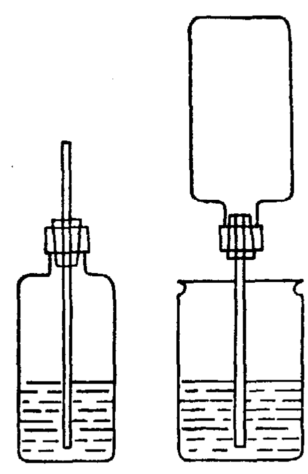
8 Expansion of liquids

Fit two or three similar medicine bottles with corks and tubes. Fill them with different liquids and immerse them in a pan of hot water. The rise inside the tubes will indicate the difference in expansion rates. If the diameter of the tubes and the capacity of the bottles are known it is possible to calculate the apparent coefficients of expansion.



9 Expansion of gases

The medicine bottles can also show the expansion of air or other gases. Push the glass tube through the cork and trap some air. A hand



placed on the bottle drives liquid up the tube.

A simple form of air thermometer can be made arranging the tube as shown on the right in the diagram. Also refer to experiment B 2 below.

Warming the bottle causes air to be expelled. This reduces pressure inside. When the bottle cools liquid is forced up the tube.

10 Expansion of gases—soap bubble

A soap bubble stretched over the neck of a medicine bottle will grow larger if warm hands are placed on the bottle.

11 Another way to show the expansion of gases

Stretch a rubber balloon over the neck of a flask which has been made from a used electric bulb. Heat the flask gently with a candle or an alcohol flame.

See also Chapter VIII, experiment B 2, page 97.

12 An expansion experiment with a balloon

Partially inflate a balloon or a basket ball. Hold the balloon or ball over a hot plate or place it in the warm sun for a while and observe the results.

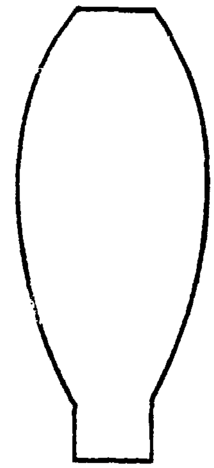
13 Fire balloon

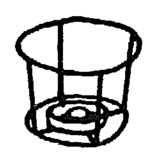
Make a simple fire balloon from a large paper bag similar to those used by milliners.

Open out the mouth with a ring of florist's iron wire having a stay across the diameter. Fix the ring to the bag with strips of gummed paper. Tie a small piece of sponge or cotton wool to the middle of the stay and dip it in methylated spirit. Light the spirit and hold the bag by the ring. There is danger of setting fire to the paper bag in this experiment, which is best performed in the open air.

This paper bag balloon is not very stable in flight. A better one can be made as follows:

Place on a table six sheets of tissue paper, one on top of the other. Cut them in the shape shown in the figure and stick them together at the edges to form a balloon. A circular disk will be needed as cap to close the top. Fix a ring to the neck as before. Such a balloon will rise to great heights and can be flown from a piece of string like a kite. Solid methylated spirit, as employed in some spirit lamps, is easier to use if it can be obtained: it can be placed on a small tin lid attached to the wire ring at the mouth of the balloon.





B. TEMPERATURE

1 Is your temperature sense reliable?

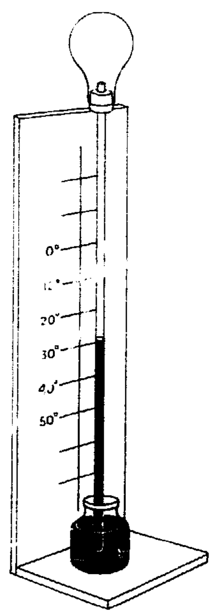
Fill three pans with water. Have one at the highest temperature you can bear your hand in. Fill a second one with ice-cold water. The third should be lukewarm. Put both hands in the lukewarm water and hold them there for about half a minute. Does the water seem to be the same temperature for both hands? Does it feel hot, cold or neither?

Next place your left hand in the hot water and your right hand in the icy water for a minute. Quickly dry your hands and plunge both into the lukewarm water again. How does the right hand feel? How does the left hand feel? Do they feel the same as when in the lukewarm water before? What do you think about your temperature sense?

2 Making an air thermometer

Fit a flask made from a used electric bulb (or a thin-walled bottle or test tube) with a one-hole rubber stopper which has a 60 cm length of glass tubing in it. The stopper must be an air-tight fit in the bulb. You can seal the stopper in by dropping some wax from a candle around the joint. Build a support for your thermometer from wood as shown in the diagram. Paste a strip of paper for a scale behind the tube. Place the lower end of the tube in a small bottle of cold water, coloured with ink. Heat the bulb of the thermometer gently to drive out some of the air. Drive out just enough air so that when the bulb cools to room temperature the coloured water will rise about half way up the tube.

To make your scale, let the thermometer stand in a room for several hours. Have another thermometer near the bulb. Make a line on the paper at the level of the water and mark the reading of the thermometer at this point. Next move your thermometer to a warm place to stand for an hour with the other thermometer near the bulb. Mark the water level and the temperature. Move again to a cool place and again mark the water level and temperature. Divide the space between these marks into equal divisions and mark off the corresponding temperatures.

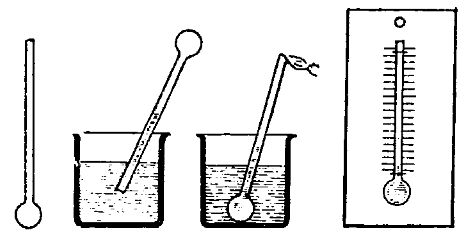


3 How a thermometer works

Fill a flask made from a used electric light bulb with water that has been coloured with ink. Insert a one-hole stopper carrying a 30 cm length of glass tubing until the water rises in the tube a distance of 5 or 6 cm. Place the flask on a tripod over an alcohol burner and observe the water level as you heat it. The water expands more rapidly than the glass and rises up the tube. Some keen observers in the class may notice that just at the moment heating is begun, the water level drops and then begins to rise. This is because the glass bulb starts to expand before the water inside reaches the temperature of the glass.

4 Making a spirit thermometer

To make a simple alcohol thermometer, accurate enough for indicating variations of temperature, use 20-30 cm of glass tubing of about 5 mm external diameter with about 1 mm bore. A bulb of about 1.5 cm external diameter is first blown in one end of the tubing; coloured industrial alcohol is allowed to enter by means of a rubber tube and a thistle funnel till the thermometer is filled and without bubbles. The thermometer is then placed in water at 60° C, which is slightly below the boiling point of alcohol, allowing the excess alcohol to ooze out. Then the open end is sealed off. With water at different temperatures the thermometer is tested and the scales are drawn.



5 Testing a thermometer

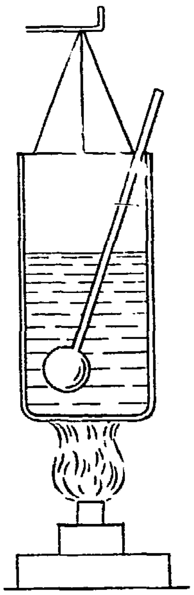
Thermometer scales are marked at two fixed points, steam temperature and the temperature of melting ice. Secure a thermometer and place it in steam immediately above the surface of water boiling in a flask. Leave it there for several minutes and notice how closely it registers 100° C, or 212° F.

Note. If you live at a high altitude the temperature of steam may be well below 100° C or 212° F because of the reduced pressure. The thermometer will register exactly only at sea level or where the barometer reading is 760 mm of mercury.

Remove the thermometer from the steam, allow to cool for a few moments and then place it in a jar of melting ice. Observe how nearly it reads 0° C, or 32° F.

6 Heat and temperature—the idea of a calorie

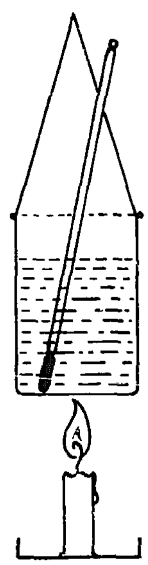
Suspend a tin containing 50 cc of water and a thermometer over a small bunsen flame or a candle. Heat it for two minutes, constantly stirring, and record the final temperature. Empty out the water and repeat the experiment with 100, 150, 200 cc of water, using the same flame. It is sufficiently accurate to count 1 cc of water as 1 g. Find the product of mass of water multiplied by rise in temperature in each case. As the same heat is given out by the flame to each mass of water, the result suggests that a convenient unit of heat would be that absorbed by 1 g of water rising in temperature by 1° C. This unit is called a *gram calorie*.



7 Calorific value for fuel

As fuels vary greatly in their heating effect, it is useful to have some way of indicating their relative effectiveness. A suitable index is the number of calories given out when one gram of the substance burns completely away: this is called the *calorific value*.

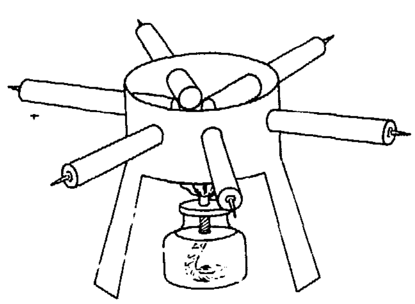
Hang a small can from a stand by means of fine wires. Pour 100 cc of cold water into it, and take the temperature. Place a small piece of candle on a tin lid and weigh it. Now place it under the can of water and light the wick. Stir the water with the thermometer and when the temperature reaches 60° C blow out the flame and weigh the tin lid and candle again. The mass of water (in cc) multiplied by the rise in temperature (in C°) gives the calories produced, and the mass of candle used can be found from the weighings. The calorific value can be calculated from these two quantities. Solid methylated spirit or a methylated spirit lamp can also be used in this experiment.



C. THE TRANSFER OF HEAT

1 Conduction in a metal bar

Secure a bar of copper, brass or aluminium at least 30 cm long. Attach tacks or nails to the bar with melted paraffin at intervals of 3 cm. Set the bar above a table top and heat one end with an alcohol or other flame. Observe the evidence that heat moves along the bar by conduction.

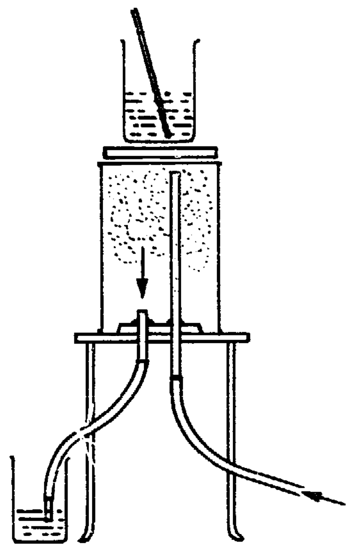


2 Metals conduct heat at different rates

Obtain 15 cm lengths of several metals. The bars should be of approximately the same diameter. Punch holes in the side of a tripod that has been made from a tin can. Insert the metal bars so that they touch at the centre of the can. Attach a tack or nail to the outside end of each bar with some paraffin. Place an alcohol flame under the tripod so that it touches the inner edge of each bar equally. Observe the order in which the tacks fall from the outer end of the bars. Most of the simple experiments on this topic are confusing because they involve specific heat as well as conduction.

3 Measurement of the heat conducted through different substances

The steam can described in Chapter II, C 5, page 36, will serve as a hot plate for experiments in conductivity if it is placed upside down on a tripod. Steam is introduced through the long pipe and condensed in cold water. Place a slab of cardboard on the hot plate and on it a small tin containing 100 cc of water and a thermometer. Measure the rise in temperature after 5 minutes and calculate the heat transmitted. Repeat the experiment using slabs of equal thickness of metal, cloth, cork, etc.



4 Metals are good conductors of heat

Hold a piece of paper above a candle flame: it will char if brought near. Place a metal coin on the paper and repeat the experiment: the metal will conduct away the heat and leave a pattern on the paper.

5 Conductivity of metal and wood

A piece of metal tube with a wooden rod fitted into it shows the same effect: if the wooden rod is held over a flame, it will not burn. A penholder with a metal band at one end can be used for this experiment. The same principle is involved in a simple experiment with a cigarette, a metal coin and a handkerchief. Wrap the coin in the handkerchief, stretching the fabric tightly over it between finger and thumb. Press the red hot ember of the cigarette on this part of the handkerchief; it does not burn.

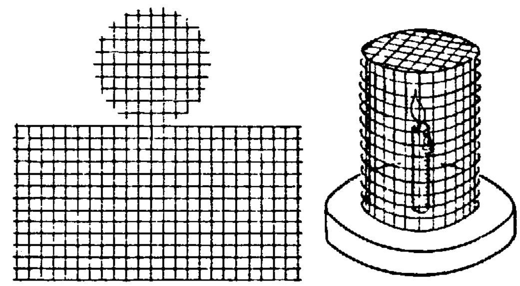
6 Conduction with a metal gauze

Hold a piece of metal gauze in an alcohol or gas flame. Observe that the flame does not come through the screen as the heat is conducted away from the flame by the wires. If you have gas in your room place a burner under a tripod and cover it with a wire screen. Turn on the gas and light it above the screen. You will observe that the gas burns only above the screen as the heat is conducted away by the screen and keeps the gas below the screen from reaching its kindling temperature. This observation gave Sir Humphrey Davy his idea for making the miners' safety lamp which prevented the explosion of gases in the coal mines.

7 A model Davy lamp

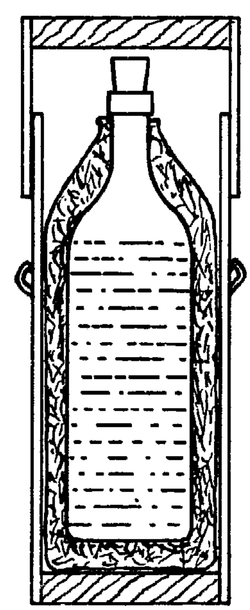
The traditional experiments on the conductivity of wire gauze can be followed by an improvised Davy lamp. A Christmas candle enclosed in a cylinder of wire gauze does not light a jet of gas played on it from a rubber tube.

A block of wood or plasticine is used as a base.



8 Haybox thermos flask

Make a cloth bag to fit loosely round a bottle, and stuff it with kapok and cotton waste. Enclose this in a cardboard or bamboo cylinder fitted with carrying string. Although no vacuum is used, drinks are kept hot or cold for several hours.



9 Water is a poor conductor of heat

Hold the bottom end of a test tube of cold water in the hand. Heat the top in a bunsen flame until it boils. The fact that you can still hold the bottom shows how bad a conductor water is.

10 Heat is transferred by convection in liquids

Secure a large glass jar that can be heated. The bottom part of a glass coffee-maker can be used. Fill the jar with water. Put some grated blotting paper particles or saw-dust in the water and give them time to settle to the bottom. Now place the jar over an alcohol lamp and begin to heat it. Observe the paths taken by the particles of paper. The paper particles follow the convection currents set up in the water.

11 What causes convection currents in water?

Fill a large jar with cold water and weigh it accurately on a balance. Fill the jar with exactly the same amount of hot water and weigh. You will observe that the jar of warm water weighs less. Volume for volume cold water is heavier than warm water; so when water is heated convection currents are set up, the warm water being lifted, because of buoyancy, by the cold surrounding water. In other words hot water is less dense than cold, and this is the cause of convection currents in a liquid.

12 Effect of temperature on the density of water

The sensitive balance described on page 34 can be used to demonstrate changes of upthrust when a body is suspended in cold and then warm water. Replace one of the pans of the balance by a key or other suitable metal object hung from the beam. Counter-poise this in a can of water. Now blow steam into the water to raise its temperature and notice that the key apparently becomes heavier owing to reduced upthrust on it. As metals expand much less than liquids the effect is easily seen. If absolute measurements are required, a correction for the expansion of the metal may be made, or an inexpansible alloy such as Invar should be used in place of the key.

13 At what temperature does water attain its maximum density?

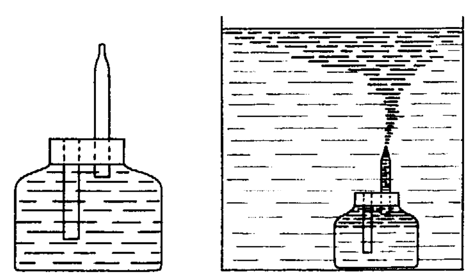
Put a piece of ice into a glass of water. Arrange two thermometers so that one measures the temperature near the surface, and the other the temperature near the bottom. It will be noticed that the water cooled by the ice falls to the bottom; this continues until the water at the bottom of the glass reaches a temperature of about 4° C. It will stay at this temperature for a long time, the colder water remaining higher up near the ice. From this it can be deduced that the water at 4° C is denser than the water at 0° C.

This curious behaviour of water is of great practical significance in nature, and explains why a pond freezes from the surface down-wards while the bottom surface seldom falls below 4° C.

14 Another way to show convection currents in water

Fit an ink bottle or paste jar with a cork carrying two pieces of glass tubing as shown in the diagram. One piece of tubing should be drawn out to a jet like the end of a medicine dropper. This tube should be put just through the cork and should extend about two inches above. The other tube should be just level with the cork and extend nearly to the bottom of the bottle. Fill the bottle with very hot water that has been coloured deeply with ink.

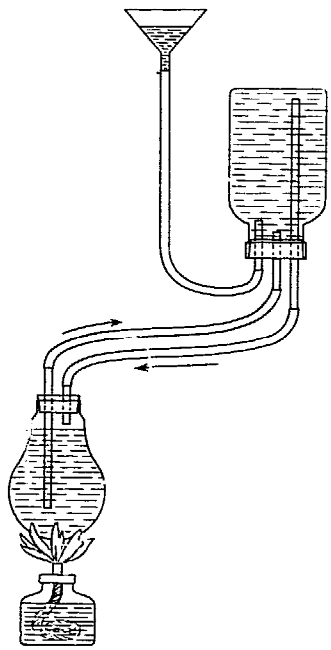
Now fill a large glass jar such as a battery jar or cookie jar with very cold water. Rinse off the ink bottle and quickly place it on the bottom of the large jar. Observe what happens. Can you explain this?



15 How to make a model hot water heating system

Make a flask from a large electric bulb. Secure a wide-mouthed bottle and a funnel. Fit the bottle with a cork carrying three glass tubes arranged as shown in the diagram.

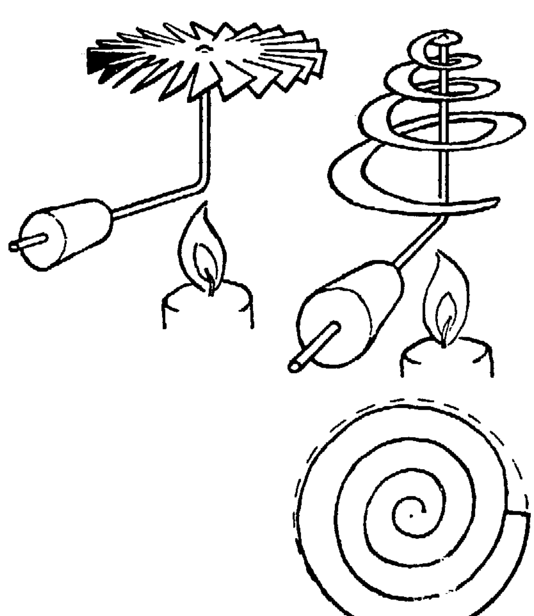
Fit the flask with a two-hole cork carrying two glass tubes, one going just through the cork and the other extending nearly to the bottom. Attach the funnel as shown. This serves as the expansion tank. Fill the system with water and heat. Observe which part of the radiator gets hot first. Can you explain how the water circulates by convection currents?



16 Convection currents in air

Obtain a circular disk of thin tin as used to close tobacco containers. Cut teeth in the circumference and pivot it on a bent knitting needle. Hold it above a candle flame, and it will revolve rapidly. A paper spiral supported on a knitting needle will revolve in a similar way.

Bring a piece of red-hot iron into contact with 'solid methylated spirit' (Meta fuel). The vapour immediately recrystallizes and fills the room with a highly diverting snow-storm. The crystals are set in motion by draughts and convection currents already in the room.



Another way of showing these air currents is by making use of the difference in refractive index of warm and cold air. A 12 volt car bulb without reflector will cast 'shadows' of convection currents from an electric heater or even from an ordinary electric lamp bulb.

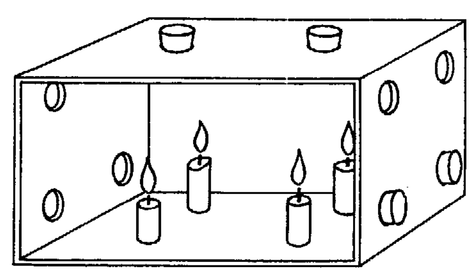
See also Chapter VIII, experiment B 6, page 97.

17 How convection currents cause winds

See Chapter VIII, experiment B 6, page 97.

18 Convection currents and ventilation

Use the box which you used for a study of winds in Chapter VIII, experiment B 5, page 97. Bore four holes in each end, two above and two below. Put solid corks in all the openings including the two on the top where the lamp chimneys were placed for the other experiment. The holes in the opposite ends represent windows which may be opened or closed at the top and at the bottom. Put four candles in the box and light them. You are now ready to study the best conditions for ventilation. Close all the windows and observe the candles for a little while. Now try different combinations of openings. One window open at top and bottom. One open at the top, the other at the bottom. Both open at the top. One only open at the bottom. Both open at the bottom. One only open at the top. What window openings provide the best ventilation?



19 Heat is transferred by radiation

In the previous experiments you have seen that heat can be transferred by material substances, by solids, liquids and gases. Heat can also be transferred by wave motion, even across a vacuum. This is called radiation. Heat travels by radiation almost instantaneously. This experiment will demonstrate some interesting things about radiation. Hold your hand under an unlighted electric bulb, palm upward. Turn on the electricity. Can you feel the heat almost as soon as you turn on the bulb? The heat could not have reached your hand by conduction because air is a very poor conductor of heat. Neither could it have reached your hand by convection because this would have carried the heat upward away from your hand. It actually came to your hand carried by very short waves. Radiation carries heat in every direction from the source.

20 Radiant heat waves can be focused

Hold a reading glass lens in the sun and focus the rays to a point on a wad of tissue paper. You will observe that the tissue paper catches fire from the focused heat rays. Try the effect of using tissue paper blackened with indian ink or soot. Does it catch alight more readily?

21 Radiant heat waves can be reflected

In the above experiment note the distance from the reading glass to the tissue paper. Place a tilted mirror about half this distance from the lens. Feel about with your hand above the mirror until you find the point where the heat waves are focused. Hold a bit of crumpled tissue paper at this point and see if it will catch alight.

22 Different kinds of surfaces affect radiation

Secure three tin cans of the same size. Paint one white, inside and out, and another one black; leave the third one shiny. Fill the three cans with warm water at the same temperature. Record the temperature. Place cardboard covers on each can, set them on a tray, and then put them in a cool place. Record the temperature of the water in each can at five-minute intervals. Was there a difference in the rate of cooling? Which surface was the best radiator of heat? Which the poorest?

Next fill the cans with very cold water, record the temperature, cover each can and place them in a warm place or in the sun. Record the temperature of the water at five-minute intervals. Which surface was the best absorber of heat? Which the poorest?

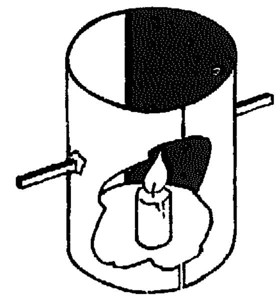
23 Another way to show how surfaces affect radiation

Cut two vertical slits opposite each other on the side of a cylindrical tin, so that the surface of the tin is divided into two parts. Blacken the inside of one half leaving the other half shiny. Put a lighted candle inside the tin, in the exact centre of the base.

A difference in temperature of the two outside surfaces can be detected with the fingers.

Matchsticks fastened to the outside with wax can also be used as indicators, and the one behind the black surface will fall off first.

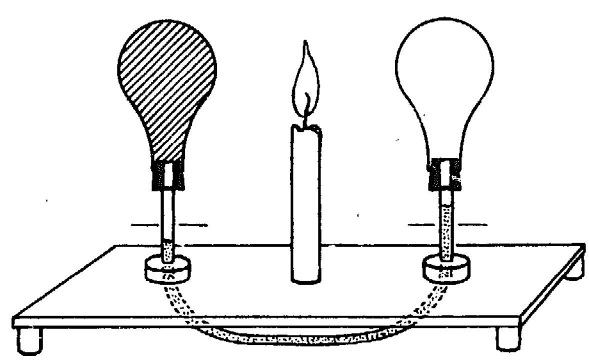
An alternative experiment is to use a coiled cylinder of fine wire gauze wrapped round the top of the tube of a bunsen burner as emitter and blackened thermometers as detectors of radiation.



24 A simple thermoscope

Flasks, or cut-off light bulbs, can be used to construct this apparatus (see page 38, item 14, and page 217, item 27). Besides the experiment illustrated with the candle, it works well for other experiments, e.g., the Leslie Cube.

Fit both bulbs with corks and tubes about 15 cm in length. Pass the lower ends of the tubes through flat corks and, having made holes about 22 cm apart in a suitable baseboard, glue the tubes in a vertical position and connect the open ends by rubber tubing. Remove one bulb and blacken the other in a candle flame. Pour liquid into the U tube so formed until the level is about 7.5 cm above the baseboard. Replace the clear bulb and slide the tube in or out a little so that the liquid remains level. Place a candle equidistant between the bulbs and wait for results.



25 How heat losses can be reduced

Secure four large tin cans of the same size and four smaller tin cans of the same size. Put three of the small cans inside three of the larger ones and pack insulating material under and around each of the smaller cans. Pack one with shredded newspaper, the second with sawdust and the third with ground cork (other more convenient insulating materials may be substituted). Inside the fourth large can place the small can resting on two corks. Fit paste board covers to each can. Have a hole in each cover for a thermometer. Now fill each small can to the same depth with water that is nearly boiling. Record the temperature of the water in each can. Take the temperature of the water in each can at five-minute intervals and notice which is the best insulator as indicated by the slowest rate of cooling.

D. MELTING AND BOILING

1 Observing a boiling liquid

Secure a very large pyrex beaker or a large tin can. Fill the vessel nearly full of cold water and place it over a flame. Leave it there until it boils. You will first observe air bubbles coming out of solution in the water and rising to the surface. When the water is near the boiling point, steam bubbles will form and collapse almost at once. As the boiling point is reached, the bubbles will form at the bottom and rise to the surface before bursting.

2 How to boil water in paper

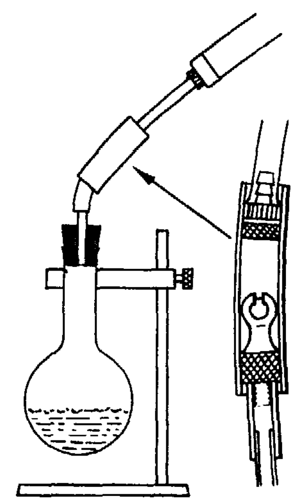
Secure some smooth paper: either wrapping paper or writing paper will do. Make a box about 25 cm square by folding the corners up and pinning them. Fill the box about half full of water and place it on a burner. You can boil the water without burning the paper. The paper conducts heat from the flame to the water and does not catch fire because its kindling temperature is above the boiling point of water (100° C or 212° F).

3 Boiling water by cooling it

Fit a flask with a tight solid stopper. Remove the stopper and fill the flask a little more than half full of warm water. Bring the water to the boiling point over a flame. Put the stopper tightly in the flask and invert it over a pan or sink. Pour cold water over the flask : the water starts boiling again. Put a piece of ice on the flask. Cooling condenses the water vapour above the water and reduces the pressure on the water. When the pressure is reduced, water boils at a lower temperature. This explains why it takes so long to cook things at high altitudes.

4 Boiling ether by reducing the pressure

Obtain a glass bottle or flask, with cork and tube. Pour ether into it to a depth of about 2.5 cm, and add a little powdered glass or sand. Replace the cork and with narrow rubber tubing attach to the glass tube a non-return valve such as the one used in a football pump adaptor. Push over this a length of



bunsen tubing, and attach the connector of a cycle pump which has previously had the washer reversed. Clamp the flask in a stand so that the liquid can easily be observed. After a few sharp strokes of the pump, the ether will boil vigorously.

5 When liquids evaporate, they absorb heat

Set up an air thermometer like the one in experiment B 2, page 143. Put some rubbing alcohol on the bulb of the thermometer. What do you observe? Where did the heat come from to evaporate the alcohol? Try carbon tetrachloride; try ether.

6 Freezing by rapid evaporation of ether

With a knife cut a depression in a softwood board or block. Place a glass tube in the rubber connector of a bicycle pump. Pour a little water in the depression you have made in the wood block and place a tin can in the water. Pour a little ether in the tin can and force air through it with the pump. As the ether evaporates it absorbs heat from the water and the can will soon be frozen to the wood by a film of ice.

7 The cooling effect of a dry wind

Obtain two similar thermometers and wrap the bulb of one of them in a small piece of wet cloth. Shield them from draughts and wait until they read the same temperature. Now place them on a window sill in a current of air. It will be seen that the thermometer with the wet bulb shows a much lower temperature. This is because the evaporating water takes heat from the bulb.The current of air assists evaporation by bringing dry air to the thermometer. This phenomenon is common in everyday life: the evaporation of sweat from the body on hot and windy days is very refreshing.

8 How heat changes solids to liquids

Place samples of such things as lead, solder, ice, sealing wax, paraffin wax in separate containers that may be heated. Small tin cans or lids will be useful. Experiment with these and see if you can get some information on the relative amount of heat needed to melt each sample.

9 Freezing water with ice and salt

Crack some ice into small lumps and place a layer in the bottom of a large can; cover this with kitchen salt and then add other layers of ice and salt. Put some water in a smaller tin can, and place this tin inside the large can. Then add more layers of ice and salt until the large can is full. Record the time taken to freeze the water in the small tin. Compare this with the time required to freeze the same amount of water if only ice is used in the large can.

10 Water expands when it freezes

Secure a small metal can which has a screw top. Fill it to overflowing with water and then screw the top on so that there is no air space. Bury the can of water in a mixture of ice and salt and leave it for some time until the water freezes. You should obtain some interesting results.

11 Heat is absorbed when solids melt

Secure a small container of chopped ice and find its temperature with a thermometer. Place the container over a flame and observe the temperature until all the ice is melted. When did the temperature begin to rise? Why did it not rise for some time? What became of this heat energy?

12 Melting by pressure and refreezing

When you apply pressure to ice you lower the freezing point. This is why skates move so easily over ice. Hold an ice cube or a piece of broken ice in each hand. Press them together over a piece of paper. Can you make water come from the ice with pressure? Push two ice cubes together forcibly and then release the pressure. Try to separate the ice cubes. The water refreezes when you release the pressure, holding the ice cubes solid.

13 Latent heat of steam found by using a tin

The rate of heat supply of a flame to 100 g of water in a tin may be found by taking the temperature at intervals and plotting a time-temperature graph.

When the water begins to boil there is no further rise in temperature but the rate of heat supply is the same. If one disregards the water lost by evaporation in bringing it to the boil, the heat required to boil 100 g of water completely away (that is until the bottom of the tin is dry), can be found from the time required for this to happen.

14 Latent heat found by using a hollow solid

An alternative way of determining the latent heat of steam is to use a heavy hollow metal solid as a condenser. A teapot can be used for a rough estimate.

The mass of water condensed in the teapot when steam from a kettle is passed into it depends on the heat capacity of the teapot.

If a brass axle cap is used, it should be fitted with a bung having inlet and exit tubes. When steam is passed into the apparatus, some time elapses before any comes out of the exit tube, because it is being condensed by the cold metal. After steam has issued for a few minutes, and the metal is therefore at 100° C, the steam supply should be stopped. The mass of steam condensed is found by taking its volume with a measuring cylinder. Given the specific heat, mass and initial temperature of the metal, the heat absorbed by it in condensing the steam is calculated.

15 Latent heat of ice

A rough value of the latent heat of ice can be obtained by measuring how much ice is melted when a heated solid is buried in ice shavings.

Weigh the solid of known specific heat and raise its temperature to 100° C by suspending it in water from a piece of cotton. Quickly transfer it to a funnel of powdered ice, and collect the resulting water in a test tube or measuring cylinder.

Calculate the heat given up by the metal in cooling to 0° C.

This apparatus can also be used to demonstrate the difference in specific heat of different materials. The volume of water obtained in each case provides a comparison of the specific heats.

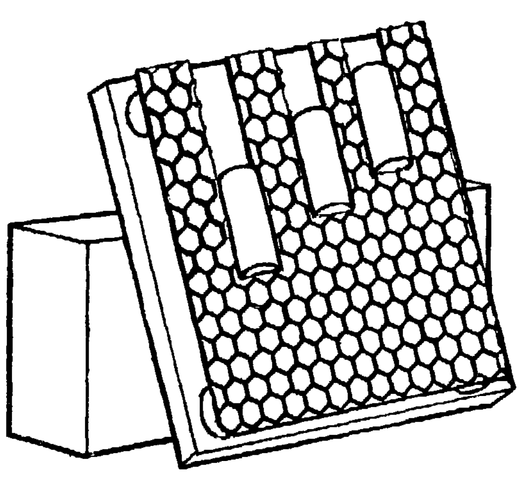
16 Specific heat using a teapot

Pour boiling water into a weighed teapot at room temperature. The temperature will remain steady at about 96° C. Measure the mass of hot water used when it has cooled a little, using a measuring cylinder. Assuming there is no loss of heat to the surroundings, the specific heat of the material can be calculated.

This experiment forms an introduction to the subject of specific heat, or might be used as part of an investigation of the qualities of different materials used in teapots.

17 Specific heat comparison

To compare the specific heats of different metals, prepare cylinders of each of them of the same mass. Bring them to the temperature of boiling water and transfer them to a nearly vertical inclined plane, made from a piece of wood, and having a sheet of beeswax cell-former fastened to the front, but held away from the board by corks.

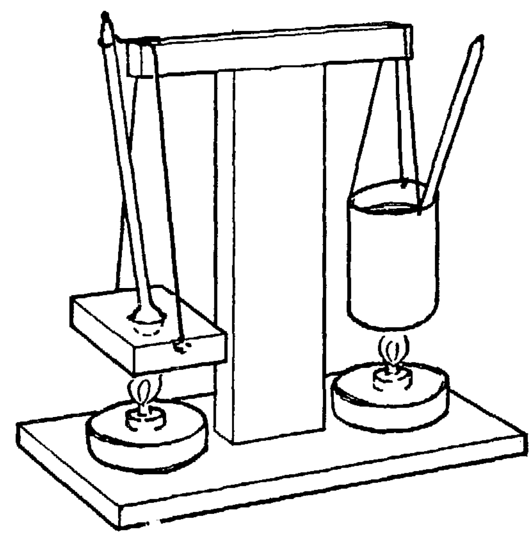


The cylinders will slide down the incline, melting tracks through the wax whose length will depend on the specific heat of the metal used.

18 Measurement of specific heat

Procure a piece of metal (say, 100 g of iron), and a tin containing 100 g of water. Suspend both above similar spirit lamps as in the diagram (a small bunsen flame will do).

The iron weight needs a hole to be drilled in it to fit the bulb of a thermometer loosely; the tin of water also requires a thermometer in it which can be used as a stirrer.



It is assumed that the lamps are supplying heat at the same rate. They are applied to these bodies for the same length of time.

Both lamps should be removed when the thermometer in the iron reaches 80 degrees, as it will probably then overshoot the mark to 100 degrees. The surprising difference in temperature emphasizes the effect of specific heat. Since 1 g of water absorbs 1 calorie for a temperature rise of 1° C, the heat supplied to both iron and water is (100 × rise in temperature of the water). The heat supplied to the iron is (100 × S × rise in temperature of iron). So the specific heat S =

$$\frac{\text{rise in temperature of water}}{\text{rise in temperature of iron}}.$$

19 Specific heat—hollow solids

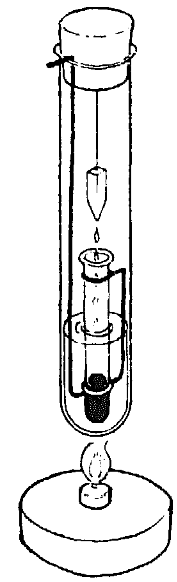
An experiment somewhat similar to the teapot determination can be carried out using a hollow solid such as a brass axle cap or a short connector for iron tubing. Heat losses can be minimized by using a cloth to cover these vessels. The procedure is the same as before. Boiling water is poured in. The final steady temperature recorded will be much lower than that in the case of the teapots.

If a brass object weighs 1 kg the final temperature may be in the region of 60° C.

20 Simple latent heat calorimeter

In this apparatus the vapour of tetrachlorethyline, which has a small latent heat, is allowed to condense on a solid (e.g. copper or aluminium) which is suspended in it. The liquid formed is collected in a small graduated test tube. When no more condensation takes place, i.e. when the metal has assumed the temperature of the vapour the liquid collected is measured.

The large test tube is about 20 cm by 4 cm in diameter; the graduated tube is a small aspirin or pill bottle, and is carried in a wire cradle. The solid is pointed, at least at the bottom, so that the liquid streams off it readily.



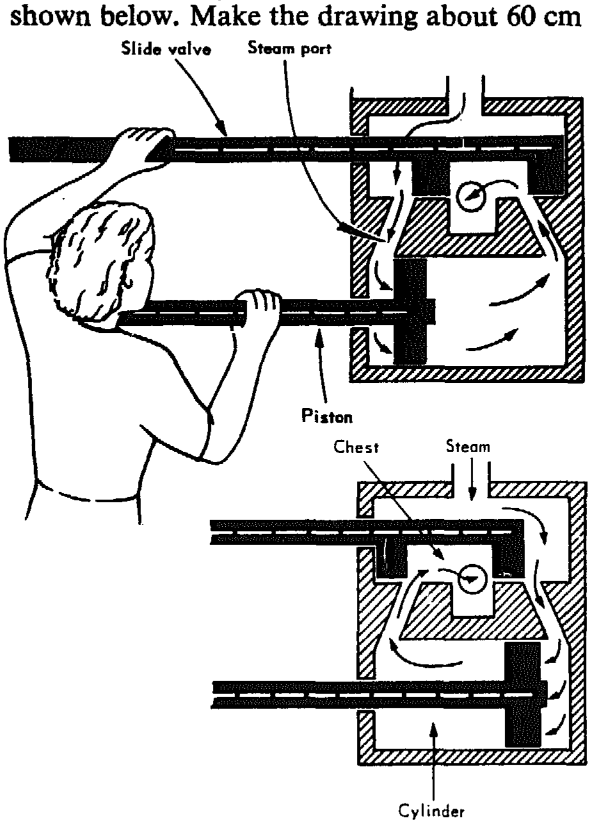
E. HEAT ENGINES

1 Pressure exerted by steam

Secure a small metal can with a friction top. Do not use a can with a screw top. Place a little water in the bottom of the can, press the lid on tightly, place over a flame and step back. In a little while you will see the expansive force of steam.

2 How a steam engine works

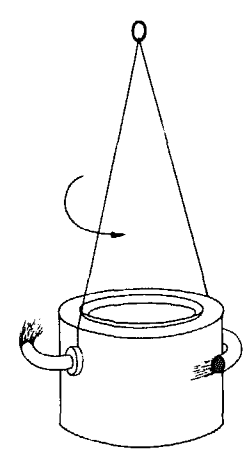
Make a drawing on a blackboard like that shown below. Make the drawing about 60 cm



square. Cut from stiff cardboard a piston and a slide valve as shown. You can have pupils move these on the drawing to show the position of the piston and slide valve when the engine is running.

3 How to make a historic steam toy

Hero, scientist of ancient Alexandria in Egypt, made a steam toy which he called the Ball of the Winds. This is how to make a model of the toy. Secure a tin can with a friction top which holds about a pint or half litre. Pierce two holes in the can on opposite sides, large enough to carry small one-hole stoppers. Bend two glass tubes as shown in the diagram. The tubes should be drawn to jets at the end. Insert the tubes in the stoppers so that the jets point in opposite directions. Fasten cord to the stoppers and suspend by a swivel or chain. Pour water in the can to a depth of about 3 cm, put the cover on tightly and place over a flame.

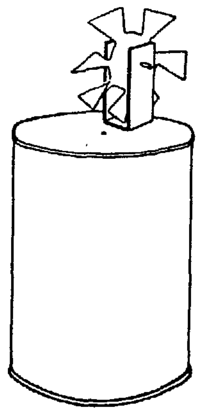


4 How to make a model steam turbine

A turbine model can be made from a tin fitted with a vane wheel. The vanes are made by cutting radial slots from a circular piece of tin, and twisting the blades which remain.

The axle is a piece of knitting needle, and the axle support is made from a strip of tin bent into a U piece and soldered to the top of the can.

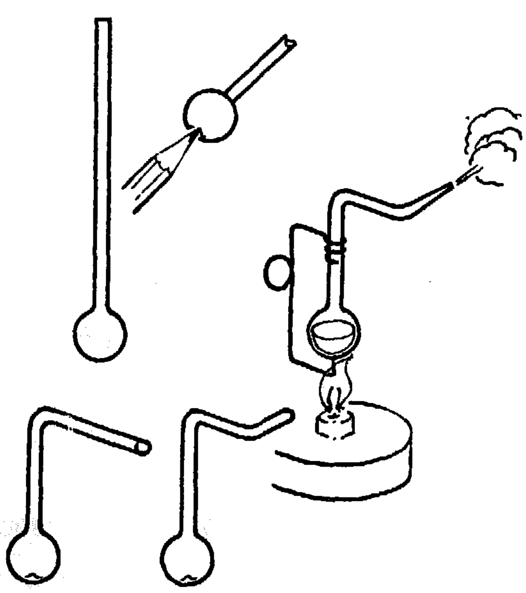
A hole for a steam jet should be made opposite the vanes.



5 How to make a model turbine from glass

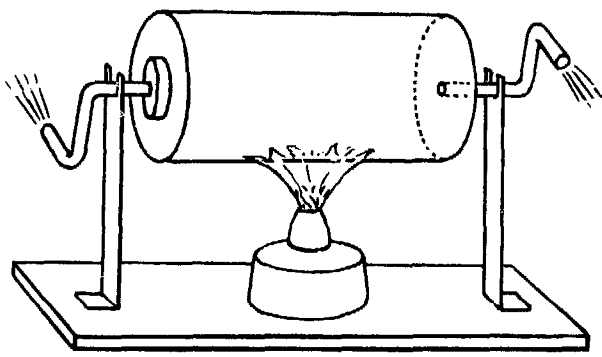
Very little glass blowing experience is needed to make this model. Seal one end of an ordinary piece of glass tubing in a flame and blow a bulb about 1.5 cm in diameter.

Soften the bottom of the bulb and press a pencil into it. This will make a depression to serve as a lower bearing for the turbine. Bend the top of the tube over at 90 degrees and draw it out to a jet bent at right angles again. Half fill the bulb with water by heating it and then immersing the open end under the surface of a beaker of water. Make a wire frame to act as a support as shown in the drawing.



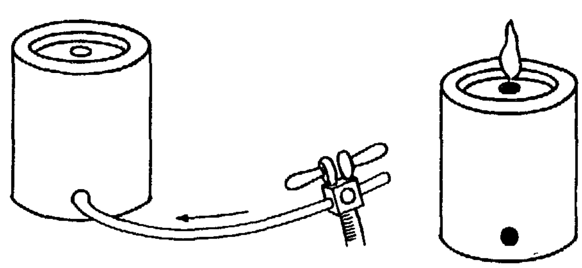
6 Heat engine from an old metal polish tin

The tin is supported horizontally on two copper pipes which serve as exit tubes. They are soldered through the centre of the bottom and the cap respectively. The tin is partially filled with water and rests on two iron brackets screwed to a wooden base.



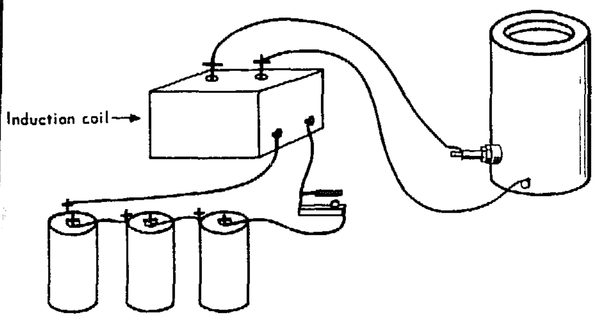
7 To show the force of exploding gas

Secure a metal can with a friction top that holds about one or two litres. In the centre of the friction top punch a hole about half a centimetre in diameter. Near the bottom of the can punch another hole about 2 cm in diameter. Press the friction top in securely. Place a hose from a gas jet in the lower hole and turn on the gas. Allow gas to enter until the can is full and you can smell gas issuing from the top hole. Remove the hose and light the gas at the top hole. Step back and wait for results. Do not go near the can even though the flame seems to have gone out. As the gas burns at the top what comes in at the bottom? When did the mixture become explosive? (How much gas as compared with the amount of air.)



8 How petrol vapour is exploded in an engine

For this experiment you will need a 1 litre metal can with a friction top. Pierce a hole near the bottom into which an ordinary automobile spark plug can be fitted. On the opposite side near the bottom punch a small nail hole. You will need an induction coil with an interruptor in the primary circuit to furnish the high voltage necessary. Connect the primary leads of the induction coil to three or four dry cells. Connect one secondary lead to the top of the spark plug and the other to the edge of the can. Warm the can. Place about ten drops of petrol in the can. Place the lid on tightly and close the switch in the primary circuit of the induction coil. An automobile ignition coil could also be used to provide the high voltage. The spark occurs when the contacts are opened, due to the sudden collapse of the magnetic field.

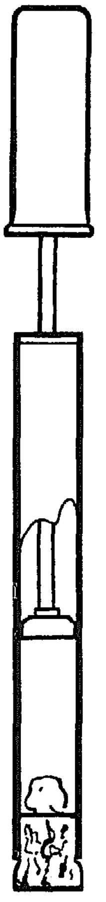


9 How to make a fire syringe

The material usually suggested for use as a fire syringe is amadou, but unless it is very dry it will not ignite. Cotton wool, soaked in carbon disulphide to which a trace of phosphorus has been added, will ignite at the temperatures produced by compression.

It is more effective if a glass fire syringe is used. Fit a piece of hard combustion tube with a good piston (a cycle pump piston will do). Introduce the cotton wool through the open end, and close with a cork. Bring the piston down sharply on a bench or table and a blue flash will be seen when the tinder ignites.

A piece of iron pipe with a slot cut in it can be used as a safety sheath, but the experiment is not really dangerous.



CHAPTER XIV

Experiments and materials for the study of magnetism

1 Natural magnets

Magnetic iron ore is quite common in many parts of the world. If it cannot be obtained locally, any supply house will provide it for a small cost. Secure a piece of such iron ore. This is a natural magnet. Sprinkle some iron filings or finely cut pieces of steel wool on a sheet of white paper and observe how the ore attracts them. Try picking up heavier things made of iron, such as paper clips or carpet tacks. Bring the lump of ore near a compass and observe. Do all parts of the lump affect the compass in the same way?

2 Securing artificial magnets

Strong and useful artificial magnets for the study of magnetism can be obtained from old radio loudspeakers, from old telephone receivers and from old automobile speedometers. Magnets can frequently be purchased in the market and may always be obtained from scientific supply houses. Artificial magnets are made in many shapes such as horseshoe, U-shaped and straight or bar magnets.

3 How to magnetize a steel rod

Use a piece of magnetic iron ore or another magnet to magnetize a steel knitting needle, a darning needle, an iron nail, a piece of clock spring or watch spring. This may be done simply by stroking the bar several times with the magnetized substance. If you wish to make a bar magnet with opposite poles at either end, use an artificial magnet. Begin at the centre of the unmagnetized bar and stroke toward the end using one end of the magnet. After several strokings turn the rod around and stroke from the centre to the other end using the opposite pole of the magnet. Test your results by using the rod to pick up iron filings or by approaching it to a compass.

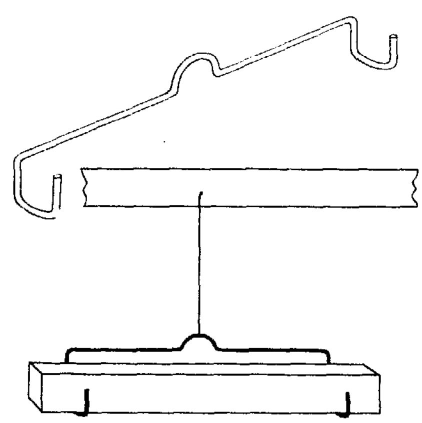
4 How to make bar magnets

Secure some flat pieces of hard steel. Old hack or metal saw blades are useful. Lengths of steel from a clock spring may be used. Cut the steel into 15 cm lengths. Next stroke the opposite ends of each piece with alternate ends of a strong magnet as instructed in experiment 3 above. Test each bar magnet with a compass. The two ends of the bar magnet should affect the compass in contrary ways. Hard steel is often quite difficult to magnetize. One should place the piece of steel on a table and strike the pole of the magnet against it as you stroke toward the end.

5 How to make a turntable cradle for magnet study

Select a piece of heavy wire. The wire from a coat-hanger will do very nicely. Bend it into the shape shown in the diagram. The distance between the two hooks at the ends should be small enough to cradle the shortest bar magnet that will be used.

Suspend the cradle with fine copper wire or nylon fishing line from a convenient hook or other support. Place a bar magnet in the cradle and bring other magnets near it.



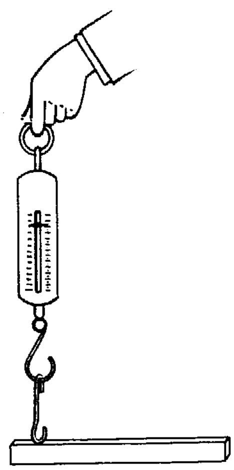
6 The concentration of magnetism in a magnet

Pour a considerable quantity of iron filings on a sheet of paper. Roll a bar magnet in the iron filings and observe that most of the filings stick to points near the ends of the bar. These places on a magnet where the magnetism seems to be concentrated are called magnetic poles. Repeat using magnets of other shapes such as a horseshoe or a U shaped magnet.

7 Variation of magnetism along a bar magnet tested by spring balance

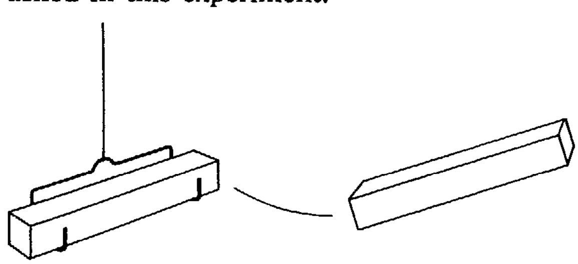
Place a bar magnet on a piece of squared paper. Tie a soft iron nail to the hook of a spring balance and test the pull required to lift it away from points along the magnet 2.5 cm apart. It may be that the hook of the balance will serve instead of the nail, but care should be taken to see that it does not become permanently magnetized.

Represent your readings as a graph between pull required and distance along magnet from one end. Is the magnet 'strongest' at the extreme ends?



8 Do magnets act through space?

Suspend a bar magnet in a cradle such as is described in experiment 5 above. Bring other magnets near the suspended magnet and make observations to answer the question asked in this experiment.



9 Are the poles of a magnet alike?

Use the same materials as in experiment 8. Mark one end of the suspended magnet with a piece of chalk or paper. Now bring one end of another magnet near the marked pole of the suspended magnet. Reverse the magnet in your hand and bring the other pole near the marked pole of the suspended magnet. Do they react in the same way? How would you describe the action in the first case? In the second case?

10 The law of magnetism

Again use the same materials as in experiment 8. Test the magnets with a compass needle. Mark the end of each magnet which repels the north end of the compass needle and attracts the south end of the compass needle. These marked ends of the magnets are called the *north* poles. The unmarked ends are the *south* poles. The south poles of the magnets should repel the south-pointing end of the compass needle and attract the north-pointing end.

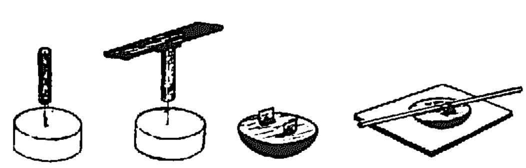
Now suspend one of the marked magnets in the turn cradle. Bring the north end of the other magnet near the north end of the suspended magnet. Do you observe attraction or repulsion? Next bring the south ends of the two magnets near each other. What do you observe? Bring the north end of the magnet in your hand near the south pole of the suspended magnet. What do you observe? Bring the south pole near the north pole of the suspended magnet. What do you observe? What can you say about like and unlike magnetic poles? This is the law of magnetism.

11 Making simple compass needles

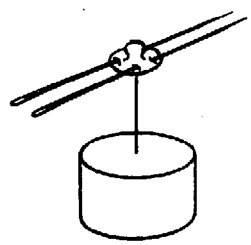
Magnetize a piece of steel strip or watch spring by stroking it with lodestone or another magnet. To convert it into a compass needle, it must have as frictionless a support as possible. This can be contrived in several ways. Close a short length (2 cm) of glass tubing at the end by heating in a flame. Support the small test tube just made on a pin pushed through a piece of wood or cork. Fix the strip of steel to the tube with sealing wax and adjust it so that it swings freely and evenly.

Another way of supporting the compass needle is to use a metal former from an old cloth-covered button. Clip the magnetized rod to the two projections and place the curved part of the button on a piece of glass or other smooth surface.

Another simple compass needle can be made using two magnetized sewing needles pushed through the holes of a large press

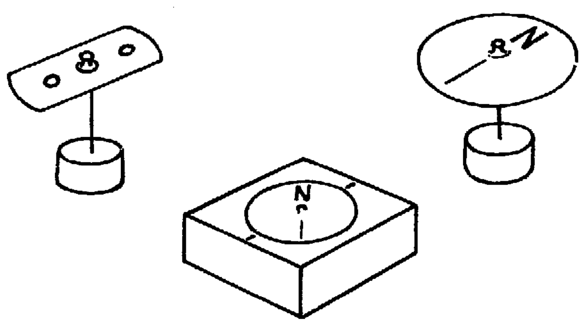


stud. This can be balanced in another needle with its eye pushed into a cork. If a smaller press stud is used the flange must be squeezed between pliers whilst pressing the needles through the small holes.



12 A razor blade compass box

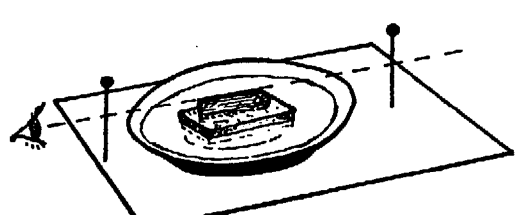
Magnetize an old three-hole razor blade by stroking it with a bar magnet. Push an old laundry stud or a piece of closed glass tube through the central hole. Glue a disc of card to the blade and suspend the combined compass on a pin stuck through a slice of cork. Mark the position of north on the top of the card. Enclose the compass in a cardboard box with a circular window in it made of cellophane. Draw a reference line on the box.



13 To determine magnetic north

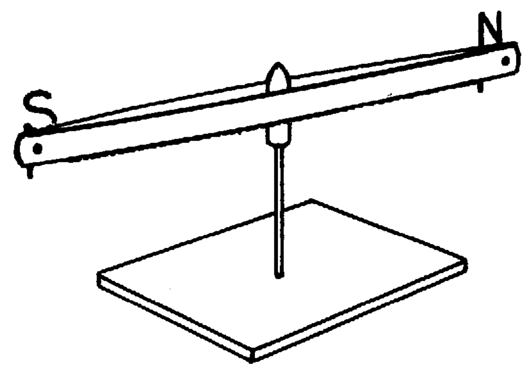
Float a piece of flat cork 10 cm by 3 cm in a saucer of water.

Magnetize a short length of hacksaw blade or other steel and fix it to the cork so that its teeth are downwards and its length is along the cork slab. When it comes to rest, sight along its upper edge using two large pins. The line joining the feet of the pins is the Magnetic Meridian.



14 A demonstration compass needle

Rivet together two old hacksaw blades through the holes at each end and then magnetize them. Use a closed piece of glass tube as a support. Push this between the blades at the midpoint and balance it on a knitting needle driven vertically into a block of wood. Fix the bearing in position with sealing wax or other adhesive. Push wire indicators N and S between the blades at the extreme ends.

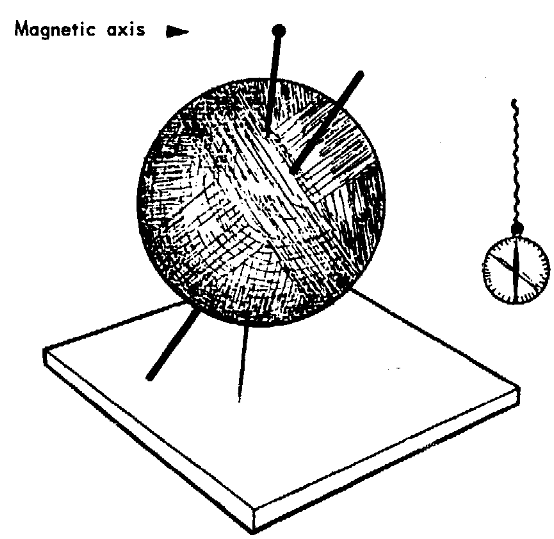


15 A model showing the earth's magnetism

A ball or round fruit is needed to represent the earth in this model. Support it on a wooden meat skewer inclined at an angle. This represents the axis of rotation of the earth.

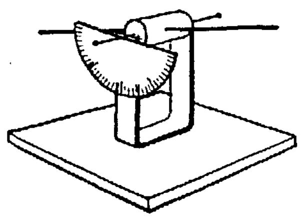
Pierce the 'earth' with a magnetized knitting needle which will be in the direction of the magnetic axis of the earth.

Examine the external field using a small plotting compass such as is often used as an ornament to a watch chain.



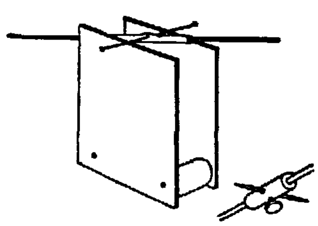
16 How to make a dip circle

Push a knitting needle through a cork in a direction parallel to a diameter of its end. Balance it horizontally on a U piece of brass strip, using pins as an axle. Take it off the knife edges and magnetize without disturbing the cork. When it is replaced on the bearings, one end will be pulled downwards by the earth's magnetic field. The protractor serves to measure this angle of 'dip'.



An alternative way of suspending the magnet is to use a piece of cycle valve tubing with a pin pushed through it as a supporting axle. Knife edges can be provided by two postcards held apart by corks maintained in position by drawing pins. The position of dip can then be marked with a pencil and measured later.

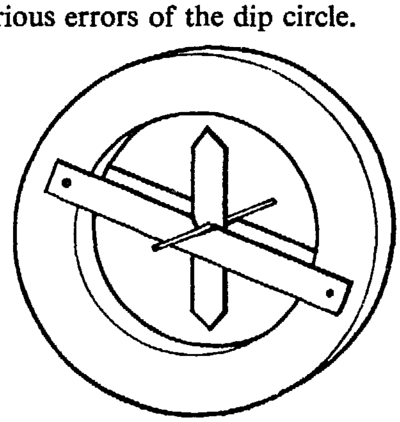
If metal 'connectors' are available, a more permanent device can be made by soldering gramophone needles to it.



17 A demonstration dip circle

Cut a ring of cardboard with an external diameter of 50 cm. Fasten two laths across a diameter to serve as supports for the dip needle. Cut a model dip needle from card and support it in notches cut in the laths.

Such a model is useful when discussing the various errors of the dip circle.



18 Exploring with a compass

Many things made of iron and steel are magnetized by the earth's magnetism. It is interesting to explore iron fence posts, iron bridges, etc., with a compass. Test them at both ends to see if they have magnetic poles. Drive an iron rod into the ground and see if it becomes magnetized. Test it at the top and near the earth. Test things around the school and at home with a compass.

19 What substances are magnetic?

Collect a variety of small objects made of paper, wax, brass, zinc, iron, steel, nickel, glass, cork, rubber, aluminium, copper, gold, silver, wood, tin, etc. Place them in a box and test each object with a magnet to see which ones are attracted and which are not.

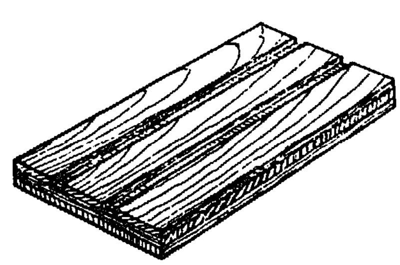
20 Magnetizing a bar by hammering

Secure an iron rod about one metre in length. An iron curtain rod will do. Test it with a compass at each end to see if it is magnetized. Hold the bar in a north-south direction and tilt. Strike the rod several sharp blows in this position and then test it again with the compass. A bar can often be demagnetized by holding it in an east-west direction and striking the end several times with a hammer.

21 Lines of force

A piece of plywood with two grooves cut in it to the depth of one ply is useful for holding magnets and magnetic materials while testing the patterns of their lines of force.

Permanent records can be made of such 'filing maps' if the paper used over the magnets is first dipped in hot candle grease and allowed to cool. Place it over the magnets under test, scatter filings on it from a height of 30 cm and tap the paper. Fix the pattern formed by warming the waxed paper with the medium flame of a bunsen burner.



22 Mapping lines of magnetic force

An alternative to the familiar waxed paper method is to use a modern black line paper. This paper, employed by architects in place of the older blue-print paper, can be used in daylight.

Place the magnet in position on the paper and scatter on the filings to produce the required pattern.

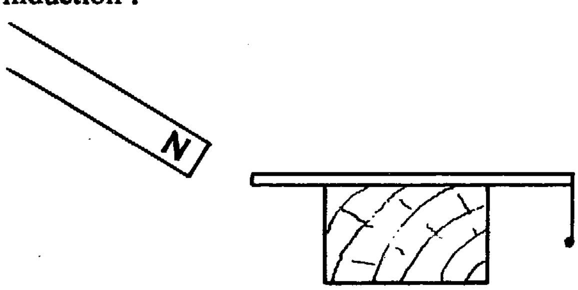
Expose to the sun or bright daylight for 10 minutes, or to the light of a small arc for 2 minutes, shake off the filings and mop over with developer on a piece of cotton wool. The prints so made are positives, and the paper can be varnished to form a permanent record.

23 What substances do magnetic lines of force go through?

Secure small pieces of as many of the following substances as possible: wood, glass, copper, brass, zinc, pasteboard, plastic, iron, aluminium, etc. Place some iron filings on one side of the sheet and move a strong magnet on the underside. By observing the iron filings you can tell which substances pass the magnetic lines of force.

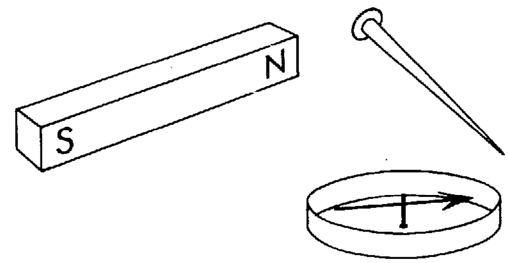
24 Magnetic induction

Place a bar of soft iron on a block of wood. Hold a tin-tack near it to test if it is magnetized. While the tack is near one end of the bar, bring a strong magnet near the other end. Is the bar magnetized? Remove the magnet and test again. Is the bar still magnetized? Magnetism produced in a substance in the vicinity of a magnet is called 'induced' magnetism. The effect involved is called 'magnetic induction'.



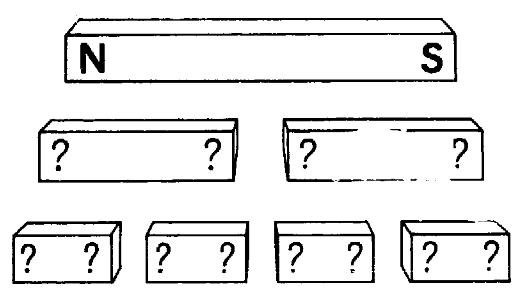
25 Testing for induced polarity

Test a strong magnet with a compass and mark the north pole and the south pole. Place a compass on the table and hold the pointed end of a 15 cm spike or piece of soft iron near it. Next bring the north pole of the tested magnet near the top end of the spike without letting them touch. Is a north or south pole induced in the end of the spike near the compass? What would you guess the polarity of the top end of the spike to be? Test it. Next hold the spike as before, but bring the south pole of the tested magnet near the top end of the spike. Is a north or south pole induced in the end near the compass? In the top end of the spike?



26 What happens when a magnet is broken?

Magnetize a piece of clock spring or a hacksaw blade about 25 cm long as instructed in experiment 3. Test the magnet with a compass to be sure that it has a north pole at one end and a south pole at the other. Mark the poles N and S with chalk. Does the compass show any polarity at the centre of the magnet? Use a pair of pliers and break the long magnet into two parts each about 12.5 cm long. Test the polarity of each end of the two magnets. What do you observe? Mark the poles of each magnet N and S. Now break the two magnets into four magnets. Test each end and mark it N or S. Continue dividing the magnets, as many times as you can. Write a conclusion to the question posed by this experiment.



27 Making a magnet with iron filings

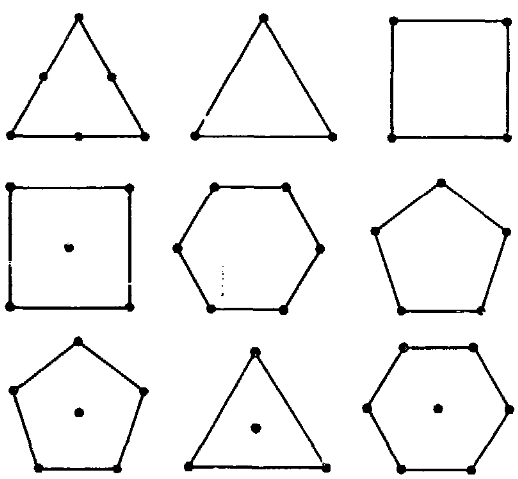
Fill a test tube or glass toothbrush tube about two-thirds full of iron filings and stopper the end with a plug of cotton or a cork. Stroke it with the poles of a strong magnet. Be careful not to shake the tube. Bring the tube of filings near a compass, and you will observe that it behaves just like a solid magnet. Shake the tube up well and again bring it near the compass. This time it does not influence the compass. From experiments such as this scientists are led to believe that the magnetism in a magnet is associated with very small particles of matter, perhaps molecules or atoms.

28 How to make floating magnets

Magnetize some used razor blades, being very careful not to cut yourself. Grease the blades lightly with oil, vaseline or kitchen grease. Fill a soup plate with water and float the razor blades on the surface. Now bring a strong magnet under the floating magnets.

29 Some experiments with floating magnets

Magnetize seven or eight steel needles so that their points all have the same polarity and the eyes all have the opposite polarity. Push the needles through small flat corks about 13 mm in diameter so that about 1 cm of the needle is above the cork. Fill a cereal dish or a soup plate with sloping sides nearly full of water. Float the magnets, pointed end down, in the water. Now bring one pole of a strong magnet above the floating needles. Try the other end of the magnet. Such floating magnets can often be arranged in different patterns in the dish. Here are some to try.



30 A vibrator with a magnet

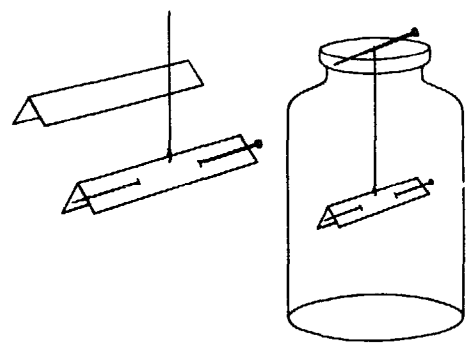
Set a U-shaped magnet on its side and place a needle or a razor blade on the lower pole. It will stand upright. Strike the free end with a pencil and observe how well it vibrates.

31 Making a needle float in air

Use a threaded needle. Draw the needle over one pole of a magnet resting on the table. Let the needle remain on this pole until it is thoroughly magnetized. Now carefully ease the needle from this pole and lift it by the thread until it is over the other pole. Careful manipulation will make the needle float in the air above the other pole. Can you explain why this happens?

32 How to make a card compass

Secure a wide-mouth glass jar. Fold a length of cardboard or stiff paper so that it will go into the bottle and not be too long to turn inside. Magnetize a steel darning needle (see experiment 3) that is just a little longer than the cardboard. Push the magnetized needle through the cardboard and suspend it on a thread so that the cardboard and needle balance. The needle may be moved in or out to get the exact balance. Tie the end of the thread to a match or longer piece of wood placed across the mouth of the jar.



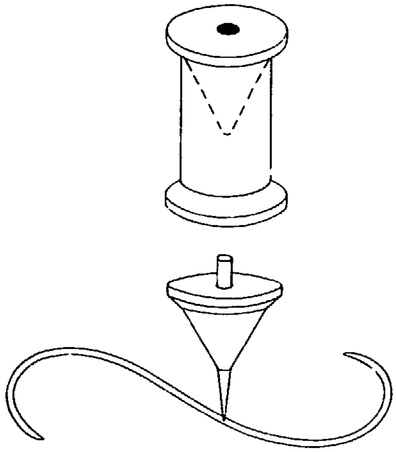
33 A magnetic fishing game

Tie a strong magnet to a string several decimetres long. Attach the string to a short fishing rod or stick. Spread a variety of small objects made of iron on a table behind a screen. Nails, tacks, screws, bolts, nuts, thumb tacks, etc., may be used. To each of the objects assign points, 5 for a large nail, 4 for a screw, 3 for a bolt, etc. The players take turns fishing over the screen with the magnet, and the score of each player is determined by what he picks up with the magnet.

34 A magic magnetic spinner

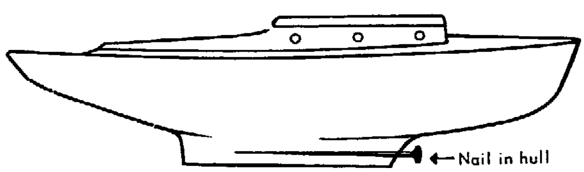
Make a spinning top from a wooden spool which has been used for thread. The spool is first cut in two. One piece is then shaped to a point like a cone. Find a nail or other piece of iron rod that will fit tightly in the hole of the spool. Cut off a length that will go through the cone and stick out about 1 cm above the top. Grind the lower end, which just sticks out, to a very sharp and evenly rounded point to make a spinning peg.

Magnetize the spindle and insert it in the wooden cone. Form a large S-curve from a piece of soft iron wire. Place this on a smooth surface. If you set the top spinning near one of the curves it will follow the wire to the end.



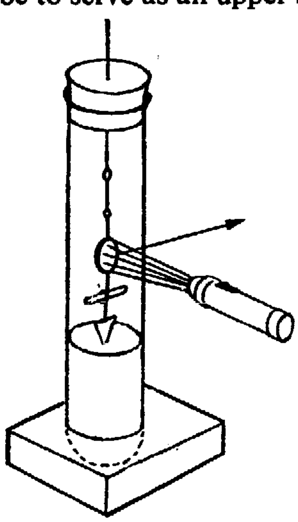
35 A magnetic boat

Fashion a small boat out of some soft wood. You may put a mast and sail on it if you like. Hollow out the inside of the boat or bore a small hole lengthwise in its hull. Magnetize an iron nail and either put it in the hole or simply lay it inside the boat. Use a plastic or aluminium pan for your ocean. You can fashion a shore line from sand or wood. Control your boat by means of a magnet which you move about under the container.



36 A sensitive magnetometer

Push a piece of copper wire through the cork of a test tube to serve as an upper support for the suspension. Make a carrier for the magnet from thin copper wire and solder a small vane to the lower end.



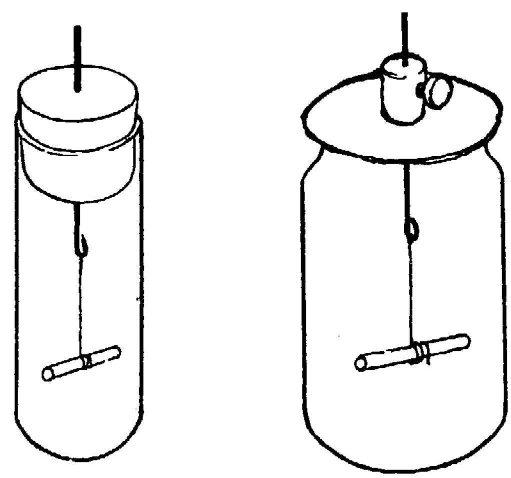
Attach a slip of mirror to the magnet carrier in order to reflect a beam of light. Pour oil into the test tube to a depth of approximately 3 cm. Lower the suspended magnet and carrier into the tube and adjust the upper support until the damping vane just dips into the oil.

37 A vibration magnetometer

Small, strongly magnetized cobalt or ticonal magnets are now available which, suspended from silk in a specimen tube, are excellent vibration magnetometers. Since there is no 'damping' here, the time of vibration of the 'swing' is a measure of the strength of the magnetic field in which it is placed.

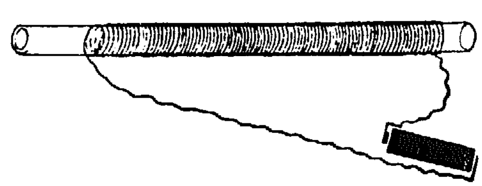
A larger model is easily made by using a preserve jar with a wooden top. A brass connector serves as a suitable clip for the upper support. The magnet can then be lowered to touch the bottom when the instrument is not in use. This precaution increases the life of the suspension.

(N.B. To damp a vibration means to lessen its amplitude.)



38 Making a magnetizing coil

A piece of ordinary glass tubing wound with close turns of copper wire serves to magnetize knitting needles. A torch battery supplies the current required, but should not be left connected longer than necessary.

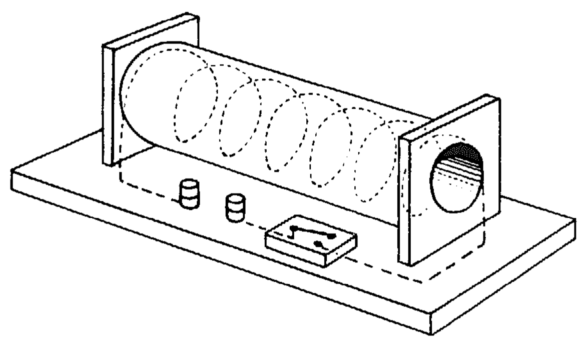


39 To make a magnetizing coil for the electric supply mains

This is just a solenoid through which a heavy current is passed for a short time. The mechanical dimensions are not critical, but the resistance of the wire must be chosen to suit the voltage employed. It will naturally be lower when used with a 12-volt accumulator than with 230-volt mains. For use with a 12-volt car battery, 4 layers of 22 SWG insulated copper wire are suitable, wound on a cardboard tube about 30 cm long and diameter about 4 cm. If the coil is for use on the 230-volt mains, many more turns are needed. Fifteen layers will give a strong magnetic field, though the number can be reduced if the last four turns are of enamelled 'Euraka' (copper nickel alloy) resistance wire. As the current is only needed for a very short time, it is a good plan to include in the circuit a 'press down' switch; a car starter switch is suitable.

Obtain a cardboard tube of the dimensions mentioned. Make two end supports with a hole into which the tube can be glued. Wind on the wire, preferably using a lathe or hand drill. Secure the solenoid by screws passed through a wooden base and into the end supports. Connect the ends of the wire to two insulated terminals with the switch in series. Connect to the source of current, hold the object to be magnetized inside the coil, and press the switch momentarily if direct current is used. The polarity produced will be the same as that of the coil. With alternating current the polarity must be found afterwards, and the strength of magnetization will depend on the exact instant at which the current is switched off. It may therefore be necessary to make more than one trial.

The coil can be used for demagnetizing with alternating current. The procedure is then to place the magnet inside the coil, switch on the current and, whilst it is still flowing, withdraw the magnet along the axis to a distance of about 2 yards outside the coil before switching off. It is quite safe to use such a coil for demagnetizing a watch, though watchmakers use a much shorter coil.



CHAPTER XV

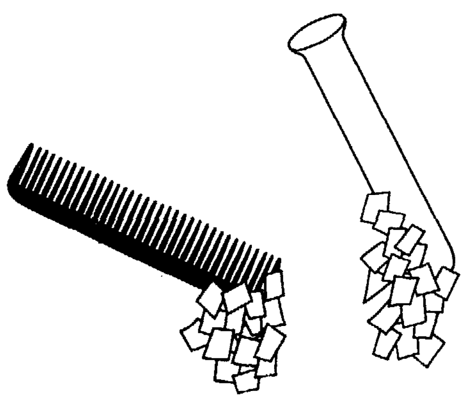
Experiments and materials for the study of electricity

A. STATIC ELECTRICITY

All these experiments work best when the air is dry

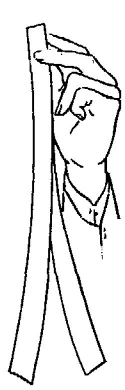
1 Electricity can be obtained by rubbing things together

Make a pile of finely divided cork particles by filing a cork. Cut up some thin paper into small pieces. Obtain a plastic comb, a plastic pencil, a plastic fountain pen, a piece of wax, a rubber balloon, a glass or china dish and any other non-metallic objects you may find. Rub each of these things briskly with your hair or a piece of fur and then bring near the pile of cork particles. Rub again and bring near the pile of thin paper. Observe what happens. Repeat the experiment rubbing each article in turn with a silk cloth. Repeat using a piece of flannel.



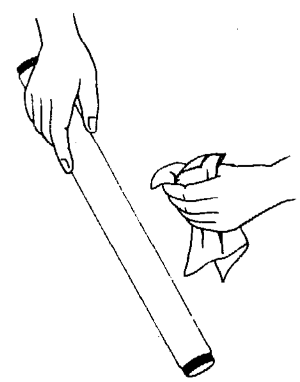
2 Static electricity is everywhere

Rub a blown up balloon on your hair and then bring it near some fine paper or cork particles. Repeat using a comb and a plastic ruler. Rub a fountain pen on your coat sleeve and test it for a static charge. Hold two strips of newspaper, about 5 cm wide and 30 cm long, together. Stroke them lengthwise with the thumb and finger of your free hand. What happens? Try to devise other experiments showing that there is static electricity everywhere.



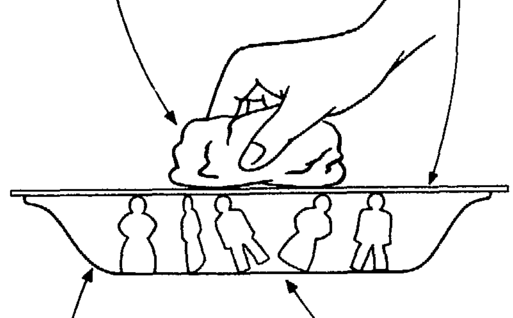
3 Light from static electricity

Secure a fluorescent light bulb. Rub it briskly with a piece of fur or flannel in a darkened room. What do you observe?



4 Dancing figures with static electricity

Secure an aluminium soup plate, about 2.5 cm deep, and a glass plate to cover it. Cut some little doll figures from thin tissue paper, as shown in the drawing. You may also cut out some other figures like boxers. The

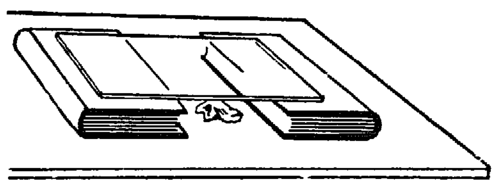


figures should be just a little shorter than the depth of the pan. Put the figures on the bottom of the pan and cover with the glass. Rub the top surface of the glass with a piece of fur or soft leather and watch the dance.

5 How to make the paper jump

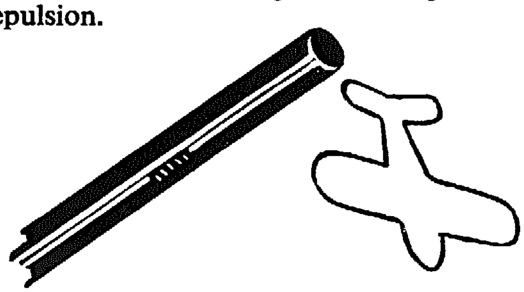
Place pieces of paper underneath a sheet of glass resting on two books. Rub the glass with silk or flannel. The papers begin to jump about in an amusing way.

It is the charge induced on them by the charged glass which causes them to be attracted. When they have given up their charge they fall back again. The paper can be cut out in the shape of frogs.



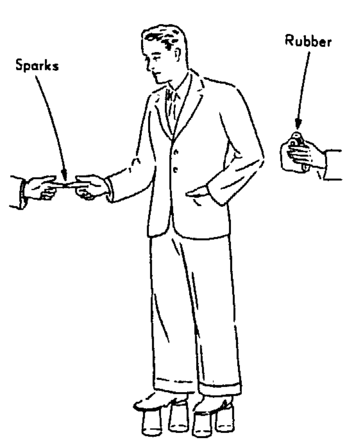
6 An electrostatic airplane

Cut a piece of light aluminium foil into the shape of a small airplane. Bring a charged ebonite or plastic rod near to it. It jumps to the rod and receives the same kind of charge as the rod has, then it jumps away again. It can then be kept in the air as long as is desired, and its direction of flight can be guided by repulsion.



7 Sparks from rubbing

Obtain four water glasses and stand them upside down on the floor, close together. They should be near some metal object such as a water pipe. Have someone stand on the glasses. Brush his clothing for a full minute either with a piece of fur or a piece of folded rubber like a cycle inner tube or a hot water bottle. Have him stick his finger out toward the finger of someone standing on the floor. Repeat and have him bring his finger near the water pipe. Observe the results.

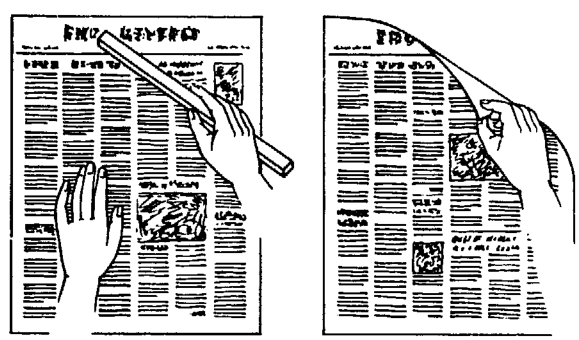


8 The balloon stays put

Blow up a toy balloon and rub it briskly with a piece of fur. Place it against the wall and observe that it stays where you place it. Repeat, rubbing the balloon on your hair. Again repeat, rubbing the balloon on a coat sleeve.

9 The newspaper stays on the wall

Spread out a sheet of newspaper and press it smoothly against a wall. Stroke the newspaper with a pencil all over its surface several times. Pull up one corner of the paper and then let it go. Notice how it is attracted back to the wall. If the air is very dry, you may be able to hear the crackle of the static charges.

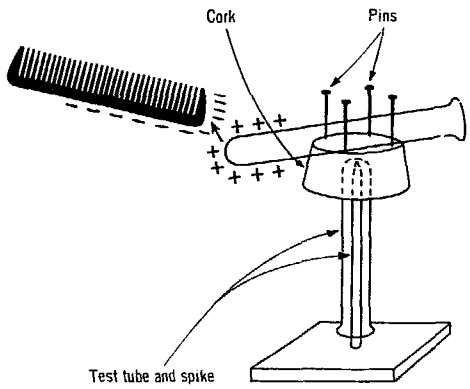


10 There are two kinds of static charge

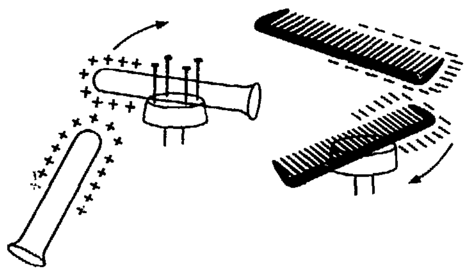
Make a turntable by driving a long nail through a wood base. Push a test tube into a hole made in a large flat cork. File the end of the nail to a sharp point and invert the test tube over it. Set pins in the top surface of the cork; they will brace the objects you place on the turntable. Secure two test tubes or other glass rods, a piece of silk such as a silk stocking, two plastic combs, and a piece of fur or flannel. Rub one glass rod with silk and set it on the turntable. Rub the other glass rod with silk and bring it near the one on the turntable. Repeat this experiment until you are sure of the results.

Again rub the glass rod with silk and place it on the turntable. Now rub a plastic comb with fur and bring it near the glass rod on the turntable. Repeat until you are sure of the results.

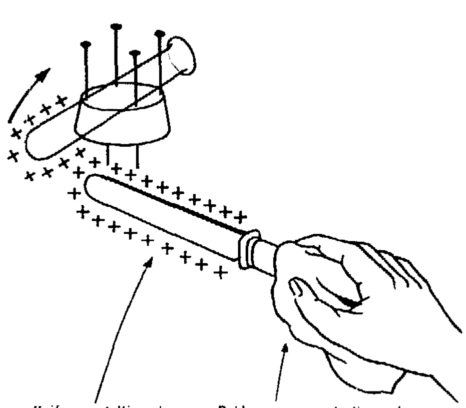
Rub a comb with fur and set it on the turntable. Rub the other comb with fur and bring it near the comb on the turntable. Repeat until you are sure your observations are correct.



Again rub a comb with fur and place it on the turntable. Rub a glass rod with silk and bring it near. Repeat until you are sure of your observations.



When plastic is rubbed with fur the plastic takes a negative charge of electricity and the fur takes a positive charge. When glass is rubbed with silk the glass takes a positive charge and the silk a negative charge. Your experiment has indicated that like static charges repel while unlike charges attract. This is a basic law of electricity.

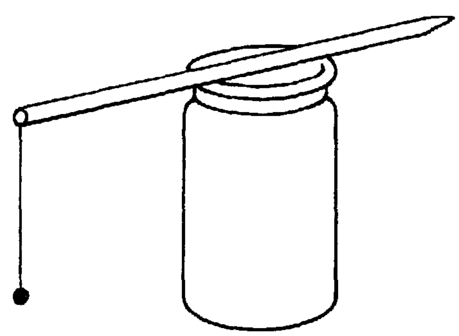


11 How to make a pith ball indicator for static charges

Secure some pith from the inside of a plant stem. Dry the pith thoroughly and then press it tightly into small balls about 5 mm in diameter. Coat the pith balls with aluminium or gold paint. Attach each pith ball to a silk thread about 15 cm in length. Make a wooden stand for the pith ball. Bring objects rubbed with silk, fur or flannel near the pith ball and observe how it behaves. Notice that it is first attracted and then repelled. Such a pith ball system is called an electroscope.

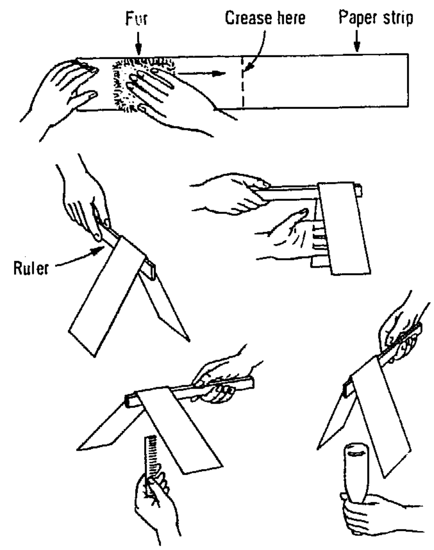
12 Metal foil ball electroscope

Roll up about 6 cm^2 of metal foil from a cigarette packet into a ball of about 6 mm diameter. Use an adhesive to attach it to a piece of silk or nylon thread about 7.5 cm long. Secure the free end to a ball pen or other insulator and rest the pen across the mouth of a jam jar so that the ball hangs clear of the side. Bring any charged body near the ball; it should first be attracted and then jump away. Now rub another plastic pen on a celluloid set square or protractor. Hold the pen near the ball and let it take a charge. Now bring the protractor near the charged ball. What does this tell you about the two kinds of charge produced by rubbing?



13 How to make an electroscope from newspaper

Cut a strip of newspaper 60 cm long and 10 cm wide. Crease it in the centre and hang it over a ruler as shown in the diagram. Hold it on the table and stroke several times with a piece of fur or flannel. Lift it from the table with the ruler and observe how it acts. Rub a comb or other plastic object with the fur or flannel and bring it between the extended leaves of newspaper. Repeat until you are sure of your results. Now rub a glass bottle with a piece of silk and bring it near the extended leaves of the newspaper. Observe the results and repeat until you are sure they are correct. What does this experiment show?



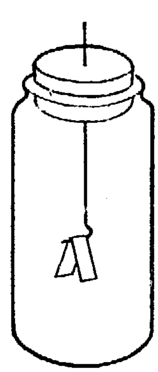
14 How to make a metal leaf electroscope

To make a device for detecting charges of electricity, a jam jar, some wire, and pieces of light foil or paper are needed.

A waxed cork is necessary to prevent the charge from leaking away. Push an L-shaped piece of brass or copper through it, and hang a piece of tissue paper or a strip of aluminium foil from the lower end.

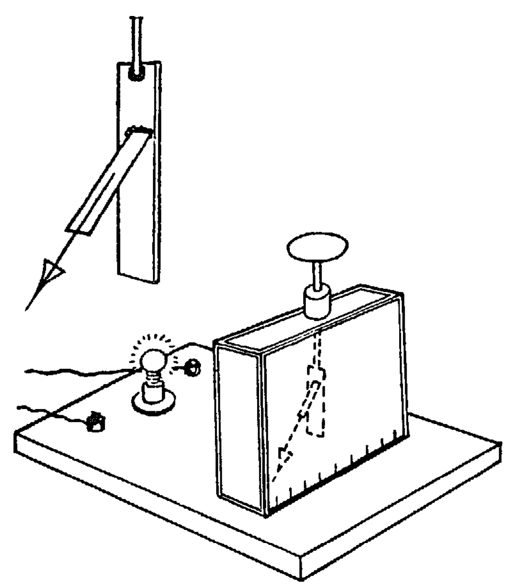
If a charged body is brought near the rod, the leaves of the paper fly apart because they have received the same kind of charge.

Insulating wax (see Chapter XVIII, item 21, page 216) or Perspex are better insulators and therefore more satisfactory than the waxed cork.



15 How to make a shadow electroscope

A very useful piece of apparatus can be made with a chalk or cigar box. The lid and bottom should be removed and replaced by a piece of clear glass in one side and a piece of linen or paper in the other (front in the diagram). The glass can be kept in position by tin corner plates, and the paper can be glued on. A hole drilled in what is now the top of the apparatus should fit a candle, ebonite or amber insulator with a brass rod down its axis. The top of the brass rod carries a metal disk forming the 'cap' of the electroscope and the other end has a strip of tin soldered to it. The gold or aluminium leaf is attached to the upper part of this tin, but the leaf is shorter. A thin glass thread, easily made in a flame, is stuck to the leaf with glue. It has a small arrow at its lower end. An electric bulb shines a light through the glass side of the apparatus and casts a shadow of the leaf and pointer on the screen. The advantage of this arrangement over the usual projection electroscope is that there is no inversion of the leaf, and movement and position of the leaf can be seen by a large class. It is also possible to put a scale on the paper calibrated in volts.



16 Fun with a kissing balloon

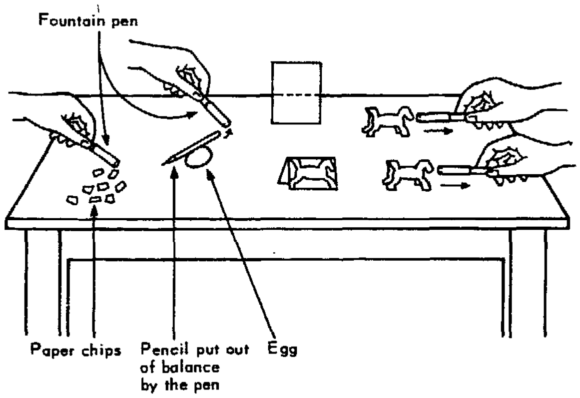
Blow up a toy balloon and tie a string to it about one metre long. You can draw faces on it with ink. Use a soft stick dipped in ink. Now hold the string while someone strokes the face on the balloon with a piece of fur or flannel. Let the balloon go and watch it touch everything around.

17 More fun with a balloon

Fix two balloons as in the experiment above. Rub the faces with fur. Hold the strings together and observe how they repel. Put your hand between them and observe what happens. Bring one of the balloons near your face. Repeat, using three balloons.

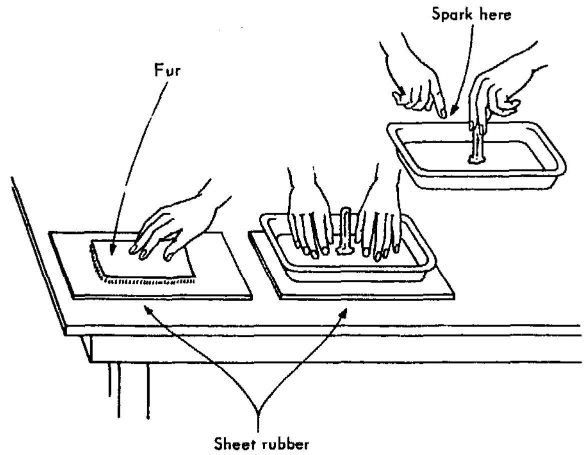
18 A static horse race

Cut small horses from a piece of folded paper so that they will stand on a table. Rub a hard plastic comb or fountain pen with fur and notice that you can pull the paper horses along the table. With several horses, you can have a horse race.



19 How to get many sparks from static electricity

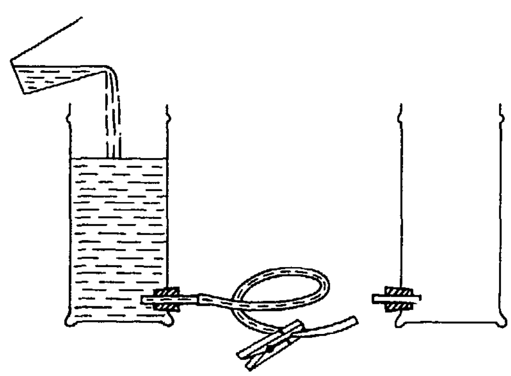
Obtain a piece of aluminium about 24 cm square. An aluminium cake tin will do. Heat the metal evenly over a flame. Touch a stick of sealing wax or a wax candle to the centre of the aluminium until it melts and sticks solidly to it as a handle. If you want a more permanent handle you can punch a hole through the aluminium and screw a plastic or wood handle to it. Unfold an old rubber inner tube from an automobile tyre and place it on a table. Stroke the surface of the rubber briskly with a piece of fur or flannel for half a minute. Now place the aluminium on the rubber and press it down hard with your fingers. Remove your fingers and lift the metal by the handle. Bring your finger near the metal and you should get a spark. You can take many charges from the rubber without further rubbing. Just press the metal against the rubber, press with your fingers and lift by the handle.



B. SIMPLE ELECTRIC CELLS AND CIRCUITS

1 To show how water flows in a tube

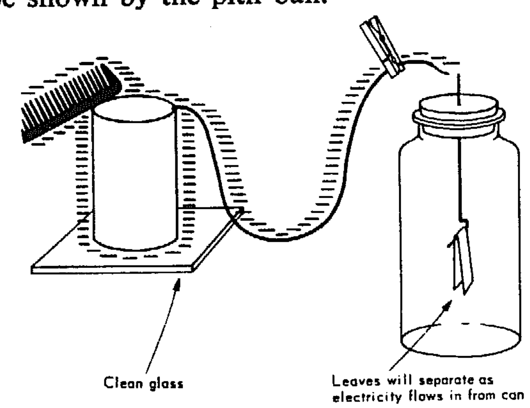
To make water flow from one can to another the source must be at a higher level. Water flows downhill. You can demonstrate this by using two large tin cans. Punch a hole near the bottom of each and then enlarge the hole so it will take a one-hole cork or stopper. Put a length of rubber tube on one can. Pinch the tube near the end with a spring clothes peg. Place the can on the table and fill it with water. Attach the tube to the other can. Let it also stand on the table. Remove the clothes peg and watch the water flow. When does it stop flowing?



2 To show how electricity flows in a conductor

Use two tin cans as in the experiment above. Fasten the bare end of a wire to one can. Place both cans on plates that have been turned over. Fasten a spring clothes peg near the free end of the wire. Now use the device for getting many sparks which you made in experiment 19 of the previous section. Hook the free end of the wire to the can to which the other end is already attached. Place a charge on the rubber pad and bring the metal plate into contact with the can to which the wire is attached. Repeat this twenty times until you have a good charge on the can.

Place the pith ball electroscope which you made in experiment 11 of the previous section so that it is in contact with the other can. Next unhook the wire from the can, using the clothes peg as a handle and hook it over the other can. Observe the pith ball. If your experiment is successful the electricity will flow from one can to the other, and this will be shown by the pith ball.

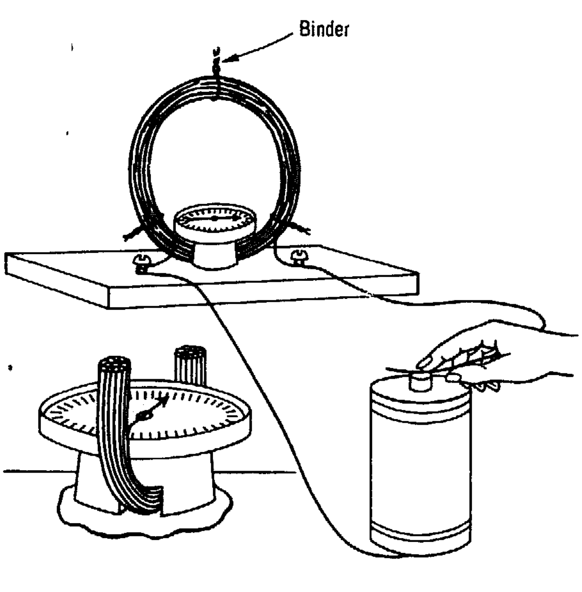


3 Another way to show how electricity flows

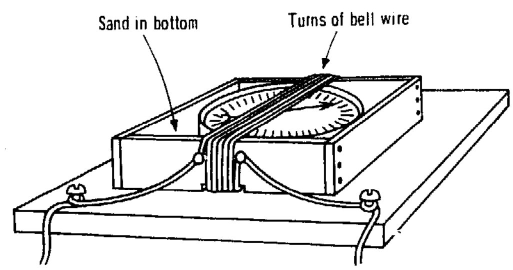
Use the can with the wire attached from experiment 2 above. This time attach the other end of the wire to the leaf electroscope which you made in experiment 14 of the previous section. Place a charge on the can with your spark device or from a plastic comb rubbed with fur. Observe the leaf of the electroscope.

4 How to make simple instruments to show electric currents

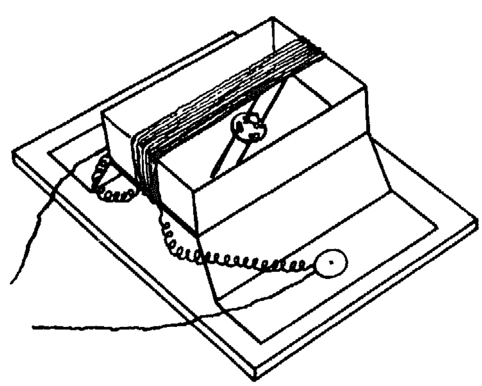
Procure some cotton-covered bell wire and neatly wrap from 50 to 60 turns to form a coil around a jar that is about 8 cm in diameter. Slip the coil from the jar and fasten it securely with short pieces of wire or with tape. Mount the coil on a wood base. A little platform to hold the compass can be made by cutting a hole in the cork for the coil to go through and then fastening the cork and coil to the base with melted sealing wax. Place a compass on the cork so that it points parallel with the direction of the coil. Connect a dry cell to the coil and observe the compass needle.



A more sensitive instrument can be made by building a little frame from cigar box wood just large enough to hold the compass. Place the compass in the frame and then wind about 20 turns of bell wire over the frame as shown in the diagram.



The press-stud compass needle described in Chapter XIV, experiment 11, page 157, can be used in both the above galvanoscopes. A useful model can also be devised using this compass needle in a matchbox. Remove the drawer from the box, and split open the case as shown in the diagram. Wind 20 turns of 26 S.W.G. double cotton-covered wire tightly round the drawer. Support the compass needle on a pin pushed through the bottom of the box.



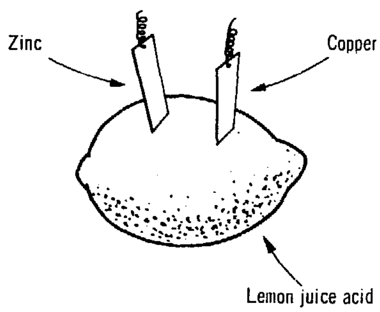
Fix the split-open case to a plywood base with drawing pins. Wind the bared end of the coil round the drawing pins, making electrical contact so that they may be used as terminals.

5 Electrical energy from chemical energy

Take two coins made of different metals. Clean them well with steel wool or fine sand paper. Fold some paper towelling or blotting paper into a pad so that it is slightly larger than the coins. Soak the blotting paper in salt water. Place one coin on top of the pad and the other underneath. Hold them between your thumb and finger. Connect both ends of the coil from your sensitive meter to the coins and watch the compass.

6 Electricity from a lemon

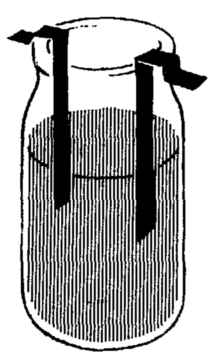
Connect one wire from your sensitive meter to a piece of zinc cut from the can of a used dry cell battery. Connect the other wire to a piece of copper. Roll a lemon on the table, pushing on it with your hand to break up some of the tissue inside. Push the two metal strips through the skin of the lemon, making sure they do not touch. Observe the compass needle.



Try this experiment using a potato. Does the distance between the plates affect the meter reading?

7 How to make a simple electric cell

If dry batteries are not available, a simple voltaic cell can be used for many experiments. Copper and zinc plates dipped into dilute sulphuric acid contained in a jar work well, but the plates must be shaken occasionally to remove the gases. A few crystals of potassium dichromate will remove the gases chemically.



8 Other simple electric cells

You can make a simple Daniell cell for class use with a boot polish or shallow meat jar.

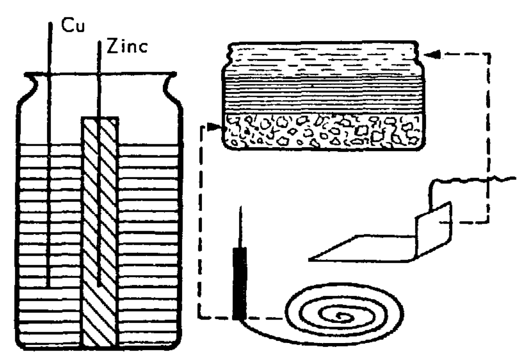
First put in a layer of copper sulphate crystals about 1.5 cm deep, moistened by about 0.5 cm of copper sulphate solution. Bury in this a pancake spiral of copper wire with an insulated lead. Pour in a layer of moist plaster of Paris and allow it to set.

For a negative plate use a strip of zinc sheet with a wire attached to it and fill up the jar with dilute sulphuric acid. This small quantity of acid can be thrown away when the cell is not in use.

A larger cell for supplying current can be improvised from a jam jar and a piece of cardboard tube.

Mix copper sulphate with plaster of Paris to a thin cream and allow to set after pouring it into the space between the jar and the central cardboard tube.

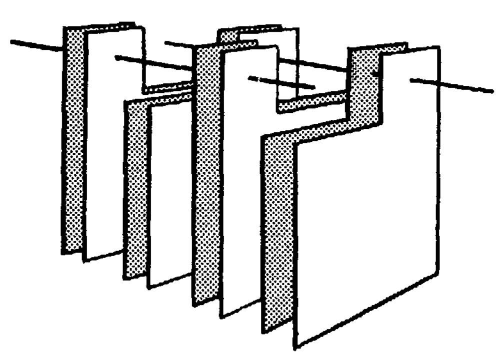
Mix another paste using plaster of Paris and zinc sulphate with a little sulphuric acid added. When the first plaster has set, pour this mixture into the central tube. Insert a copper plate and a zinc rod as electrodes before the pastes are hard.



9 How to make a simple accumulator or storage battery

Strip the lead covering from some electric cable. Cut it into pieces, 1.5 cm by 3 cm with a short projection or 'lug' on the short side of each.

Now prepare pieces of thin wood 1.5 cm by 3 cm from a matchbox to act as 'spacers' to separate the plates.



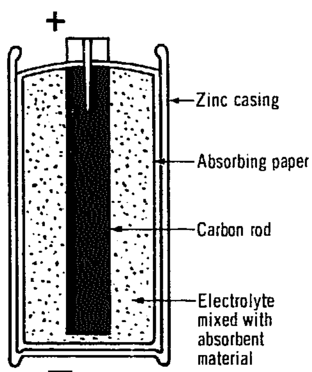
Arrange a pile of plates with lugs placed alternately and separate each plate by a spacer.

Connect the lugs on each side by a copper wire.

Immerse this arrangement in dilute sulphuric acid and pass a current to 'form' the plates. Even after a few minutes the accumulator will light a small torch bulb. Alternate charging and discharging will improve the condition of the plates.

10 How a dry cell is constructed

Remove the outer covering from an old dry cell. With a saw, cut the battery in half and observe its structure. Observe the carbon or positive pole in the centre, the zinc can which is the negative pole and the material between the two poles which is the chemical that acts on the plate of the cell. Notice how the zinc has been eaten away by the chemical. Observe that the chemical materials were sealed into the zinc can with hot pitch.

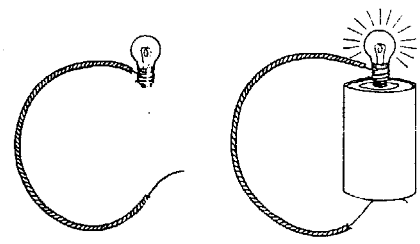


11 Using a dry cell in a circuit

Wrap the end of one of the short pieces of bell wire around the screwlike base of a flashlight bulb so that it holds the bulb tightly. Bend the remainder of the wire in the shape of the letter C. Set the tip of the flashlight bulb on the centre terminal of a flashlight cell and adjust the free end so that the springiness of the wire holds it against the bottom of the cell. If the connexions are tight, the bulb should light. Any flashlight bulb should operate when connected in this way, but the kind made for a single cell flashlight will give a much brighter light.

Look closely at the bulb and notice the fine metal wire held in position by two heavier wires inside. A hand lens will make this easier to see. The fine metal wire is made of wolfram, formerly called tungsten. Passage of the electric current through the wolfram wire causes it to become very hot and give off light.

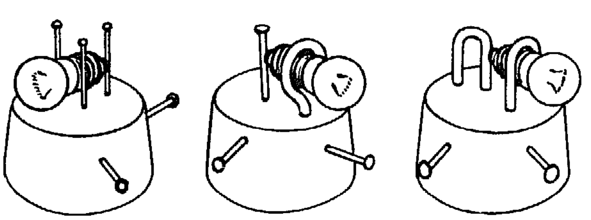
Turn the cell upside down and reverse the terminals. Note that the lamp still operates, though the electricity is flowing in the opposite direction.



Make a diagram showing the path of the current through the bulb and around to the other end of the cell. Develop the meaning of the term 'electric circuit'.

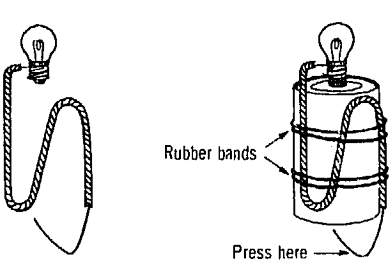
12 Flashlight bulb holders

Wire nails, screw eyes or staples can be used for supporting flashlight bulbs. Three nails driven into the top of a cork as shown in the diagram will support the bulb. Two more nails or screws in the side of the cork and touching two of the vertical nails serve to make electrical connexions.



13 How a flashlight works

Bend the bell wire and fasten it to the cell with a piece of friction tape or rubber band. Adjust the wire so that the tip of the bulb touches the centre terminal of the cell. Use the free end of the wire as a switch by pressing it against the bottom of the cell.

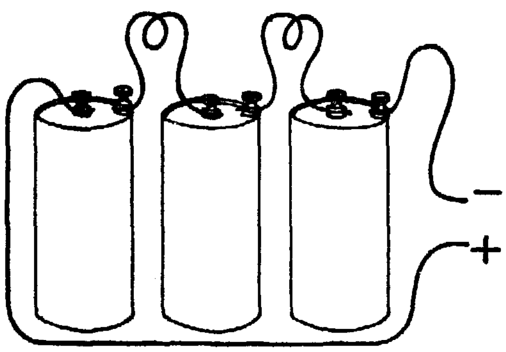


14 How to connect cells in series

Connect three dry cells in series as shown in the diagram. Note that the outside terminal of each cell is connected to the centre terminal of the next cell or vice versa. When the cells are connected in this way, the total voltage or electrical pressure is the sum of the voltages of the cells. In this case, the total voltage is 4.5 volts since the voltage of each cell is 1.5 volts.

Now connect the two lead wires to a lamp for a three-cell flashlight. Disconnect one of the wires and attach the same lamp to a single cell. Note the difference in brightness.

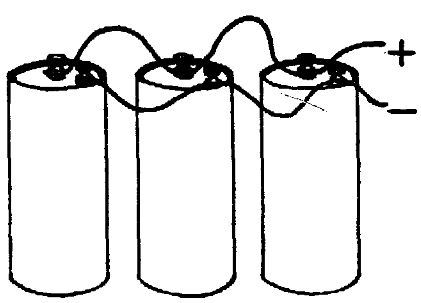
Connect the same lamp to two cells in series and compare the brightness with that produced by one cell and by three cells.



Cells connected in series

15 How to connect cells in parallel

Connect three cells in parallel by attaching all the centre terminals to one wire and all the outside terminals to another wire. Connect the lead wires to a receptacle and insert a bulb for a one-cell flashlight.



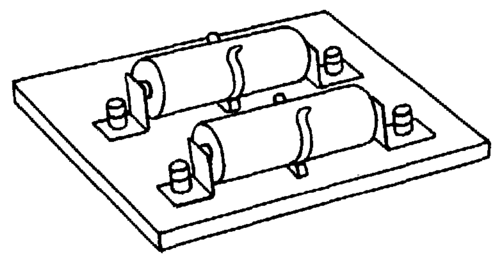
Cells connected in parallel

Disconnect one of the cells and note that there is no difference in the brightness of the lamp. Disconnect two cells and still the brightness does not change. When cells are connected in parallel the total voltage is no greater than that of a single cell.

Develop the distinction between the term 'cell' and 'battery'. A battery is two or more cells in connexion.

16 Torch battery holders

When several torch cells are needed for an experiment they can be held in spring clips fastened to a wooden base. These can be made of steel baling strip bent in the form of an angle bracket and secured by a terminal so that series and parallel arrangements are possible. For greater security, circular clips of standard pattern can be added to grip the cells round the circumference.



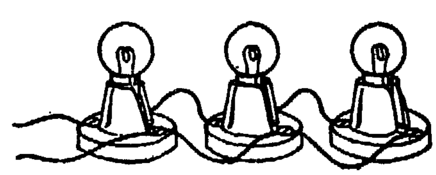
17 How lamps are connected in series

Connect three lamps in series and attach them to a single cell. Connect the same three lamps to two cells in series, then three cells in series. Unscrew one of the bulbs and note that the other two lamps go out, because the circuit is broken. Relate this to Christmas tree lights. In many Christmas tree cords, the lamps are connected in series. If one lamp in the series burns out, all the other lamps go out because the circuit is broken.

Lamps connected in series

18 How lamps are connected in parallel

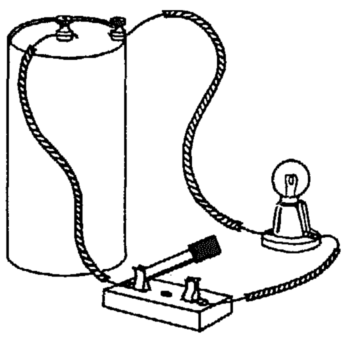
Connect three lamps in parallel and attach them to a single cell. Unscrew one of the bulbs and note that the other two stay lighted. Increase the brightness of the lamps by adding a second cell in series. Unscrew one bulb, then two bulbs, then three bulbs.



Lamps connected in parallel

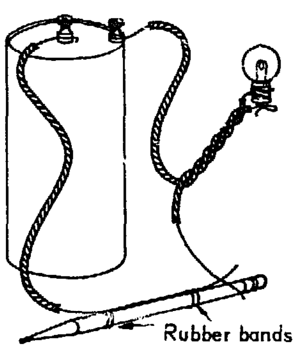
19 How a switch is used to control an electric circuit

Place a knife switch in a circuit with a cell and a lamp and turn the light on and off by operating the switch. Replace the lamp with a bell or buzzer and operate the switch. Replace the knife switch with a pushbutton switch. Discuss the appropriateness of each kind of switch for different uses.



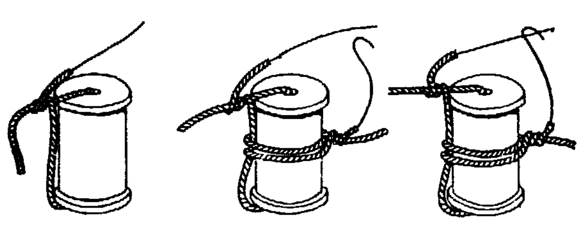
20 How to make a simple switch

A simple switch can be made by fastening the end of a piece of bell wire to a pencil with two rubber bands as shown in the diagram. A second wire spliced under it makes a suitable connexion.



21 Another simple switch

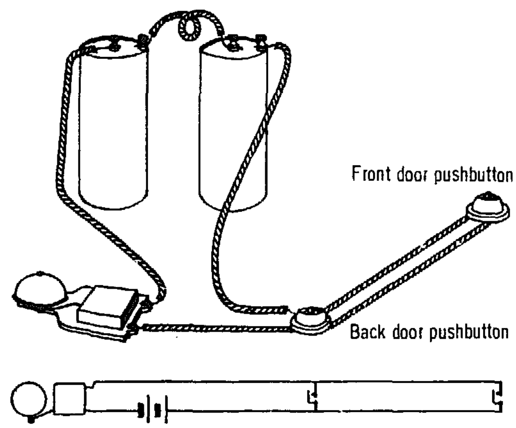
Run a piece of bell wire through a spool (reel) and fasten it. Wind a second piece around the spool (see the second figure).



Adjust the free ends of the wires so that the switch can be opened and closed easily.

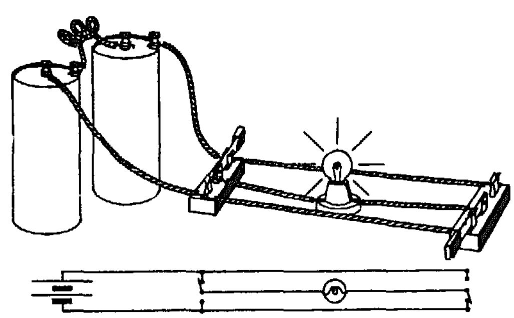
22 How a door bell can be rung from two pushbuttons

Using two cells, two pushbuttons and a bell, show how a doorbell can be operated from two different points, such as the front door and back door of a house. Lay out the circuit on a table as shown in the diagram. Draw an electrical diagram of the circuit, using standard symbols.



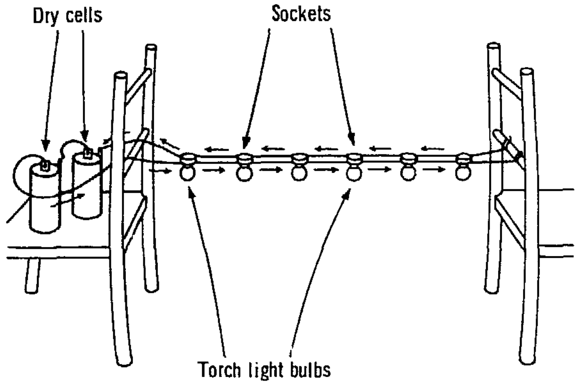
23 How a light is controlled from two switches

With two double throw knife switches, two cells and a lamp, show how a hall light can be operated from either the upstairs or the downstairs switch. Lay out the circuit on a table as shown in the diagram. Draw an electrical diagram of the circuit, using standard symbols.



24 A miniature street lighting system

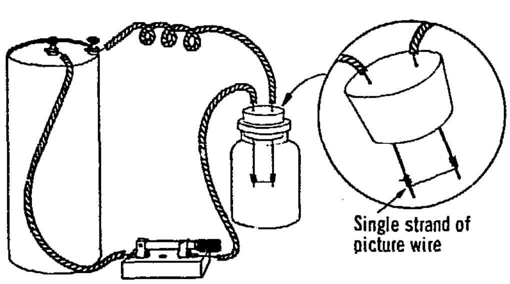
Cut two lengths of insulated bell wire about three metres long. Remove the insulation at six places along each wire and connect miniature light bulb sockets in parallel along them. Fasten the wires between two chairs as shown in the diagram, leaving the wires apart at one end. Connect the wires at the other end with two dry cells. Screw torch light bulbs into the sockets.



25 How we get heat and light from electricity

Push the ends of two pieces of bell wire through a flat cork that fits a small bottle. A suitable flat cork can be made by cutting off the end of a longer cork, or a two-hole rubber stopper may be used instead. Now untwist a piece of ordinary iron picture cord and cut off a short piece of a single strand. Wind the ends of this short piece of picture wire around the projecting ends of the copper wires and insert the cork into a bottle. The result will serve as a crude model of an electric lamp.

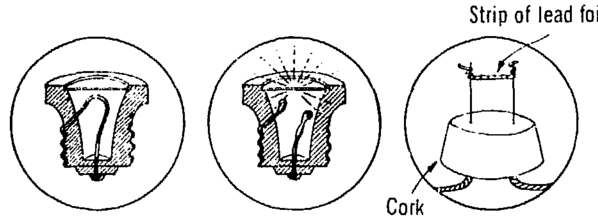
Connect the electric lamp model into a circuit with one or more dry cells and a switch. Close the switch until the fine wire (filament) begins to glow, then open the switch again. With care the lamp can be lighted several times before the filament is consumed, but finally the heated iron wire combines with the oxygen of the air inside the bottle and burns away. Commercially made lamp bulbs contain no oxygen, and the wolfram wire is heated to such a high temperature that it glows brightly. In addition to protecting the filament, the glass bulb also makes an electric lamp safe to use.



26 How fuses protect electric circuits

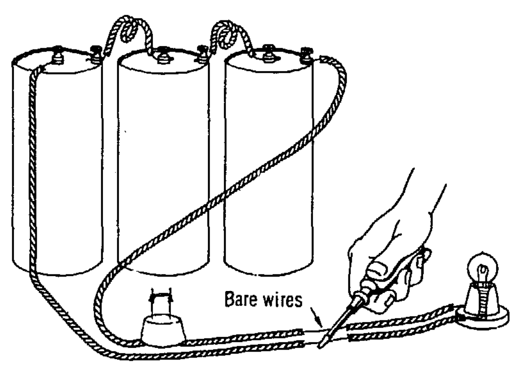
Examine normal and burned out fuses. Fuses are safety devices that break an electric circuit when the circuit is overloaded. The fuse wire melts when an unsafe amount of current is flowing through a circuit.

Cut a very thin strip of metal foil from a candy bar or other wrapper and fasten it between the ends of two wires projecting through a cork. This will represent a model of a fuse that should work with dry cells. Experiment with different types and widths of foil until the working model operates satisfactorily.



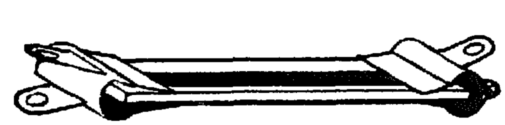
27 How a short circuit burns out a fuse

Place the model fuse shown in a circuit with several cells and a lamp. Then short circuit the lamp. If the fuse does not melt, cut a thinner strip of foil. Experiment with different kinds and widths of foil until the fuse carries the current when connected properly but melts when there is a 'short' in the circuit.



28 How to make a simple fuse holder

Tin foil used for cigarette and packing purposes is useful for experiments on fuses. It can be cut in strips and stuck on a piece of gummed tape which will hold it flat. The metal foil with paper backing which was used during the war for radar camouflage is excellent for the above experiment and can be cut easily with a pair of scissors to give different fusing values.



The ends can be held by bulldog paper clips to a slat of wood or a ruler. The device can then be incorporated with the circuit board set if desired. Different lengths and widths of tin foil should be tried to find the fusing current.

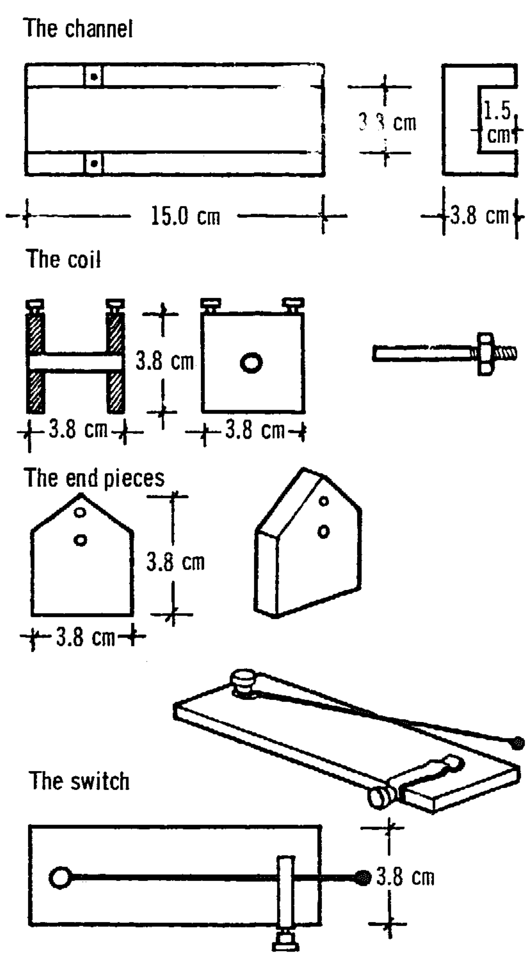
29 How electrical resistance varies with temperature

Connect a coil of about two metres of florist's thin iron wire in series with a torch battery and bulb. Heat the coil with a match; the increase in resistance will reduce the current so that the bulb no longer glows.

C. MAGNETISM AND ELECTRICAL ENERGY

1 An apparatus for building up simple electrical instruments

The different pieces of apparatus used in elementary electricity have so much in common, electromagnets, switches, etc., that it is worth while constructing some multiple sets of apparatus in which they can be used in several different ways. The following arrangements have been found useful for boys of 11-13, and require little more than a penknife to assemble, once the basic parts are made. The devices suggested are not entirely foolproof, because little is learned of the difficulties of a subject if one needs only to follow instructions to the letter.



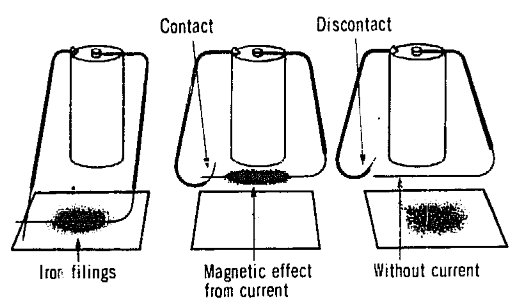
The apparatus consists of a short wooden channel which acts as a base for all experiments; a square-ended former for winding a coil which fits the groove fairly tightly, a few terminals, bits of tin, etc., are all that are required to make a morse sounder, buzzer, bell indicator, electromagnet repulsion meter and attraction meter.

The coil is made of two square end pieces of wood with holes in their centre. They are joined by cardboard tube glued into these holes.

An old carriage bolt with the head cut off makes a convenient iron core.

2 Magnetism from an electric current

Cut two lengths of copper wire and remove the insulation from the ends. Connect the wires to a dry cell and arrange the bare ends as shown in the figure. Place some iron filings on a piece of paper and run one of the bare ends through them. Now let the current flow through the circuit and quickly lift the wire and observe the iron filings. Break the contact and the iron filings will drop from the wire. Do not leave the cell connected long; it will quickly run down when connected this way.

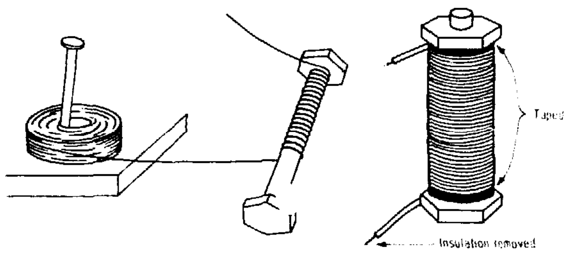


3 Another way to show the magnetic effect of a current

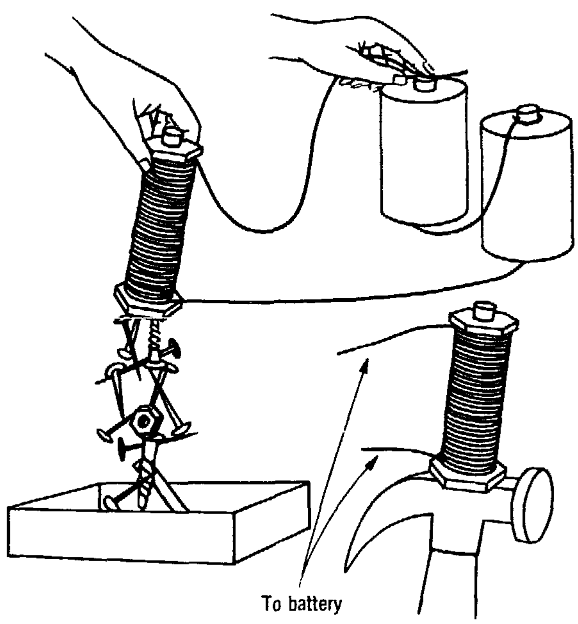
Repeat the experiment above, replacing the iron filings with a magnetic compass. Observe the difference in the compass when it is placed over the wire and under the wire.

4 How to make an electromagnet from a bolt

Secure an iron bolt about 5 cm long which has a nut and two washers. Place a washer at each end and screw the nut just on to the bolt. Wind layers of insulated bell wire on the bolt between the washers, making certain to leave 30 cm of wire sticking out when you start winding the coil. When you have filled the bolt between the washers with several layers of turns of wire, cut the wire, again leaving

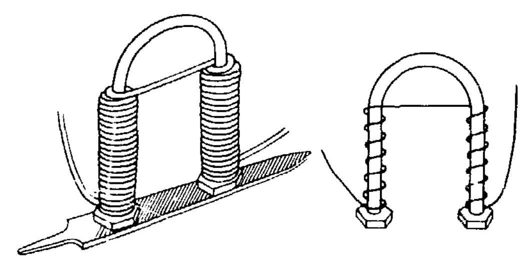


about 30 cm sticking out. Twist the two ends of the wire close to the ends, then wind short lengths of tape at the ends of the bolt to keep the wire from unwinding. Remove the insulation from the two ends of wire. Connect two dry cells in series and attach your electromagnet to them. Pick up some tacks and nails. Disconnect one wire from the battery while the tacks are still attached. Pick up other objects made of iron or steel. Test the poles of each end of the magnet with a compass while the current is turned on.



5 How to make a horseshoe electromagnet

Secure a slender bolt or a piece of iron rod about 5 mm in diameter and 30 cm long. Bend this into the shape of the letter U. Wind a coil of several layers of bell wire on each arm of the magnet, leaving the curving part free as shown. Begin at the end of one arm. Leave about 30 cm of wire sticking out for connexions. Wind about three layers on this pole, then carry the wire across the top to the other end; be sure to wind this pole exactly as shown in the diagram. Wind about three layers of wire on this pole. When you have finished, tape the wire to keep it from unwinding. Remove the insulation from the ends of the coil, attach to two dry cells, and test the poles of the electromagnet. One should



be a north pole and the other a south. If each has the same polarity, you have wound the second coil in the wrong direction. It will be necessary to unwind the coil and rewind it in the opposite direction.

Try picking up different things with the magnet. Compare the strength of this electromagnet with the straight one you made.

6 How to increase the strength of an electromagnet

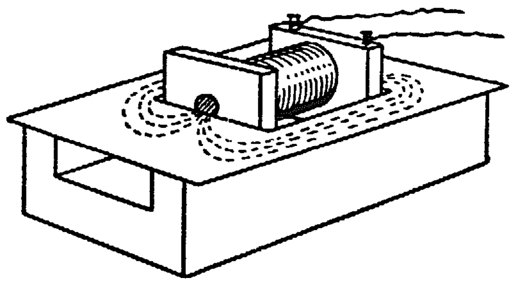
Wrap 100 turns of bell wire on a straight iron bolt. Connect the ends of the magnet with one dry cell and count the number of tacks you can pick up with the magnet. Make three trials, and take the average as the number that this magnet with one battery will pick up. Next attach two batteries to the magnet and repeat. Count the number of tacks. How is the strength of the magnet affected by increasing the current flowing through it?

Next wrap another 100 turns of wire on the magnet in the same direction. Attach to one battery and see how many tacks you can pick up. Repeat three times and take the average. Compare this number with the number picked up with one battery and a magnet of 100 turns of wire. How does increasing the number of turns of wire affect the strength? Make a statement on increasing the strength of an electromagnet.

7 How to study the magnetic field of a coil

Use the apparatus made in experiment 1 of this section.

A postcard with a square hole cut in it enables the coil to pass through. The card acts as a tray on which the effect of using different cores in the coil can be studied by making iron filing maps.

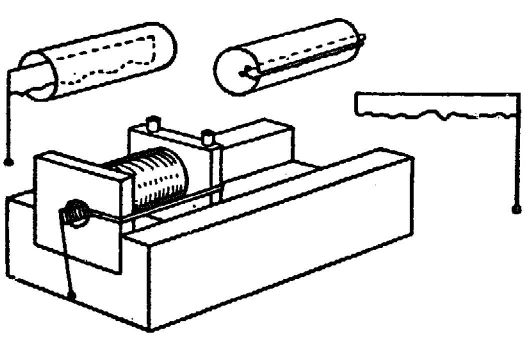


8 How to make a repulsion meter

Use the equipment made in experiment 1 of this section.

A piece of tin can about 4 by 5 cm with a wire soldered to one end is required for the 'movement' of the meter. A blob of solder on the end of the wire acts as a gravity control to the meter.

The coil becomes magnetized when a current is passed. Both the fixed and moving elements are magnetized in the same direction, and repulsion occurs. The fixed element is a soft iron wire held in position by a rubber band. It will give readings 0-5 amps, depending on the wire and the magnetic properties of the metals used.

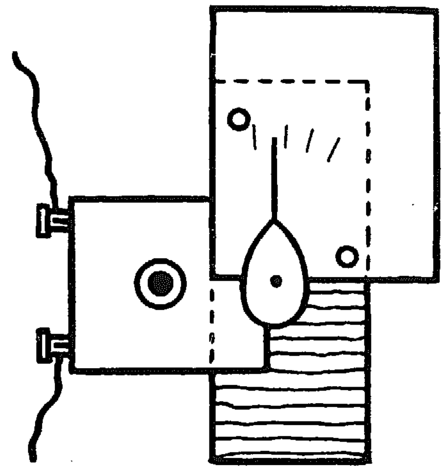


9 How to make an attraction meter

Use the equipment made in experiment 1 of this section.

For this apparatus the channel is laid on its side with the coil fitted as before. The iron core is pushed in and a current is passed. This attracts a pear-shaped piece of tin can pivoted on a pin stuck in the end of the block. A fine wire soldered to the tip of the metal acts as a pointer and graduations can be made on a piece of card held in position by drawing pins.

These are only a few of the devices which can be assembled from the above components. A boy of 12 can discover many more : the electric signal, the sucking bar, the relay, etc.



10 How to make a telegraph key and sounder

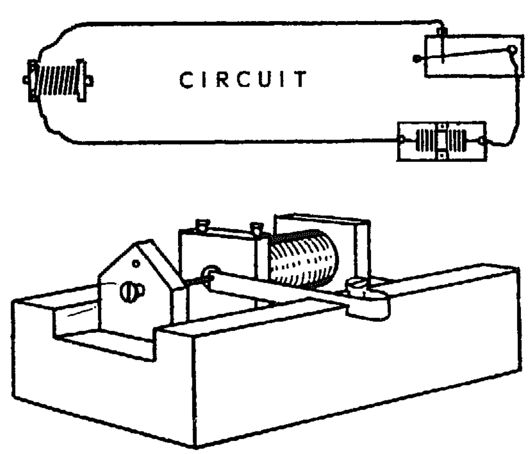
Again use the equipment made in experiment 1 of this section.

The coil should first be wound with any available copper wire, the ends being fastened under the terminals.

The completed coil is pressed into the groove and the iron core slid in; if necessary, wedge it in place with a piece of paper.

A strip of tin can about 10 cm long is then pressed into the saw cuts in the edge of the channel and secured by a terminal. One of the end pieces with a terminal in its lower hole will act as the sounder.

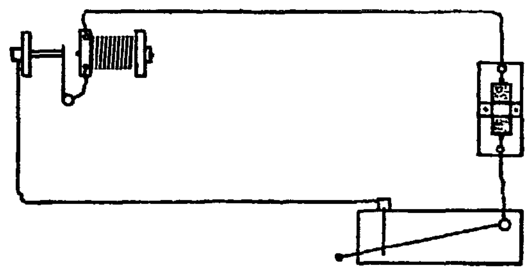
When the switch is depressed, the coil becomes a magnet, and the piece of tin can is pulled forward to hit the metal core with a 'click': as it springs back at the release of the switch, it hits the terminal on the end piece with a 'clack'.



11 How to make an electric buzzer

Use the equipment made in experiment 1 of this section.

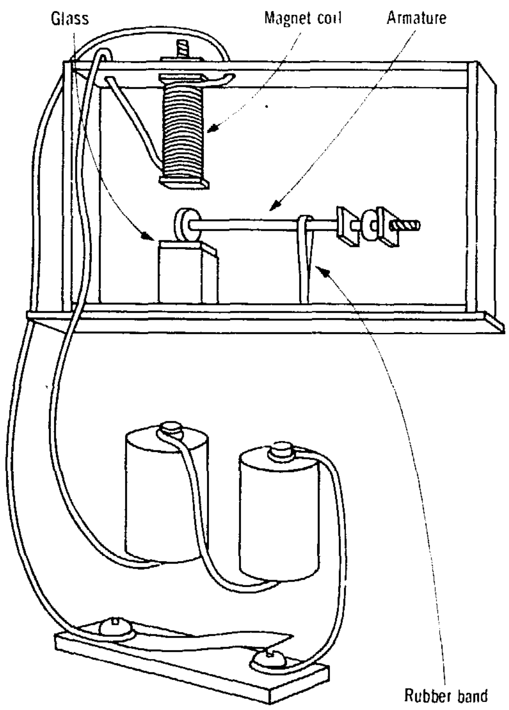
A simple rearrangement of the circuit converts the sounder into a buzzer. The contacts soon become fouled, and it is necessary to scrape them with a penknife.



12 How to make a cigar box telegraph and a key

Seventy-five to 100 turns of magnet wire neatly wound on to a 6.5 to 8 cm bolt will serve for the coil. Leave enough of the threaded end for two nuts and the thickness of the box, so that the coil can be fastened to the box. For the armature, a 10 cm bolt, 5 mm in diameter and with a round head, is most satisfactory. Support it between two nuts by a screw-eye fixed to the back of the box so that the head will extend just beneath the coil. A block of wood with a small piece of window glass cemented to it makes an effective anvil. Attach the anvil securely to the box. Hot sealing wax is ideal for both purposes. Any glue, however, will do. The height of the anvil should be such as to allow not less than 3 mm of clearance space for the end of the armature, and it should not exceed this amount by more than a trifle. The remaining feature now is a spring to pull the armature away from the magnet in case it tends to cling after the current is broken. A rubber band will work well. Slip it over the end of the armature and attach it to the box with a thumb tack. Give it just enough tension to prevent the armature from sticking to the magnet.

You are now ready to assemble a key. Secure a small piece of board about 8 cm by 15.5 cm and about 0.5 cm thick. Cut a strip of metal from a can about 2.5 by 13 cm. Go over it thoroughly with sandpaper or steel wool to remove any lacquer or tarnish from its surface. A piece of clock spring is also excellent for this purpose. Holes may be punched with a large nail and a sharp blow from a hammer. Set a screw in one end of the block and attach the metal at the other end so that it will bridge the space when the metal is pressed to the screw head.



Connect your telegraph sounder, two cells and key in series as shown. You are now ready for your trial message. If, on vibrating the key, you do not get a series of clicks, it means that either your connexions are loose or an adjustment of the rubber band is needed.

13 Another way to make a buzzer

A buzzer is essentially the same as a telegraph instrument except that it produces a buzzing sound instead of a clicking sound when you close the circuit. It is arranged so that it will automatically make and break the circuit many times per second while you hold down the key. The armature vibrates rapidly enough to produce the buzzing sound, which continues as long as the key is down. The buzzer is very fine for sending code—a short buzz for a 'dot' and a longer buzz for a 'dash'. It sounds just like radio code and is therefore better than the telegraph instrument for learning to send and receive by radio.

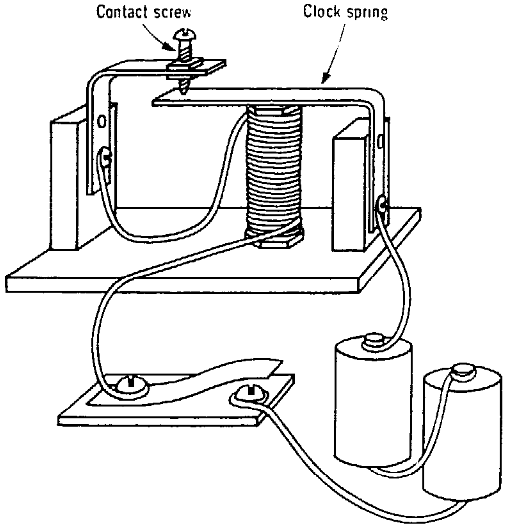
For the base and mountings, cut out three pieces of board to the following dimensions respectively, 13 by 15.5 cm, 5 by 5 cm and 5 by 7.5 cm. Drill a hole smaller than the bolt through the baseboard about 6.5 cm from one end to hold the magnet. For the magnet coil secure an 8 cm by 4 mm bolt at the hardware store. Put on two washers as collars to hold the wire and a nut leaving a little more than 1.5 cm of the threaded end clear. Wind on 100 turns of bell wire in a neat fashion, leaving about 45 cm of the ends free. Either tie the wire at the last turn or tape it to prevent unwinding. Now mount the coil by turning it into the prepared hole securely.

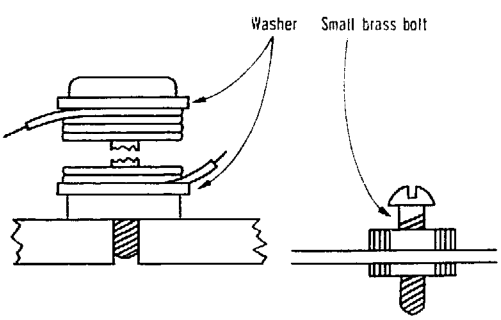
For the vibrator bend a 10.5 cm strip of thin iron about 2 cm wide into a right angle so that one arm will be 7.5 cm long. A piece of softened clock spring is excellent. To soften the spring bring it to red heat and allow to cool slowly. Punch two holes in the short arm by laying the strip on the end of a block and forcing the point of a large nail through with a sharp blow from a hammer. Attach the strip to the smaller block with screws, and nail the block to the base. Care should be taken to have the vibrator not more than 3 mm above the magnet. If it is not just right, it can be adjusted later by bending the vibrator strip.

For the contact point, secure a small brass bolt about 2.5 cm by 6 mm, and two nuts to fit, and a 5 cm angle iron. Set the brass bolt in one of the holes of the angle iron. Mount this angle iron with screws on the 5 by 7.5 cm block so that when it is nailed in position the horizontal arm of the angle iron will stand about 1.5 cm above the vibrator.

Now connect your buzzer with two cells and a key of your own construction. Be sure all connexions are tight and that all wire is free from insulation where the connexions are made. Press the key down and hold it while you turn the contact screw down into contact with the vibrator. If it does not vibrate, use sandpaper or steel wool to polish the surface thoroughly under the contact point. As soon as you get it vibrating, you can improve the tone by finer adjustment of the contact screw and also by bending the vibrator to ensure a space about the thickness of a dinner knife between the vibrator and the magnet.

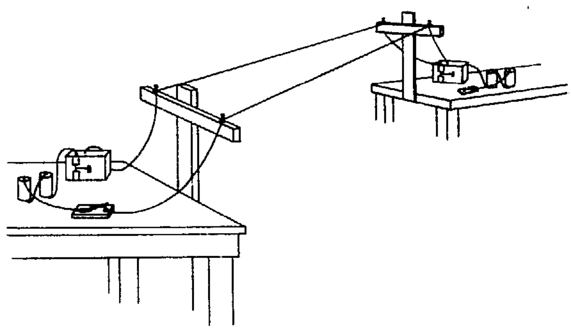
Now you can practice the code. If several buzzers are made, you may connect them to a line in the room, or you may signal between two houses.





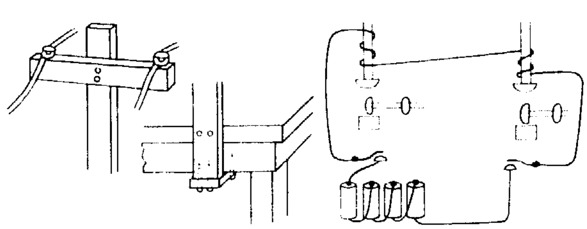
14 How to connect up a two-way telegraph system

If you can secure two telegraph sounders and two keys like the ones made in experiment 12



above, you can set up a two-way telegraph system by following the diagrams below.

When one key is being used for sending, the other one must be fastened down so that the electric current will go through it.



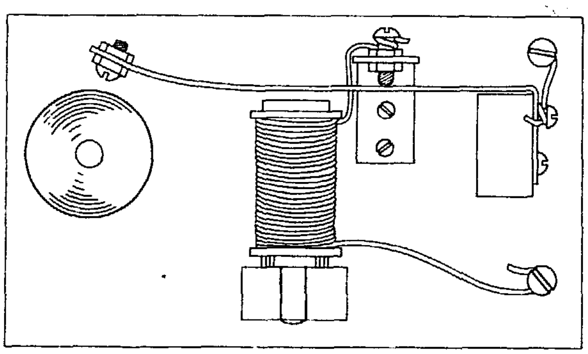
15 How to make an electric bell

If you study the diagrams, you will see how simple it is to adapt a few worthless pieces of material to your purpose of making a bell that will ring nicely on electric dry cells. You will need three pieces of board—one for the base, about 13 by 18 cm, one to hold the magnet, and one to hold the vibrator, each about 5 by 5 cm. Wind not less than 100 turns of cotton-covered magnet wire or bell wire on to an 8 cm bolt for the magnet. Plan to have several centimetres of wire free at the ends when finished. Use a nut and two washers to form the spool. Leave at least 1.5 cm of the threaded end of the bolt free for attaching the magnet to the block as shown in the diagram. Mount the magnet about midway on the base with nails of the proper size.

For the vibrator or clapper, an 18 cm piece of softened clock spring not less than 1.5 cm wide is excellent. The clock repair man in your town should be willing to give you an old spring. Soften a portion of the spring by heating it red hot—over the gas flame of the cook stove, if you do not have a gas burner. Be sure it gets red hot and then let it cool slowly. This takes some of the springiness out of it and softens it so that it will not retain magnetism. Punch a hole very near one end and two more holes about 2.5 cm apart at the other end. In one end set a small bolt, with two nuts to fit, to serve as the hammer. Bend about 4 cm of the other end at right angles and attach it to the wooden block with small screws; attach the block to the base. It should be placed so that the vibrator will stand about 6 mm from the magnet when finally adjusted.

For the contact point, a 2.5 cm angle iron will serve very well as the support, and a small bolt about 10 mm long, preferably of brass, set with two nuts as in the figure, makes a satisfactory contact. Attach to the base with screws at a point about 9 cm from the hammer end of the vibrator, being careful to locate it so that the vibrator can be adjusted correctly, as described above. Before setting, you should spring the vibrator out from the magnet just enough so that when the contact point is set, the vibrator will be pressing against it with a fairly firm pressure.

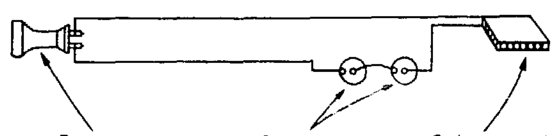
Before mounting the gong, the wires should be connected and the contacts adjusted, as follows. The plan for connecting the wires is clearly shown. Now connect to two cells and make the proper adjustment of the contact point by setting it in or out. The watch spring should vibrate vigorously.



Be sure that all connexions are good and that the clock spring is sandpapered or scraped down to the clean metal where it presses against the contact point. The end of the contact bolt, too, should be sandpapered. While the hammer is vibrating, find the best position for the gong, then fasten it to the baseboard. A little bending of the spring or changing of the pressure at the contact, or the space between the vibrator and magnet, or re-sandpapering the contact points, may improve its performance.

16 How to set up a simple telephone line

Secure two copper plates about 10 cm square. Punch a hole in each and attach about a metre of bell wire after removing insulation from the ends. It is best to solder the wire to the copper plates. Remove the carbon rod from an old dry cell. Break it up into pieces about 5 mm in diameter. Make a selection of carbon pieces of about the same size. You will need a small handful. Next secure a cigar box and an alarm clock. Place the clock face up on the cigar box. Place one copper plate on the alarm clock. Connect the wire from this plate to two dry cells connected in series. Connect a telephone receiver to the other side of the battery and to the wire of the other copper plate. Next place the pieces of carbon on the copper plate and then cover them with the other copper plate. Listen in the receiver, and you will hear the ticking of the clock. You may have to adjust the top copper plate by moving it a little one way or another.



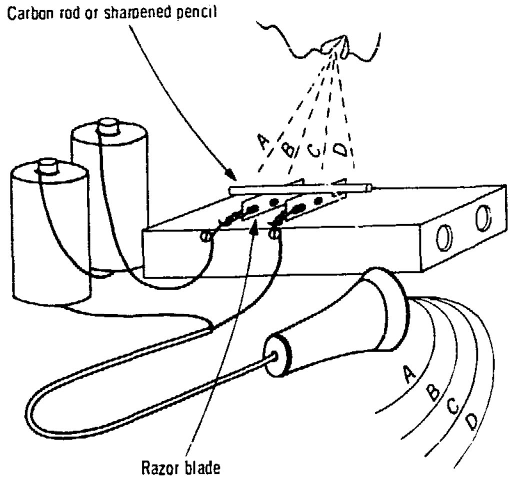
17 How to make a simple telephone transmitter

Cut parallel grooves, about 4 cm apart, into the top surface of a cigar box with the point of a pocket knife. Force the back of a razor blade firmly into each. This should hold the blades securely in position. If it does not hold them securely, set them in with hot sealing wax (heat the blade and rub it on the wax and, while still hot, force it into the prepared groove). Twist wires into the blades for connecting purposes. Now sharpen a short piece of pencil at both ends and set across the sharp edges of the two blades. Be sure to have the pencil sharpened back far enough, so that the carbon, and not the wood, contacts the blades. Your telephone is now complete.

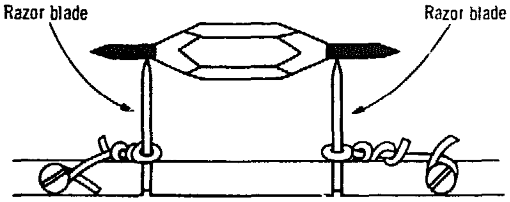
Obtain a telephone receiver from some convenient source. If you know someone connected with the telephone company, he may be able to get you a discarded one. Connect with dry cells as illustrated in the diagram.

To test your connexions, put the receiver to your ear and raise and lower the pencil. Move it about, and you should hear noise in the 'phone something like static on the radio.

To get your 'phone tuned up for the voice, set a clock on the box and, while listening in the receiver, adjust the position of the rod or pencil until you can hear the clock ticking two or three times louder than ordinary. When a sensitive position is found, remove the clock and speak directly and distinctly into the box. Your friend, with the receiver to his ear, should hear what you say. Of course, he should close his other ear unless you have a long line.



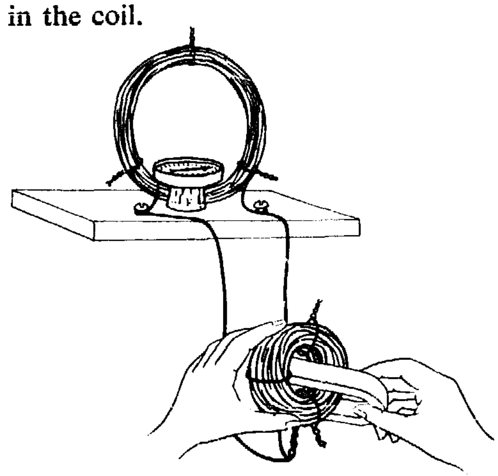
You have now achieved the near magic of making a cigar box reproduce your voice and send it over a wire. Try to figure out how it works. You realize that the sound waves of the voice cause the box to vibrate. Rest your fingers on the box while you make some sounds and feel the vibrations. This vibrating of the box causes the pencil to rattle or vibrate likewise. This, in turn, interrupts the steady current and makes it pulsate as it goes through the electromagnet of the receiver.



This causes the diaphragm in the receiver to rattle or vibrate and produce the same kind of sound waves as those that strike the box at the other end of the line. Rub the box and listen. Drop grains of sand on the box and listen in the phone to hear them strike. Jar the table and listen. Do these tests seem to confirm the above explanation?

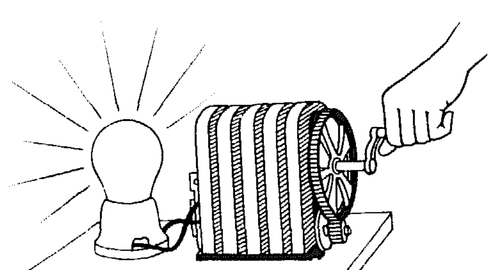
18 Producing electricity with a magnet and a coil

You will need to use the sensitive current detector which you made in experiment B 4 above for this experiment. Attach a coil of about fifty turns of bell wire to the current detector, leaving the lead wires long enough so that the magnet is well away from the compass. Move the coil over one pole of a permanent horseshoe magnet. Observe the compass needle. Now remove the coil from the pole and observe the needle. Move the coil on and off the other pole of the magnet. Next hold the coil and plunge the magnet into the coil. Whenever magnetic lines of force are broken by a coil a current is set up in the coil.



19 Electricity from a hand generator

You will need a magneto from an old-fashioned wall telephone. This type of telephone is still used in some localities. If you have a friend who works for the telephone company, it is very probable that he could get



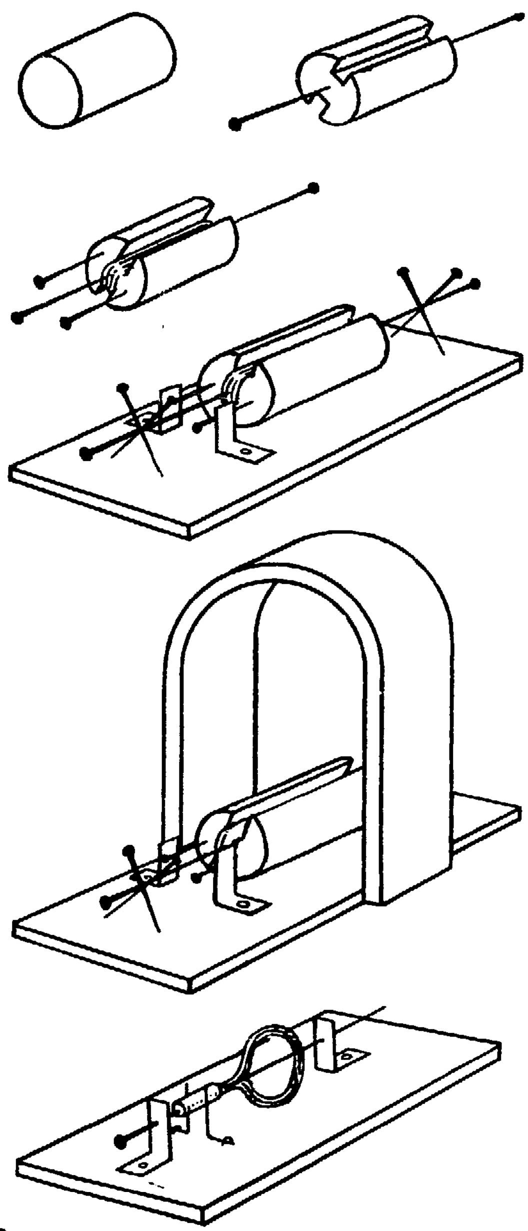
one for you without cost, because they are often replaced with a more modern type.

Remove the magneto from the cabinet and mount it toward one end of a board about 15.5 by 30 cm. Attach a regular lamp socket near the other end. Connect the socket to the terminals of the generator. Place a 10 watt, 100 volt lamp into the socket.

The machine is now ready to use. Turn the crank and light the lamp. Turn it slowly, and the lamp glows faintly. Turn it fast, and it glows brightly. Why? Close your eyes and while you turn, let someone screw the bulb out and in. Can you tell when the bulb is out and when it is in by the amount of effort you must use to turn the crank? Why is it harder to turn when the lamp is lighted?

20 How to make a pin and cork motor

The armature of this motor is made by winding a coil of thin insulated wire in a groove cut into a cork with a razor blade.



Two pins, one stuck in each end, act as an axle. The ends of the wire (bared) are wrapped round two more pins which serve as terminals through which the current enters and leaves the coil. Strips of thin tin or copper foil are used as brushes, being held to the baseboard by drawing pins.

A horseshoe magnet placed over this arrangement completes the model, which can be driven by a dry cell.

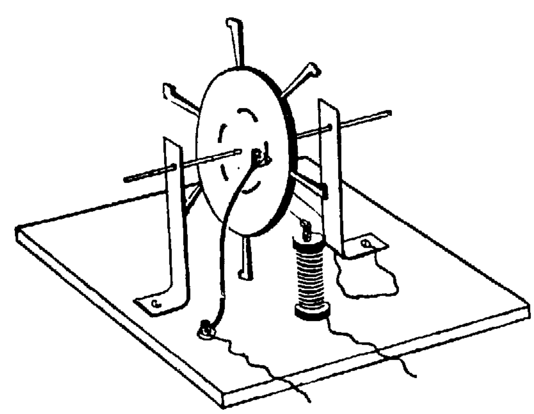
A midget armature can be made by using one pin and no cork. The wire is first wrapped round a pencil and tied into a loop with cotton. The ends are also secured with cotton to a piece of gummed paper rolled round the pin, which serves as commutator.

Small pieces of bent tin act as supports and fine wires lead the current to and from the commutator.

21 How to make an attraction motor

In this motor, a soft iron armature is attracted by an electromagnet. Continuous motion is secured by attaching a current breaker to the armature, so that the various segments of the motor are attracted in turn. The iron parts are 7 cm 'cut' nails; six are required for the armature, and one for the electromagnet.

To make the armature, cut three circles of cardboard 6 cm in diameter. In one of them, cut six equally spaced radial slots to fit the nails, and glue the other two circles to it,



one on each side. Now mark a circle of 2 cm radius on the armature, and thread 18 gauge bare copper wire through 12 holes equally spaced round its circumference. This will provide six contacts which should be connected to the axle by winding the free end of the wire round it. A knitting needle is used for the axle.

To make the electromagnet, drive a nail through two cardboard disks or through two old tap washers, to act as end-pieces for the coil. Wind two layers of insulated bell wire on the nail and drive the completed electromagnet into a piece of wood which will serve as the baseboard.

Make the armature supports from two strips of tin cut from an ordinary can; punch holes for the axle and for fixing it to the base, using a pointed nail.

The method of assembly and the remaining details, including the bare wire to act as contact breaker, can be seen from the drawing.

If low voltage alternating current, say from a bell transformer, is available, the contact breaker can be dispensed with. The alternating current is then fed straight to the electromagnet, and after a little practice the armature can be spun at just the right speed to keep in step with the alternations of the current. This illustrates the action of the mains electric clock motor.

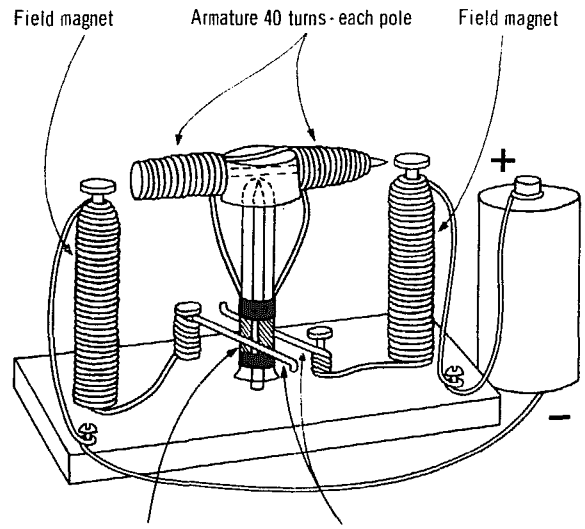
22 Another simple motor

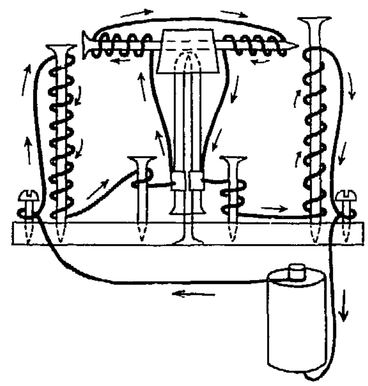
This simple model will give you real satisfaction. It uses current from the battery to excite the field magnets as well as the armature coil.

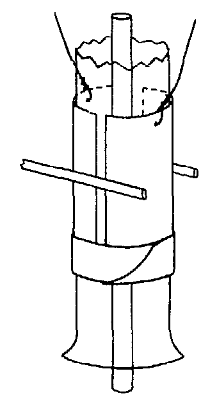
Prepare a board 20 by 25.5 cm for the base. Drill a small hole through the centre and drive a 15.5 cm spike up through it. Wind 100 turns of insulated bell wire neatly onto two other 15 cm spikes, leaving about 30 cm for free ends. Drive these spikes into the base 15.5 cm apart. Drive two small nails on the diagonal and 5 cm from the spike at the centre. Strip the free ends of each coil and twist them several times around the nails and bend them so that they will rest in contact with the central spike. These ends will serve as brushes. Care must be taken to have the field coils wound in the proper direction. The diagram is a complete plan for the direction of windings. It will work in no other way. The other ends of the coils may be fastened to screws in the corners of the base.

Your field magnets and brushes, two of the four essential parts of a motor, are now complete. The armature coil and commutator remain to be constructed. Drill a hole crosswise through the top of a 4 cm cork and force a 13 cm spike through it. Wind about 40 turns of insulated bell wire on to each end, being sure the direction of windings is as shown. Scrape the free ends. Now gouge out the centre of the cork neatly; round with a penknife and insert the closed end of a 10.5 cm or 13 cm test tube. This completes the armature coil.

You are now ready to make the commutator. Cut out two rectangular pieces of sheet copper about 4 cm long, and wide enough







to reach around the test tube with about 6 mm space between. Curve these to fit the tube. Punch small holes and into each twist one of the scraped free ends of the armature windings. Then bind these commutator plates securely into position at top and bottom with adhesive tape.

Your rotor, consisting of armature and commutator, is now complete. Set it into position on the vertical bearing and bring the brushes into contact with the commutator. Now if your windings and connexions are all as shown, connect to one or two cells and with a slight push of the armature it should start off at a lively speed. If it does not go, examine the brushes to see whether they make a light, but certain contact. It may also help to change the angle of the brushes. To test this point, untwist the brushes from the nails and hold them lightly against the commutator plates with the fingers. While holding them, always parallel, swing them around at different angles while a helper turns the armature with his hand. Note the point at which the armature picks up most speed and set the brushes at that point. With a little patience you will be successful and will be well rewarded for your efforts in making this interesting and instructive toy.

D. HEAT AND LIGHT FROM ELECTRICAL ENERGY

1 How to get heat and light from electrical energy

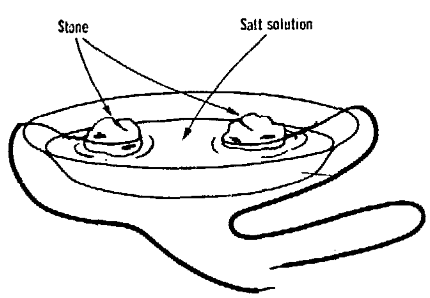
See experiment B 25 of this chapter.

2 How to make a simple rheostat

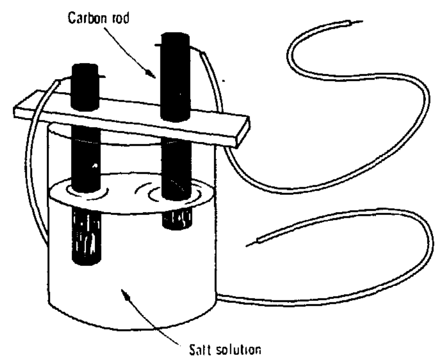
In some of the experiments which follow, you will need to reduce the strength of the electric current.

This can be done by causing the current to flow through a poor conductor, called a resistance or rheostat, at some point in the circuit. There are several different kinds of rheostats possible. You will find it easier to use what is know as a water rheostat. Water is a poor conductor of electricity. Therefore, allowing a container of water to constitute one stretch of the path through which the current must travel will cut down the strength of the current. Pure water would conduct almost no current. A few grains of salt added to the water will make it sufficiently conducting to serve your purpose. Now, the farther the current has to flow through this salt water, the more its strength will be reduced. So, if you can arrange a scheme that will permit you to vary this distance at will, you will be able to increase or decrease the strength of current as needed.

A convenient way to set up such a rheostat is illustrated. Secure a Pyrex glass bake dish or an earthen tray about 25 or 30 cm across. (Caution: do not use a metal tray or container.)

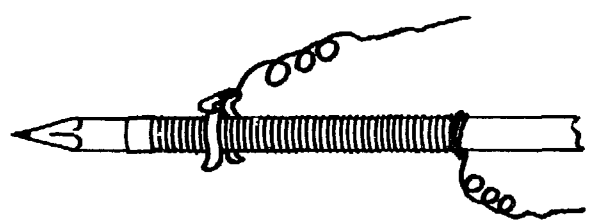


Secure two metal can covers of any kind about 8 cm in diameter. Punch a hole in the side of each and attach the clean ends of insulated wire for connectors. Set the covers into the dish a few centimetres apart and place in each a fair-sized cobble-stone to weight it down. Now dissolve a level teaspoonful of table salt in two litres of water. Pour enough of this into the bake dish to submerge the covers. Your water rheostat is now complete. You can connect it into any circuit and regulate the strength of current at will merely by changing the distance between the covers. Use insulating material for moving the covers, and do not put your hands into the water. Instead of the can covers, carbon rods may be used as shown in the second figure.



3 A resistance wire dimmer

A small rheostat for controlling model stage lighting or dimming electric torch bulbs can be made from 30 SWG bare nichrome wire. Wind about 100 turns around a pencil and anchor one end to two or three turns of thick copper wire which will serve as one terminal. Hold the other end of the resistance wire down by a strip of adhesive tape. Solder a piece of connecting wire to a midget spring clip and fit it over the resistance wire.

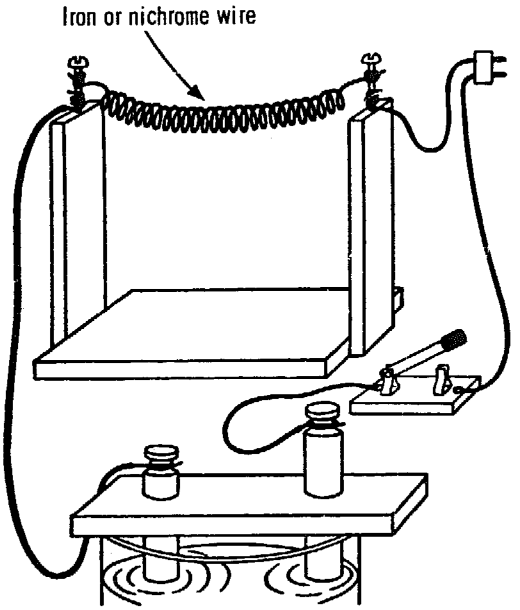


4 How to heat a wire red hot with electricity

This experiment will give you an opportunity to study how electricity will heat different kinds of wire. Build a wooden support with baseboard 15 by 15 cm and two vertical strips about 20 cm high. Drive a screw or nail part-way into the upper end of each support. Now to prepare a spiral-form element, wind about 1.5 metres of iron wire, size between No. 30 and 24, in one layer neatly onto a pencil. Slip this off and stretch it long enough to reach from nail to nail and twist the ends to support it. Connect this with a water rheostat and lamp socket (but be careful!). Be sure the rheostat is wide open before plugging into the socket. Then gradually reduce the resistance and notice how the wire gets hotter until it glows bright red. Hold your hand close to it. Touch a piece of paper or a splinter of wood to the wire and kindle it. Now increase the current until the wire burns or melts off.

Try to secure a piece of nichrome wire and use it instead of the iron. Nichrome wire is the kind that is used for electric heater elements. Can you get this much hotter than the others before it burns apart?

Does this experiment suggest a way to make an electric heater?



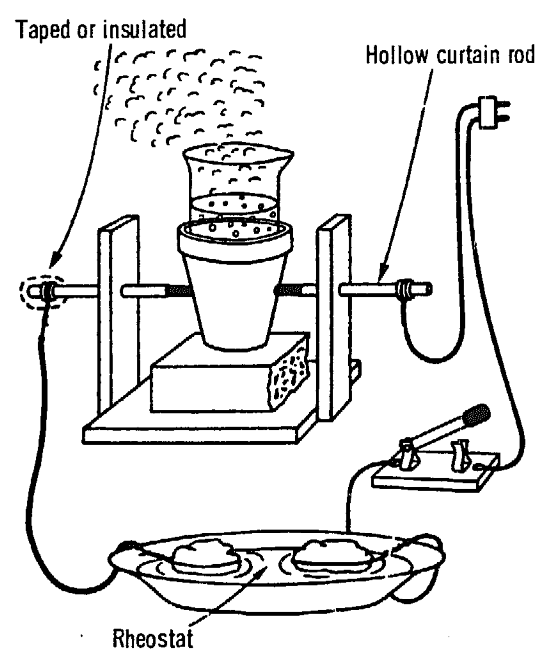
5 How to make an electric arc heater

The electric arc is not only the brightest light known but also almost the most intense source of heat known to man. The brightest point at the end of the carbon rod gets as hot as 3760 degrees Centigrade! Boiling water is 100 degrees Centigrade. Iron melts at 1535 degrees Centigrade.

You certainly will not want to miss the opportunity of making an electric arc heater or furnace, especially when it requires only a small plant jar, two carbons from discarded flashlight batteries, two pieces of hollow curtain rod and some bits of wood.

Secure an ordinary 8 cm unglazed plant jar. Drill two holes directly opposite each other and a bit more than 2.5 cm from the bottom. If you do not have a drill, you can work a hole through with the end of a triangular file in your hand, or with almost any sharp-pointed metal object. When you get the holes broken through, ream them large enough with the file or other appropriate object to allow the carbon rods to slip through easily. Now cut off two pieces of hollow curtain rod about 12 cm long. If you have no better means of cutting metal, this thin metal can be cut easily by filing a groove all the way around with a triangular file and then breaking it off. Insert the carbon rods into the ends of the metal tubes, and you have all the essential parts of your furnace complete.

You now need a rack to support these parts. Nail two vertical strips of wood about 15 cm long to a baseboard about 15 by 15 cm. Place half a brick or even a small piece of flat stone onto the baseboard and put the prepared plant jar onto this. It will improve your heater to cement the brick to the base, and the jar to the brick, with black asbestos furnace cement. Obtain this from the hardware store or the plumbing shop. Just smear a bit of the cement onto the bottom and press the jar into place. Determine the height at which the holes shall be drilled in the vertical wooden supports in order to have the rods project through them and into the jar so that both will be in horizontal alignment. Bore the holes large enough to allow the metal tubes to slide easily. This done, insert the rods, and your furnace is ready to go.



Connect the furnace into the circuit with water rheostat and lamp socket as shown in the diagram. Establish the arc as described in D 7 below. (Caution: Do not take hold of the rods unless you have their ends covered with tape, or keep gloves on your hands.) It is advisable to wear dark glasses when using your furnace.

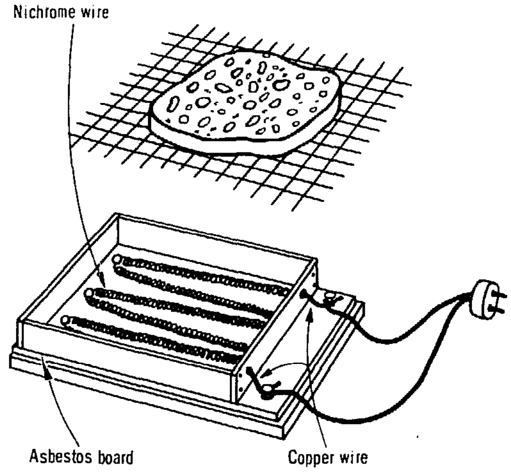
6 How to make an electric toaster

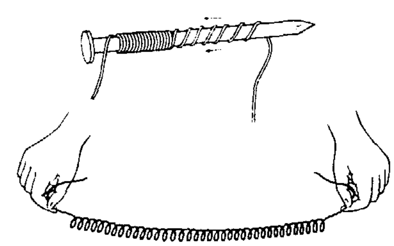
Your problem is to find a convenient way to mount 5 metres (no less!) of nichrome wire in a space not much larger than a slice of bread. Nichrome wire is the kind of wire used in all electric heating devices you ordinarily buy for home use. The wire can be obtained at the electric repair shop. You should use No. 24 gauge wire (0.559 mm diameter) for 110 volts. For other voltages, ask the electrician to tell you the length and gauge of wire for a 500-watt element.

The method of winding the wire into a spiral is shown in the figures. Measure off the wire and wind it neatly onto a round rod about 5 mm in diameter. Keep the turns pushed over into close contact each time you wind on a few. This keeps them regular. You should of course leave about 10 or 12 cm at each end. Now slip the coil off the rod and slowly draw it out far enough so that it will remain in the form of a spiral about 75 cm long. Now twist about 10 cm of copper wire tightly on to each end of the element close to where it begins to spiral to serve as lead-in wires.

To prepare your mount for the element, secure a 30 cm square of asbestos board from the lumber dealer. Cut out one piece 15 by 20 cm for the base and cut four strips 2.5 by 15 cm each for the sides. Put these together as shown. They may be put together by drilling holes and using small screws or by using furnace cement. Asbestos furnace cement is excellent. It may be obtained at the hardware store or plumbing shop. Now cut a piece of board to fit the base; with two narrow strips of asbestos board to furnish air space, attach the frame to the board.

You are now ready to instal your element. At the front end drill four small holes equally spaced and three holes equally spaced at the opposite end. Turn small screws about 2.5 cm long partly into the holes. Drill two holes through the front of the frame for the copper lead-in wires. Also set two screws into the front corners of the base for terminals. Now loop your element back and forth onto the screws. Plan this part so there will be equal amounts of the element in each segment. Set each segment into a thread of its screw support so that they will all be supported about 5 mm above the base. Bring the copper lead-ins through the holes prepared for them and twist them around the terminals. This completes your toaster, except for a grill to hold the toast. Cut out a square piece of wire screen with a 1 cm mesh for this or use some small grill from the kitchen. Make sure that the grill can never touch the element or the terminals.





For a connecting cord you may be able to find a broken flat iron cord. Strip the ends of the wires and twist them around the terminals. Plug the other end of the cord into a lamp socket or baseboard receptacle and proceed to toast bread and cook or heat any food you desire. (Caution: Keep pupils' fingers well away from the exposed wires. Take out the plug if any water is spilled onto the toaster.)

7 How to make an arc lamp

Use the carbons from two discarded flashlight batteries to serve as the electrodes. Connect the carbons, salt water rheostat, and an ordinary double wire electric lead. An old flat-iron cord with some of the outer fabric stripped off the lower end is good for the purpose. Set the rheostat plates wide apart and plug into the socket.

Now pick up the carbons with clothes pegs, one in each hand, or if you wear dry heavy gloves you may hold them in the fingers. (Caution: Never pick up the carbon rods directly with the bare fingers. Why?) Touch the ends together lightly while someone else slowly reduces rheostat resistance. Never close the rheostat far enough to cause the metal covers to touch each other. Why?

Touch and then barely separate the carbon rods repeatedly while the rheostat is being closed. You should notice the ends heating to a glow and flashes of white light each time you separate them. (Caution: It is highly advisable to wear dark sun glasses when doing this part of the experiment.) At this stage supply just a little more current by closing the rheostat more, and you should have a steady and very brilliant light as you hold the rods steadily with about a 3 mm gap. Practice this until you succeed.

You have now been able to produce a very brilliant light with electricity. Does any of the carbon seem to be consumed? What carries the electricity across the gap? What do you think of this type of lamp as a means of lighting homes?

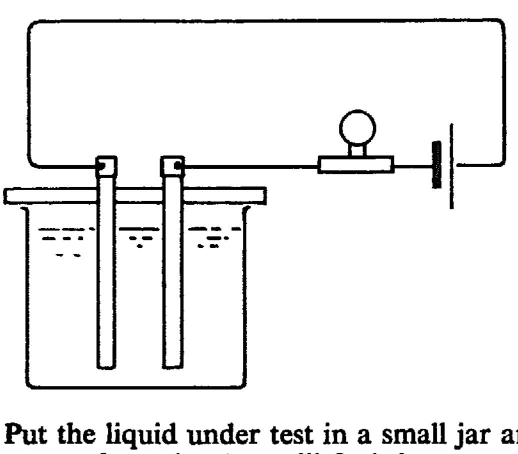
E. ELECTRICITY AND CHEMISTRY

In Chapter IX, experiment A 1, page 102, it was shown how water is decomposed when an electric current passes through it. This is just one example of a general phenomenon: many liquids are similarly affected by an electric current. The process is called electrolysis, and substances which behave in this way are called electrolytes. The effects are often complicated by interaction of the products of electrolysis with the electrodes by which the current is led into the electrolyte, but some of the principles can be studied in the following experiments.

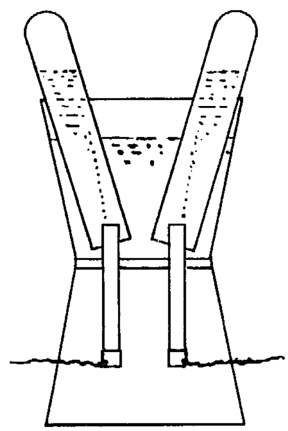
1 Conduction effects in different types of liquids

Liquids can be divided into different chemical classes. The following can easily be studied: (a) distilled water, oils, methylated spirit; (b) acids and alkalis, e.g. dilute sulphuric acid, dilute hydrochloric acid and silver nitrate.

Obtain two small carbon rods from an old torch battery and pass them through holes about 2.5 cm apart in a strip of wood 2.5 cm wide and 10 cm long. Solder copper wires to the brass caps and join up a series circuit as shown in the diagram, using a 6 volt dry battery as current supply and a 2.5 volt bulb as current detector.



Put the liquid under test in a small jar and immerse the rods. You will find that some of the liquids do not conduct electricity, gases are released from others, and that in some cases changes take place on the surfaces of the rods.



2 Collecting the gaseous products of electrolysis

If the gases released by electrolysis are collected separately they can be identified. A simple apparatus for doing this, called a voltameter, can be constructed using an ice-cream carton as container for the liquid, carbon rods as electrodes, and small glass test tubes or tubular pill bottles for collecting the gases. Solder copper wires to the carbon rods as before, and fit them through the holes made with a cork borer in the bottom of two cartons; the second carton is used as a stand for the apparatus. Hold the two carton bottoms together, and using balsa wood or other cement, seal the rods in position with about 2.5 cm protruding into the upper cup. Pass connecting wires through holes in the side of the lower cup. Pour dilute hydrochloric acid into the upper cup and fill the glass tubes with it, inverting one over each carbon rod. Connect the wires to a 6-volt dry battery as before and wait for results. As chlorine is soluble, it is necessary to wait until the solution is saturated, but finally equal volumes of hydrogen and chlorine will be collected.

3 To make a bleaching solution by electrolysis

Make a strong solution of common salt by dissolving as much as possible in half a tumbler of water. Fit a cardboard wedge between the carbon rods of the voltameter used in the last experiment, thus dividing it into two equal compartments. Pour in the salt solution, and put a piece of red litmus paper in each compartment. Connect the rods to a grid bias battery, using 7.5 volts. Bubbles of *hydrogen* will immediately be released at the cathode (negative) but no chlorine will appear at the anode (positive) for the reason given in the last section. After about twenty minutes, however, the litmus paper in the anode compartment will be bleached, while in the cathode compartment the paper will turn blue owing to the formation of sodium hydroxide.

When bubbles of chlorine appear, stop the current, remove the wedge, and stir up the liquid. Sodium hypochlorite will then be produced. This is the compound contained in commercial bleaching fluids; examine its effect on a test tube of water coloured with a drop of ink.

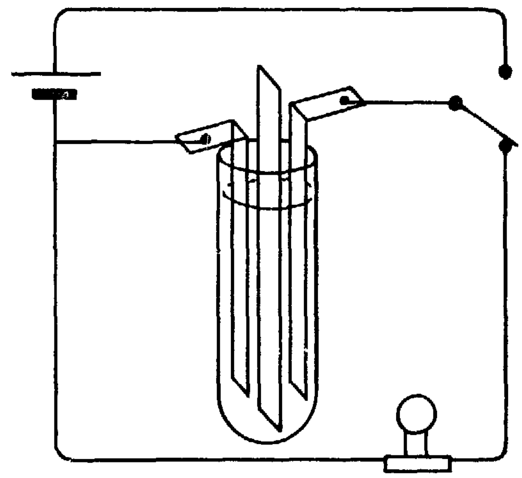
4 To examine the electrolysis of special solutions: (a) zinc sulphate; (b) lead acetate

(a) Pour a weak solution of zinc sulphate into the voltameter and electrolyse it, using a 9-volt grid bias battery. Almost immediately a spongy mass of zinc appears on the cathode.

(b) Add a few grams of lead acetate to half a tumbler of water. To remove cloudiness, stir the solution with a glass rod which has been dipped in acetic acid. Pour the liquid into the voltameter and connect to a battery as before. Lead quickly deposits on the cathode in the form of a 'tree' which is fascinating to watch as it grows.

5 To study the action of a simple lead accumulator

From a sheet of lead about 1.5 mm thick cut strips 15 cm long and about 15 mm wide for use as plates of the cell. Punch holes near the end of each plate and thread through copper connecting wires. Wash the plates in water and clean them with steel wool or emery cloth. Put them into a boiling tube containing a little dilute sulphuric acid and separate them by a wooden splint. Also bend over the tops of the plates so that they can never touch one other. First transform these plates into spongy lead and lead peroxide respectively by passing current from a 6-volt dry battery. After a few minutes one of the plates becomes a red-brown colour, whilst the other remains grey. When this has happened disconnect the battery and connect in its place a 2 volt torch bulb. If the bulb does not light, join the plates to the battery again for a few more minutes and then carry out the test.



Now arrange a circuit as shown so that the plates can be charged and discharged through the bulb at the turn of a switch. Connect the battery for one minute, then discharge through the bulb, noticing the time in seconds that the bulb remains alight. Repeat this experiment, charging in turn for 2, 3, and 4 minutes and recording the time taken to discharge through the bulb.

As a further test take a few more readings with the plates half immersed in acid. Put a thermometer in the acid and notice if there is any change in temperature after charging for some time. If facilities are available, try to detect any change in the density of the acid after charging for half an hour.

6 How to make a more serviceable accumulator

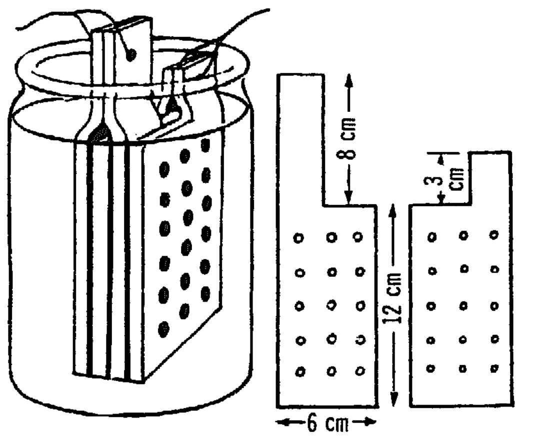
The preceding way of forming the plates is only suitable for demonstration purposes.

To make a working accumulator, larger and thicker plates must be used, and chemicals must be embedded in holes drilled in the plates.

Use lead sheet about 5 mm thick—old gas or water pipe hammered out will do. Prepare plates of the dimensions shown, with holes drilled in them, and fill up the holes with the following pastes:

Positive plate	*Negative plate*
1 part litharge.	6 parts litharge.
4 parts red lead.	1 part sulphuric acid.
1 part sulphuric acid.	

Separators of wood, about 5 mm thick, the same as before but with holes drilled in them, will be required.



Assemble the plates by fastening the two negative plates together and holding in the separators, etc., by a rubber band, or a piece of string. Insert the whole into a jam jar filled with dilute sulphuric acid (S.G. 1.5), so as to just cover the plates.

The cell should be charged as before. When charged, the positive plate will be a red-chocolate colour, and the negative plate a light grey.

7 Electro-plating nickel and copper

Electro-plating is now familiar to everyone. It is done by forming a layer of metal on the object which is used as a cathode in a voltameter containing a salt of the metal to be deposited. To get lasting results the object must be carefully cleaned and degreased; the correct anode must be used, and the solution must be carefully prepared and used at a temperature of about 5° C. The copper anode used for copper plating and the nickel anode for nickel plating need only be degreased. The following baths have proved satisfactory.

Copper		*Nickel*	
Cupric sulphate	200 g	Nickel sulphate	240 g
Sulphuric acid	60 g	Nickel chloride	54 g
Water up to	1000 ml	Boric acid	30 g
		Water up to	1000 ml

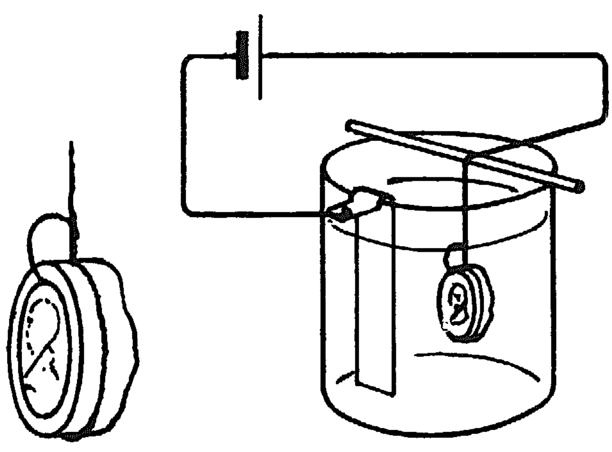
Copper plating. Pour the electrolyte into a jar and immerse in it a strip of copper which serves as an anode. Clean a sheet of brass with fine emery cloth, and degrease it with a mixture of magnesia and water on a wad of cotton wool. Rinse it in water, immerse it in the bath and connect it to the negative terminal of a 3-volt torch battery. Complete the circuit by joining the anode to the positive pole of the battery. Note the deposit of copper produced. Too heavy a current may result in a spongy deposit; the correct value for a hard deposit is 4 amperes per 100 cm² of area.

Nickel plating. Use a strip of copper as a cathode, cleaning and degreasing it as before. A nickel spatula can be used as an anode, but if this is not available a strip of lead may be used; this will mean that the electrolyte becomes weaker during use. Join up to the battery as before, when a good deposit of nickel will be obtained. The surface, after washing, can be polished using jewellers' rouge or cigarette ash on a piece of soft cloth.

8 To copy a scout badge or medal by electrolysis

This process, called electrotyping, is much used in industry. A mould is made of the object to be copied. This is then made conductive by various methods and a shell of this impression is made by depositing copper on it electrolytically. The object is removed from the mould, and the copy is strengthened by pouring typemetal into it.

First warm the badge in a clean bunsen flame and make an impression on the end of a short piece of candle or alkathine rod. Make the surface of the mould conducting by scraping some lead from a pencil over it, or by coating it with colloidal graphite. Another way to do this is to scatter some iron filings over it after moistening it with a solution of copper sulphate; the iron will displace the copper and cover the surface of the mould with a layer of copper. Now heat a piece of copper wire and press it into the wax in such a way that connexion is made to the conducting surface without disfiguring the shape. Use the wire to hang the mould in a copper-plating bath. Also suspend a strip of copper in the solution to serve as an anode,



facing the mould. Connect to a 3-volt torch battery through a small rheostat and leave it overnight. The next day a good strong layer of copper will have been deposited. Strip this from the mould, and if necessary strengthen it by pouring molten solder into the back of the shell. Trim the badge with a pocket knife and solder a safety pin to the back. If desired it can now be plated as in the last experiment.

CHAPTER XVI

Experiments and materials for the study of light

A. LIGHT TRAVELS IN A STRAIGHT LINE

1 Making tracks

Find a dusty road or a sandy beach. Fix your eyes on a distant object and walk towards it without changing your line of vision. Now observe the tracks you have made, and you will see that you have been following a straight line.

2 With a string

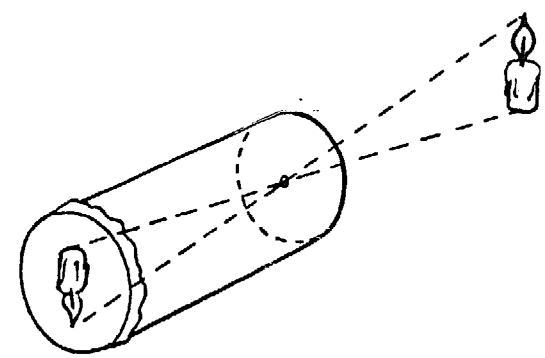
Obtain a piece of string that is at least 25 metres in length. Fasten one end of the string to a post or a tree. Pull the string taut and hold it to the eye. Look along the string, and you will see the object to which it is fastened. Now look in another direction, not along the string, and you do not see the object. This shows that light comes to the eye from such objects in a straight line.

3 An experiment with cards

Cut four pieces of cardboard about 10 cm square. Tack them to small wood blocks so that they will stand upright. Punch a small hole through each card at exactly the same place so that when the cards are set up and arranged in a straight line you can look straight through all four holes. Place a candle flame so that it can be seen by looking through all the cards spaced about 30 cm apart. Now pull one of the cards a little out of line with the others and try to look through them at the candle flame. Can you see it? Why not? What does this show?

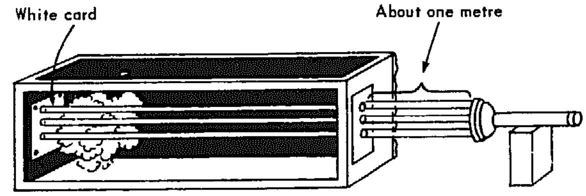
4 A pinhole camera

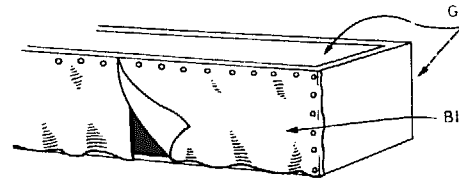
A simple pinhole camera can be made by making a fine hole in the bottom of a tin and receiving the image on tissue paper, stretched across the top of the tin. Roll a sheet of brown paper round the tin so that a tube projects and shields the tissue paper. This will keep daylight from the screen, and enable an image of a window or candle flame to be observed. What do you notice about the image? How does this show that light travels in straight lines?



5 Making a smoke box to study light rays

Obtain or construct a wooden box about 30 cm wide and about 60 cm in length. Fit panes of window glass in the top and front of the box. Leave the back open, as shown in the diagram, and cover with loosely hung black cloth which drapes like a curtain. Hang this curtain in two sections making about a 10 cm overlap at the centre of the box. Paint the inside of the box with matt black paint. About midway between the top and bottom of one end and about 8 or 10 cm from the glass front, cut a window 10 cm long and 5 cm wide. This is to let in light rays. You can cover the window with different kinds of openings cut from cardboard and fastened with drawing pins.



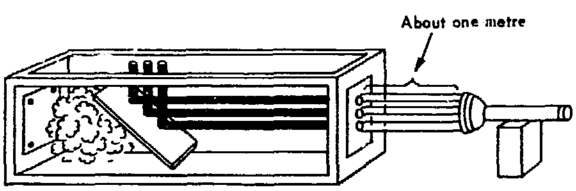


For the first experiment cut a piece of black cardboard with three equidistant holes about 5 mm in diameter. Fix over the window with drawing pins. Fill your box with smoke. This can be done with dry rotten wood, incense candles or smouldering cigarettes placed in a dish and set in one corner of the box. Next set up an electric torch about one metre from the window. Focus the light down to a parallel beam and direct it at the holes in the window. Observe the light rays in the box made visible by the smoke. Does this experiment show that light travels in straight lines?

B. THE REFLECTION OF LIGHT

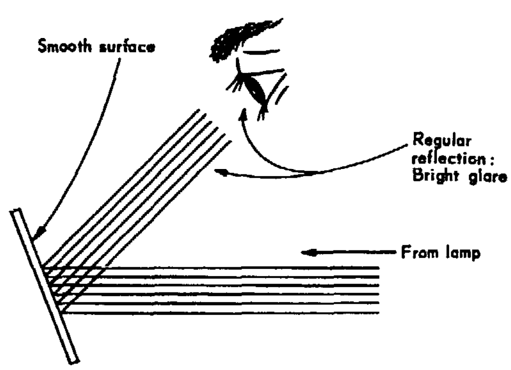
1 Regular reflection with the smoke box

Fill the smoke box with smoke. Shine the torch beam on the three holes in the window as in the last experiment. Now hold a plane mirror inside the box and observe how clearly the rays are still defined after reflection from the mirror. When light rays are thus reflected without scattering they are said to be *regularly reflected.*

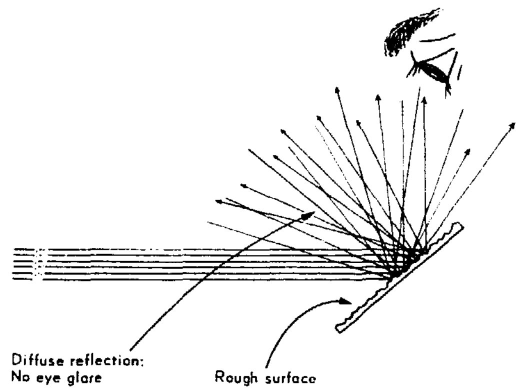


2 Diffuse reflection with the smoke box

Place a piece of clear cellophane on a pane of glass and roughen it by rubbing with a piece of steel wool until the surface has a uniformly dull appearance. Fix the piece of dulled cellophane to the glass with glue or rubber bands. Hold in the beam of the torch inside the smoke box and observe the results.



Compare with the regular reflection in the previous experiment. When light is scattered by reflection from an irregular surface it is called *diffuse* reflection. Place your eye in direct line with the reflected beam from a mirror. Repeat, using the dulled cellophane reflector. Observe and describe the differences.



3 Reflection with a rubber ball

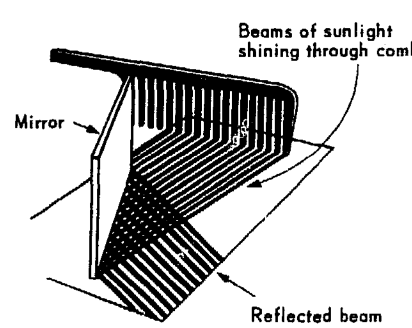
Study reflection from a floor or wall by bouncing a rubber ball straight and at angles to the reflecting surface. Try to observe and compare the angle at which the ball strikes the surface with the angle at which it is reflected.

4 Reflection with a mirror

Place a plane mirror on the floor where a beam of sunlight will strike it and be reflected. Stand a drinking straw upright at the place where the beam strikes the mirror. Compare the angle made by the incident beam and the straw with the angle made by the reflected beam and the straw.

5 Making reflected beams of light

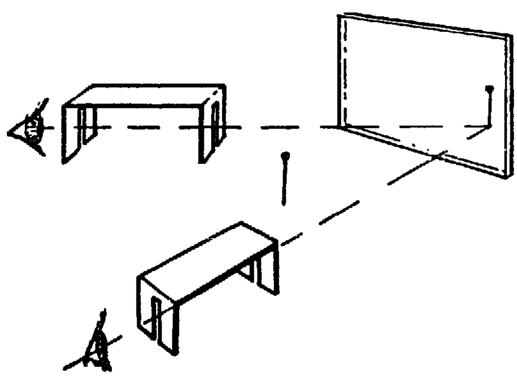
Hold a comb in a sunbeam falling on a piece of white cardboard. Tilt the cardboard so that



the beams of light are several centimetres long. Place a mirror diagonally in the path. Observe that the beams which strike the mirror are reflected at the same angle. Turn the mirror and observe how the reflected beams turn.

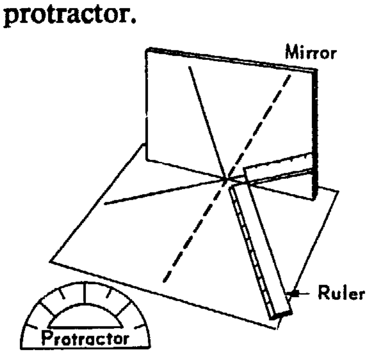
6 How to make a sighting stool for the study of reflected light

Though 'pin optics' are rather out of fashion at the moment, this method is capable of yielding accurate results. Confusion often arises with juniors because pins are used both as object and to track rays of light. This confusion is avoided if sighting stools are used in the first experiments. A piece of tin, 12 by 1.5 cm, is bent in the form of a stool; the ends form legs and a slit is cut with a hacksaw blade in each of them. A pin is used as object, and its image is sighted through the slits. Pencil marks are then made to track down the path of the light.



7 The laws of reflection

Draw a broken line on a piece of paper with a ruler. Next draw a straight line from it at any angle. Set a small mirror upright at the point where the two lines meet. Turn the mirror until the reflection of the dotted line is in line with the real dotted line. Now look into the mirror and line up one edge of your ruler with the reflection of the straight line. Draw this line with your pencil and measure the angles on each side of the broken line with a protractor.

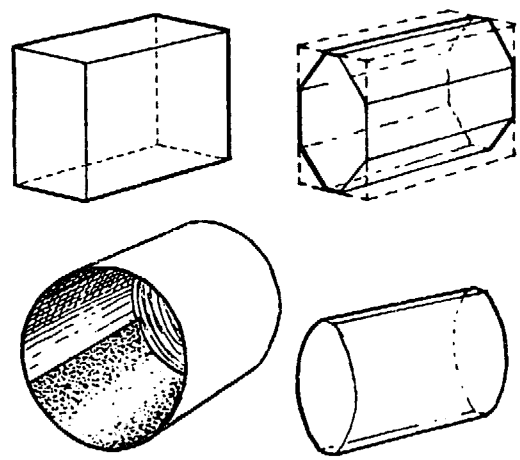


Repeat this experiment several times, changing the size of the angle each time. The evidence should show that light is always reflected at the angle at which it strikes the mirror.

8 How to make a cylindrical lens for a ray box

File down the edges of a piece of perspex or lucite 5 by 3 by 6 cm. Grind it by using the inside of a can with a layer of emery paper glued inside.

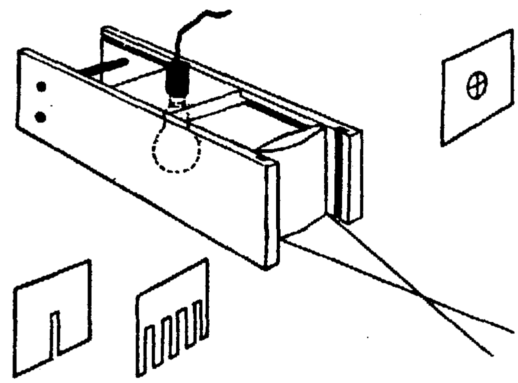
Final polishing is done with metal polish and cotton wool.



9 How to make a ray box for beams of light

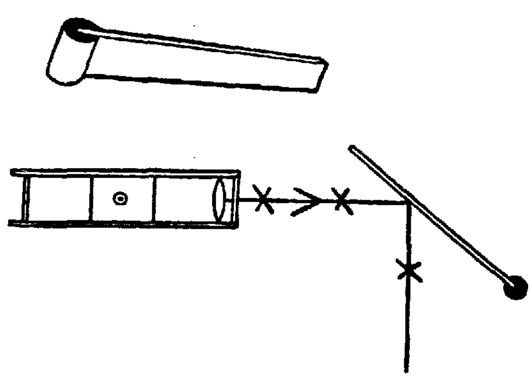
The cylindrical lens described in experiment B 8 above can be used in a ray box. This apparatus consists of two sides of an oblong box 22 by 6 cm held together in this case by 2 BA rod, with the lens placed at one end of the box. The box has no bottom, and in use rests on paper pinned to a drawing board. The light source is a 12-volt 24-watt automobile lamp. The lampholder has a sleeve of brass tubing just fitting in a hole in a wooden slide, which forms the top of the box. The groove in front of the lens is for screens and filters. A piece of card with a slit in it provides narrow rays and a painter's graining comb will give a bundle of rays. Convergent, parallel or divergent beams are obtained by adjusting the position of the slider. All the usual experiments with rays can be performed using slips of plane mirror, glass blocks and prisms. A curved piece of tin will show a caustic curve.

In experiments with lenses and in refraction, the lamp should be pushed down as far as possible so that the light does not pass over the top of the obstacle. A card with a hole and cross wires can be used in front of the lens, as a source for optical bench experiments.



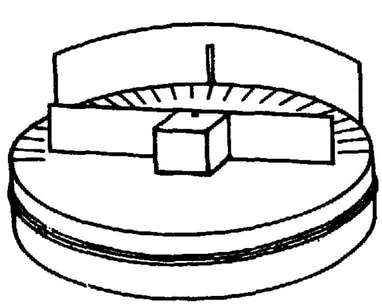
10 Laws of reflection with a ray box

A slip of mirror can be made to stand vertical by inserting one end in a piece of cork with a groove in it, or in a paperclip. Beams of light shone along the paper are marked by crosses. The incident, and reflected rays, and the normal, are recorded by joining up the crosses by pencil lines.



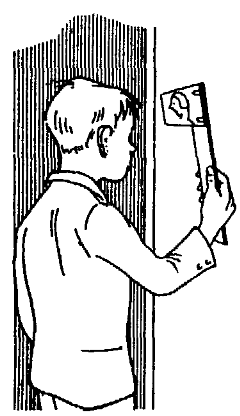
11 A simple optical disc

Obtain a shallow can of roughly the same diameter as an ordinary protractor. Cut out a piece of white card to put on the top of the can: glue it down and mark degrees on it. Fix a strip of mirror to a small block of wood and mount it on a nail which fits loosely through a hole in the centre of the scale and the can. Cut a narrow slit in a rectangular sheet of metal as shown in the diagram, and bend the sheet round the circumference of the can, fixing it in position so that the slit is opposite the 90° mark on the circular scale. Place the can on the bench so that the sun or a distant source of light throws a ray which passes through the slit to the centre of the scale. Adjust the mirror so that the light is reflected along its own path. Now rotate the mirror through 10°. What do you notice about the angle through which the reflected ray is turned?



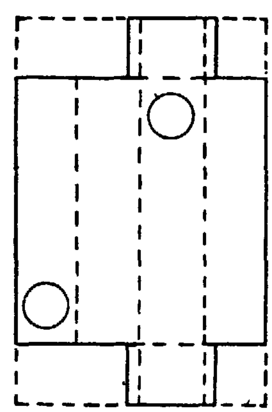
12 A mirror on a stick

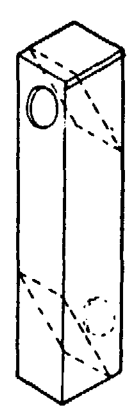
Fasten a mirror to the end of a ruler with a paperclip. Stand on one side of a door and hold the mirror outside the door opening. Explain how reflected light enables you to see around the corner.



13 How to make a model periscope

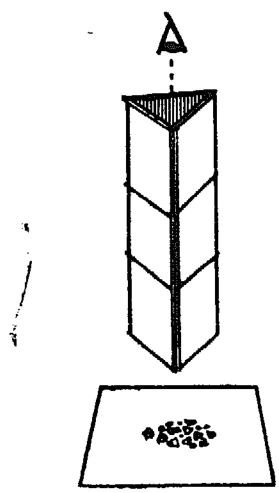
Score three lines parallel to the long side of a postcard and 2 cm apart. These will divide the card into four strips. Cut away pieces from the ends 2 cm wide as shown in the diagram. Cut holes in the positions shown, using a cork borer, and then fold up the card into a rectangular box. Stick small pieces of mirror opposite the apertures, using plasticine or gummed paper.





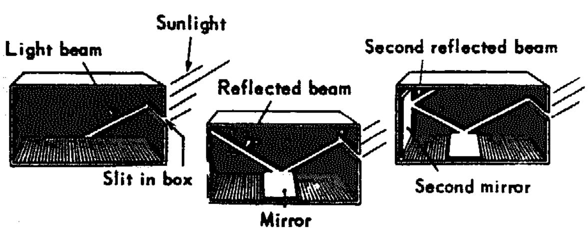
14 How to make a kaleidoscope

Fasten together two slips of mirror about 10 cm by 3 cm and a piece of card the same size, with a rubber band or gummed paper. Look down the axis of the triangular prism so formed. Objects viewed through it will form a regular pattern. If silvered glass is not available, black paint on the outer side of plain glass will give quite good results.



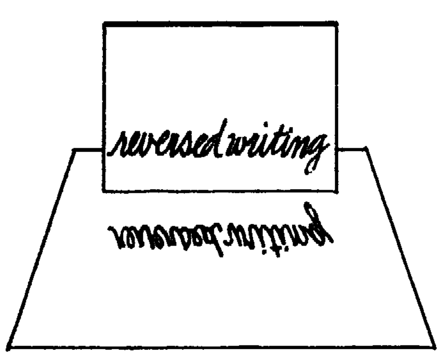
15 Double reflection

Cut a slit about 1 cm wide in one end of a small cardboard box. Be sure to cut the slit all the way to the bottom of the box. Set the box on one side and place it in bright sunlight. Adjust the box so that the beam of sunlight falls along the bottom of the box and place mirrors as shown in the diagram.



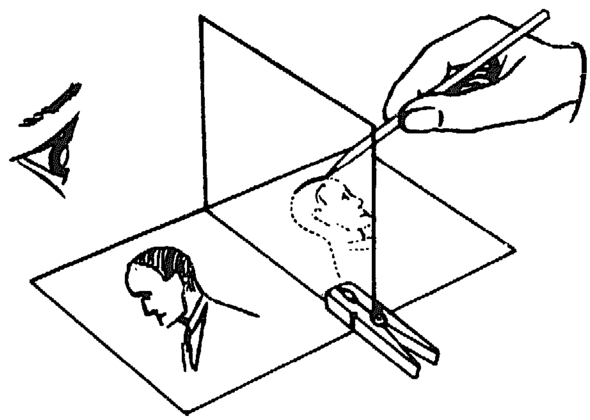
16 Reversed writing

Produce reversed writing by placing a piece of carbon paper, carbon side up, under a sheet of plain paper. Write something on the paper and you will have reversed writing on the other side. Read the reversed writing by holding it in front of a mirror. Write something while you look in the mirror at the paper and watch the pencil.



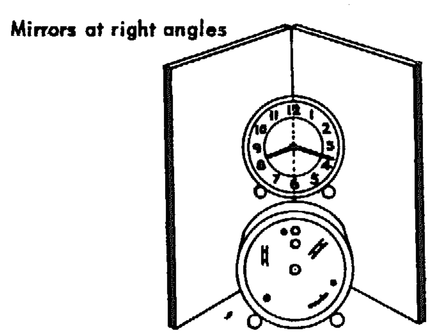
17 Copying drawings by reflection

Use a wooden clothes peg to support a sheet of clear glass vertically on the bench. Place the drawing to be copied on one side of the glass and a piece of white paper on the other. Look through the glass at the white paper and draw over the reflection of the drawing. Why must the glass be vertical? How does the copy differ from the original? Why is it an improvement to shield daylight from the paper you are drawing on?



18 The clock face and a mirror

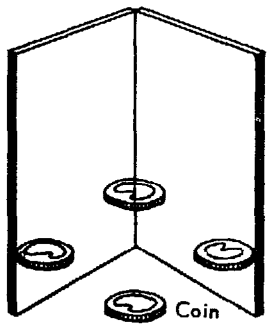
Stand two mirrors at right angles to each other with their edges touching. These edges may be joined with strips of tape. Place a clock in front of the mirror with the midline of its face opposite the junction of the two mirrors. Observe the image and compare with the image seen with a single mirror.



19 Making money with reflection

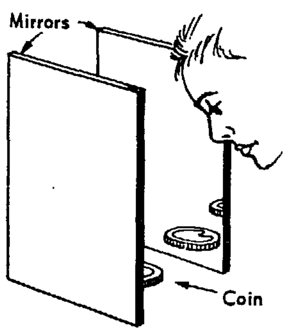
Hinge two mirrors together with a piece of tape and set them up as shown in the diagram.

Place a coin between the mirrors and observe the number of images formed. See if you can increase the number of images by varying the angle of the mirrors. Place a lighted candle between the mirrors and observe the images.



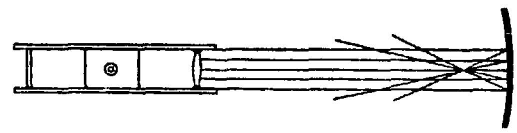
20 Reflection with parallel mirrors

Stand two mirrors on edge with the reflecting surfaces facing each other. Place a coin or a lighted candle between the mirrors. Look in one mirror and see how many images are formed. Look in the other mirror.



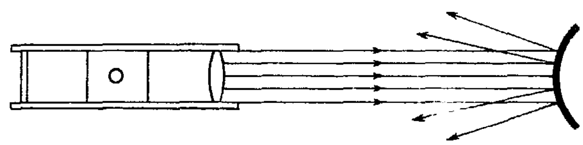
21 Reflection from a concave mirror with a ray box

Use the ray box constructed in experiment B 9 above. The focal length can be measured directly by directing a parallel beam of light on to a curved strip of tin, or a part of a metal ring.



22 Reflection from a convex surface

Obtain a convex mirror such as an automobile wing mirror. Use this with the ray box and observe the reflected rays of light. Compare with the reflection from a plane mirror and a concave mirror.



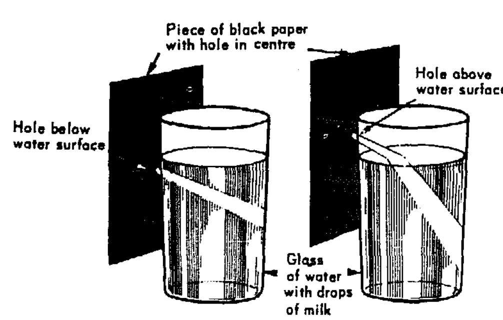
C. THE REFRACTION OF LIGHT AND ITS USES

1 The stick appears to bend

Place a stick in a tall jar of water, so that part of the stick is above the surface. Observe where the stick enters the water and appears to be bent. This is caused by the bending or refracting of the light rays as they reach the air from the water. Light travels faster in air than in water and so is bent slightly when it passes from one medium to the other.

2 Refraction in a beam of light

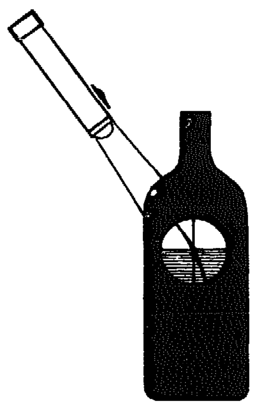
Pour a few drops of milk into a glass of water in order to cloud the water. Punch a small hole in a piece of dark paper or cardboard. Place the glass in direct sunlight. Hold the card in front of the glass. A beam of sunlight will shine through the hole. Hold the



card so that the hole is just below the water level and observe the direction of the beam in the water. Now raise the card until the beam strikes the surface. Observe the direction of the beam of light. Experiment to find out how the angle at which the beam strikes the water affects the direction of the beam in the water.

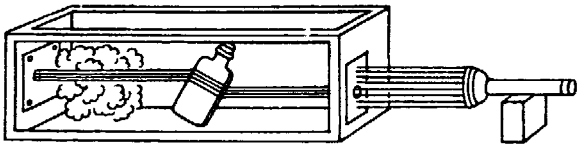
3 How to make a refraction bottle

Paint the outside of a medicine bottle black. Scratch a circle off one side and fill the bottle with water until the surface is just level with the centre of this circle. Shine a beam of light through the top of the bottle (the paint should be removed from a small area). A drop of milk in the water will make the beam show up better. The angles of incidence and refraction are now measured with a protractor.



4 Refraction shown with the smoke box

Over the window of the smoke box (see experiment A 5 above) fasten a piece of black cardboard with a single hole in it about 8 mm square. Arrange the torch to shine a beam of light into the box as in previous experiments. Fill a large rectangular bottle with water and add a few drops of milk or a pinch of starch or flour to make the water cloudy. Cork the bottle. Fill the box with smoke. Hold the bottle at right angles to the beam of light and observe the direction of the light through the water. Next tilt the bottle at different angles to the beam of light and observe how the path of light through the bottle is affected.



5 Making a coin appear with refraction

Place a coin in the bottom of a teacup on a table. Stand away and arrange your line of vision so that the edge of the cup just interferes with your seeing the coin in the bottom. Hold this position while another person pours water carefully into the cup. What do you observe? How do you account for this?

6 How a prism affects light rays

Use the smoke box exactly as you did for experiment C 4 above. Hold a glass prism in the single beam of light and observe how the beam is refracted.

7 How lenses affect light rays

For these experiments, you can take the lenses from an old pair of spectacles or used optical instruments, or purchase reading glass lenses and hand magnifiers.

Cover the window of the smoke box with a piece of black cardboard in which you have punched three holes. The holes should be the same distance apart, but the distance between the two outside holes should be a little less than the diameter of your lens. Arrange the torch to supply the light rays as in previous experiments. Fill the box with smoke and hold a double convex lens in the path of the three beams of light so that the middle beam strikes the centre of the lens. Observe the beams on the opposite side of the lens from the source of light. How are they affected?

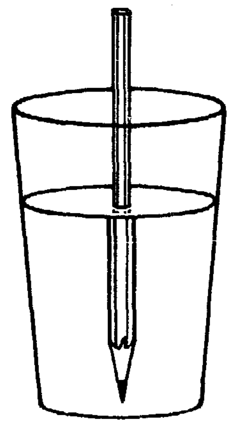
Repeat the experiment using a double concave lens. Compare the observations made in this experiment with those made in experiment C 6 above. Think of the double convex lens as made up of two prisms put together base to base and the double concave lens as two prisms put together tip to tip.

8 Rough lenses from bottle bottoms

Bottles can be found with convex or concave bottoms. These can be cut off by any of the methods indicated (page 218) and the rough edges removed by rubbing on a stone surface. Whilst rarely good enough to provide a clear image, they can be used to illustrate how bush fires may be started by old bottles lying in dry grass, etc., and focusing the sun's rays.

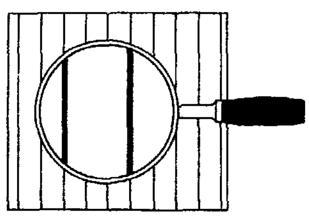
9 How lenses magnify

Dip a pencil (or your finger) into a glass of water, and look at it from the side. Is it magnified? Observe a fish in a fish bowl, looking at it from the top and from the side. Do the bowl and the water magnify the fish? Observe olives or other things placed in circular jars. Are they magnified? Clear glass marbles act as lenses also.



10 How to measure the magnifying power of a lens

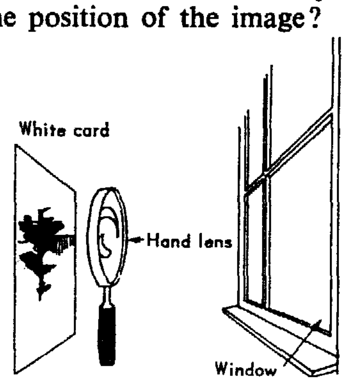
Focus a hand lens over some lined paper. Compare the number of spaces seen outside



the lens with a single space seen through the lens. The lens shown in the diagram magnifies three times.

11 How a convex lens forms a picture image

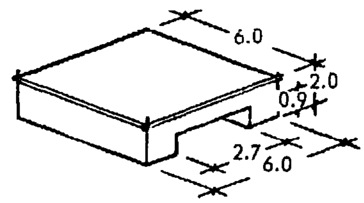
Darken all the windows in a room but one. Have a pupil hold a lens in the window directed at the scene outside. Bring a piece of white paper slowly near the lens until the image picture is formed. What do you observe about the position of the image?

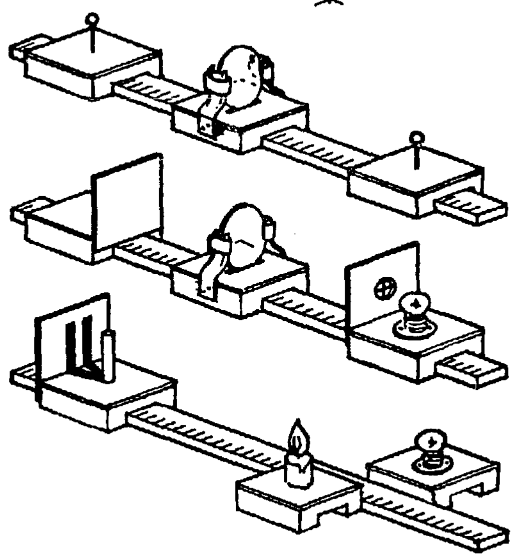


12 How to make a simple apparatus to study lenses

All that is needed for an optical bench is a firm surface, a way of holding mirrors and lenses, and a convenient way of measuring distances.

A metre scale laid flat on the bench serves as the basis of this simple apparatus. Wooden blocks, with grooves that just fit over the scale, can be adapted as holders. A layer of cork or soft cardboard glued on the top makes it easy to stick pins, such as object and search pins, into each block; strips of tin screwed to





the side make convenient lens holders. A groove in the top of a block helps to keep the lens in position, and rubber tubing over the tin increases the grip.

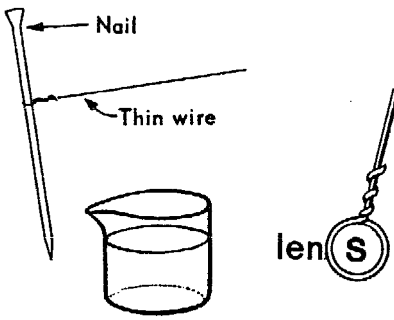
Light sources and screens can be improvised with card and torch bulbs fastened to the blocks. It is worth while to make complete sets of this apparatus so that individual work on lenses can be attempted. The groove is easy to make with a chisel after two sawcuts have been made in the wood.

Many other experiments, for instance on interference and diffraction, can be attempted using this apparatus.

13 A simple microscope

Make a single turn of copper wire around a nail to form a loop. Dip the loop into water and look through it. You will have a microscope like the earliest ones used. Often such a lens will magnify four or five times.

If you tap the wire sharply against the edge of the glass a drop of water will fall off. Because of adhesion between the wire and the water, the liquid remaining will form a lens which is very thin at the centre, i.e., a concave lens.



14 A water drop microscope

Place a drop of water carefully on a plate of glass. Bring your eye close to the drop and look at something small through the water drop and glass. This serves as a simple microscope.

15 A model compound microscope

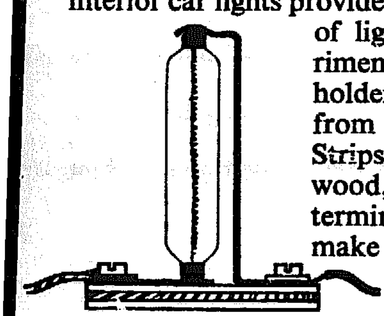
Arrange a short focus lens on the optical bench made in experiment C 12. Place a lighted candle behind a piece of window screen on one side of the lens. On the other side of the lens place a white cardboard sheet at the point where the clearest image of the screen is formed. Remove the cardboard sheet and place another double convex lens slightly farther away than where the cardboard was. Look through both lenses at the screen. It will appear enlarged.

16 A model refracting telescope

Arrange a long focus lens on the end of the optical bench pointing at some scene through a window. As in the previous experiment, bring a white cardboard up on the opposite side of the lens to the place where the sharpest image of the scene is formed. Now bring a short focus lens up behind the cardboard until the cardboard is a little nearer the lens than its focal length. Remove the cardboard and look through the two lenses at the scene.

17 How to make a line light source

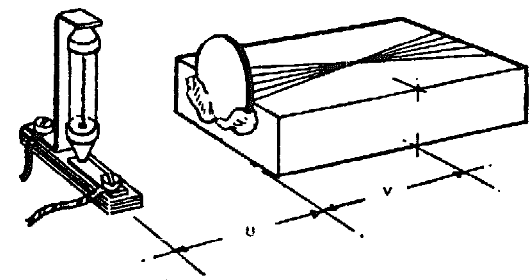
A bulb as used in direction indicators and interior car lights provides a useful line source of light for optical experiments. A convenient holder can be made from a piece of plywood. Strips of tin tacked to the wood, or held by screw terminals, can be used to make electrical connexion to the caps.



18 Image and object relationships for a lens

The lens can be fastened to the front of a wooden block with plasticine. The image position is where the rays cross. It is interesting to plot u against v and test the formula

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}.$$

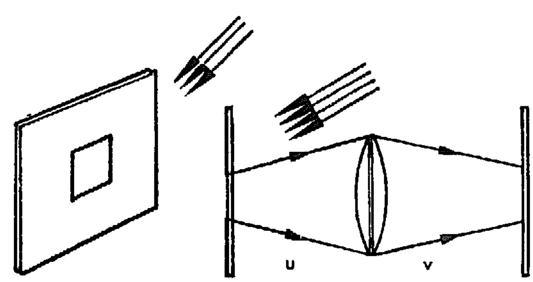


19 Image and object relation for a lens (without source)

A piece of mirror about 5 cm square can replace a source of light. The object is then a 1 cm square at the centre of the mirror from which the silvering has been removed.

The mirror should face the light, when the image can be caught on a piece of cardboard on the side away from the light.

The relationship $\frac{\text{image size}}{\text{object size}}$ can also be tested.



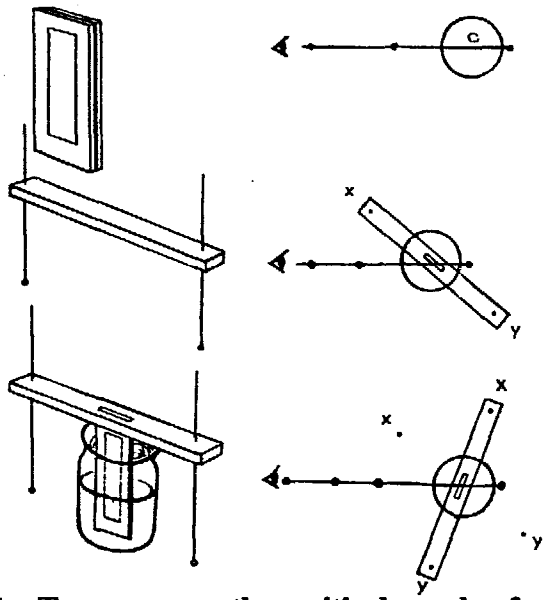
20 Critical angle

Make an air cell from two microscope slides by cutting a tinfoil frame and sticking it between the slides with Canada balsam or Bostik cement.

Fit this in a slot in a piece of wood about 20 cm long. Push knitting needles through the ends of the wood to act as pointers, indicating the position of the lath.

When this rod rests on a beaker of water with the air cell inside it, the needles should just touch the paper on which the beaker stands. This is the critical angle apparatus.

In use a base line of three pins is used, a diameter of the beaker. The rod is moved until total reflection occurs. There will be two positions for this, and the points of the needle should be marked in each case.

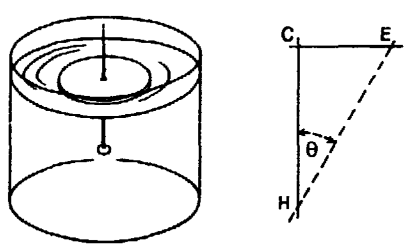


21 To measure the critical angle for water

Cut a disk 4 cm in diameter from a piece of waxed cardboard.

Pass a long pin through the centre of the card and float it head downwards in a vessel of water. Viewing the pinhead from above the surface it will be found that its position can be adjusted until it just disappears behind the card. In this position, a ray of light from the pinhead is refracted so that it passes along the surface and cannot reach the eye.

The angle θ can be measured directly or by measuring $\frac{CE}{CH}$ and using tangent tables.

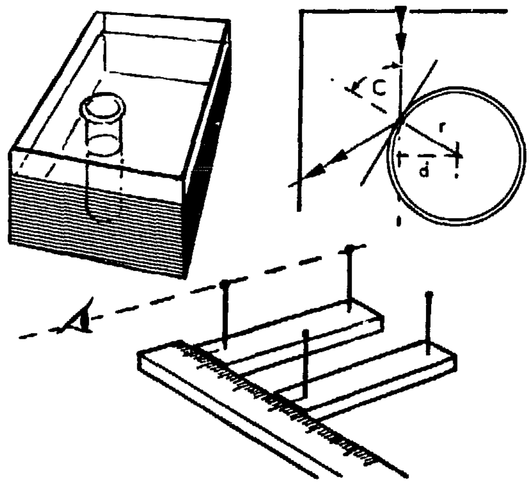


22 Another critical angle experiment

Put a small specimen tube or pill bottle in a rectangular glass tank, and look through the sides. The centre part of the tube will act as a cylindrical diverging lens, but the edges will appear to be silvered.

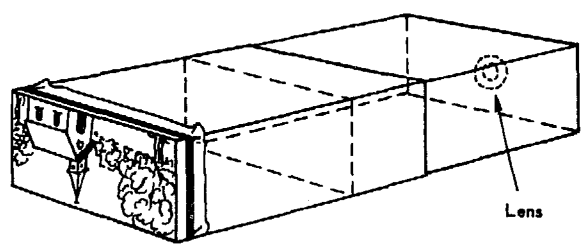
From the ray diagram it will be seen that $\sin C = \frac{d}{r}$.

These two distances can be measured by using sighting stools with their ends against a ruler parallel to the face of the tank.



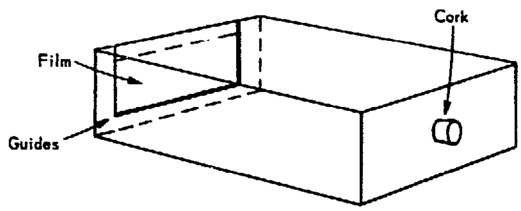
23 How a camera works

Secure two boxes which will telescope over one another rather tightly. Cut one end out of each box and slip the boxes over each other, with the cut ends together. Now cut the back end from one box and fit a piece of grease-proof or tissue paper over it. Cut a hole the size of a lens in the other end and fix a convex lens in the hole. Now move the boxes in and out until the lens focuses an image of an outside scene on the paper screen. In a camera the sensitive film is placed where the paper is on the model.



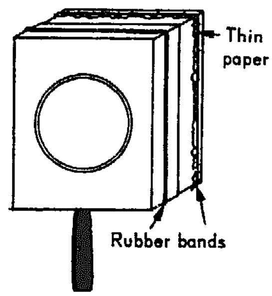
24 How to take a picture with a pin-hole camera

Make a pinhole camera (see experiment A 4 of this chapter) from a wooden box such as a chalk box. Paint the inside black. Bore a 1 cm hole in the centre of one end. On the inside of the box cover the hole with a piece of thin metal foil. With a needle punch a hole in the centre of the metal foil and be sure that the hole is very neat. Inside the opposite end of the box fit some guides, into which you can slide sections of cut film. Fit a cork tightly in the hole to cover the pinhole. In a dark room cut some photographic film to the proper size to slide into the guides. Cover the top of the box and take your camera outside. Point it at the scene you wish to take a picture of. Remove the cork for a second or two and replace it. In the dark room remove the exposed film and develop it or wrap it in black paper and take it to a photographic shop for developing.



25 A simple view camera

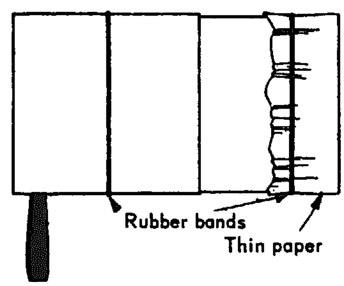
A simple view camera can be made as follows. With a hand lens focus the image of a distant hill or tree on a card. Measure the distance between the lens and the card and cut down a small carton so that its height equals this distance. In the centre of the bottom cut a hole a little smaller than the lens. Fix the lens over this hole with a piece of cardboard



containing a hole the same size as the first. Tie a sheet of thin tissue paper over the open top of the box. This view camera may be used in a darkened room with the lens directed towards a window.

26 A focusing view camera

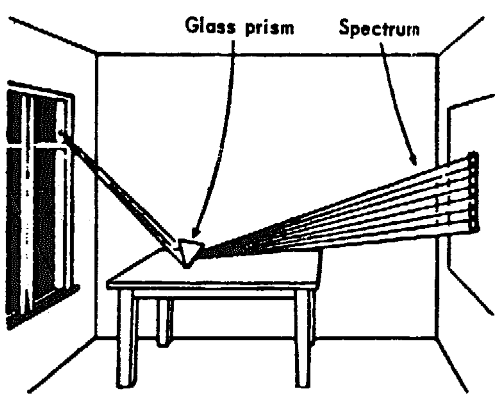
A focusing view camera can be made in much the same way as one described in experiment C 25. A second box telescopes into the first to allow focusing. The brighter the object viewed and the darker the screen of tissue paper, the better the results will be.



D. EXPERIMENTS WITH COLOUR

1 What is the colour of sunlight?

Darken a room into which the sun is shining. Punch a small hole in the window shade to admit a thin beam of light. Hold a glass prism in the beam of light and observe the band of colours, called a spectrum, on the opposite wall or ceiling. Can you name the colours thus found in a spectrum of the sun?

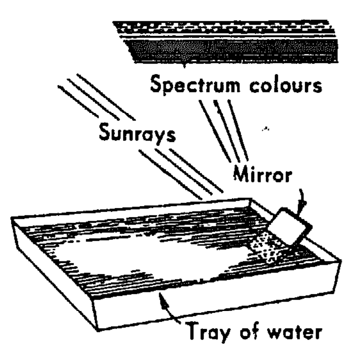


2 Putting spectrum colours together

Hold a reading glass lens in the colour band on the opposite side of the prism from the white sunlight. What happens to the colour band on the wall?

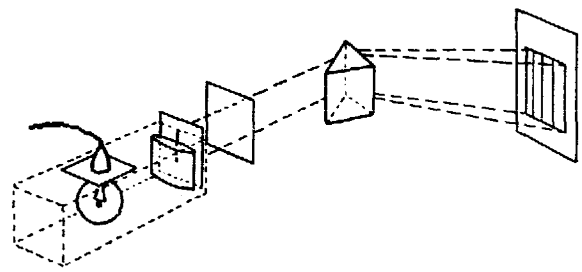
3 Another way to make a spectrum

Set a tray of water in bright sunlight. Lean a rectangular pocket mirror against an inside edge and adjust it so that a colour band or spectrum appears on the wall.



4 Studying a spectrum with the ray box

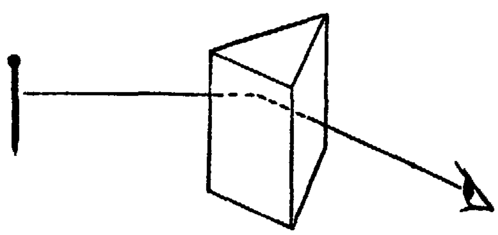
A glass prism will produce a good spectrum from a parallel beam of light using a ray box. In front of the lens the ray box should have



a narrow slit, which can be cut from a piece of card. Interposing coloured gelatine filters and packing papers in the beam will suppress certain colours. For instance, when a transparent purple paper is used, only red and blue lines will be seen on the screen.

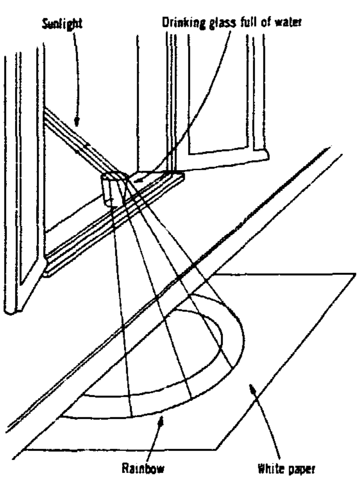
5 How to see a line spectrum

To make a simple optical slit scratch some silver off the back of a mirror with a needle, or remove in the same way some of the emulsion from a fogged photographic plate. For viewing a line spectrum, the slit can be replaced by a needle held parallel to the refracting edge of the prism, and illuminated by the light under examination.



6 How to make a rainbow

Stand a tumbler very full of water on a window ledge in bright sunlight. Let it project a little over the inside edge of the window ledge. Place a sheet of white paper on the floor and you will be able to see a rainbow or spectrum band.

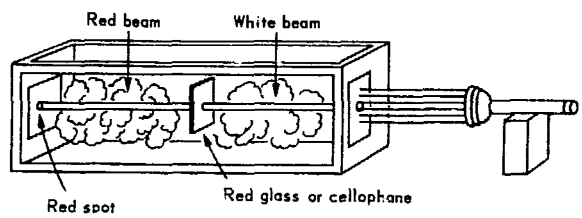


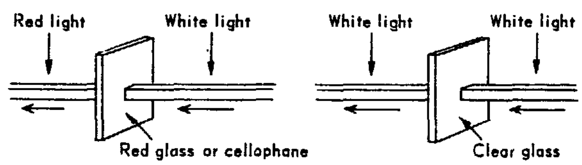
7 Another way to make a rainbow

Early in the morning or late in the afternoon of a bright sunny day, spray water from a hose against a dark background of trees with your back toward the sun. You will see a lovely rainbow.

8 The colour of transparent objects

Use the smoke box (see experiment A 5 above) as in previous experiments. Have a single ray of light enter the box. Hold a clear sheet of glass or cellophane in the beam of light and note that the beam on the white screen in the box is white. Next hold a sheet of red glass or cellophane in the white beam and observe that the beam which reaches the white screen is red. All the other colours of the white light have been absorbed by the red. Experiment with other coloured transparent sheets. You will observe that such objects have colour due to the colours they transmit and that they absorb other colours.





9 The colour of opaque objects

Get a good spectrum on a wall or a sheet of white paper in a darkened room. Place a piece of red cloth in the blue light of the spectrum. What colour is it? Place it in the green and in the yellow. How does it appear? Place it in the red light. How does it appear? Repeat using blue, green and yellow coloured cloth. You will observe that they appear black except when placed in the same coloured light. Thus opaque objects have colour because of the light they reflect; they absorb the other colours of the spectrum.

10 Mixing coloured pigments

Take a piece of blue chalk and a piece of yellow chalk. Crush them and mix them. The resulting colour is green. These are not pure colour pigments. Notice that green is between yellow and blue in the spectrum. The yellow absorbs all colours but yellow and green. The blue absorbs all colours but blue and green; thus the yellow and blue absorb each other, and the green is reflected to the eye.

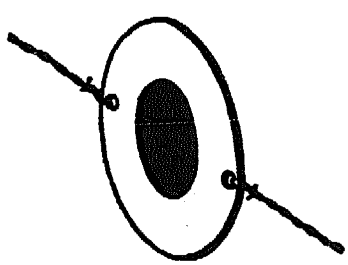
Try the same experiment by mixing paints from a painter's box.

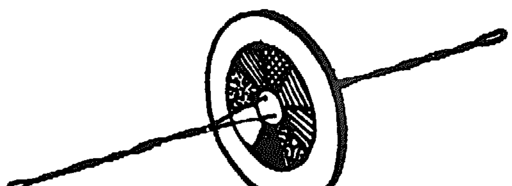
11 Mixing coloured lights

(a) Mixing of coloured lights can be achieved by using water colours painted on disks of cardboard.

One suggestion is to paint a yellow 'egg yolk' on one side of a 10 cm disk, and a blue 'yolk' on the other side. When the disk is suspended by short pieces of string, and twirled between the fingers and thumbs, the result is nearly white, if the colours are carefully chosen.

Other colour mixtures can be investigated in a way similar to that used on the toy 'colour tops'. Radial segments are painted, say, alternately red and green. The resulting mixture of red and green lights reflected to the eye by spinning the disk on string is, of course, yellow in this case.





(b) Three of the boxes described for experiments on rays in elementary optics can also be used for mixing coloured lights. Any similar box containing a car bulb will serve the same purpose.

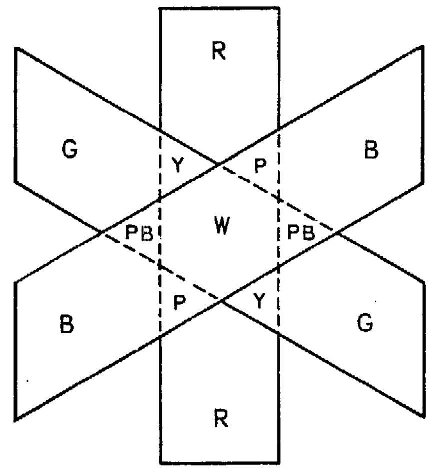
Place red, green and blue theatrical filters in the front of the box and cast rectangular patches of light on a white screen.

Red and green give *yellow*.

Blue and red give *purple*.

Green and blue give *peacock blue*.

Red, green and blue give *white*.



12 Colours in a soap film

Make a strong soap solution such as would be used for blowing soap bubbles. Fill a flat dish with the solution and dip an egg cup or a tea cup into the solution until a film forms across the cup. Hold this in a strong light and observe the colours you can see. Thin films often have colours.

13 Colours in an oil film

Fill a shallow dish with water. Colour the water with black ink until it is very dark. Put the dish in a window where light from the sky is very bright, but not in direct sunlight. Look into the water so that light from the sky is reflected to your eye. While looking at the water place a drop of oil or gasoline on the surface at the edge of the dish nearest to you. You should see a brilliant rainbow of colours flash away from you toward the opposite edge. By blowing on the surface you will observe a change in the colours.

14 Colours from a feather

Look at a distant candle flame through the end of a feather. You should see two or three candle flames on each side of the actual flame and a flattened X with four coloured arms. If the feather is good you will see two blue and red bands in each of the four arms.

15 How colours change

Paste some coloured illustrations from a magazine on a piece of cardboard. Pour three tablespoonfuls of salt in a saucer and add several tablespoonfuls of alcohol. Mix and light. This produces a very brilliant light that gives out only yellow. View the picture in this light in a darkened room and observe how all colours but the yellow change.

E. OPTICAL PROJECTION

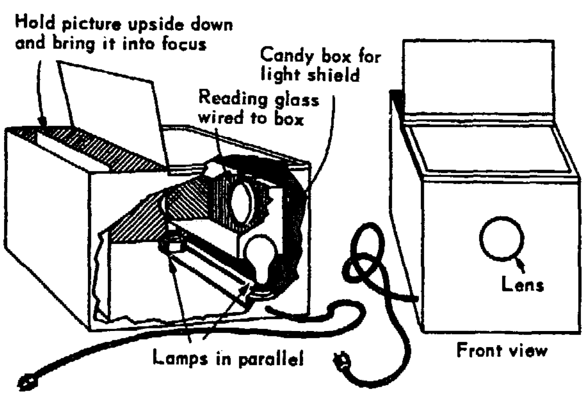
In order to produce a good image or picture on a screen, a lens must be of good quality. A magnifying glass may be used, but better results are obtained with an old camera lens. Used in this way the lens is called the 'objective' or object lens, and the magnification obtained depends on its focal length.

Opaque objects must be strongly illuminated because only the light reflected from the surface will pass through the lens. Transparencies can be illuminated from behind; in this case an extra 'condensing' lens is used behind the slide or film to ensure even illumination of the image produced on the screen.

1 How to make a projector for coloured pictures

A projector for coloured pictures can be made from simple materials as shown in the diagram. Use a box slightly longer than the focal length of the lens to be used. For most lenses the box should be between 30 and 100 cm long. Use a small candy box as light shield for the lens as shown. Connect two lamp sockets in parallel and put one on either side of the shield. Two 50-watt lamps should provide sufficient illumination. Use gummed tape to fasten down the front portion of the top of the larger box and hinge the rear portion.

Place a picture upside down in the back of the box, focusing by moving it back and forth until a clear image appears on the wall or screen in front of the projector.



2 To construct a projector for filmslides or strips

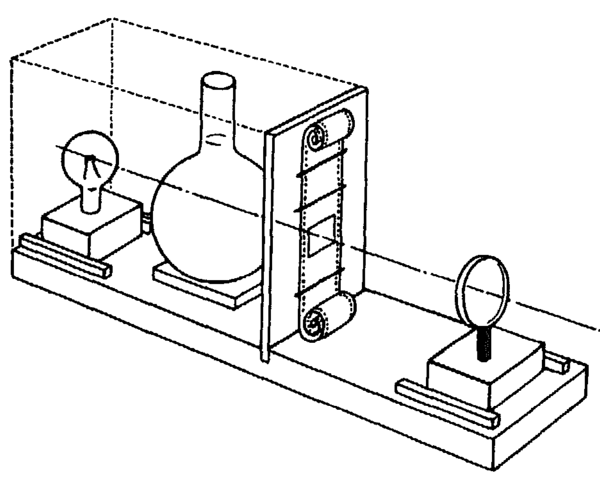
The base of the instrument is a piece of wood 40 by 10 by 3 cm. A plywood board 10 cm wide and 25 cm long fits into a groove cut across the base, and serves as filmstrip carrier. A hole 35 by 23 mm cut in this wood serves as an 'aperture' or gate to limit the light passing to one frame of the strip. The strip itself is held close to the gate, in a vertical position, by staples made from wire paper fasteners. These are easily bent to the width of the film; the ends are cut off short and sharpened with a file, and they can then be pressed into position on the plywood board.

No reels are necessary. The strip can be moved on from one frame to the next by pulling on the end of the film; there is sufficient 'curl' to hold it stationary.

The lamp, which is an automobile head-lamp in a holder mounted on a block, is adjustable; it can be slid between two strips of wood nailed to the base. A carafe or flask of water can be used as condensing lens and should be placed so that the whole of the gate is illuminated by the image of the lamp. When it has been so positioned, the lamp and condensing flask are fixed in place with glue.

The object lens is mounted on a piece of wooden dowelling which is a fairly tight fit in a hole drilled into a block of wood arranged, like the lamp support, to slide between two wooden guides. The lens can then be adjusted for height by sliding the rod in or out of the hole so that the centre of the lamp, condenser and objective are all the same distance from the baseboard.

A plywood, metal or cardboard case is required to enclose the lamp and the condenser as shown by the dotted line in the diagram. A darkened room is necessary for this apparatus. Commercial instruments using 100 watt bulbs can be used in a semi-darkened room, but the problem of dissipating the heat from the lamp is then considerable.



3 A simple microprojector

The optical system of this instrument is the same as that of the strip projector. The differences in construction are necessary because of the size of the objects (microscope slides or small objects similarly mounted), and the need to use a very short focus objective to obtain high magnification. The lamp is a 12-volt car bulb, the condenser is a small glass bulb 1.5 to 2 cm in diameter blown on a piece of quill tubing, and the object lens is the objective of a commercial microscope.

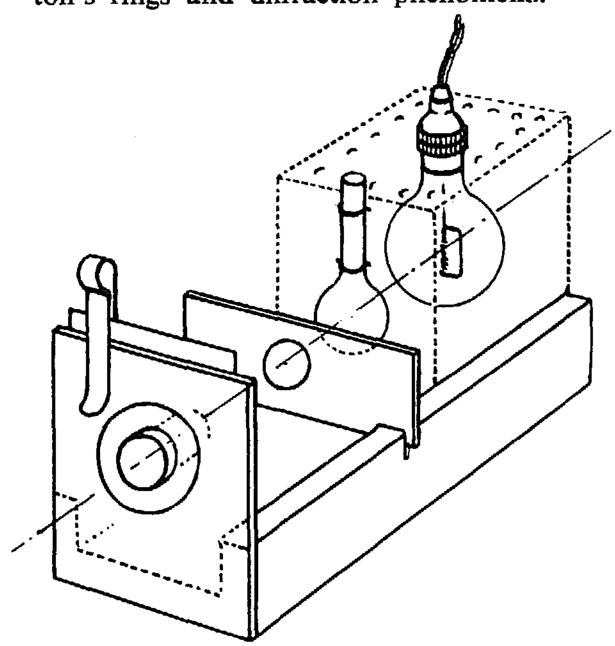
The base of the apparatus is a small wooden trough 10 by 7 by 4 cm made by nailing two strips of wood 4 cm wide to the sides of a piece measuring 10 by 5 by 1 cm. These sizes are not critical, and may be varied to suit the other available materials. A support for this objective is provided by closing one end of the trough by a piece of plywood 9 by 7 cm with a 2.5 cm hole in it.

Into the channel fits a rectangular lamphouse; this is easily improvised by fixing a car bulb and holder inside a household mustard or other rectangular tin. Holes drilled round the top provide ventilation, and a hole 1.5 cm in diameter serves to support the condenser. Copper wire passing round the stem of the bulb and through holes punched through the tin hold the condenser firmly in position.

The slide holding the object to be projected fits into grooves cut across the edges of the channel, and is thus held in a vertical plane so that the light from the condenser passes through it. The position of the grooves is determined in the way indicated below.

The microscope objective fits tightly into a hole in a piece of plywood, 7 by 4 cm, which is held in contact with the end plate by a trouser cycle clip in such a position that the lens can be adjusted to be on the axis of the optical system.

The diagram shows the components mounted further apart than in actual practice; this is done to show the relative positions more clearly. In adjusting this apparatus the slide, lamphouse and condenser are moved forward together until the light passes through the objective and forms an image (of, say, a botanical specimen) on a ground glass screen 30 cm square placed about 60 cm away from the end of the trough. Once the correct position for the slide has been found, the sawcuts are made in the edge of the trough and serve for all other slides used. This apparatus can also be used for projecting Newton's rings and diffraction phenomena.



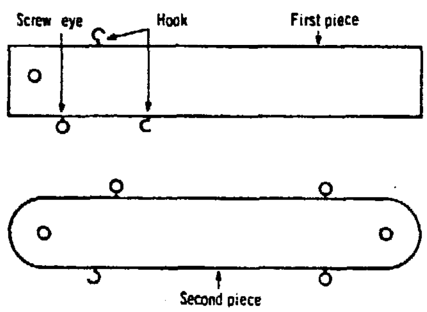
CHAPTER XVII

Experiments and materials for the study of the human body

A. THE BONES AND MUSCLES

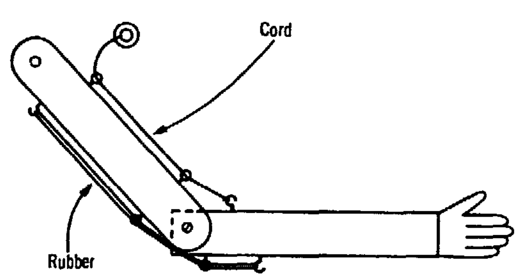
1 A model of the arm

Obtain two pieces of wood about 5 to 8 mm thick (plywood will work very well), 5 cm wide and 30 cm long. Drill a hole in the upper corner of one piece of wood. Round the ends of the other piece and drill a hole near each end as shown in the diagram:



Next, put two cup hooks and a screw eye in the first piece of wood approximately at the places indicated. In a similar way place one cup hook and three screw eyes in the second piece. Put the two pieces together with a short bolt and nut as shown in the diagram below.

Cut some long strands of rubber from old bicycle or automobile inner tubes and fasten them to the cup hooks on the under side of the two pieces after threading them through the screw eyes. Thread a strong cord through the screw eyes on the upper side and attach to the hook. When the string is pulled, you will have a good representation of the way the bones and muscles of the arm work.

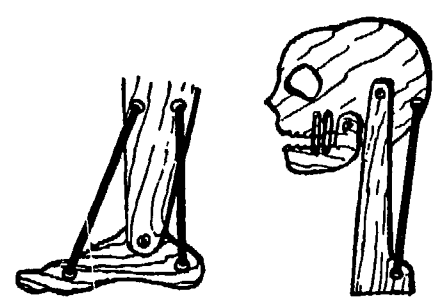


2 A model of the foot

Cut, from thin wood or cardboard, sections to represent the foot and leg as shown in the diagram. Attach rubber strands cut from old inner tubes, as indicated.

3 A model of the head and neck

The diagram indicates how this model may be improvised from wood or cardboard.



4 The walking hairpin

Hold a dinner knife tightly in your hand. Place a hairpin astride the knife and lift it just enough for the legs of the hairpin to rest lightly on the table with the pin in a slanting position. Observe that the pin walks along the knife blade. This is caused by the slight movement of the arm muscles.

B. YOUR SENSES

1 Your sense of smell

With pupils sitting perfectly still and evenly distributed in the room, release, in one corner, some substance with a penetrating odour. A little ether or ammonia poured on a cloth works well for this purpose.

Ask pupils to raise their hands as soon as the odour is detected. Note the progress of the diffusion of the odour through the air across the room.

Quote examples of ways in which the sense of smell protects us from danger.

2 The best reading distance

Ask pupils to read something and to hold their books at the distance where reading is most comfortable; 35 to 40 cm is normal. If the most comfortable distance is greater or less than this, spectacles may be needed to correct the vision.

3 Proper illumination

With the curtains or blinds drawn, hold a lighted 40-watt electric lamp exactly 60 cm above an open book. This amount of illumination is about right for comfortable reading. Show that the illumination rapidly diminishes as the lamp is moved farther away. At a distance of a little under 1 m, a 100-watt bulb is needed to provide the same illumination that a 40-watt bulb gives at 60 cm.

Demonstrate proper reading positions to prevent glare. Decide whether there is proper lighting in all parts of the classroom. If not, discuss methods of correcting the unsatisfactory conditions.

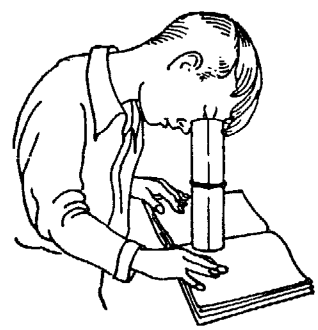
4 The adjustment of the eye

Roll 10 or 12 sheets of white paper into a hollow roll so that each sheet extends twice around the roll. Slip a rubber band around the roll. Set the roll on the page of a book and press one eye against the top so that no light is admitted at the bottom or the top. It should be impossible at first to read any of the words. If any of the words can be read immediately, add a few more sheets of paper to the roll.

With the other eye closed, keep looking through the roll for a minute or two without admitting any light. The print will slowly become legible in the dim light diffused through the paper.

As soon as the print can be read clearly, look quickly into a mirror and note the size of the pupils of the eyes. Keep watching the pupils for a minute and see how they change in size as the bright light of the classroom enters the eyes. Each of the children should have the opportunity to perform this experiment for himself.

Suggest some advantages of this ability of the pupils of the eye to change in size: contraction of the pupils protects the eyes against very bright light; enlargement helps us to see in very dim light; adjustment of the pupils helps us avoid danger.



5 Can you find your blind spot?

At the place where the optic nerve enters the eyeball there is a little blind spot only a few millimetres in diameter. You can find this blind spot by a very simple experiment. Draw a black dot on a white sheet of paper and about 5 cm to the right draw a black cross. Close your left eye and stare steadily at the black dot with your right eye, while the sheet rests on the table. Now pick the sheet up and move it slowly towards your eye while still staring at the dot. You will find a point where the image of the cross to the right will disappear. You can find the blind spot of your left eye by closing the right one and staring at the cross. When the book is brought near your eye, the black spot will disappear.

6 Optical illusions

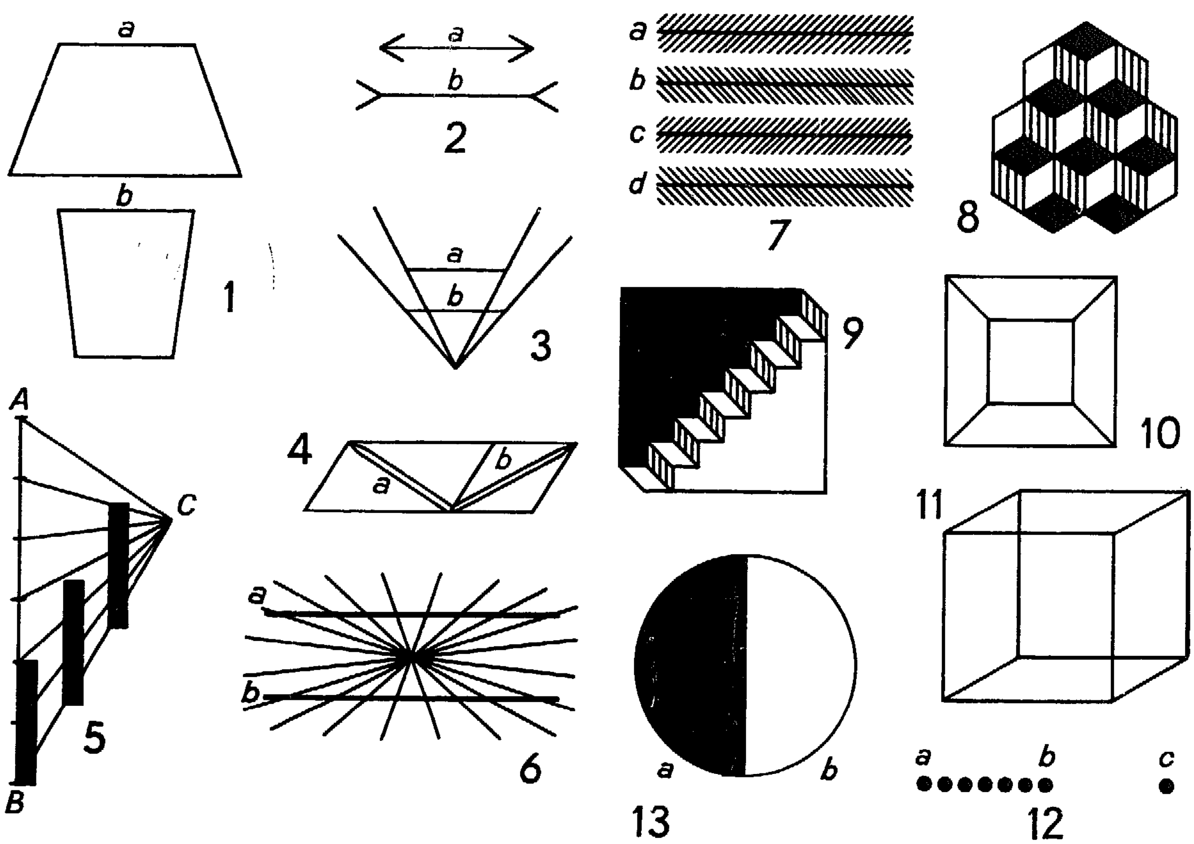
There are several very striking optical illusions in everyday life. When near the horizon, the sun and moon appear to be much larger than when seen high in the heavens. When seen rising behind a hill, they seem to move much more rapidly than they do when they are above us. Measurement of the sun's or moon's regular diameter by an instrument or of their bearing when rising and setting does not confirm our first impressions. Our estimates of sizes and distances near the horizon are inaccurate because we adopt comparatively near terrestrial objects as our standard of comparison.

Make use of the theodolite or astrolabe and sextant made in Chapter VI, in measuring the speed of the sun or the moon during its setting or rising. Compare its movement when it is above us.

Vision is not merely a static copy of the changing world. We have to learn to use our eyes as we have to learn to use any other instrument. Our estimates of distance, direction and position do not merely depend on what the retina of the eye (see experiment C 1 below) tells us. They involve complex movements of the muscles that move the lens of the eye, of the muscles that change its curvature and of the muscles that move the eye itself in its socket, together with the movements of the muscles of the neck and limbs and all the signals which these muscles send to the brain when they move. We learn to co-ordinate our bodily movements with those of our eye muscles and with the pattern of light on the retina from the common experience of everyday life.

Part of our everyday experience is that light travels in straight lines. We learn to put things *in line*. The delicate adjustment which makes us able to grasp a thing by seeing it, or to direct our gaze to the thing we touch, is easily upset.

The following diagrams are of some well-know optical illusions. See that accurate measurements do not confirm your impressions.



Nos. 1, 2, 3, 4. Look at lines *a* and *b* and compare their lengths.

No. 5. The black fence-posts appear to differ in height.

Nos. 6, 7. Look at the horizontal lines; are they parallel?

No. 8. Count the cubes and then carefully recount them.

No. 9. Look steadily at the staircase. Then turn your book slowly so that the staircase becomes inverted.

No. 10. The inside square appears to shift back and forth.

No. 11. Sometimes you appear to be looking at the top of the cube and sometimes at the bottom.

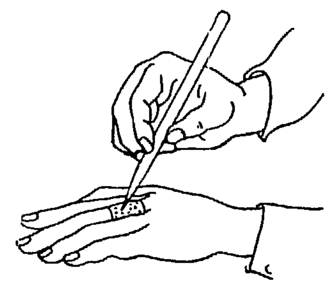
No. 12. Look at the figure and compare the distances *ab* and *bc*.

No. 13. Glance at the figure; is it a true circle?

7 Your sense of feeling

With a pencil mark off a 1 cm square on the back of the first joint of the middle finger. Sharpen the pencil and press the point firmly against the skin at many places within the square. Nerve endings that register sensations of touch, heat, cold and pain are located in the skin. Find the points within the square that produce each of these sensations.

Quote examples of situations in which the sensations of touch, heat, cold and pain might help us avoid harm or danger.



8 Testing your temperature sense

See Chapter XIII, experiment B 1, page 143.

C. SOME ORGANS OF THE HUMAN BODY

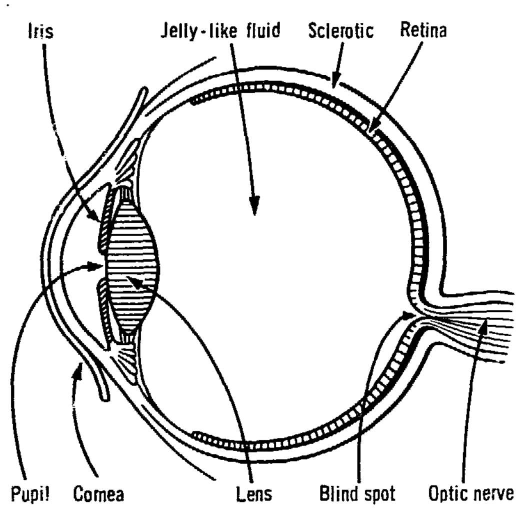
I The eye

1 How to dissect an eye

A bull's or a sheep's eye can be used. Remove the clear front skin or cornea. This will reveal the iris, and behind it the crystalline lens.

This lens divides the eye into two parts, the front containing a thin liquid called 'aqueous humour' and the back a jelly-like liquid, the 'vitreous humour'.

Removing the lens and vitreous humour, the retina or sensitive surface can be seen. It is more richly served with sensitive cells at a spot opposite the lens called the yellow spot. The nerves carrying the sensations pass out through a hole in the outer sclerotic membrane; this spot is therefore not sensitive to light and is called the blind spot.



2 How an image of an object appears on the retina

See Chapter XVI, experiment A 4, page 191, on the pinhole camera.

3 How the lens of the eye forms an image on the retina

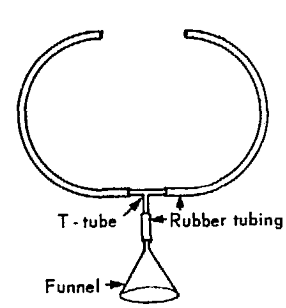
See Chapter XVI, experiment C 11, page 198, on image formation by a convex lens.

II The heart

1 Making a simple device for listening to the heart beat

Make a stethoscope and have pupils use it to listen to the heart action.

A very satisfactory demonstration stethoscope can be made from a small funnel, a glass T-tube or Y-tube, and some rubber tubing. Slip a piece of rubber tubing 7 or 8 cm long over the tip of the funnel. (Any kind of small funnel will do, such as a glass laboratory funnel or the kind used to fill babies' milk bottles.) Insert the T-tube into the other end of the short piece of rubber tubing and attach longer pieces of tubing to both arms of the T-tube.



To use the stethoscope, have one pupil hold the funnel firmly over his heart while another holds the ends of the long tubes in his ears. Heart sounds will be heard very clearly though of course, pupils will not be able to interpret them. A doctor uses a stethoscope to find out if the heart action is normal.

This experiment will naturally lead to a discussion of what the heart does and its importance in maintaining good health. Dangerous activities that might injure the heart and diseases that sometimes result in heart impairment might also be discussed.

2 Taking the pulse rate

Demonstrate the proper method of taking the pulse rate by placing two fingers on the wrist and applying slight pressure by pushing against the back of the wrist with the thumb. Practise finding the pulse rate by counting for 15 and 30 seconds.

3 The effect of exercise on the pulse

Have several pupils take their pulse rate at rest and after vigorous exercise. Summarize the results in a table.

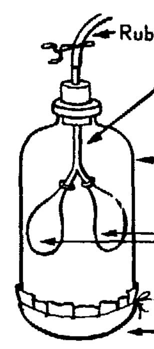
4 Watching the pulse beat of the heart

Stick a drawing pin into the end of a kitchen match. Hold your hand out with the inside of the wrist up and level. Place the head of the drawing-pin on your wrist at the point where you can feel the heartbeat. Observe the match as it sways each time the heart beats.

III The lungs

1 How the lungs work

Demonstrate the action of the diaphragm by means of the apparatus shown in the accompanying diagram. The rubber balloons represent the lungs, the tube represents the windpipe and the open bottom jar represents the bony thoracic girdle. Lowering the diaphragm reduces the pressure inside the chest cavity and air flows into the lungs. Raising the diaphragm reverses the flow of air. Try moving the diaphragm with the clamp closed.



2 What is your lung capacity?

Pupils may be interested in finding the volume of air that the lungs can displace. This can be determined quite easily.

Fill a jar with water and fit a two-hole stopper. Insert a rubber tube through one hole; the other hole serves as an outlet. Invert the jar in a larger vessel and have a pupil make one exhalation through the tube. Place the fingers over the outlet and remove it from the large vessel. Use the graduate to measure the amount of water needed to refill the jug. The amount of water needed will equal the volume of air that was exhaled.

CHAPTER XVIII

Some useful notes for teachers

1 Cleaning of glassware

Dissolve 100 g of potassium dichromate in a solution of 100 g of concentrated sulphuric acid in 1 litre of water. Glassware can be soaked in the solution, which may be used over and over again.

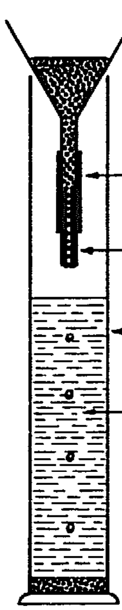
Caution: Great care should be taken to avoid getting this very corrosive solution on skin or clothes. When diluting concentrated sulphuric acid use a stone or earthenware vessel. Pour the acid very slowly into the water as a great amount of heat is given out in the process.

The teacher should use his knowledge of chemistry to remove stains of know origin. If dirty vessels have contained alkalis, or salts with alkaline reactions, then obviously the cleaning effect of a little dilute acid should first be tried; if the stain is due to potassium permanganate, then the effect of sodium sulphite solution, acidified with dilute sulphuric acid, should be tried, etc.

Alkalis slowly attack glass, and bottles which have contained caustic soda, etc., for a long time, will never recover their original transparency.

2 Cleaning of mercury

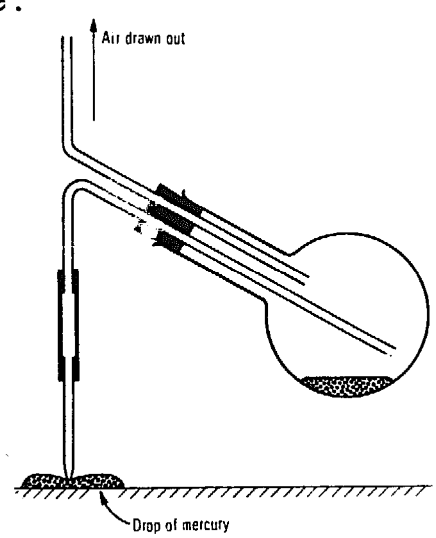
When mercury, flowing over a surface, begins to leave 'tails', it should be cleaned. It is allowed to drip into a tall cylinder containing nitric acid slightly more dilute than the usual bench reagent. If the mercury falls through the acid in a fine stream, as it does when made to pass through a capillary tube attached to the end of a funnel, so much the better. The mercury is then shaken up with water in a strong bottle to wash it free from acid. Finally it is allowed to pass through a pinhole made in the middle of a filter paper, which is folded in a funnel in the usual way. The last drops of mercury remaining in the funnel should be kept for the next occasion when mercury is cleaned. The mercury may be warmed in an air oven before the final filtering, if required particularly dry.



3 Removal of air bubbles from, and the recovery of, spilt mercury[1]

Air bubbles appear in a tube which is being filled with mercury. To remove them the tube is closed with the finger, before it is quite full, and inverted to allow a large air bubble to travel up it. As it moves upwards, the large bubble collects the smaller ones. When the tube is turned up again the large bubble reverses its track, moves upwards and escapes. The small amount of mercury needed to fill the tube is then added.

Mercury spilt on tray, bench or floor, may be recovered by sucking it into a small 'wash-bottle'.



4 Collections of biological materials

These have little value unless they are kept in good condition, and the various kinds require different treatment.

1. Note taken from H. N. Saunders, *The Teaching of General Science in Tropical Secondary Schools*, London, Oxford University Press, 1955. (Unesco Handbooks on the Teaching of Science in Tropical Countries, vol. 7.)

Flowers and plants: A collection of dried specimens is called a herbarium. Its main purpose is to provide a supply of identified plants for general reference and to facilitate the naming of freshly collected specimens. The teacher must always have at hand a supply of material with which to illustrate the various kinds of flowers, leaves, fruit and roots. A specimen is not complete until all the parts of a plant are present. As flowers and fruits do not always appear at the same time, it may be necessary to collect specimens of a plant on more than one occasion.

Plants can be dried by pressing between sheets of newspaper. Special paper can be purchased for the purpose, but newspaper makes a satisfactory substitute if two or three sheets are put on each side of the specimen. A number of layers of specimens can be pressed at the same time. Drying is assisted by inserting sheets of stiff corrugated paper between every few layers. The pressing can be carried out by putting the sheets on a table under a heavily weighted drawing board. But drying is quicker between two wire frames pressed together by spring fasteners, adjustable screw fasteners, or straps. For the first few days the specimens should be removed and placed between fresh dry paper every day, but as they become drier the changes need be made less frequently.

Specimens are less subject to the growth of mould if brushed over gently with a solution of 0.5 g of mercuric chloride in 100 ml of methylated spirit (methyl alcohol). The specimens should then be gummed, or glued, to sheets of stiff drawing paper, or to cards (about 25 × 45 cm) specially made for the purpose. The gum, or glue, should be made up with a little mercuric chloride, which also helps to repel insects. Alternatively, or in addition, the specimen can be sewn to the card, or fastened to it with transparent adhesive tape.

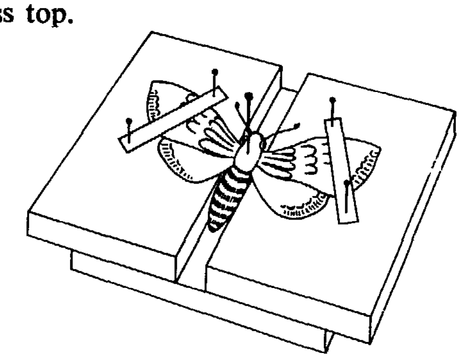
Each specimen should be labelled with at least: (a) the name and family of the species; (b) the name of the person, or group, which has identified the specimen; (c) the place and date of finding; and (d) the name of the finder.

Fruits or other bulky material associated with the specimen may have to be labelled and stored separately, but small seeds can be put in an envelope and attached to the mounting card.

Insects: These are best killed in a wide-mouthed bottle containing a suitable poison. A killing bottle is easily made as follows. Some plaster of Paris is stirred to a thin paste with a 20 per cent solution of potassium cyanide (the 'commercial' mixture of potassium and sodium cyanides is satisfactory) and quickly poured, to a depth of about 1 cm, into the bottom of the bottle, where it soon sets hard. Cut a piece of blotting paper to place over the cyanide and plaster of Paris. Punch the circle full of holes. The bottle should have a screw-cap or a well-fitting air-tight stopper, when it will remain effective for some months.

Caution: The cyanides of potassium and sodium are deadly poisonous and should be handled with the utmost care.

A captured insect becomes merely insensitive when first put into a killing bottle; so it should be left for a few hours until it is dead. It may then be removed to a setting board. A good substitute for the usual 'board' with a half-round groove consists of two sheets of compressed cork, or thick cardboard, with a gap between their edges, fixed on a third sheet, as shown in the figure. The setting board should be just large enough to hold the insect satisfactorily. A long thin pin, of the 'entomological' type, is then pushed through the middle of the insect's thorax, securing it in position in the groove. The wings, legs and antennae are then spread out carefully by means of seekers or fine tweezers, and kept in place by narrow strips of paper. (The strips are held down by pins, which must not touch the insect.) The specimen must now be dried thoroughly—not always an easy matter, in the tropics, unless the setting board can be left in a desiccator for some days. When it is dry the strips of paper are removed, as the various parts of the insect will now remain in place. It tends to be brittle, so no attempt should be made to move the thorax pin. By means of this pin the insect is lifted from the setting board and pinned in a suitable position on the mounting card. This is a sheet of cardboard or compressed cork previously cut to fit the bottom of a flat tin or other suitable box, the lid of which may be replaced by a glass top.



The preservation of specimens in the tropics is somewhat difficult, the chief problem being to prevent the attack of various kinds of ants.

Some minute species seem eager for viscera, fresh or dried, and determined to remove everything except head, thorax and wings. The specimens must be kept, therefore, either in ant-tight cases, or in cases on some support completely surrounded by liquid. (Water requires frequent replacement owing to evaporation, and a layer of oil or disinfectant to prevent mosquitoes from breeding. Used engine oil, from a car sump, needs less attention and is just as effective as water.) Probably the best answer to the problem is to keep the insect boxes on a table with its legs standing in tins of oil or disinfectant. The legs remain clean and dry if they stand on smaller tins inverted in the middle of the liquid. Ants and other harmful insects are unable to cross the liquid surface.

Other biological specimens: Amphibians, reptiles, birds and mammals are killed with chloroform, a pad of cotton wool, soaked in the liquid, being placed in the containing box. Mammals can be preserved in either 70 per cent alcohol or 4 per cent formalin. Amphibians, reptiles, molluscs and crustaceans are most suitably preserved in alcohol.

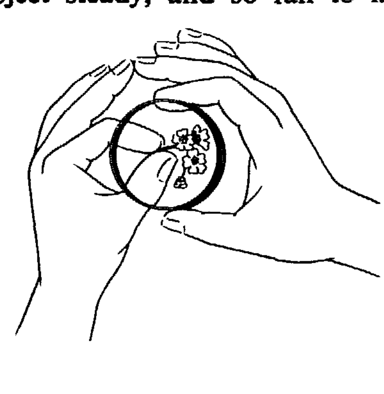
The cleaning of small skeletons, and the removal of viscera from large horny beetles, are jobs which, in the tropics, can be left to ants. The dead creatures are exposed in a suitable place. Their presence is soon detected by various ants, and before long a perfectly cleaned specimen remains. Bones can be scrubbed with an old toothbrush; bleaching powder should first be applied, and then hydrogen peroxide.

5 Botanical specimens

To keep these fresh until there is time to press them, they may be put in a closed tin in a refrigerator, where they readily remain stiff and fresh for a week.

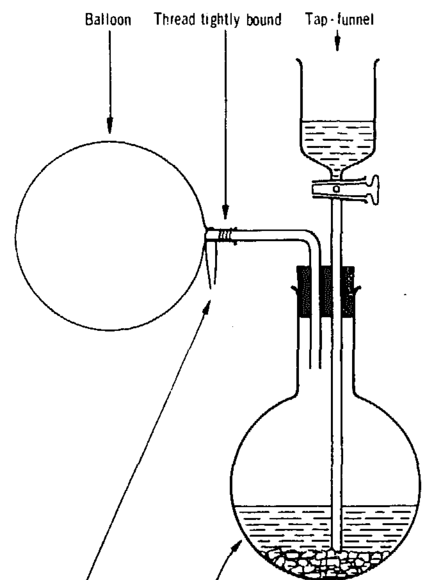
6 Hand lens

Young pupils find difficulty in holding lens and object steady, and so fail to keep the image in focus. Control is much easier if the thumb and forefinger of one hand hold the object, and those of the other hand hold the lens, and the tips of the middle fingers are pressed together.



7 Hydrogen balloons[1]

In filling a toy balloon with hydrogen, the usual thistle funnel can be replaced by a funnel fitted with a tap. The delivery tube should be of as large a diameter as possible. The end of the balloon tube should be tied to the very end of the glass tube. This allows the final tying-off of the balloon to be done without first removing it from the glass tube. The acid is run into the vessel and the tap closed. The vessel should be a stout flask or bottle.



8 Tropical conditions

There are many causes of trouble in a laboratory, especially during a wet season, in the tropics. Materials perish, papers stick together, instruments rust, specimens go mouldy, lenses develop a fungus which quickly renders them useless and ruins their accurately ground surfaces. In addition, ants, termites and other insects continue their endless work of destruction.

Whatever can be kept in an air-tight container should be so kept. Glass jars, such as specimen jars with lids well greased, are ideal. Screw-capped bottles, e.g. those which

1. Note taken from H. N. Saunders, *The Teaching of General Science in Tropical Secondary Schools*, London, Oxford University Press, 1955. (Unesco Handbooks on the Teaching of Science in Tropical Countries, vol. 7.)

have contained sweets, are very useful. Metal containers, such as biscuit tins, cake tins, etc., can be rendered fairly air-tight by strapping the joint between the lid and container with insulating tape.

Lenses of microscopes should be kept in a desiccator when not in use. A piece of string soaked in creosote and placed with the eyepiece in the lens container has been found useful for retarding the growth of mould.

During the rainy season, microscopes, galvanometers and other sensitive instruments should if possible be stored in an air-tight cupboard with a 50-watt electric bulb continuously burning. Needles can be inserted in a piece of material in which some vaseline has been rubbed. Metal instruments such as screw gauges, vernier callipers, tuning forks, etc., should be greased. The screws of retort stand bases, rings and clamps should be oiled frequently. Scalpels should be smeared with vaseline and kept in a case. The metal parts of tools should be rubbed over with an oily rag.

Paste, gum and glue should contain some chemical to make them repellant to insects. Such adhesives are sold specially prepared for the tropics. But, if the teacher makes his own, the addition of a very small quantity of a solution of mercuric chloride, during the preparation, is generally effective. (Also, consult a pamphlet on *It's Easy to Reduce Humidity*, published by the Calcium Chloride Institute, 909 Ring Building, Washington, D.C., U.S.A.)

9 Culture solution (for plants)

The following salts, of *purest* quality, should be dissolved together in 1 litre of distilled water:

- 0.70 g potassium nitrate
- 0.25 g calcium sulphate (hydrated)
- 0.25 g calcium hydrogen phosphate (hydrated)
- 0.25 g magnesium sulphate (hydrated)
- 0.08 g sodium chloride
- 0.005 g iron (ferric) chloride (hydrated)

To the solution should then be added:

- 1 ml 0.06 per cent boric acid solution
- 1 ml 0.04 per cent manganese chloride solution.

10 Stains

In general it is preferable to buy stains ready made up in solution, but the following are useful recipes:

(a) *Aniline sulphate.* A few drops of dilute sulphuric acid are added to a saturated solution.

(b) *Borax carmine.* 4 g of borax are dissolved in 100 ml of water; 3 g of carmine are added and the solution warmed until the carmine is dissolved; 100 ml of 70 per cent ethyl alcohol are then added and the solution filtered.

(c) *Safranin.* 1 g is dissolved in 100 ml of water *or* 100 ml of 50 per cent aqueous ethyl alcohol.

11 Sea water

A useful substitute for sea water can be obtained by dissolving the following in 2 litres of water:

- 45.0 g sodium chloride
- 3.5 g magnesium sulphate
- 5.0 g magnesium chloride
- 2.0 g potassium sulphate

12 Lime water

Lime is not very soluble in water, but the solution required for class use is easily made by adding 10 g of slaked lime to 1000 cc distilled water. After shaking, allow it to settle before use.

13 Litmus solution

Litmus decomposes on heating; it should therefore be prepared by extracting the solid litmus with cold distilled water. It should also be stored in bottles which allow access to air, otherwise the colour will disappear.

14 Accumulator solutions

(a) *Lead accumulator.* The specific gravity of the sulphuric acid in various conditions of the battery is as follows:

- Fully charged 1.28
- Half charged 1.21
- Discharged 1.15

The above figures are approximate. The recommendations of the makers, usually printed on the battery, should be followed. A rough guide to the making of a solution of sulphuric acid of specific gravity 1.28 is as follows:

Concentrated sulphuric acid is added slowly, with stirring, to a beaker two-thirds full of distilled water, until the solution is almost boiling. The solution is allowed to cool, and more acid is added, with similar precautions, until the solution is again almost boiling. After cooling to room temperature, the specific gravity is adjusted by the addition of more acid or more water, according to the hydrometer reading.

(b) *Nickel-iron (Nife) accumulator.* The specific gravity of the caustic soda solution is as follows:

Specific gravity when the battery is	*Temperature*		
	60°C	*80°C*	*100°C*
First filled	1.190	1.185	1.180
Working and fully charged	1.170	1.165	1.160

Four pounds (2 kg) of caustic soda are dissolved in 1 gal (5 l) of water to provide a solution of the approximate strength required. It can then be diluted with water as necessary.

15 Pole finding paper

Blotting paper is soaked in a solution of sodium sulphate to which a few drops of phenolphthalein has been added. Damp the paper before use, and apply the wires to it a short distance apart. The paper touched by the negative pole becomes red.

16 Electroplating solutions

(a) *Copper.* About 100 g of copper sulphate crystals are dissolved in about 300 ml of water; 6 g of potassium bisulphate and 5 g of potassium cyanide are then added. The solution is made up to 450 ml. (The solution should be kept cold while it is being made.)

(b) *Silver.* About 20 g of sodium cyanide (poison) and 40 g of crystalline sodium carbonate are dissolved in about 500 ml of water. About 20 g of silver nitrate are dissolved separately in 250 ml of water. The second solution is added slowly to the first, and the mixture made up to 1 litre.

(The *current* to be passed through the solutions depends on the area of the electrode upon which the metal is to be deposited. It should not exceed about 2 amps for 100 cm^2 of surface. It should be proportionately less if the electrode is smaller. The deposited metal will appear dull. It will not present the expected bright and shining appearance until it has been burnished, by rubbing, for instance, with a bone spatula or some other hard, smooth, non-metallic surface.)

17 Silvering solution (for depositing a bright silver mirror on glass)

First, 12.5 g of silver nitrate are dissolved in 100 ml of water, and 32.5 g of sodium potassium tartrate are dissolved separately in 100 ml of water. The two solutions are mixed, warmed to 55° C, and kept at that temperature for 5 minutes. The mixture is then cooled and the clear liquid poured off from the precipitate and made up to 200 ml for solution A. Second, 1.5 g of silver nitrate are dissolved in 12 ml of water. Dilute ammonium hydroxide solution is added until the precipitate first formed is almost entirely redissolved. The liquid is made up to 200 ml for solution B. The solutions A and B are then mixed. (The surface to be silvered, having been cleaned very carefully to free it from all traces of grease, should be suspended upside down in the solution, just below the surface. The solution can be put into a clean test-tube, or small flask, and a mirror deposited on the inside of the vessel. The solution can be slightly warmed to hasten the deposition of the silver.)

18 Heat sensitive paper

A solution of cobalt chloride in water is added to a solution of ammonium chloride in water. (The proportions do not matter.) The solution is diluted until it is pale pink. Filter paper soaked in the solution and allowed to dry appears to be almost colourless, but on heating it will turn a bright green colour.

19 Commercial adhesives

Many glues are now available for special purposes and it is worth selecting them carefully. China, glass and metal can all be stuck by china cements. But if the mended articles are likely to be put into hot water the only completely satisfactory results are from the new epoxy resins such as araldite. Paper and card can be stuck with almost anything. Cleanest and easiest to use are the vegetable glues, such as Croid No.22; Gripfix; Ste-fix; and Gloy. Textiles, leather and carpets are best stuck by the rubber lattice glues including Copydex; Fabrex; and Jiffytex.

To stick two different plastics is very difficult. Best results are normally obtained with a cement of the same base as the plastic, e.g. PVC sheeting with a PVC cement such as Pac or Plastitex. The impact adhesives are very suitable for sticking laminated plastics to other materials.

Evostick and Formica Adhesive are rubber solutions, and can be removed from the hands by petrol. Most other domestic adhesives yield to soap and water.

There are many types of adhesive suitable for wood, of which the following are good examples :

Hot animal glues: Cake Glue, Pearl Glue, Croid Aero.

Cold animal and fish glues: Croid Universal, Duroglue, Seccotine, Le Page's Fish Glue.

Casein cold water glues: Casco, Croid Insol, Neverpart.

Urea Resins: Aerolite, Cascamite.

PVA Emulsions: Casco PVA, Croid Polystic, Le Page's Suregrip, Unibond.

Animal glue and the emulsions are not resistant to cold water; resin glues are, and—for a time—to hot water. Casein glues are less strong, have a fair resistance to heat and damp, but stain some woods.

Sticking things takes time. The more trouble taken in preparing and applying the glue the better the result.

20 Cements, waxes and alloys

Other cementing compounds can easily be made up in the laboratory by following the recipes below:

Cements

Acid-proof cement

1 part rubber solution
2 parts linseed oil
3 parts powdered pipeclay

Aquarium cement

(a) Equal parts of powdered sulphur, ammonium chloride, and iron filings are mixed. Boiled linseed oil is then added and all are mixed thoroughly. White lead is added to form a thick paste. The cement should be applied while fluid.

(b) Mix red lead with sufficient gold size to make a smooth paste and apply immediately. Allow a few days to set and rinse the aquarium before using.

Celluloid cement

Celluloid scraps can be dissolved in acetone or amyl acetate. This cement is useful when making up small accumulators.

Cement for iron

90 parts fine iron filings
1 part flowers of sulphur
1 part ammonium chloride
Mix to a paste with water immediately before use.

Waxes

Chatterton's compound

1 part Archangel pitch
1 part resin
Melt these together and add three parts of crêpe rubber in small pieces.

Faraday's cement

5 parts resin
1 part beeswax
1 part yellow ochre
Melt the resin and wax together in a tin and stir in the ochre.

Alloys

Wood's alloy (melting point 70° C)

2 parts lead
4 parts tin
8 parts bismuth
2 parts cadmium

Darcet's alloy (melting point 70° C)

5 parts lead
3 parts tin
8 parts bismuth

21 Insulating material for electrostatics experiments

Melt some paraffin wax in a can surrounded by a water bath. Add flowers of sulphur and stir until a pasty mass is formed. This can then be moulded to fit the neck of a flask or cast into slabs as required.

22 Replacing eyepiece cross-wires

Drawn out glass tubing, monofilament nylon (obtained by unravelling a piece of nylon material) or spider web can all be used for this purpose. Remove the supporting ring from the instrument. To make a frame for holding the fibre, bend a U-piece of copper wire so that the arms are about 1 cm further apart than the diameter of the ring. Place the arms under the fibre and stick it to them with a strong adhesive before breaking off the ends. Now lift the frame and place the fibre in position over the supporting ring. Fix it down with adhesive, and allow it to dry before trimming the ends.

If spider web is to be used, it is better to apply the adhesive to the frame before taking the filament from the web, and to the supporting ring before placing it in position.

Satisfactory threads can also be made from Durofix, Centofix and Seccotine by making a blob on a piece of paper and allowing it to dry partially. Very fine filaments of glue can then be drawn from the blob by touching it with a pin or the nozzle of the tube. These can then be fitted as before, though with some practice the operation can be carried out in the supporting ring, and the cross-wires fitted directly.

23 Soldering

Solder is an alloy of 66 per cent tin and 34 per cent lead which is used for making mechanical and electrical joints between two metals. It is generally obtained in the form of rods or sticks. It is applied in the molten state from a pointed block of copper known as a 'bit'. This may be heated electrically (in which case a 75 watt heater is sufficient for general purposes) or it may be heated in a bunsen flame.

Whatever method of heating is used, the surface of the bit must be cleaned by scraping or dipping in a liquid flux, or the solder will not stick to it. When the right temperature has been reached, a little solder applied from the stick will flow all over the bit. This process, a preliminary to the actual making of the joint, is known as 'tinning'.

The surfaces to be joined must also be cleaned and tinned. In this case the heat is supplied by holding the hot copper bit on the object. When the solder begins to flow, it can be spread over the required area by rubbing gently with the tip of the bit.

When both surfaces have been tinned, they should be brought together and heat applied again by the bit while they are held in the required position. The solder from the two surfaces runs together, and on cooling makes a strong joint. Naturally large surfaces require more heat, and it may be necessary to use a flame to bring the object to the required temperature.

The three essentials to successful soldering are cleanliness, flux and heat.

Fluxes

Rosin is the most useful flux, especially for copper, brass, and tinplate, but it is not satisfactory for iron and steel.

'Dead' zinc chloride or 'killed spirits' is the easiest flux to use, but it is corrosive, and it is best to avoid it in electrical work. It is easily made by pouring hydrochloric acid on scraps of zinc and waiting until all action has ceased. The liquid can then be filtered off into a wide-necked container.

There are many commercial fluxes for special purposes. Fluxite is perhaps the best for all general purposes.

Soldering paste is now obtainable. A combination of solder and flux, it is applied with a brush and only needs the heat of a soldering iron to make a satisfactory joint.

Tallow is used for joining lead to lead, or brass to lead, and rosin or killed spirits for joints in brass, copper, tinplate, zinc; killed spirits are suitable for iron and silver. After soldering, killed spirits should be washed off with water, and rosin or Fluxite with methylated spirit.

24 Blackboard dressing

A satisfactory dressing can be made using:
100 g shellac
1000 ml alcohol
100 g powdered pumice
100 g crushed lamp black

The alcohol and shellac should be mixed first, as the shellac takes some time to dissolve. Some of the alcohol should be set aside for mixing with the lamp black. This mixture should be added later through a muslin strainer, and the whole should be well shaken before use.

25 'Dead black'

This is useful for painting the inside of 'light' apparatus, so that unwanted reflected light may be eliminated, rays made less diffused, and images made sharper. Lamp black is mixed with gold size, and turpentine added, with constant stirring, until the mixture is sufficiently thin for use as a paint.

26 Fluorescin solution

(This is useful because the track of a ray of light travelling through a dilute solution of fluorescin can be seen very clearly.) One gram of fluorescin is dissolved in 100 ml of industrial, or methylated, spirit.

27 Cutting glass

(a) *Sheet glass*. First prepare a firm, flat surface on which to lay the glass: a table with a blanket or felt thrown over it is satisfactory.

Using a rule and with a firm grip on the diamond or glass cutter, make a scratch along the required line. Turn the sheet over and tap gently along the line of the scratch with the wooden end of the cutter. If this does not result in a crack spreading along the line, turn the sheet over again and grasp it with one hand on each side of the scratch and boldly bend it about, using this line as a hinge.

(b) *Glass tubing*. Tubing is best cut with a glass knife, and 'everlasting' knives are now available. A file, though often used, makes a rounded valley in the glass instead of a crevice.

Make a scratch at the required point and holding between the thumb and finger each side of the cut, pull the tubing apart, flexing slightly upwards.

To cut off a very short piece, hold in one hand and place the scratch over some firm pivot such as a gas tap. Strike the short end a smart blow with some hard object.

Wide tubing must be scratched all round to make a neat cut. A molten piece of glass rod placed carefully on one part of the scratch will cause a crack to run round the circumference in each direction. If the two cracks do not exactly join, the tube should be bent about the uncracked part as hinge in order to separate the two pieces.

(c) *To cut the bottom off a bottle.* Make a scratch round the bottle at the required level. Wrap strips of damp blotting paper on either side of this scratch. Play a fine gas flame on the cut, rotating slowly as the glass begins to crack at this point.

If no gas flame is available the crack can be made in another way. See that the bottle is dry and well corked. Then tie a length of very absorbent cotton around it horizontally, keeping the knot as flat as possible and cutting off the loose ends. Level off carefully, so that the thread is exactly the same height up the bottle all round. Turn the bottle on its side and soak the thread with kerosene from an eye-dropper. See that no kerosene runs on the glass; if any does, wipe it off with cotton wool or filter paper. With the bottle still on its side and resting on two wood blocks with a gap between them, set fire to the thread and rotate the bottle on its axis with both hands until the whole thread is burning uniformly. Set the bottle upright on the table until the thread is burnt out, at which stage the bottle may split in two of its own accord along the line of the burn. If this does not happen as the flame goes out, gently lower the bottle upside down and vertically into cold water. It must be kept absolutely vertical and must not be immersed beyond the line of the thread.

Smooth off the raw edge with a file, or by rubbing on a flat ground-glass plate on which has been smeared a paste of carborundum powder.

(These bottles are useful for electrolysis experiments and as bell jars. In the latter case, a ring of soft rubber can be used to make an air-tight seal.)

(d) For (a) and (c), if electricity, either AC or DC, is available, it is also possible to place a round of wire, german silver or nichrome on the scratch. Switch on the current; the red hot wire will crack the glass along the scratch. This method is also found useful in cutting used electric bulbs.

28 Extinguisher

Materials for putting out a fire must be kept handy in definite places. Teacher and pupils should know how to use them quickly and correctly.

First-aid kit

A first-aid kit should be kept in each laboratory or adjoining preparation room, preferably in a separate cupboard. It must be kept in good condition, and the teacher must know how to use its contents.

29 Blueprinting

Solution 1: potassium ferricyanide 10 g; water 50 ml.

Solution 2: ferric ammonium citrate 10 g; water 50 ml.

The solutions are prepared separately and kept in a dark room or in subdued light. For use, mix equal quantities in subdued light and place in a shallow glass or enamelled tray. The paper is sensitized by brushing the mixed solution over it with a soft, wide brush, or the paper may be placed on the surface of the solution and allowed to float there for a few seconds. After sensitizing, the paper should be hung to dry in the dark room.

An opaque object, a drawing in black ink on tracing paper or any material to be printed is placed and fixed (on frame) on the paper. It should be exposed to sunlight (or artificial light) for several minutes and then washed thoroughly in running water.

30 Shellac coating

Dissolve 1 part of shellac in 5 parts of alcohol, and apply with a soft brush.

31 Preparation of common alloys

Lower melting alloys

These may, in general, be produced by using a bunsen burner as a source of heat. The bismuth and lead are melted together, and then the other ingredients added. The temperature should not be higher than necessary to prevent excess oxidation. The parts indicated are by weight.

Alloy	*Lead*	*Tin*	*Bismuth*	*Cadmium*
Wood's metal	4	2	7	1
Solder	1	1	0	0
Electric fuse alloy	8.5	2.5	1.3	0

Higher melting alloys

These may be produced using a furnace. The copper should be melted first, and the other metals added to it.

Alloy	*Copper*	*Tin*	*Zinc*
Bronze	80	5	15
Brass, malleable	58	0	42
Brass, casting	72	4	24

32 Dyeing

(a) *Direct.* The dyeing of cotton should be preceded by removing the sizing from the fabric. This is accomplished by boiling it for 5 chloric acid). This solution is made by adding 1 part of concentrated HCl to 10 parts of water. The following formula makes a satisfactory dye:

Congo red 0.5 g
$NaHCO_3$ (sodium bicarbonate) 2.0 g
Na_2SO_4 (sodium sulphate) 1.0 g
H_2O (distilled) 200.0 ml

The fabric should be boiled for 4 to 5 minutes and then rinsed in cold water and dried.

Instead of the congo red, methylene blue or primuline brown may be used. The dye and salts should be mixed together first and then added slowly, with stirring, to the water. White silk, rayon or wool may be dyed in the same way.

(b) *Use of a mordant.* Show the use of a mordant by heating a piece of white cotton fabric for 10 minutes in a dilute solution of $(NH_4)_2SO_4$ (ammonium sulphate). It should stand for a few minutes in dilute NH_4OH (ammonium hydroxide), after which it is rinsed. White silk may be mordanted by boiling for 5 minutes in a tannic acid solution. It should then stand for a few minutes in a solution of tartar emetic. The effect of the mordant may be studied by boiling the mordanted and unmordanted pieces of cotton and silk in alizarin solution for a few minutes, after which they are rinsed and dried.

(c) *Basic dyes.* Show the use of basic dyes using malachite green. Boil samples of mordanted and unmordanted cotton and mordanted and unmordanted silk in a solution of malachite green (or methylene blue) for 5 minutes. They are then rinsed and dried. The malachite green solution is made by dissolving 1 g of dye in 200 g of water. Two hundred grams of water are acidified with acetic acid. Forty grams of the dye solution are added to the acidified water.

(d) *Ingrain or developed dyes.* The development in the fibres of colours known as ingrain or developed dyes requires the use of three solutions. The first consists of 0.1 g of primuline and 0.1 g of $NaHCO_3$ (sodium bicarbonate) dissolved in 100 ml of water. Boil a strip of unsized cotton in this solution for 1 minute, then transfer it to the second solution. This solution is made by adding 0.5 g of $NaNO_2$ (sodium nitrite) and 3 ml of HCl to 100 ml of water. The strip is permitted to remain in this bath for 15 minutes and is then transferred to the developing bath. The developing bath is made by dissolving 0.05 g of NaOH (sodium hydroxide) and 0.05 g of phenol in 100 ml of water. (Instead of phenol, alpha naphthol or resorcinol may be used.) The solution should be kept warm and the cloth allowed to remain in it for 20 minutes, after which it is rinsed and dried. The results of various types of dyeing may be studied for quality.

33 Making matches

Make small splints of wood or use matchsticks from which the heads have been cut before they are used. The ends of these sticks are dipped in melted paraffin wax. A mixture of 2 g of powdered $KClO_3$ (potassium chlorate) and 1 g of red Sb_2S_3 (antimony trisulphide) is made. *Do not grind.* The two solids should be mixed with the fingers. A thin mucilage is added to make a paste. The paraffined end of the matchstick is dipped in this mixture, and it is hung head down to harden for a day. A surface for igniting the matches is prepared by adding mucilage to equal volumes of red phosphorus and fine white sand. This is spread on a cardboard or wooden surface and permitted to dry. The matches ignite when rubbed on this surface.

The matches so prepared should be compared with commercially-made safety matches and with those that are not of the safety variety.

34 Chemical 'flower gardens'

Chemical 'flower gardens' are the result of osmotic action. A water glass (sodium silicate) solution of specific gravity of 1.1 is desirable. Into 400 ml of this solution in a beaker are dropped pieces of the sulphates of copper, iron, nickel and aluminium; the chlorides of copper and iron; and the nitrates of copper, iron, cobalt, nickel and calcium. From these pieces the 'flowers' grow rapidly. The silicates form membranous sacs which have a high concentration on the inside, thus promoting the rapid growth of the sac.

35 Winding a spiral spring

Phosphor bronze or steel wire (SWG 26) is suitable for an average spring. Choose a nail 15 cm long and clamp the point in the jaws of a hand drill. Trap the end of the wire in the jaws also. Fix the drill horizontally in a vice. Turn the handle of the drill, and pull hard on the free wire, using a piece of cloth or a leather glove to protect your hand. When you have made the spring as long as you need, use a pair of pliers to bend the free end round the nail, and cut the wire. The wire will uncoil a little, but this does not matter. Release the wire from the jaws of the drill, cut off the ends of the spring so formed and remove the nail. Using pliers, grip the two end turns of the spring together and bend them at right angles to form a loop. Repeat this at the other end of the spring.

CHAPTER XIX

Some new tendencies in science teaching

Science has been taught in schools for approximately a hundred years. It began as natural philosophy, and by about fifty years ago had settled down to become a course of scientific knowledge which was mainly factual and descriptive. During the last few years the science programmes of many countries have been under scrutiny. The rapid progress of scientific knowledge during this century has brought with it many new concepts, and a new unity of ideas. The manner as well as the matter of science has changed: individual research has been replaced by team work; new techniques have appeared, and the apparatus in use has become much more elaborate. The science taught in schools has become divorced from everyday life, and many teachers have begun to feel that it is no longer sufficient to teach the science of even a generation ago, but that matter should be included in the courses which is more relevant to a modern age. There is nothing essentially new in this—sooner or later the skills and achievements of society have always been reflected in the curriculum of the schools. But the great advances that have been made in science and mathematics, and in the associated technology, seem to have outstripped the progress of educational theory and practice.

For this reason, many countries are rethinking their educational programmes, and because physics is the most advanced of the sciences, and possibly produces the most far-reaching effects on human life, it is this subject which has received first consideration. The conclusions reached bear equally on the other science subjects, but in what follows physics will be stressed because in this subject some complete syllabuses and schemes have been worked out and tried as pilot schemes. In a short survey it is not possible to give in detail the educational schemes of different countries, and in what follows the emphasis is on the principles involved in the construction of the courses. Mention will be made of the work done by the Physical Sciences Study Committee in the United States of America, by the Science Masters' Association in the United Kingdom, and by the International Union of Pure and Applied Physics, and a brief note is added on physics teaching in the Union of Soviet Socialist Republics.

The work of the Physical Sciences Study Committee

The Physical Sciences Study Committee is a group of university and secondary school physics teachers, who undertook in 1956 the task of developing an improved physics course for American secondary schools. Its work has been administered by Educational Services Incorporated, a non-profit making corporation. It has stimulated a general movement in the United States to improve secondary school science education; similar groups are now working in the areas of biology, chemistry and mathematics.

A critical examination of school textbooks, apparatus, visual aids and library material revealed the following deficiencies:

1. Textbooks in general reflected a scientific outlook which dated back half a century, and was no longer representative of the views of the scientific community.
2. Genuine attempts to remain abreast of scientific developments had given even the best textbooks a patchwork quality in which the unity of the subject had disappeared. The sheer mass of the material had become unreasonably great.
3. With the increasing application of science to everyday life the books had become further overloaded by more and more attention to technology.
4. The laboratory manuals suffered the same defects.
5. The potentialities of audio-visual aids were not being adequately exploited.

It was then decided to formulate a new physics course in which the unity of the subject would be preserved, and modern ideas would fall naturally into place. This has now been embodied in a textbook entitled *PSSC Physics.* Naturally, this book is designed to fit the educational schemes of the United States, and in fact is intended to be a one-year course for the last year of the secondary school. But the outline of the syllabus, the ingenious experiments which have been incorporated in the laboratory manual, and the supporting films and library books are of interest to teachers in all countries.

The syllabus divides naturally into four parts. The first is an introduction to time, space, matter and motion. The second includes optics and waves. A particle model of light is developed to explain wave behaviour. When the particle model is found inadequate, a kinematic picture of wave behaviour is introduced as an alternative. In the third part, mechanics is presented through the dynamics of Galileo and Newton, leading to a study of momentum, energy, and the conservation laws. The fourth part begins with an introduction to electricity and magnetism, and the behaviour of particles in fields. Discovery of the photoelectric effect leads back once more to a more subtle consideration of the nature of light. The synthesis of wave behaviour and particle mechanics in a description of the atom bring the course to a conclusion.

In close relation to the ideas developed in the textbook, a laboratory programme was then conceived; in this the following considerations were used as a guide:

1 Experiments should be true experiments, and not routine accumulation of data to agree with a result well known in advance.
2 They should be performed with simple apparatus that can be quickly assembled by the student.
3 They should encourage further work along suggested lines, and should lead to the consideration of theoretical ideas growing from the experiment, and be guided by those already mentioned in the textbook.

It was originally the intention of the committee to develop laboratory apparatus of a type which could be constructed by the teachers and students themselves, but it was soon discovered that although there would be obvious advantages in this, the burden on the teachers would be too great. The apparatus described in the laboratory manual is now manufactured commercially to designs which have made it possible to set the commercial price at a minimum.

Visual aids were then considered, and an examination of the many educational films available showed that there were few which in manner and content furthered the ideas outlined in the textbook. Accordingly, a new set of about sixty films was planned. The intention of these films is: (a) to ease the load on the teacher; (b) to provide visual presentation of operations too difficult to carry out in the laboratory or to show by demonstration experiments; (c) to present a new subject, or to summarize and integrate a field of study; (d) to show, where possible, real scientists at work in real situations, and speaking directly to the students.

A further activity of the committee has been the production of a set of paperback books about science and scientists. Their primary purpose is to take the load off the textbook, leaving it free for the elucidation of general principles. Sixty books are at present envisaged, which will provide a survey of physics within the grasp of those following the main course. Some tell of the role of physics in the service of man, others are biographical in nature and tell the stories of discoverers and their great discoveries. It is hoped, too, that besides supplementing the course, they may be comprehensible to the layman, and perhaps help to bridge the gap between the science and arts student.

Trials of the course outlined above showed that some teachers would find a guide to the textbook helpful. The final effort of the committee was therefore to produce a set of teachers' notes for this purpose, including solutions to the problems in the text, and suggestions for teaching the subject. This comprehensive guide is now available, and will prove invaluable to all attempting to adopt the course, or to adapt it to their own special needs.

Further information

The Physical Science Study Committee is interested in rendering whatever services may be of use to those individuals and schools who wish to know exactly what the new course is, and how it has come into being in its present form. Such information, as well as advice on the present status of foreign translations and adaptations, may be obtained from:

Physical Science Study Committee, Educational Services Incorporated, 164 Main Street, Watertown 72, Mass.

Copies of the textbook and laboratory guide and teacher's guide may be obtained from:

D. C. Heath and Co., 285 Columbus Avenue, Boston 16, Mass.

A catalogue of the laboratory apparatus may be obtained from:

Macalaster-Bicknell Co., 253 Norfolk Street, Cambridge 39, Mass.

A film catalogue, and information on previewing the films, may be obtained from:

Modern Talking Picture Service, Inc., 3 East 54th Street, New York 22, N.Y.

The Science Study Series—a library of paperback books for outside reading in fields related to the PSSC course—may be obtained from:

Doubleday and Company, Inc., 575 Madison Avenue, New York 22, N.Y.

Up to the present time, arrangements have been completed for the translation of the Science Study Series into Arabic, Bengali, Dutch, Finnish, German, Indonesian, Italian, Japanese, Persian, Polish, Spanish, Swedish and Urdu, and for the publication of the series in the British Commonwealth.

References

Modern high school physics: A recommended course of study. Bureau of Publications, Teachers' College, Columbia University, New York, N.Y.

Science in your school. American Association of Science Teachers.

Education for an age of science, by President Eisenhower's Science Advisory Committee. United States Information Service, 1959.

International education in physics, by Brown and Clark. John Wiley and Sons, 440 Park Avenue S., New York 16, N.Y.

The work of the Science Masters' Association and the Association of Women Science Teachers in the United Kingdom

In 1957, motivated by the considerations mentioned earlier, the above associations issued a policy statement on science teaching in schools. Subject panels later compiled syllabuses for the biological, chemical and physical parts of the science course below the sixth forms, as well as for the specialist teaching which follows.

The general recommendations were that science should be the 'core' subject in grammar schools in much the same way for example as English and mathematics are at present, and as classics used to be. Believing that all students should study science up to the fifth form years, and that all specialists should study some science, the authors of the statement laid down the following principles. Teaching should be divided into three phases: an introductory phase covering the first two years, an intermediate phase up to about sixteen years of age, and an advanced phase to include some specialization.

In 1960 the committee issued syllabuses for physics, chemistry and biology covering these three phases. To make it possible to include material more closely connected with modern life, difficult concepts, ideas and numerical problems on energy, magnetism, and certain aspects of heat and light were omitted from the early and intermediate phases of the physics course. The criterion for the inclusion of any item at the advanced phase was, 'Is it fundamental to physics today?' Subjects more properly included under the heading of applied physics or technology have also been excluded. These have been replaced by substantive sections on mechanics, the understanding of which is so essential and fundamental to an appreciation of modern physics. The same general principles have been applied to chemistry. Although it can be claimed that the teaching of chemistry in British schools has at its best been as good as any in the world, some modifications are necessary to meet the new situation. The past syllabuses have been too heavily weighted with facts, preparation, and details of procedure.

The general plan of the early stages in chemistry, it is suggested, should be visualized as a series of empirical investigations, with the emphasis on experimentation and observation. Speculations in the light of ascertained facts will then arise, and opportunities will be provided for the invention of simple theories. These in turn will lead to new theories and the discovery of new facts. In the second phase, it is suggested that the pupil should learn to appreciate the nature of scientific laws, the inter-relationship between facts and theories, and the intimate relation between matter and electricity. Some ideas, too, should be formed concerning the need to assume a particle structure of atoms when considering the reactions in which matter takes part, as well as the factors which can affect chemical reactions in general. On the sound basis of the first two phases of teaching, it should now be possible to discuss the material basis of chemistry, types of materials and changes, and their full explanation in terms of molecules and ions.

The committee, reviewing the teaching of biology, emphasized that this term implies not a single science, but a whole group of sciences. It was further realized that biology can be used to unite all the sciences, and to link them with psychology, the social sciences, and with history and the arts. To achieve this linking effect, biology should be centred on the study of whole organisms, and not on anatomical, physiological, cytological or biochemical abstractions.

In the introductory and intermediate phases biology should be part of an introduction to science as a whole. Personal observations on live organisms should be made, and prominence given to practical work. The organisms studied should be selected from easily available local flora and fauna, and simple habitat studies are eminently suitable. Nutrition and respiration can be studied as parts of wider science topics with physical, chemical and biological aspects. At the intermediate phase an advance should be made in greater depth and on a narrower front than at the introductory phase. A further suggestion was that a syllabus based. on that of the ordinary level of the Cambridge Local Examinations Syndicate meets the above requirements, and contains more useful suggestions to teachers than many of the other syllabuses. The syllabus at the advanced stage grows out of that of the earlier phases. Sixth formers approach the subject with more mature minds: more advanced practical work is possible. Individual dissections of animals can take the place of the previous demonstrations. The staining and mounting of some microscopical preparations can also be undertaken. Teachers can develop particular sections according to their own outlook and interests, and to the local conditions, especially as regards field work. The syllabus would therefore include further study of the mammal and of flowering plants; a variety of patterns of life; elementary ecology, and a number of general biological topics under the general title of 'The nature, continuance and diversification of life'.

The work of all these planning committees is not complete, but the suggestions outlined have been embodied in detailed syllabuses published by the associations. The great freedom allowed to British teachers allows them to be interpreted in many different ways. Pilot schemes are in operation in the schools, and in the next few years much will be learnt of how best to achieve the desired objectives.

Publications

The following publications of the Science Masters' Association and the Association of Women Science Teachers are obtainable at 2s. each from the Librarian, Science Masters' Association, 52 Bateman Street, Cambridge:
A policy statement on science education.
Physics for grammar schools.
Chemistry for grammar schools.
Biology for grammar schools.

The work of the International Union of Pure and Applied Physics

In July 1960 an international conference on physics teaching took place in Paris. It was sponsored by the Organization for European Economic Co-operation (now OECD), Unesco and the International Union of Pure and Applied Physics, and was part of a wider study of the teaching of science, mathematics and chemistry being undertaken by OEEC. Delegates from the Netherlands, Switzerland, Italy, Denmark, France, the United States of America, Japan, Poland, Germany and the United Kingdom considered topics including examinations, laboratory work, the training of teachers, and the use of films and television in science teaching. They further considered the defects of the present systems, the approach to the teaching of physics and the supply of physics teachers.

The diversity of conditions and facilities in the various countries made it very difficult to arrive at general conclusions. Some countries were inevitably criticised for over-emphasizing the theoretical aspects of the subject, and others for the inclusion of too much practical work. But all were agreed that drastic changes in the method and content of physics teaching were necessary. General agreement was however found in an agreed syllabus, and suggestions were made for its implementation. These are to be found in a full report of the conference. This is now published under the title *International Education in Physics*, John Wiley and Sons Inc., 440 Park Avenue S., New York 16, N.Y.

Science teaching in the Union of Soviet Socialist Republics

The revision of the science teaching programme in the Soviet Union began as early as 1919, when a State Council was set up to provide, amongst other things, general and methodological guidance and curricula for the higher schools. In 1921 a further special commission declared the aim of the Soviet high schools, and set up schemes for the training of scientists and teachers.

But the greatest step forward was made in 1957, when the regulations of the Ministry of Education required all scientists in post-graduate training to study pedagogics, psychology, logic, and methods of teaching special subjects, as well as the skill of conducting classes. This resulted in a great increase in the numbers of scientists available for teaching.

The Academy of Pedagogical Science set up in 1943 has rendered great help to the teachers. It provides information on new teaching methods, and promotes constructive co-operation between teachers and educational authorities, and furthers the production of textbooks. It is also responsible for the syllabuses and supply of apparatus, as well as for the textbooks to be used. The syllabus thus includes a full list of the demonstration experiments to be shown, the topics to be discussed, the films to be shown, and the expeditions and factory visits to be made. Regional training institutes set up in all areas supplement the work in the academy by organizing courses, lectures and seminars.

Education is now compulsory from 7 to 18 years of age, and all pupils have the same basic course for the first eight years. The schools are co-educational, and classes must not exceed 30 in number, though more usually they do not exceed 24. There is no 'streaming'; all pupils go through this same basic course. For the last three years the pupils proceed to a type of school suited to their abilities.

Biology is the first science to be taught, but in the last three years gives way to physics. The syllabus here includes advanced work on atomic structure; nuclear energy; isotopes; the physics of light; supersonics; the photoelectric effect, semi-conductors, as well as work on three-phase alternating current. There is a great emphasis on practical work by the students, and also on good demonstration experiments. Most schools possess an oscilloscope and the necessary apparatus for teaching alternating current. As mentioned, the apparatus is supplied by the academy, and is thus of a type most suitable for the purpose.

The syllabus outlined is only a minimum; sufficient time is allowed for individual teachers to follow their own ideas. The intention of the syllabus, the suggestions and the provision of apparatus is merely to ensure that all pupils are adequately taught, even by the less gifted teachers.

This brief outline shows what consistent effort, immense energy and resources have been directed towards science teaching during the last 40 years. The result is seen in the outstanding position of Soviet science today.

References

The training of scientists in the Soviet Union, by G. Galkin (1959).

Education in the USSR, by M. I. Kondakov (1961).

APPENDIX A

BOOKS FROM A SCIENCE MASTER'S LIBRARY

France

Anatomie végétale, by Bourceau. 3 volumes, Presses Universitaires de France.
Biologie végétale, by Cannefort and Paniel. Doin
Cours de physique générale, by Bruhat. 4 volumes, Masson.
Cours de physique, by Lemoine and Guyot. 5 volumes, Bordas.
Cours de physique, by Moussa and Ponsonnet. 2 volumes, Desvignes.
Cours de physique, by Faivre, Dupaigre and Lamirand. 3 volumes, Masson.
Chimie générale, by Rumeau and Gallais. Delagrave.
Chimie générale, by Pascal. 4 volumes, Masson.
Cours de chimie, by Lamirand, Brunold and Pariselle. 4 volumes, Masson.
Chimie propédeutique, by Lombard. Gauthier-Villars.
Encyclopédie française: tome II: Physique, by Dubois. Larousse.
Flore complète, 120 fascicules et table, by Bonnier. Orlhac.
Géologie générale et pétrographie, by Theobald and Gama. Doin.
Manuel de paléontologie animale. Masson.
Manuel de paléontologie végétale. Masson.
Minéraux et les roches (*Les*), by Buttgenbach. Dunod.
Monde vivant (*Le*), by Gautière. 3 volumes, Béranger.
Morphologie et physiologie animales, by Bresse. Larousse.
Nouveau traité de chimie minérale. 10 volumes parus, Masson.
Paléontologie, by Theobald and Gama. Doin.
Physique générale et experimentale, by Fleury and Mathieu. 6 volumes, Eyrolles.
Physique de base, by Llibantry. Masson.
Précis de biologie animale: PCB-Licence, by Aron and Grasse. Masson.
Précis de biologie végétale: PCB, by Guilliermond and Mangenot. Masson.
Précis de géologie, by Moret. Masson.
Précis de minéralogie, by Lapadu and Hargues. Masson.
Principes de géologie, by Fourmarier. 2 volumes, Masson.
Tableaux des minéraux des roches, by Christophe, Michel and Lévy. Éditions du CNRS.
Technique générale du laboratoire de physique, by Surugue. 3 volumes, Éditions du CNRS.
Traité de botanique (*systématique*), by Chadefaud and Emberger. 2 volumes, Masson.

Union of Soviet Socialist Republics

The following books in English are obtainable from Foreign Languages Publishing House, 21 Zubovsky Boulevard, Moscow:
Archaeology in the USSR, by Mongait. £2 5s. (Survey ranging from Stone-Age Russia to the Middle Ages.)
Astronomy for entertainment, by Perelman. 7s. 6d.
Bees, by Khalifman. 7s. 6d. (Complete guide to bees and bee-keeping.)
Celestial mechanics, by Ryabov. 7s. (Simplified explanation of the calculation of the movements of the heavenly bodies and earth satellites.)
Cerebal cortex and the internal organs (*The*), by Bykov. £1 1s.
Control of communicable diseases in the USSR, by Zhdanov. 1s. 3d.
Cosmic rays, by Zhdanov. 6s.
Fundamentals of geology, by Obruchev. 12s. 6d.
General chemistry: a text book, by Glinka. 4s. 6d.

Geochemistry for everyone, by Fersman. 12s. 6d.
Life of the plant (The), by Timiryazev. 7s. 6d.
Origin of man (The), by Nesturkh. £1 10s.
Pavlov: his life and work, by Asratyn. 3s. 6d.
Pavlov: selected works. 10s. 6d.
Sea bed (The), by Zenkovich. 4s. 6d.
Sun (The), by Severney. 6s.
Textbook of physiology, by Bykov. £2 5s.
Theoretical physics, by Kompanyets. £1 17s. 6d.
Theory of the origin of the earth (A), by Schmidt. 4s. 6d.
Training of scientists in the Soviet Union (The), by Galkin. 6s.
Universe (The), by Oparin and Fesenkov. £1 17s. 6d. (Examination of the possibility of life in neighbouring planets and throughout the universe.)

United Kingdom

Alternating currents, by Dance, Savage and Ghey. John Murray. (Modern Science Memoirs.)
Atom and its energy (The), by Andrade. Nelson.
Dictionary of physics, by Gray. Longmans, Green.
Dictionary of science, by Uvarov and Chapman. Penguin Books.
Introduction to laboratory techniques, by Ansley. Macmillan.
Lecture experiments in chemistry, by Fowles. Bell.
Rural science and school gardening, by Hilton. Batsford.
School experiments with alternating current, by Pearce. Bell.
School laboratory management, by Sutcliffe. John Murray.
Science books for the school library. Science Masters' Association. (Supplements are issued with the *School science review* and are available from the librarian, price 6d. each.)
Science data, by Friend. Griffin.
Science master's book (The). (Experiments selected from the *School science review*.)
- Series I
  - Part I *Physics*.
  - Part II *Chemistry and biology*.
- Series II
  - Part I *Physics*.
  - Part II *Chemistry and biology*.
- Series III
  - Part I *Physics*.
  - Part II *Chemistry*.
  - Part III *Biology*.
  - Part IV *Experiments for the modern school*.
- Series IV
  - Part I *Physics*.

Secondary modern science teaching. Parts I and II, by John Murray.
Simple experiments in biology, by Bibby. Heinemann.
Simple experiments with insects, by Kalmus. Heinemann.
Tables of physical and chemical constants, by Kaye and Laby. Longmans, Green.
Teaching of astronomy in schools (The), by Beet. Cambridge University Press.
Teaching and learning of biology in secondary schools (The), by Green. Allman.
Teaching chemistry, by White. University of London Press.
Teaching of chemistry (The), by Newbury. Heinemann.
Teaching of colour in elementary science courses (The), by Savage. John Murray. (Modern Science Memoirs.)
Teaching of science in secondary schools (The). John Murray.
Teaching science to the ordinary pupil, by Laybourn and Bailey. University of London Press.

The following titles appear in the series of Unesco handbooks on the teaching of science in tropical countries:

Teaching of science in tropical primary schools (The), by Joseph. Oxford University Press.

Teaching of physics in tropical secondary schools (The), by Boulind. Oxford University Press.
Teaching of chemistry in tropical secondary schools (The), by Newbury. Oxford University Press.

United States of America

Animals without backbones, by Buchsbaum. University of Chicago Press.
Biology investigations, by Oho, Blanc and Towle. Henry Holt and Co.
Chemistry, by Sienko and Plane. McGraw Hill Book Co.
College zoology, by Hegner and Stiles. Macmillan.
Condensed chemical dictionary, by Rose and Rose. Reinhold Publishing Co.
Demonstration experiments in physics, by Sutton. McGraw Hill Book Co.
Fundamentals of microbiology, by Frobisher. W. B. Saunders Co.
General chemistry, by Pauling. W. L. Freeman and Co.
Handbook of chemistry and physics. 42nd edition. Chemical Rubber Co.
Introduction to concepts and theories of physical science, by Holton. Addison-Wesley Publishing Co.
Laboratory and field studies in biology, by Lawson. Holt, Rinehart and Winston.
Laboratory exercises in animal biology, by Braungart. C. V. Mosby Co.
Laboratory introduction to chemistry, by Weaver and Weaver. McGraw Hill Book Co.
Machinery of the body, by Carlsen, Apton and Johnson. University of Chicago Press.
Matter and light, by L. de Broglie. Dover.
Organic chemistry, by Morrison and Boyd. Allyn and Bacon.
Physical chemistry, by Daniels and Alberty. John Wiley and Sons.
Physics, by the Physical Sciences Study Committee. Educational Services Inc.
Physics in your school, by the American Institute of Physics. McGraw Hill Book Co.
Plant physiology, by Meyer and Anderson. Van Nostrand Co.
Plant world (The), by Fuller. Holt, Reinhart and Winston.
Saturday science, by Blumle. E. P. Dutton and Co.
Science education for the elementary school teacher, by Tannheim. Ginn and Co.
Science teaching in secondary schools, by Richardson. Prentice-Hall.
'Scientific American' book of projects for the amateur scientist, by Strong. Simon and Shuster.
Scientific experiments in chemistry, by De Bruyne, Kirk and Beers. Henry Holt Co.
Semi-micro chemistry, by De Bruyne, Kirk and Beers. Henry Holt Co.
Source book for biological science, by Marholt, Evelyn and others. Harcourt Brace.
Source book for physical science, by Moreholt. Harcourt, Brace and World.
Textbook of physiology, by Zoethout and Tuttle. C. V. Mosby Co.
Universe and Dr. Einstein (The), by Barnett. New American.
Van Nostrand's scientific encyclopedia. D. Van Nostrand Co.

APPENDIX B

PERIODICALS FOR SCIENCE TEACHING AND SCIENCE CLUB LIBRARIES

Australia

Australian journal of science, six issues per year, 25s. The Australian and New Zealand Association for the Advancement of Science, Science House, 157 Gloucester Street, Sydney.

Australian science teachers' journal, 1s. per issue. 156 Pelham Street, Melbourne, N.3.

Science education news. Science Teachers' Association of New South Wales, Box 3328 PP, GPO Sydney.

Science Teachers' Association of Queensland's newsletter. Mr. F. T. Barrell, The Cavendish Road High School, Holland Park, Brisbane.

Austria

Natur und Technik, monthly. Wien VII. Burggasse 28-32.

Der Osterreichische Schulfunk, monthly. Prof. Franz Gregora, Wien IV, Argentinierstrasse (Funkhaus).

Universum Natur und Technik, fortnightly, DM 0.90 per copy. R. Spies and Co., Wien V, Straussengasse 16.

Belgium

Bulletin, International Union for the Conservation of Nature and Natural Resources, 31 rue Vautier, Brussels.

Ciel et terre, 25 frs per copy. Av. Circulaire 3, Uccle, Brussels.

Dia-Revue: enseignement et vulgarisation des sciences par la diapositive et la photo, bimonthly. 125 Belgian francs per annum, 17 Belle-Voie, Wavre.

Brazil

Matemática, Técnica e Ciêcia, monthly. Praia de Botafogo 244-A, 1º ander-Rio de Janeiro.

Canada

Canadian nature, bimonthly, 35 cents per copy. Audubon Society of Canada, 177 Jarvis Street, Toronto 2, Ontario.

Ceylon

Young scientist, 3 issues, Rs. 1.90 Gotami Rd., Colombo 8.

Czechoslovakia

Ochrana Prirody (nature study), bimonthly, 48 Kcs. Praha II, Ostrovini ul c 30.

Denmark

Naturviden-Ungdommens naturvidenskabelige forening, Denmarks tekniske Hojskole, Oster Voldgade 10 N, Kobenhavn K.

Finland

Maatalouskerho-neuvoja (4-H Club), Bulevadi 28, Helsinki.
Molekyyli, Postilokero 252, Helsinki.

France

Air et l'espace (L'), monthly, year's subscription 27 NF; 2.50 NF per copy. 51, avenue des Ternes, Paris-17e.
Atomes, monthly, year's subscription 21 NF; 1.80 NF per copy. 4, place de l'Odéon, Paris-6e.
Bulletin du Musée national d'histoire naturelle, bimonthly, year's subscription 20 NF; 2.50 NF per copy. 57, rue Cuvier, Paris-5e.
Électricien, monthly, year's subscription 18 NF; 1.80 NF per copy. Librairie Dunod, 92, rue Bonaparte, Paris-6e.
Énergie nucléaire, monthly, year's subscription 53 NF. 28, rue Saint-Dominique, Paris-7e.
Enseignement des sciences, five issues per year, year's subscription 12 NF. Librairie Hermann, 115, boulevard Saint-Germain, Paris-6e.
Humanités scientifiques, monthly, year's subscription 22 NF. Librairie Hatier, 59, boulevard Raspail, Paris-6e.
Information scientifique, monthly, year's subscription 19 NF. Librairie Baillière, 19, rue Hautefeuille, Paris-6e.
Ingénieurs et techniciens, monthly, year's subscription 25 NF; 2.50 NF per copy. 30, rue Tronchet, Paris-9e.
Naturalia, monthly, year's subscription 25 NF; 2 NF per copy. 122, rue des Rosiers, Saint-Ouen (Seine).
Mathématiques élémentaires, monthly, year's subscription 10 NF. Librairie Vuibert, 63, boulevard Saint-Germain, Paris-5e.
Nature (La), monthly, year's subscription 33 NF; 2.80 NF per copy. 92, rue Bonaparte, Paris-6e.
Nucleus, monthly, year's subscription 45 NF. Librairie Dunod, 92, rue Bonaparte, Paris-6e.
Oiseaux de France, quarterly, 2 NF per copy. 129, boulevard Saint-Germain, Paris-6e.
Radio et TV, monthly, year's subscription 17 NF; 1.80 NF per copy. Éditions Chiron, 40, rue de Seine, Paris-6e.
Revue du son (Arts et techniques sonores), 2.50 NF per copy. Éditions Chiron, 40, rue de Seine, Paris-6e.
Science et nature, bimonthly, year's subscription 18 NF; 2.80 NF per copy. 12 *bis*, place Henri-Bergson, Paris-8e.
Sciences et avenir, monthly, year's subscription 18 NF; 1.50 NF per copy. 14, rue de la Baume, Paris-8e.
Terre des jeunes, monthly, year's subscription 9 NF; 0.70 NF per copy. 5, rue Palatine, Paris-6e.

Federal Republic of Germany

Deutscher Jugendbund für Naturbeobachtung, Hamburg, Volksdorf, Wiesenhöfen 7.
Hobby, Das Magazin der Technik, Stuttgart-W, Paulinenstr. 44.
Kosmos, Monatsschrift für Naturfreunde, Stuttgart-O, Pfizerstr. 5/7.
Lupe, Dieter Koenig, Premervörde, Zevenerstr. 3.
Naturwissenschaftliche Rundschau, quarterly, DM 4.80, Stuttgart, Tübingen Str. 53.
Orion, Naturwissenschaftliche Zeitschrift für jedermann, Murnau/München, Seidlpark.
Schulfunk, Hessischer Rundfunk, monthly, Prof. Gottfried Hausmann, Frankfurt am Main, Liebfrauenberg 37.
Die Umschau in Wissenschaft und Technik, fortnightly, DM 42, Frankfurt am Main, Stuttgarter Str. 20/22.

Ghana

Bulletin of the Ghana Association of Science Teachers, J. K. Lamptey (Editor), Fijai Secondary School, Sekondi.

Indonesia

Mimbar teruma, monthly, Djl. Karangtinggal 23, Pos Hegarmanah, Bandung.

Pengantar pengetahuan, monthly, Jajasan Pendidikan Masjarakat, Djl. Karangtinggal 23 Pos Hegarmanah, Bandung.

Italy

Scienza e lavoro, monthly, 1,500 lire, La Scuola, Brescia.

Japan

Bulletin of the National Science Museum, monthly. Ueno Park, Tokyo.

Netherlands

Amoeba, N.J.N., monthly. Aart van Rossum, Sassenheimstraat 49 I, Amsterdam W.
Hobby club, quarterly, F.5. Van Miereveldstraat 1, Amsterdam Z.
Natuur en Landschap, quarterly, F.5. Herengracht 540, Amsterdam C.

New Zealand

Science review, monthly, 25s. G.P.O. Box 3001, Wellington.

Spain

Aldea—Revista para la juventud del campo, monthly, 2.50 pesetas per copy. Alcala, 44 6°, Madrid.
Matualidades y cotos escolares de previsión, monthly, 2 pesetas per copy. Manuel Silvela 4, Madrid.

Sweden

Fältbiologen, 4 Kr., Riddargatan, Stockholm Ö.

Switzerland

Jeunesse magazine, monthly, 6 frs. Jordils 5, Lausanne.
Jugend Woche, monthly. Jenatschstrasse 4, Zürich 2.
Leben und Umwelt, monthly, 5.20 frs. Oberalpstrasse 13, Basel.
Lehrerzeitung, weekly. Zürich 4, Stauffacherquai 36.

Thailand

Science, monthly, 30 bahts. Science Society of Thailand, Physics Building, Chulalongkorn University, Bangkok.

Union of Soviet Socialist Republics

The following periodicals in Russian are obtainable from Mezhdunarodnaja Kniga, Moscow, G-200, at the annual subscription rate indicated:

Pedagogical

Biology in school, bimonthly, 18s.
Chemistry in school, bimonthly, 18s.
Information bulletin of higher and specialized education, monthly, 18s.
Physics in school, bimonthly, 18s.
School and industry, monthly, £1 2s.
Teacher's gazette, 156 issues per year, £1 5s.

Scientific

Astronomical journal, bimonthly, £5 15s.
Atomic energy, monthly, £5 16s.
Biochemistry, bimonthly, £5.

Biophysics, bimonthly, £4 7s.
Journal of acoustics, quarterly, £2 6s.
Journal of botany, monthly, £10 16s.
Journal of scientific and applied photography and cinematography, bimonthly, £2 14s.
Radio and electronics abstracts, 24 issues per year, £4 13s.

Bulletins of higher schools (*Ministry of Higher and Specialized Secondary Education*)
Colloids, bimonthly, £3 16s.
Crystallography, bimonthly, £5 7s.
Instruments and techniques of experiments, bimonthly, £5 7s.
Physics, bimonthly, £3 16s.
Radiophysics, bimonthly, £3 16s.

Magazines for the young
Science and life, monthly, £1 2s.
Young naturalist, monthly, 12s.
Young technician, monthly, £1 7s. (With supplement *For skilful hands*.)

United Kingdom

Advancement of science, quarterly, 7s. 6d. per copy. British Association, 18 John Adam Street, London, W.C.2.
Aeromodeller, monthly, 2s. per copy. Argus Press, 8-10 Temple Avenue, London, E.C.4.
Atom, monthly. Information bulletin of the UK Atomic Energy Authority, 11 Charles II Street, London, S.W.1.
Bird notes, quarterly, 2s. per copy. 25 Eccleston Square, London, S.W.1. (Journal of the Royal Society for the Protection of Birds.)
British trade alphabet, yearly. Lofthouse, Wakefield, Yorkshire.
Bulletin of amateur entomologists, monthly, 1s. 3d. per copy. 3 Salcombe Drive, Morden, Surrey.
Contemporary physics, bimonthly, 5s. per copy. Taylor and Francis, Red Lion Court, London, E.C.4.
Discovery, monthly, 2s.6d. per copy. Jarrold and Sons, Norwich.
Endeavour, quarterly. Imperial Chemical Industries, Millbank, London, S.W.1.
Farming, monthly, year's subscription, 19s. Jarrold and Sons, Norwich.
Journal of the East Kent Science Teachers' Association, 1s. 3d. (post free). Miss C. E. Groves, Glebe Corner Cottage, St. Martin's Hill, Canterbury.
Journal of the Royal Society of Arts, monthly, 5s. per copy. 6 John Adam Street, London, W.C.2.
London science teacher, quarterly, 2s. 6d. per copy. H. E. Knock, Esq., 17 Salcombe Gardens, North Side, London, S.W.4. (Journal of the London Science Teachers' Association.)
Meccano magazine, monthly, 1s. per copy. Meccano, Binns Rd., Liverpool, 13.
Model aircraft, weekly, 1s. 6d. per copy. Percival Marshall, 19-20 Noels Street, London, W.1.
Model engineer, weekly, 1s. per copy. Percival Marshall, 19-20 Noels Street, London, W.1.
Mond magazine, monthly. The Mond Nickel Co., Thames House, Millbank, London, S.W.1.
Model railway news, monthly, 2s. per copy. Percival Marshall, 19-20 Noels Street, London, W.1.
Nature, weekly, 2s. 6d. per copy. Macmillan and Co., St. Martin's Lane, London, W.C.2.
New era in home and school, year's subscription (10 issues), £1. 1 Park Crescent, London, W.1.
New scientist, weekly, 1s. per copy. Cromwell House, Fulwood Place, High Holborn, London, W.C.1.
Observatory. Royal Observatory, Greenwich, London, S.E.10.
Practical mechanics, monthly, 1s. 6d. per copy. George Newnes, Tower House, Southampton Street, London, W.C.2.
Practical wireless, monthly, 1s. per copy. George Newnes, Tower House, Southampton Street, London, W.C.2.
Proceedings of the Royal Institute, quarterly, 8s. 6d. per copy. 21 Albemarle Street, London, W.1.
Railway magazine, bimonthly, 2s. 6d. per copy. 33 Tothill Street, London, S.W.1.
School nature study, quarterly, 3s. 6d. per copy. 5 Dartmouth Chambers, Theobalds Road, London, W.C.1.
School nature study union, 1s. per copy. 23 Crystal Palace Road, East Dulwich, London, S.E.22.

School science review, 3 issues per year, 12s. 6d. per copy. 52 Bateman Street, Cambridge.

Science club, fortnightly, year's subscription £1 2s. 6d. Junior Clubs Publications, 5 St. James Street, London, W.C.1.

Science Museum bulletin. Science Museum, South Kensington, London, S.W.7.

Scientific film, bimonthly, 3s. 6d. per copy. 55a Welbeck Street, London, W.1. (Journal of the Scientific Films Association.)

Science progress, quarterly, year's subscription £2 12s. Edward Arnold, 41 Maddox Street, London, W.C.1.

Science teacher, fortnightly, year's subscription 5s. Junior Clubs Publications, 5 St. James Street, London, W.C.1.

Short wave magazine, monthly, year's subscription £1 13s. 55 Victoria Street, London, S.W.1.

Space flight, monthly, 3s. 6d. per copy. 3 Cork Street, London, W.1.

Technology, weekly, 1s. per copy. The Times, Printing House Square, London, E.C.4.

Times science review, quarterly, 1s. per copy. The Times, Printing House Square, London, E.C.4.

Trains illustrated, monthly, 2s. per copy. Ian Allen, Hampton Court, Surrey.

Trees, quarterly, 2s. 6d. per copy. The Men of Trees, Stansted Park Estate Office, Rowlands Castle, Hants.

World science review, 2s. 6d. per copy. 11 Eaton Place, London, S.W.1.

United States of America

American biology teacher, monthly (Oct.-May), $6 (abroad $6.75). National Association of Biology Teachers, P. Webster, Bryan City Schools, Bryan, Ohio, *or* Herman C. Kranzer, College of Education, Temple University, Philadelphia 22, Pa.

American journal of physics, monthly (Sept.-May), $10. American Association of Physics Teachers, American Institute of Physics, 335 East 45th Street, New York 17, N.Y.

Audubon junior membership leaflet. National Audubon Society, 1130 Fifth Avenue, New York 28, N.Y.

Bausch and Lomb focus. Bausch and Lomb, Rochester 2, N.Y.

Bi-weekly newsletter. US National Commission for Unesco, Department of State, Washington 25, D.C.

Chemical and engineering news, weekly, $6 (abroad $20). American Chemical Society, 1155 16th Street, N.W. Washington, D.C.

Film news, bimonthly, $4 (abroad $5). 54 West 40th Street, New York 18, N.Y.

Geographic school bulletins, 30 issues per year, $2 (USA), $2.25 (Canada), $2.50 (elsewhere). National Geographic Society, Washington 6, D.C.

Illinois Junior Academy of Science year book, Illinois State Academy of Science, Donald G. Hopkins, State Chairman of the Junior Academy, Carl Sandburg High School, Orland Park, Ill.

Industrial research newsletter, monthly. Armour Research Foundation of Illinois, Institute of Technology, Technology Center, Chicago 16, Ill.

Journal of chemical education, monthly, $4 (abroad $5). American Chemical Society, Division of Chemical Education, American Chemical Society, 20th and Northampton Streets, Easton, Pa.

Laboratory, Fisher Scientific Co., 711 Forbes Avenue, Pittsburgh 19, Pa.

Metropolitan Detroit science review, quarterly, $2. Metropolitan Detroit Science Club, 14709 Wilfred, Detroit 13, Mich.

Monsanto magazine. 800 North Lindberg Boulevard, St. Louis 66, Mo.

Physics today, monthly, $4 (abroad $5). American Institute of Physics, 335 East 45th Street, New York 17, N.Y.

SCA sponsor handbook, *Science projects handbook*, etc. Science Clubs of America, 1719 N Street, N.W. Washington 6, D.C.

School science and mathematics, monthly (Oct.-June), $6 (abroad $6.50). Central Association of Science and Mathematics Teachers, P.O. Box 108, Bluffton, Ohio. (Journal for all science and mathematics teachers.)

Science, weekly, $8.50. American Association for the Advancement of Science, 1515 Massachusetts Avenue, N.W., Washington 5, D.C.

Science counselor, quarterly. Duquesne University Press, Pittsburgh 19, Pa.

Science digest, monthly, $3.50 (abroad $4.50). 200 East Ontario Street, Chicago 11, Ill.
Science education, 5 issues per year, $5 (abroad $6). National Association for Research in Science Teaching, Council of Elementary Science International, C. M. Pruitt, University of Tampa, Tampa, Fla.
Science newsletter, weekly, $5.50. Science Service, 1719 'N' Street, N.W. Washington 6, D.C. (Weekly summary of current science.)
Science on the march (formerly *Hobbies*), 5 issues per year, year's subscription $1, $0.25 per copy. Buffalo Museum of Science, Humboldt Park, Buffalo 11, N.Y.
Science teacher, 8 issues per year, $6. National Science Teacher's Association, 1201 16th Street, N.W., Washington 6, D.C.
Science world, biweekly, $1.50. Scholastic Magazine, 33 West 42nd Street, New York 36, N.Y.
Scientific American, monthly, $6. 415 Madison Avenue, New York 17, N.Y.
Sky and telescope, monthly, $5 (abroad $7). Sky Publishing Corporation, Harvard College Observatory, Cambridge 38, Mass.
Sponsor's guide book, $5 (inc. annual supplement services). Future Scientists of America, NSTA, 1201 Sixteenth Street, N.W., Washington 6, D.C.
Weatherwise, bimonthly, $4. American Meteorological Society, 45 Beacom Street, Boston 8, Mass.
Welch. 1515 Sedgwick Street, Chicago 10, Ill.

Unesco[1]

Education abstracts, monthly, year's subscription $2 *or* 10s. *or* 6 NF; $0.25 *or* 1s. 3d. *or* 0.75 NF per copy.
Impact of science on society, quarterly, year's subscription $1.75 *or* 9s. 6d. *or* 4.50 NF; $0.50 *or* 2s. 6d. *or* 1.25 NF per copy.
International journal of adult and youth education (formerly *Fundamental and adult education*), quarterly, year's subscription $1.50 *or* 7s. 6d. *or* 4.50 NF; $0.50 *or* 2s. 3d. *or* 1.25 NF per copy.
Museum, quarterly, year's subscription $6.50 *or* £1 12s. 6d. *or* 20 NF; $2 *or* 10s. *or* 6 NF per copy.
Unesco Courier, monthly, year's subscription $3 *or* 10s. *or* 7 NF; $0.30 *or* 1s. *or* 0.70 NF per copy.

1. Place de Fontenoy, Paris-7e. France. Copies may also be obtained in most countries from Unesco's national distributors.

APPENDIX C

ROCKS AND MINERALS

A *mineral* is a natural inorganic[1] substance, having a nearly constant chemical composition and fairly definite physical characteristics.

An *ore* is a rock or mineral that contains enough of one or more metals to make mining profitable. The amount of metal in ores varies greatly. Some iron and lead ores will run as high as 50 to 75 per cent metal. On the other hand, an ounce of gold per ton of rock is considered good gold ore. Metals rarely occur in their native state. Many valuable ores are oxides, sulphides, or carbonates.

Identification of minerals

A mineral may be identified by certain properties or characteristics. Some minerals are easily identified; others require careful examination and often chemical analysis. Properties of minerals are as follows:

1. The *colour* of some minerals is very definite. For example, azurite has a deep blue colour. Certain other minerals, however, such as quartz, may occur in several colours.

2. The *streak* of a mineral is the colour of a mark that it makes on unglazed porcelain. Examples: graphite, black; hematite, reddish brown; malachite, light green.

3. Certain minerals break so that smooth plane surfaces are produced. This is called *cleavage*. Galena, for example, cleaves in three planes. These are at right angles to each other, so that a large piece of galena may be broken into many cubes.

4. The *lustre* of a mineral is the appearance of its surface, as affected by the peculiarities of its reflecting qualities. Many ores have a metallic lustre. The diamond has a brilliant lustre called *adamantine*. Chrysotile, the chief source of asbestos, has a silky lustre; kaolin, a form of hard clay, a dull lustre.

5. The *hardness* of minerals ranges from 1 to 10. Talc, which can be easily scratched with the fingernail, has a hardness of 1. The opposite extreme is represented by the diamond, the hardest known substance, which has a hardness of 10. The fingernail has a hardness of about 2½, and a knife blade, about 5½. The hardness of a specimen is ascertained by comparison with the standard series of minerals given below. Care should be exercised in testing for hardness. If one mineral scratches another, the scratch cannot be rubbed off. If it can be rubbed off, it indicates that the powder of the softer mineral has formed on the harder one and no scratch has been made.

1. Talc	6. Orthoclase feldspar
2. Gypsum	7. Quartz
3. Calcite	8. Topaze
4. Fluorite	9. Corundum
5. Apatite	10. Diamond

6. *Specific gravity* is a number that represents the weight ratio between 1 cubic centimetre (or other unit of volume) of a substance and 1 cubic centimetre of water. If 1 cubic centimetre of sphalerite (zinc ore) weighs 4 times as much as 1 cubic centimetre of water, then the specific gravity of sphalerite is said to be 4. The specific gravity of most minerals ranges between 2 and 4. Liquid petroleum, since it floats on water, has a specific gravity of less than 1. Pure gold has a specific gravity of 19.

7. *Effervescence in acid* is a property of some minerals. If a drop of hydrochloric acid is put on a piece of limestone, marble, or calcite, chemical reaction will result in bubbles of gas being given off. This is called *effervescence*. It can be used as a test for certain minerals known to possess this property.

8. The *crystalline form* of minerals varies greatly. Only four crystalline forms will be mentioned here: cubical crystal, represented by galena and halite (common salt); hexagonal (six-sided), by quartz; octahedron, by pyrite and the diamond; rhombohedron, by calcite.

Classes of rock

A *rock* is defined as a combination of two or more minerals, although some rocks are

1. Coal and petroleum are derived from substances that were originally organic, but they have been so changed by time that they are now considered to belong to the mineral kingdom. They are always spoken of as 'the mineral fuels'.

composed almost entirely of one mineral. Granite is composed mainly of three minerals: quartz, feldspar and mica. On the other hand, sandstone and quartzite are mainly quartz; limestone and marble, mainly calcite. It is important to remember that minerals have definite chemical compositions, but rocks have not.

Rocks are classified as igneous, sedimentary, or metamorphic.

Igneous rocks are formed when molten rock cools and solidifies. Examples:

1 Granite: red or grey; composed principally of quartz, feldspar and mica; the speckled appearance is due to different mineral crystals being visible.
2 Basalt: dark greenish black; sometimes shows small cavities, probably caused by steam; a common form of solidified lava.
3 Obsidian: volcanic glass; black, brown, green, etc.
4 Pumice stone: white to grey; porous; floats on water.
5 Scoria: black, grey, dark red; resembles cinders.

Sedimentary rocks are formed of sediment deposited by water. Examples:

1 Limestone: white to grey; composed mainly of calcite; often contains many fossils of marine animals; effervesces in acid; may be coloured yellow brown by limonite (iron oxide).
2 Sandstone: grey or red; mainly quartz; sand particles visible.
3 Shale: dark grey, black, red; can usually be broken into thin layers; clay odour when wet; oil shale is black.
4 Bituminous coal: black; composed of carbon and carbon compounds; may contain impurities such as hard shale.
5 Conglomerate: rounded pebbles cemented together.

Metamorphic rocks are other types that have been altered by pressure and heat. Examples:

1 Gneiss: mainly a metamorphosed granite; the minerals quartz, feldspar and mica often occur in layers; the mica may be the white variety (muscovite) or the black (biotite).
2 Marble: metamorphosed limestone; many colours; a beautiful rock when polished; effervesces in acid.
3 Quartzite: metamorphosed sandstone; extremely hard and compact; grey or red; sand particles firmly cemented together.
4 Slate: metamorphosed shale; usually black; splits into thin layers; harder than shale.
5 Anthracite: harder and not so dusty as bituminous coal; a superior fuel.

TABLE I

WEIGHTS AND MEASURES

Linear measure

12 inches (in)	=	1 foot (ft)
3 feet	=	1 yard (yd)
5½ yards	=	1 rod (rd)
16½ feet	=	1 rod
320 rods	=	1 mile (mi)
1,760 yards	=	1 mile
5,280 feet	=	1 mile
6 feet	=	1 fathom

Square measure

144 square inches (sq.in)	=	1 square foot (sq.ft)
9 square feet	=	1 square yard (sq.yd)
30¼ square yards	=	1 square rod (sq.rd)
160 square rods	=	1 acre (A)
640 acres	=	1 square mile (sq.mi)
1 square mile	=	1 section (US)
36 square miles	=	1 township (US)

Cubic measure

1,728 cubic inches (cu.in)	=	1 cubic foot (cu.ft)
27 cubic feet	=	1 cubic yard (cu.yd)

Wood measure

16 cubic feet	=	1 cord foot (cd.ft)
128 cubic feet 8 cord feet	=	1 cord (cd)

Table of counting

12 units	=	1 dozen (doz)
12 dozen	=	1 gross (gro)
12 gross	=	1 great gross (gt.gro)
24 sheets of paper	=	1 quire
20 quires or 480 sheets	=	1 ream

Avoirdupois weight

7,000 grains (gr)	=	1 pound (lb)
16 ounces (oz)	=	1 pound
100 pounds	=	1 US hundredweight(cwt)
112 pounds	=	1 British hundredweight (cwt)
2,000 pounds	=	1 US ton (T)
2,240 pounds	=	1 US gross ton, 1 British ton

Troy weight (for precious metals, jewels, etc.)

24 grains	=	1 pennyweight (dwt)	
20 pennyweights	=	1 ounce	
12 ounces	=	1 pound	
437½ grains	=	1 ounce	Av.
7,000 grains	=	1 pound	Av.
480 grains	=	1 ounce	Troy
5,760 grains	=	1 pound	Troy

Apothecaries' weight

20 grains	=	1 scruple
3 scruples	=	1 dram
8 drams	=	1 ounce
12 ounces 5,760 grains	=	1 pound

Apothecaries' liquid measure

60 minims	=	1 fluid dram
8 fluid drams	=	1 fluid ounce
16 fluid ounces	=	1 pint
8 pints	=	1 gallon

Measure of time

60 seconds (sec)	=	1 minute (min)
60 minutes	=	1 hour (hr)
24 hours	=	1 day (da)
7 days	=	1 week (wk)
365 days or 12 months (mo)	=	1 year (yr)
10 years	=	1 decade
10 decades	=	1 century

Liquid measure (US)

4 gills (gi)	=	1 pint (pt)
2 pints	=	1 quart (qt)
4 quarts	=	1 gallon (gal)
231 cu. in.	=	1 gallon
31½ gal.	=	1 barrel
1 liquid quart	=	57.7 cubic inches

Dry measure (US)

2 pints (pt)	= 1 quart (qt)
8 quarts	= 1 peck (pk)
4 pecks	= 1 bushel (bu)
32 quarts	= 1 bushel
2,150.4 cubic inches	= 1 bushel

Liquid and dry measure (British)

2 pints (pt)	= 1 quart (qt)
4 quarts	= 1 gallon (gal)
2 gallons	= 1 peck (pk)
4 pecks	= 1 bushel (bu)
8 bushels	= 1 quarter (qr)
1 quart	= 69.318 cubic inches
1 gallon	= 277.274 cubic inches

Household measures

1 teaspoon	= 5 cc
3 teaspoons	= 1 tablespoon
16 tablespoons	= 1 cup
2 cups	= 1 pint

Miscellaneous

1 US gallon of water weighs 8.33 lb
1 British gallon of water weighs 10 lb
1 cubic foot of water weighs 62.3 lb
1 British billion means 1 million millions
1 US billion means 1 thousand millions
1 British trillion means 1 million billions
1 US trillion means 1 thousand billions, or
1 US trillion = 1 British billion

THE METRIC SYSTEM

Measures of length

10 millimetres (mm)	= 1 centimetre (cm)
10 centimetres	= 1 decimetre (dm)
10 decimetres	= 1 metre (m)
10 metres	= 1 decametre (dam)
10 decametres	= 1 hectometre (hm)
10 hectometres	= 1 kilometre (km)
10 kilometres	= 1 myriametre (mn)

Measures of surface

100 sq.millimetres (mm^2)	= 1 sq.centimetre (cm^2)
100 sq.centimetres	= 1 sq.decimetre (dm^2)
100 sq.decimetres	= 1 sq.metre (m^2)
100 sq.metres	= 1 sq.decametre (dam^2)
100 sq.decametres	= 1 sq.hectometre (hm^2)
100 sq.hectometres	= 1 sq.kilometre (km^2)

Measures of volume

1,000 cu. millimetres (mm^3)	= 1 cu. centimetre (cm^3)
1,000 cu.centimetres	= 1 cu. decimetre (dm^3)
1,000 cu. decimetres	= 1 cu. metre (m^3)

Measures of capacity

10 millilitres (ml)	= 1 centilitre (cl)
10 centilitres	= 1 decilitre (dl)
10 decilitres	= 1 litre (l)
10 litres	= 1 decalitre (dal)
10 decalitres	= 1 hectolitre (hl)
10 hectolitres	= 1 kilolitre (kl)
Note: 1 cc	= 1 ml

Measures of weight

10 milligrams	= 1 centigram
10 centigrams	= 1 decigram
10 decigrams	= 1 gram
10 grams	= 1 decagram
10 decagrams	= 1 hectogram
10 hectograms	= 1 kilogram
1,000 kilograms	= 1 metric ton

EQUIVALENTS

1 inch	= 2.54 centimetres
1 foot	= 30.48 centimetres
1 quart (US liq.)	= 0.9464 litre
1 quart (US dry)	= 1.101 litres
1 quart (British)	= 1.1351 litres
1 pound av.	= 0.4536 kilogram
1 centimetre	= 0.3937 inch
1 metre	= 39.37 inches
1 litre	= 1.051 quarts (US liq.)
1 litre	= 0.9081 quart (US dry)
1 litre	= 0.8809 quart (British)
1 kilogram	= 2.205 pounds

TABLE II

STARS AND PLANETS

A. Stars in descending order of brightness

Star (a)	Constellation (b)	Time of northing or southing: 8 p.m. Month (c)	Time of northing or southing: 10 p.m. Month (d)	N or S of sun's position at noon (e)
Sirius	Big Dog	February	January	10° S
Canopus	Ship Argo	February	January	40° S
α-Centauri	Centaur	June	May	80° S
Vega	Lyre	August	July	30° N
Capella	Charioteer	January	December	70° N
Arcturus	Herdsman	June	May	0°
Rigel	Orion	January	December	10° N
Procyon	Little Dog	February	January	20° N
Achernar	River Eridanus	December	November	30° S
β-Centauri	Centaur	June	May	80° S
Altair	Eagle	September	August	10° N
Betelgeuse	Orion	February	January	20° N
α-Crucis	Southern Cross	May	April	80° S
Aldebaran	BULL	January	December	40° N
Pollux	HEAVENLY TWINS	March	February	30° N
Spica	VIRGIN	May	April	30° S
Antares	SCORPION	July	June	50° S
Formalhaut	Southern Fish	October	September	20° S
Deneb	Swan	September	August	40° N
Regulus	LION	April	March	0°
β-Crucis	Southern Cross	May	April	80° S
Castor	HEAVENLY TWINS	March	February	30° N

The columns of Table A give the following data: (a) The names of the brightest stars in descending order of brightness. (b) The name of the constellation in which the star appears (the *signs of the zodiac* are printed in capitals). (c) The month when the star reaches its highest point above the horizon at about 8 p.m. local time. (d) The month when the star reaches its highest point above the horizon at about 10 p.m. local time. (e) The angle between the elevation of the star, when it is at its highest in the sky, and the elevation of the sun at *noon*, local time, during the month given in column (c). For example, to find Capella during January at 8 p.m., the observer should first look toward the place where the sun appeared to be at *noon* by local time, and then turn his gaze *northward* through 70° (approximately). Of course, all these stars are not visible from any one point of the earth. For instance, a star immediately above an observer at a point 60° N will appear on the horizon to an observer at a point 30° S, and will be below the horizon (i.e. invisible) to an observer at any point further south.

Notes: α-Centauri and β-Centauri are the 'pointers' for the Southern Cross. α-Centauri is the farthest from the Cross. It is the nearest bright star to the Earth, which its light takes about four years to reach.

Of the four bright stars which outline the Southern Cross, α-Crucis is the farthest south, and β-Crucis the farthest east.

In the Heavenly Twins, Castor is to the north of Pollux.

B. Planets in increasing order of distance from the sun

Planet	*Distance from sun (millions of miles)*	*Diameter (thousands of miles)*	*Time taken to complete orbit (years)*
Mercury	36	3.2	0.24
Venus	67	7.85	0.62
Earth	93	7.9	1.00
Mars	142	4.25	1.88
Jupiter	483	89	11.9
Saturn	887	75	29.5
Uranus	1,785	31	84
Neptune	2,797	33	165
Pluto	3,675	4	248

The columns of Table B show the names of the planets, their distances from the sun, their diameters, and the times taken for their orbits.

The positions of the planets relative to the stars vary during the course of the year, and the brightness of each is also variable. (The positions of the planets in the sky at a particular time must be found from an appropriate almanac.)

Notes: *Mercury* is visible for only half an hour at most, either before sunrise or after sunset.

Venus is visible for not more than three hours either before sunrise or after sunset.

Mars, Jupiter and *Saturn* are often very conspicuous objects in the sky.

Of the remainder, only *Uranus* is visible to the naked eye; it has the appearance of a faint star.

C. Latitudes and dates when the sun is directly overhead at noon

Latitude	*Dates*		*Latitude*	*Dates*	
23.5° N	June 21 [1]	June 21 [1]	23.5° S	Dec. 22 [2]	Dec. 22 [2]
23° N	July 3	10	23° S	Jan. 2	11
22° N	12	1	22° S	10	3
21° N	19	May 26	21° S	16	Nov. 27
20° N	24	21	20° S	21	22
19° N	29	16	19° S	25	18
18° N	Aug. 2	12	18° S	29	14
17° N	6	8	17° S	Feb. 2	10
16° N	9	5	16° S	5	7
15° N	12	1	15° S	9	3
14° N	16	Apr. 28	14° S	12	Oct. 31
13° N	19	25	13° S	15	28
12° N	22	22	12° S	17	25
11° N	25	19	11° S	20	22
10° N	28	16	10° S	23	20
9° N	31	13	9° S	26	17
8° N	Sept. 2	11	8° S	28	14
7° N	5	8	7° S	Mar. 3	12
6° N	8	5	6° S	6	9
5° N	10	3	5° S	8	6
4° N	13	Mar. 31	4° S	11	4
3° N	16	29	3° S	13	1
2° N	18	26	2° S	16	Sept. 29
1° N	21 [4]	23 [3]	1° S	18	26
Equator	23 [4]	21 [3]	Equator	21 [3]	23 [4]

1. Summer solstice.
2. Winter solstice.
3. Spring equinox.
4. Autumn equinox.

TABLE III

ATOMIC NUMBERS OF THE ELEMENTS

Actinium	89	Europium	63	Mendelevium	101	Samarium	62
Aluminium	13			Mercury	80	Scandium	21
Americium	95	Fermium	100	Molybdenum	42	Selenium	34
Antimony	51	Fluorine	9			Silicon	14
Argon	18	Francium	87	Neodymium	60	Silver	47
Arsenic	33			Neon	10	Sodium	11
Astatine	85	Gadolinium	64	Neptunium	93	Strontium	38
		Gallium	31	Nickel	28	Sulphur	16
Barium	56	Germanium	32	Niobium	41		
Berkelium	97	Gold	79	Nitrogen	7	Tantalum	73
Beryllium	4			Nobelium	102	Technetium	43
Bismuth	83	Hafnium	72			Tellurium	52
Boron	5	Helium	2	Osmium	76	Terbium	65
Bromine	35	Holmium	67	Oxygen	8	Thallium	81
		Hydrogen	1			Thorium	90
Cadmium	48			Palladium	46	Thulium	69
Calcium	20	Indium	49	Phosphorus	15	Tin	50
Californium	98	Iodine	53	Platinum	78	Titanium	22
Carbon	6	Iridium	77	Plutonium	94	Tungsten	74
Cerium	58	Iron	26	Polonium	84		
Cesium	55			Potassium	19	Uranium	92
Chlorine	17	Krypton	36	Praseodymium	59		
Chromium	24			Promethium	61	Vanadium	23
Cobalt	27	Lanthanum	57	Protoactinium	91		
Copper	29	Lawrencium	103			Xenon	54
Curium	96	Lead	82	Radium	88		
		Lithium	3	Radon	86	Ytterbium	70
Dysprosium	66	Lutecium	71	Rhenium	75	Yttrium	39
				Rhodium	45		
Einsteinium	99	Magnesium	12	Rubidium	37	Zinc	30
Erbium	68	Manganese	25	Ruthenium	44	Zirconium	40

THE ELEMENTS

Atomic number	*Name of element*	*Symbol*	*Atomic weight*	*Atomic number*	*Name of element*	*Symbol*	*Atomic weight*
1	Hydrogen	H	1.0080	10	Neon	Ne	20.183
2	Helium	He	4.003	11	Sodium	Na	22.997
3	Lithium	Li	6.940	12	Magnesium	Mg	24.32
4	Beryllium	Be	9.013	13	Aluminium	Al	26.98
5	Boron	B	10.82	14	Silicon	Si	28.09
6	Carbon	C	12.010	15	Phosphorus	P	30.975
7	Nitrogen	N	14.008	16	Sulphur	S	32.066
8	Oxygen	O	16.0000	17	Chlorine	Cl	35.457
9	Fluorine	F	19.000	18	Argon	A	39.944

Atomic number	*Name of element*	*Symbol*	*Atomic weight*	*Atomic number*	*Name of element*	*Symbol*	*Atomic Weight*
19	Potassium	K	39.096	62	Samarium	Sm	150.43
20	Calcium	Ca	40.08	63	Europium	Eu	152.0
21	Scandium	Sc	44.96	64	Gadolinium	Gd	156.9
22	Titanium	Ti	47.90	65	Terbium	Tb	159.2
23	Vanadium	V	50.95	66	Dysprosium	Dy	162.46
24	Chromium	Cr	52.01	67	Holmium	Ho	164.94
25	Manganese	Mn	54.93	68	Erbium	Er	167.2
26	Iron	Fe	55.85	69	Thulium	Tm	169.4
27	Cobalt	Co	58.94	70	Ytterbium	Yb	173.04
28	Nickel	Ni	58.69	71	Lutecium	Lu	174.99
29	Copper	Cu	63.54	72	Hafnium	Hf	178.6
30	Zinc	Zn	65.38	73	Tantalum	Ta	180.88
31	Gallium	Ga	69.72	74	Tungsten	W	183.92
32	Germanium	Ge	72.60	75	Rhenium	Re	186.31
33	Arsenic	As	74.91	76	Osmium	Os	190.2
34	Selenium	Se	78.96	77	Iridium	Ir	193.1
35	Bromine	Br	79.916	78	Platinum	Pt	195.23
36	Krypton	Kr	83.80	79	Gold	Au	197.2
37	Rubidium	Rb	85.48	80	Mercury	Hg	200.61
38	Strontium	Sr	87.63	81	Thallium	Tl	204.39
39	Yttrium	Y	88.92	82	Lead	Pb	207.21
40	Zirconium	Zr	91.22	83	Bismuth	Bi	209.00
41	Niobium	Nb	92.91	84	Polonium	Po	210
42	Molybdenum	Mo	95.95	85	Astatine	At	211
43	Technetium	Tc	99	86	Radon	Rn	222
44	Ruthenium	Ru	101.7	87	Francium	Fr	223
45	Rhodium	Rh	102.91	88	Radium	Ra	226.05
46	Palladium	Pd	106.7	89	Actinium	Ac	227
47	Silver	Ag	107.880	90	Thorium	Th	232.12
48	Cadmium	Cd	112.41	91	Protoactinium	Pa	231
49	Indium	In	114.76	92	Uranium	U	238.07
50	Tin	Sn	118.70	93	Neptunium	Np	237.07
51	Antimony	Sb	121.76	94	Plutonium	Pu	239.08
52	Tellurium	Te	127.61	95	Americium	Am	243
53	Iodine	I	126.92	96	Curium	Cm	244
54	Xenon	Xe	131.3	97	Berkelium	Bk	245
55	Cesium	Cs	132.91	98	Californium	Cf	(246)
56	Barium	Ba	137.36	99	Einsteinium	E	(253)
57	Lanthanum	La	138.92	100	Fermium	Fm	(254)
58	Cerium	Ce	140.13	101	Mendelevium	Me	(256)
59	Praseodymium	Pr	140.92	102	Nobelium	No	(—)
60	Neodymium	Nd	144.27	103	Lawrencium	Lw	(—)
61	Promethium	Pm	145				

TABLE IV

DENSITIES

(In grams per cubic centimetre)

Alcohol, 95 %	0.807	Marble	2.5-2.8
Aluminium	2.7	Mercury	13.6
Brass	8.4	Milk	1.03
Carbon tetrachloride	1.6	Nickel	8.9
Coal (anthracite)	1.4-1.8	Paraffin	0.824-0.94
Copper	8.93	Platinum	21.5
Gasoline	0.75	Sea water	1.03
Glass (flint)	3.0-3.6	Silver	10.5
Glass (crown)	2.4-2.7	Tin	7.3
Gold	19.3	Wood — Ebony	1.2
Ice	0.917	Oak	0.7-0.9
Iron	7.1-7.9	Pine	0.4-0.6
Lead	11.4	Lignum vitae	1.33
Magnesium	1.74	Zinc	7.1

Stones, Brick, Cement (Kent)

Agate	2.615	Gravel	1.600-1.920
Asphaltum	1.390	Gypsum	2.080-2.400
Brick (soft)	1.600	Hornblende	3.200-3.520
Brick (common)	1.790	Lime (quick)	0.800-0.880
Brick (hard)	2.000	Limestone	2.720-3.200
Brick (pressed)	2.160	Magnesia (carbonate)	2.400
Brick (fire)	2.250-2.400	Marble	2.560-2.880
Brickwork in mortar	1.600	Masonry (dry rubble)	2.240-2.560
Brickwork in cement	1.790	Masonry (dressed)	2.240-2.880
Cement (Rosendale)	0.960	Mortar	1.440-1.600
Cement (Portland)	1.250	Pitch	1.150
Clay	1.920-2.400	Plaster of Paris	1.180-1.280
Concrete	1.920-2.240	Porcelain	2.380
Diamond	3.530	Quartz	2.640
Earth (loose)	1.150-1.280	Sand	1.440-1.760
Earth (rammed)	1.440-1.760	Sandstone	2.240-2.400
Emery	4.000	Slate	2.720-2.880
Glass (crown)	2.520	Soapstone	2.650-2.800
Glass (flint)	3.000-3.600	Trap	2.720-3.400
Glass (green)	2.640	Tile	1.760-1.920
Granite	2.560-2.720		

TABLE V

HEAT CONSTANTS

Substances	*Specific heat*	*Melting point (°C)*	*Boiling point (°C)*	*Coefficient of linear expansion (per °C)*
Solids				
Aluminium	0.22	658	2,200	0.000023
Brass	0.092	900		0.0000189
Copper	0.092	1,083	2,300	0.0000167
Glass, ordinary	0.16	1,100		0.000085
Ice	0.50	0		
Iron	0.12	1,530	3,000	00.00012
Lead	0.031	327	1,755	00.00029
Mercury	0.033	—39	356.7	
Tin	0.055	232	2,260	0.000023
Zinc	0.093	419	907	0.000029
Liquids				
Alcohol, ethyl	0.58	—130	78.3	
Glycerine	0.576	17	290	
Kerosene	0.5-0.6			
Mercury	0.033		357	
Sulphuric acid	0.34	10.5	330	
Water	1.00		100	
Gases				
Air	0.24		—190	
Alcohol, ethyl	0.41			
Ammonia gas	0.52	—78	—33	
Carbon dioxide	0.20	—56.6	—79	
Hydrogen	3.38			
Nitrogen	0.25			
Oxygen	0.22			
Steam	0.48			

EQUIVALENT TEMPERATURES IN DIFFERENT SCALES

	Absolute	*Centigrade*	*Fahrenheit*	*Reaumur*
Absolute zero	0° A	—273° C	—459° F	—218° R
Fahrenheit zero	255° A	—18° C	0° F	—14° R
Freezing point of water	273° A	0° C	32° F	0° R
Boiling point of water	373° A	100° C	212° F	80° R

Table V

CENTIGRADE TO FAHRENHEIT CONVERSION TABLE

°C	°F	°C	°F	°C	°F	°C	°F
0	32						
1	34	26	79	51	124	76	169
2	36	27	81	52	126	77	171
3	37	28	82	53	127	78	172
4	39	29	84	54	129	79	174
5	41	30	86	55	131	80	176
6	43	31	88	56	133	81	178
7	45	32	90	57	135	82	180
8	46	33	91	58	136	83	181
9	48	34	93	59	138	84	183
10	50	35	95	60	140	85	185
11	52	36	97	61	142	86	187
12	54	37	99	62	144	87	189
13	55	38	100	63	145	88	190
14	57	39	102	64	147	89	192
15	59	40	104	65	149	90	194
16	61	41	106	66	151	91	196
17	63	42	108	67	153	92	198
18	64	43	109	68	154	93	199
19	66	44	111	69	156	94	201
20	68	45	113	70	158	95	203
21	70	46	115	71	160	96	205
22	72	47	117	72	162	97	207
23	73	48	118	73	163	98	208
24	75	49	120	74	165	99	210
25	77	50	122	75	167	100	212

TABLE VI

RELATIVE HUMIDITY (PERCENTAGE)—°F

Temperature of dry bulb (°F)	*Depression of the wet bulb (°F) i.e. difference between wet and dry bulb readings*																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
120	97	94	91	88	85	82	79	77	74	72	69	67	64	62	59	57	55	53	51	48
118	97	94	91	88	85	82	79	76	74	71	69	66	63	61	59	56	54	52	50	48
116	97	94	90	87	84	82	79	76	73	71	68	65	63	61	58	56	54	51	49	47
114	97	94	90	87	84	81	79	76	73	70	68	65	63	60	58	55	53	51	48	46
112	97	94	90	87	84	81	78	75	73	70	67	65	62	59	57	55	52	50	48	46
110	97	93	90	87	84	81	78	75	72	69	67	64	61	59	56	54	51	49	47	45
108	97	93	90	87	84	81	78	75	72	69	66	63	61	58	56	53	51	49	46	44
106	96	93	90	87	84	80	77	74	71	68	66	63	60	58	55	52	50	48	45	43
104	96	93	90	86	83	80	77	74	71	68	65	62	60	57	54	52	49	47	44	42
102	96	93	90	86	83	80	77	73	70	67	65	62	59	56	54	51	48	46	43	41
100	96	93	89	86	82	79	76	73	70	67	64	61	58	55	53	50	47	45	42	40
	99	*98*	*96*	*95*	*94*	*93*	*91*	*90*	*89*	*87*	*86*	*85*	*83*	*82*	*80*	*79*		*76*		*72*
98	96	93	89	86	82	79	76	72	69	66	63	60	57	54	52	49	46	44	41	39
96	96	93	89	85	82	78	75	72	68	65	62	59	57	54	51	48	45	43	40	38
94	96	93	89	85	81	78	75	71	68	65	62	59	56	53	50	47	44	42	39	36
92	96	92	88	85	81	78	74	71	67	64	61	58	55	52	49	46	43	40	38	35
90	96	92	88	84	81	77	74	70	67	63	60	57	54	51	48	45	42	39	36	34
	89	*87*	*86*	*85*	*83*	*82*	*81*	*79*	*78*	*76*	*75*	*73*	*72*	*70*	*69*	*67*		*63*		*59*
88	96	92	88	84	80	77	73	69	66	63	59	56	53	50	47	44	41	38	35	32
86	96	92	88	84	80	76	72	69	65	62	58	55	52	49	45	42	39	36	33	31
84	96	92	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35	32	29
82	96	91	87	83	79	75	71	67	64	60	56	53	49	46	43	40	36	33	30	27
80	96	91	87	83	79	74	70	66	63	59	55	52	48	45	41	38	35	31	28	25
	79	*77*	*76*	*74*	*73*	*72*	*70*	*68*	*67*	*65*	*63*	*62*	*60*	*58*	*56*	*54*		*50*		*44*
78	95	91	86	82	78	74	70	66	62	58	54	50	47	43	40	36	33	30	26	23
76	95	91	86	82	78	73	69	65	61	57	53	49	45	42	38	34	31	28	24	21
74	95	90	86	81	77	72	68	64	60	56	52	48	44	40	36	33	29	26	22	19
72	95	90	85	80	76	71	67	63	58	54	50	46	42	38	34	31	27	23	20	16
70	95	90	85	80	75	71	66	62	57	53	49	44	40	36	32	28	24	21	17	14
	69	*67*	*66*	*64*	*62*	*61*	*59*	*57*	*55*	*53*	*51*	*49*	*47*	*44*	*42*	*39*		*33*		*26*
68	95	90	84	79	75	70	65	60	56	51	47	43	38	34	30	26	22	18	15	11
66	95	89	84	79	74	69	64	59	54	50	45	41	36	32	28	23	20	16	12	8
64	94	89	83	78	73	68	63	58	53	48	43	39	34	30	25	21	17	13	9	5
62	94	88	83	77	72	67	61	56	51	46	41	37	32	27	23	18	14	10	5	
60	94	88	82	77	71	65	60	55	50	44	39	34	29	25	20	15	11	6	2	
	58	*57*	*55*	*53*	*51*	*49*	*47*	*45*	*43*	*40*	*38*	*35*	*32*	*29*	*25*	*21*				
58	94	88	82	76	70	64	59	53	48	42	37	31	26	22	17	12	7	2		
56	94	87	81	75	69	63	57	51	46	40	35	29	24	19	13	8	3			
54	93	87	80	74	68	61	55	49	43	38	32	26	21	15	10	5				
52	93	86	79	73	66	60	54	47	41	35	29	23	17	12	6					
50	93	86	79	72	65	59	52	45	38	32	26	20	14	8	2					
	48	*46*	*44*	*42*	*40*	*37*	*34*	*32*	*29*	*26*	*22*	*18*								
48	92	85	77	70	63	56	49	42	36	29	22	16	10	4						
46	92	84	77	69	62	54	47	40	33	26	19	12	6							
44	92	84	75	68	60	52	45	37	29	22	15	8								
42	91	83	74	66	58	50	42	34	26	18										
40	91	82	73	65	56	47	39	30												
	38	*35*	*33*	*30*	*28*	*25*														

Note: In this table, the dew points are in italics

Table VI

RELATIVE HUMIDITY (PERCENTAGE)—°C

Temperature of dry bulb (°C)	*Depression of the wet bulb (°C)*														
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
50	94	89	84	79	74	70	65	61	57	53	46	40	33	28	22
45	94	88	83	78	73	68	63	59	55	51	42	35	28	22	16
40	93	88	82	77	71	65	61	56	52	47	38	31	23	16	10
35	93	87	80	75	68	62	57	52	47	42	33	24	16	8	
30	92	86	78	72	65	59	53	47	41	36	26	16	8		
25	91	84	76	69	61	54	47	41	35	29	17	6			
20	90	81	73	64	56	47	40	32	26	18	5				
15	89	79	68	59	49	39	30	21	12	4					
10	87	75	62	51	38	27	17	5							

TABLE VII

PRESSURE OF SATURATED WATER VAPOUR IN MILLIMETRES OF MERCURY AT DIFFERENT TEMPERATURES

^0C	+0	+1	+2	+3	+4	+5	+6	+7	+8	+9
0	4.6	4.9	5.3	5.7	6.1	6.5	7.0	7.5	8.0	8.6
10	9.2	9.8	10.5	11.2	12.0	12.8	13.6	14.5	15.5	16.5
20	17.5	18.6	19.8	21.0	22.3	23.7	25.1	26.7	28.3	29.9
30	31.7	33.6	35.5	37.6	39.8	42.0	44.4	46.9	49.5	52.3

	+0	+2	+4	+6	+8	+10	+12	+14	+16	+18
40	55.1	61.3	68.1	75.4	83.5	92.3	102	112	123	135
60	149	163	179	195	214	233	255	277	301	327
80	355	384	416	450	487	525	567	611	657	707
100	760	815	875	938	1004	1075	1149	1227	1310	1397

Examples: Pressure of saturated water vapour at 12^0 C (= $10^0 + 2^0$) is 10.5 mm; at 94^0 C (= $80^0 + 14^0$) it is 611 mm.

TABLE VIII

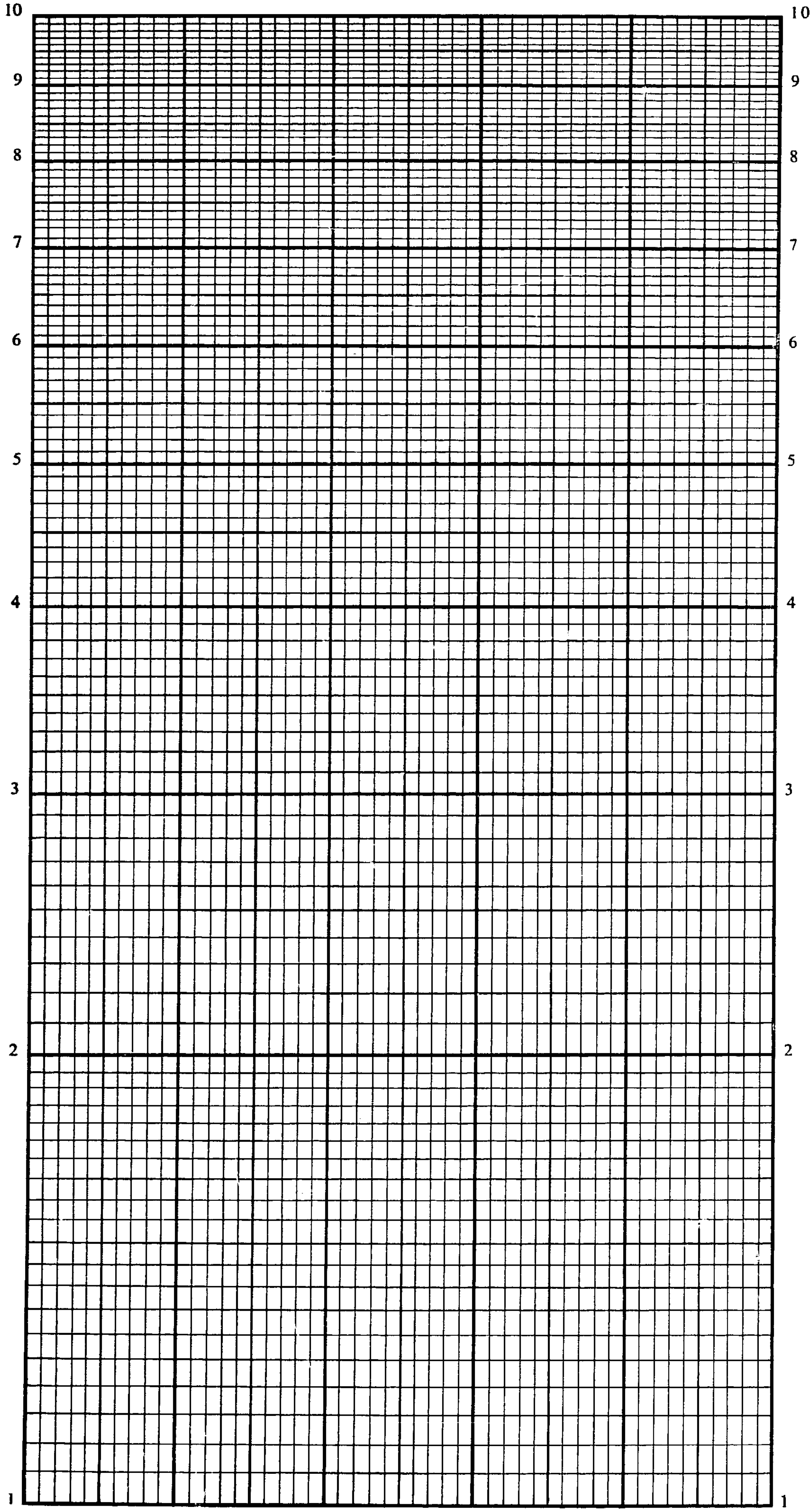
GREEK ALPHABET

Alpha (a)	Α α	Nu (n)	Ν ν
Beta (b)	Β β	Xi (x)	Ξ ξ
Gamma (g)	Γ γ	Omicron (o)	Ο ο
Delta (d)	Δ δ *or* ẟ	Pi (p)	Π π
Epsilon (e)	Ε ε	Rho (r)	Ρ ϱ
Zeta (z)	Ζ ζ	Sigma (s)	Σ σ *or* ς
Eta (h)	Η η	Tau (t)	Τ τ
Theta (th)	Θ θ	Upsilon (u)	Υ υ
Iota (i)	Ι ι	Phi (ph)	Φ φ *or* ϕ
Kappa (k)	Κ ϰ	Chi (ch)	Χ χ
Lambda (l)	Λ λ	Psi (ps)	Ψ ψ
Mu (m)	Μ μ	Omega (o)	Ω ω

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170						4	9	13	17	21	26	30	34	38
						0212	0253	0294	0334	0374	4	8	12	16	20	24	28	32	37
11	0414	0453	0492	0531	0569						4	8	12	15	19	23	27	31	35
						0607	0645	0682	0719	0755	4	7	11	15	19	22	26	30	33
12	0792	0828	0864	0899	0934	0969					3	7	11	14	18	21	25	28	32
							1004	1038	1072	1106	3	7	10	14	17	20	24	27	31
13	1139	1173	1206	1239	1271						3	7	10	13	16	20	23	26	30
						1303	1335	1367	1399	1430	3	7	10	12	16	19	22	25	29
14	1461	1492	1523	1553							3	6	9	12	15	18	21	24	28
					1584	1614	1644	1673	1703	1732	3	6	9	12	15	17	20	23	26
15	1761	1790	1818	1847	1875	1903					3	6	9	11	14	17	20	23	26
							1931	1959	1987	2014	3	5	8	11	14	16	19	22	25
16	2041	2068	2095	2122	2148						3	5	8	11	14	16	19	22	24
						2175	2201	2227	2253	2279	3	5	8	10	13	15	18	21	23
17	2304	2330	2355	2380	2405	2430					3	5	8	10	13	15	18	20	23
							2455	2480	2504	2529	2	5	7	10	12	15	17	19	22
18	2553	2577	2601	2625	2648						2	5	7	9	12	14	16	19	21
						2672	2695	2718	2742	2765	2	5	7	9	11	14	16	18	21
19	2788	2810	2833	2856	2878						2	4	7	9	11	13	16	18	20
						2900	2923	2945	2967	2989	2	4	6	8	11	13	15	17	19
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3817	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8

	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9868	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

Note: **These tables are so constructed that the fourth figure of a logarithm obtained by their use is never more than one unit above or below the best 4-figure approximation. E.g. if the logarithm found is 0.5014 the best 4-figure approximation may be 0.5013, 0.5014 or 0.5015. Greater accuracy than this cannot be obtained by the use of a uniform table of differences of this kind.**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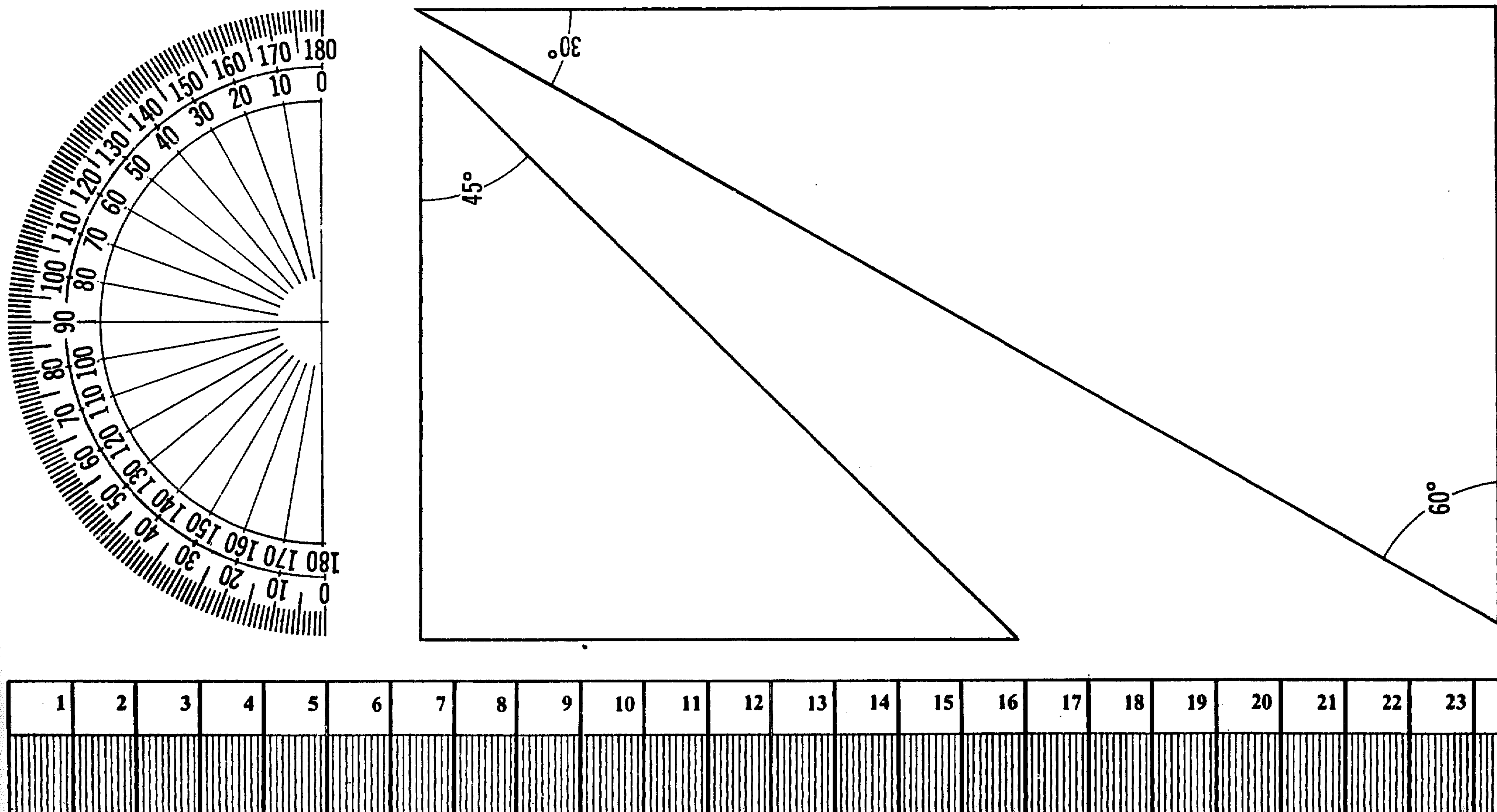
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Guidebook to Constructing Inexpensive Science Teaching Equipment Volumes 1-3

Published by:
The International Clearinghouse on Science and Mathematics Curriculum Developments
Science Teaching Center
University of Maryland
College Park, MD 20742 USA

Paper copies are $10.00 for the set of three volumes.

Available from:
The International Clearinghouse on Science and Mathematics Curriculum Developments
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GUIDEBOOK TO CONSTRUCTING INEXPENSIVE SCIENCE TEACHING EQUIPMENT

Volume I: Biology

Inexpensive Science Teaching Equipment Project
Science Teaching Center
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Inexpensive Science Teaching Equipment Project
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Donald Urbancic	1970-71
Ruth Ann Butler	1971-72
Technical Assistants	
David Clark	1970-72
Chada Samba Siva Rao	1970-71

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The Guidebook is presented in three volumes:

Volume I, Biology

Volume II, Chemistry

Volume III, Physics

The following table refers only to the contents of this volume, but the listing at the back of each volume provides an alphabetical index to all three volumes.

References within the text normally indicate the volume, chapter and number of the item referred to (e.g., PHYS/V/A3), but where a reference is to an item within the same volume, the reference indicates only the chapter and number of the item (e.g., V/A3).

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FOREWORD

History

The Inexpensive Science Teaching Equipment Project was initiated by Dr. J. David Lockard, and got underway under his direction in the summer of 1968. Originally entitled the Study of Inexpensive Science Teaching Equipment Worldwide (IS-TEW or IS-2 Study), the Project was to (1) identify laboratory equipment considered essential for student investigations in introductory biology, chemistry and physics courses in developing countries; (2) improvise, wherever possible, equivalent inexpensive science teaching equipment; and (3) produce designs of this equipment in a Guidebook for use in developing countries. Financial support was provided by the U.S. Agency for International Development through the National Science Foundation.

The initial work of the Project was undertaken by Maria Penny and Mary Harbeck under the guidance of Dr. Lockard. Their major concern was the identification of equipment considered basic to the teaching of the sciences at an introductory level. An international survey was conducted, and a list of equipment to be made was compiled. A start was also made on the writing of guidelines (theoretical designs) for the construction of equipment.

Work on the development of the Guidebook itself got underway in 1970, with the arrival of Reginald F. Melton to coordinate the work. Over 200 guidelines were completed during the year by Donald Urbancic (Biology), Chada Samba Siva Rao and John Delaini (Chemistry), and Reginald Melton (Physics). Full use was made of project materials from around the world which were available in the files of the International Clearinghouse on Science and Mathematics Curricular Developments, which is located in the Science Teaching Center of the University of Maryland. The guidelines were compiled into a draft edition of the Guidebook which was circulated in September, 1971, to some 80 science educators around the world for their comments and advice.

The work of constructing and developing equipment from the guidelines, with the subsequent production of detailed designs, began in a limited way in 1970, the major input at that time being in the field of chemistry by Chada Samba Siva Rao, who was with the project for an intensive two-month period. However, the main work of developing detailed designs from the guidelines was undertaken between 1971 and 1972 by John Delaini (Biology), Ruth Ann Butler (Chemistry) and Reginald Melton (Physics). Technical assistance was given by student helpers, with a special contribution from David Clark, who was with the project for a period of 18 months.

Thanks are due to those graduates, particularly Samuel Genova, Melvin Soboleski and Irven Spear, who undertook the development of specific items of equipment while studying at the Center on an Academic Year Institute program; to student helpers, especially Don Kallgren, Frank Cathell and Theodore Mannekin, who constructed the equipment; and to Dolores Aluise and Gail Kuehnle who typed the manuscripts.

Last, but not least, special acknowledgement is due to those individuals, and organizations, around the world who responded so willingly to the questionnaires in 1968 and to the draft edition of the Guidebook in 1971.

The Guidebook

The designs presented in the Guidebook are based on the premise that many students and teachers in developing countries will wish to make equipment for themselves. This does not mean that students and teachers are expected to produce all their own apparatus requirements. It is recognized that teachers have specific curricula to follow, and that "class hours" available for such work are very limited. It is also recognized that teachers, particularly those in developing countries, are not well paid, and often augment their salaries with supporting jobs, thus placing severe limits on the "out-of-class hours" that are available for apparatus production.

However, in designing equipment for production by students and teachers, two factors have been kept in mind. One, project work in apparatus development can be extremely rewarding for students, bringing both students and teachers into close contact with the realities of science, and relating science and technology in the simplest of ways. Two, it is not difficult for cottage (or small scale) industries to adapt these designs to their own requirements. The Guidebook should therefore not only be of value to students and teachers, but also to cottage industries which may well be the major producers of equipment for schools.

Although all the designs in the Guidebook have been tested under laboratory conditions in the University of Maryland, they have not been tested in school situations nor produced and tested under local conditions in developing countries. It is therefore recommended that the designs should be treated primarily as limited resource materials to be subjected to trial and feedback. It is suggested that the first time that an item is constructed it should be made precisely as described in the Guidebook, since variations in the materials, or the dimensions of the materials, could alter the characteristics of the apparatus. However, once this item has been tested the producer is encouraged to make any number of modifications in the design, evaluating the new products against the original.

Before producing new equipment in quantity, it is recommended that educators with experience in the field of science education should be involved in determining how best to make use of the Guidebook. They will wish to relate the apparatus to their own curriculum requirements, and, where necessary, prepare relevant descriptions of experiments which they recommend should be undertaken using the selected apparatus. They will want to subject the experiments and related equipment to trials in school situations. Only then will they consider large-scale production of apparatus from the designs in the Guidebook. At this stage educators will wish to control the quality of apparatus production, to train teachers to make the best use of the new apparatus, and to insure that adequate laboratory conditions are developed to permit full utilization of the apparatus. Too often in the past apparatus has sat unused on many a classroom shelf, simply because the teacher has been untrained in its usage, or the laboratory facilities have been inadequate, or because the apparatus available did not appear to fit the requirements of the existing curriculum. Such factors are best controlled by educators in the field of science education in each country. Clearly the science educator has a crucial role to play.

Apparatus development, like any aspect of curriculum development, should be considered as a never ending process. This Guidebook is not presented as a finished product, but as a part of this continuing process. There is no doubt that the designs in this book could usefully be extended, descriptions of experiments utilizing the apparatus could be added, and the designs themselves could be improved. No extravagant claims are made concerning the Guidebook. It is simply hoped that it will contribute to the continuing process of development.

TOOLS AND RAW MATERIALS

The raw materials required to make specific items of equipment are indicated at the beginning of each item description. However, there are certain tools and materials which are useful in any equipment construction workshop, and these are listed below.

Tools

Chisels, Wood

3, 6, 12, 24 mm
(i.e., 1/8", 1/4", 1/2", 1")

Cutters

Bench Shears: 3 mm (1/8") capacity
Glass Cutter
Knife
Razor Blades
Scissors: 200 mm (8")
Snips (Tinmans), Straight: 200 mm (8")
Snips (Tinmans), Curved: 200 mm (8")
Taps and Dies: 3 to 12 mm (1/8" to 1/2") set

Drills and Borers

Cork Borer Set
Countersink, 90^{0}
Metal Drill Holder (Electrically Driven), Capacity 6 mm (1/4")
Metal Drills: 0.5, 1, 2, 3, 4, 5, 6, 7 mm
(i.e., 1/32", 1/16", 3/32", 1/8", 5/32", 3.16", 7/32", 1/4") set
Wood Brace with Ratchet: 250 mm (10")
Wood Auger, Bits: 6, 12, 18, 24 mm
(i.e., 1/4", 1/2", 3/4", 1")

Files, Double Cut

Flat: 100 mm, 200 mm (4", 8")
Round: 100 mm, 200 mm (4", 8")
Triangular: 100 mm (4")

Hammers

Ball Pein: 125, 250, (1/4, 1/2 lb)
Claw 250 g (1/2 lb)

Measuring Aids

Caliper, Inside
Caliper, Outside
Caliper, Vernier (may replace above two items)
Dividers: 150 mm (6"), Toolmakers
Meter, Electrical (Multipurpose - volts, ohms, amps, etc.)
Meter Stick
Protractor
Scriber

Measuring Aids (Continued)

Set Square
Square, Carpenter's: 300 mm (12") blade
Spoke Shave: 18 mm (3/4")
Wood Smoothing Plane

Pliers

Combination: 150 mm (6")
Needle Nose: 150 mm (6")
Side Cutting: 150 mm (6")
Vise Grips

Saws, Metal

300 mm (12") blades

Saws, Wood

Back Saw: 200, 300 mm (8", 12")
Coping Saw: 200 mm (8")
Cross Cut: 600 mm (24")
Hand Rip: 600 mm (24")
Key Hole Saw: 200 mm (8")

Screw Drivers

100 mm (4"), with 2 and 3 mm tips
150 mm (6"), with 5 mm tip
200 mm (8"), with 7 mm tip

Vise

Metal Bench Vise: 75 mm (3")
Wood Bench Vise: 150 mm (6")

Miscellaneous

Asbestos Pads
Goggles, Glass
Oil Can: 1/2 liter (1 pint)
Oil Stone, Double Faced
Punch, Center
Sandpaper and Carborundum Paper, Assorted grades
Soldering Iron: 60 watts, 100 watts

Raw Materials

Adhesives

All Purpose Cement (Elmers, Duco)
Epoxy Resin & Hardener (Araldite)
Rubber Cement (Rugy)
Wood Glue (Weldwood)
Cellophane Tape
Plastic Tape
Masking Tape

Electrical Materials

Bulbs with Holders: 1.2, 2.5, 6.2 volts
Dry Cells: 1.5, 6 volts
Electrical Wire: Cotton or Plastic covered
Fuse Wire: Assorted
Lamps: 50, 75, 100 watts
*Magnet Wire: #20, 22, 24, 26, 28, 30, 32, 34
Nichrome Wire: Assorted
Parallel Electrical Cording
Plugs
Switches

Glass and Plastic

Acrylic (Plastic) Sheets: 2 cm and 2.5 cm thick
Plates, Glass
Tubes, Glass: 3, 6 mm (1/8", 1/4") internal diameter

Hardware

Bolts and Nuts, Brass or Steel; 3 mm (1/8") diameter: 12, 24, 48 mm (1/2", 1", 2") lengths
Nails: 12, 24 mm (1/2", 1") lengths
Screws, Eye
Screws, Wood: 12, 18, 24, 26 mm (1/2", 3/4", 1", 1 1/2") lengths
Thumbtacks
Washers (Brass and Steel): 6, 9 mm (1/4", 5.16") diameter
Wingnuts (Steel): 5 mm (3/16")

Lumber

Boxwood (Packing Case Material)
Hardboard: 6 mm (1/4") thick
Kiln Dried Wood: 2.5 x 15 cm (1" x 6") cross section
1.2 x 15 cm (1/2" x 6") cross section
Plywood: 6, 12 mm (1/4", 1/2") thickness
Wood Dowels: 6, 12 mm (1/4", 1/2") thickness

---

* U.S. Standard Plate numbers are used in this book to indicate the gauge of different wires. Where wires are referenced against other numbering systems appropriate corrections should be make in determining the gauges of materials required. The following comparison of gauges may be of interest:

Standard	Diameter of #20 Wire
Brown & Sharp	0.08118
Birmingham or Stubs	0.089
Washburn & Moen	0.0884
Imperial or British Standard	0.0914
Stubs' Steel	0.409
U. S. Standard Plate	0.09525

Metal Sheets

Aluminum: 0.2, 0.4 mm (1/100", 1/64") thickness.
Brass: 0.4, 0.8 mm (1/64", 1/32") thickness.
Galvanized Iron: 0.4 mm (1/64") thickness.
Lead: 0.1 mm (1/250") thickness.
Spring Steel, Packing Case Bands

Metal Tubes:

Aluminum, Brass Copper: 6, 12 mm (1/4", 1/2") internal diameter.

Metal Wires

Aluminum: 3 mm (1/8") diameter
Coathanger: 2 mm (1/16") diameter
*Copper: #20, 24
Galvanized Iron: 2 mm (1/16") diameter
*Steel: #20, 26, 30.

Paint Materials

Paint Brushes
Paint Thinner
Varnish
Wood Filler

Miscellaneous

Aluminum Foil
Cardboard Sheeting
Containers (Plastic or Glass)
Corks (Rubber or Cork)
Grease
Hinges: Assorted
Machine Oil
Marbles
Mesh (Cotton, Nylon, Wire)
Modelling Clay (Plasticene)
Paper Clips
Pens: Felt (Marking Pens)
Pins and Needles
Rubber Bands
Soldering Lead
Soldering Paste
Spools
Steel Wool
Straws
String (Cord, Cotton, Nylon)
Styrofoam
Syringes: Assorted
Wax (Paraffin)

*See footnote on previous page.

I. MAGNIFIERS AND MICROSCOPES

A. MAGNIFIERS

Magnifiers are used for low power magnification. The three included here can be employed wherever it is desirable to see a little more detail than is obtainable with the naked eye.

B. MICROSCOPES

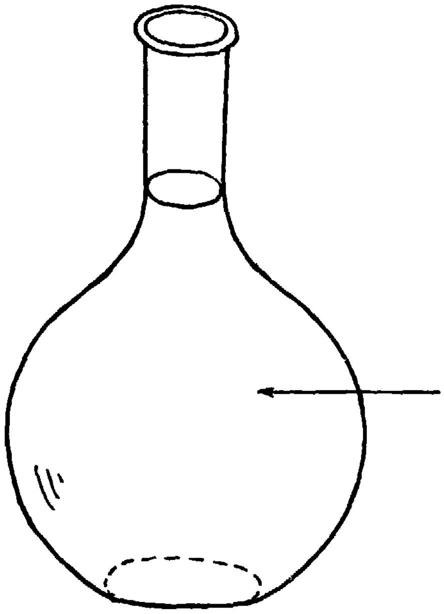
Where high power magnification is needed, microscopes can be used. The ones in this section can, for the most part, be adapted to use water drop, glass bead, or penlight bulb lenses. Magnifications up to around 60X - 80X may be gotten using these microscopes. All are designed for use with freshly and/or permanently mounted glass slides.

C. SUPPLEMENTARY APPARATUS

These items are essential for preparing the slides to be viewed with the microscopes.

A. MAGNIFIERS

A1. Water Filled Magnifier



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Flask	1	Spherical Body Flask (A)	50-500 ml

b. Construction

(1) Flask

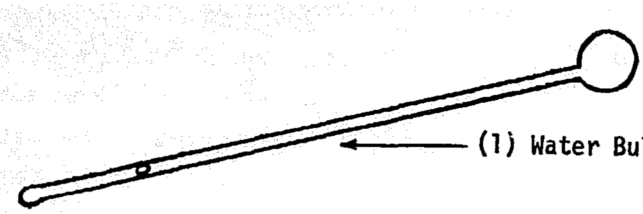
Simply fill the flask (A) with clear water up to the neck.

c. Notes

(i) A 250 ml flask (about 7.5 cm in diameter) will magnify approximately the same as a double convex magnifying glass 4 cm in diameter and 0.7 cm in thickness.

(ii) Smaller diameter flasks appear to magnify more than larger diameter ones.

A2. Water Bulb Magnifying Glass *

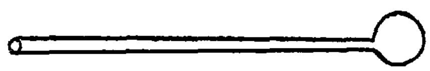


a. Materials Required

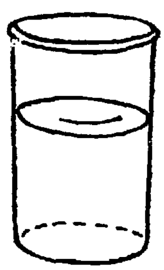
Components	Qu	Items Required	Dimensions
(1) Water Bulb Magnifying Glass	1	Glass Tubing (A)	0.3 cm diameter, 10-13 cm long

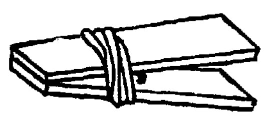
b. Construction

(1) Water Bulb Magnifying Glass

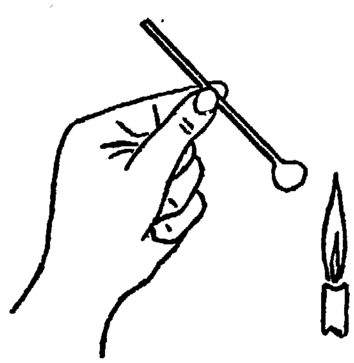


Use a Bunsen Burner or gas burner and fuel system (CHEM/II/C1 and 2) as a heat source. Follow the glass-blowing instructions (CHEM/I/D6) and blow at one end of the glass tube (A) a bulb of about 0.8 cm diameter.



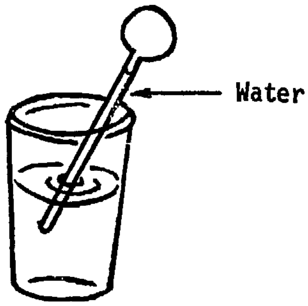


Provide a glass or cup of water and a wooden clothespin, pinch clamp (CHEM/IV/A4) or a few square centimeters of cloth to serve as a holder.

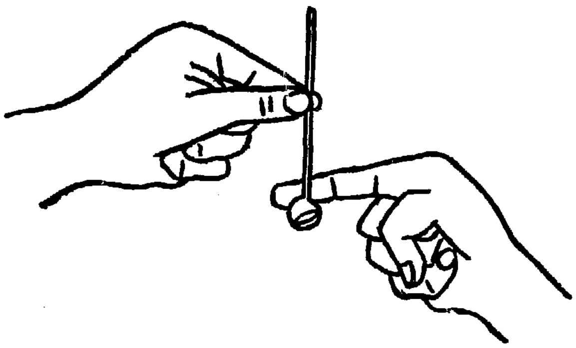


Rotate the bulb near, but not in, the flame to expand the air in the bulb.

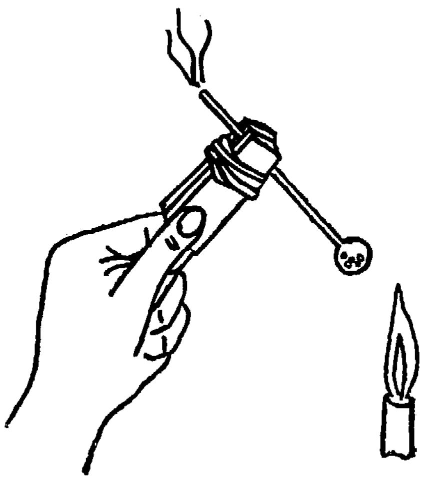
*Adapted from James E. Hammesfahr and Claire L. Strong, Creative Glassblowing, (San Francisco: W. H. Freeman and Company, 1964), pp 108-9.



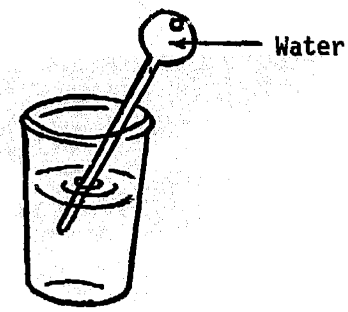
After a few seconds of heating, quickly invert the piece and put the open end into the water. Allow the piece to remain in the water a few seconds. The air in the bulb contracts and water is drawn up into the tube.



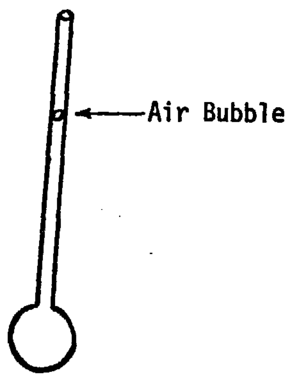
Remove the piece from the water and hold it, bulb down, in one hand near the open end of the tube. Lightly flick the bulb with the index finger of the other hand. Continue flicking until the water has gone from the tube into the bulb.



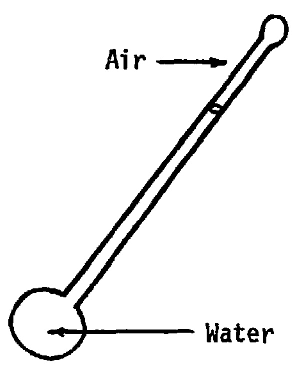
Next, grasp the tube with the clothespin, pinch clamp, or folded cloth, and again hold the bulb close to the flame until the water boils. Point the open end of the tube away from yourself and anyone else.



Heat the bulb while steam escapes from the tube for about 5 seconds. Then quickly invert the tip of the tube into the water. Allow the tube to remain in the water until the bulb is full, or nearly full, of water. If after a few minutes, the bulb has not filled with water, repeat the heating and filling process.



Remove the piece from the water and invert it so that any air remaining in the bulb can enter the tube. Flick the bulb, as before, and the bubble will rise to the open end of the tube.



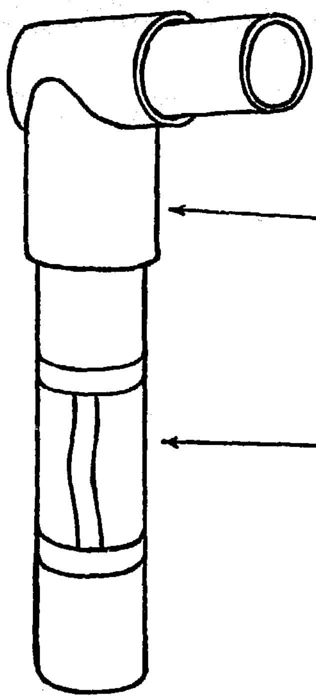
Holding the bulb with the tube upright, heat the end of the tube in the hottest part of the flame to seal the tip. As the tip seals, the expanding air of the trapped bubble blows a tiny bulb at the end of the tube.

c. Notes

(i) The first heating of the bulb expands the air, which, when it contracts, draws a small amount of water into the bulb. Converting this water into steam expels all the air and causes the bulb to fill completely with water as the steam condenses.

(ii) When this water-filled bulb is held about 0.5 cm from an object, the object will appear distorted around the edges, but clear and greatly enlarged at the center of the bulb.

A3. Illuminated Hand Magnifier



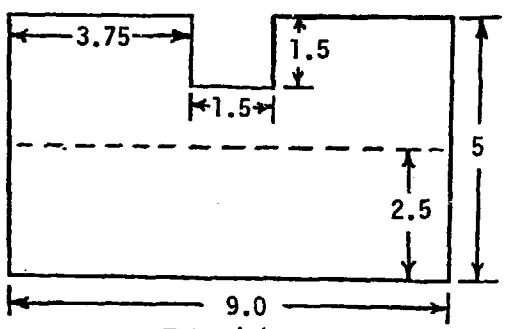
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Eyepiece	1	Double Convex Lens (A)	2.5 cm diameter
	1	Single Convex Lens (B)	2.5 cm diameter
	1	Cardboard Tube (C)	5 cm long, 2.5 cm inside diameter
	1	Cardboard Tube (D)	5 cm long, 2.8 cm inside diameter
(2) Adaptor	1	Cardboard Tube (E)	5 cm long, 3.5 cm inside diameter
(3) Barrel	1	1.5 Volt Penlight Bulb (F)	2.2 cm long, 1.0 cm diameter
	1	Tin Sheet (G)	3.7 diameter, 0.05 cm thick
	2	Electrical Wire (H)	10 cm long, #26 gauge (about 0.05 cm in diameter); strip insulation from 1 cm of each end

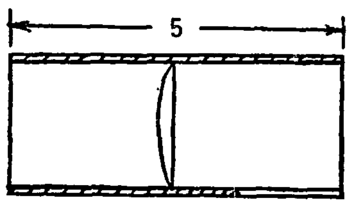
2	1.5 Volt Dry Cells (I)	3.2 cm diameter. 5.7 cm long
1	Steel Bolt (J)	2 cm long, 0.5 cm diameter
1	Steel Nut (K)	0.5 cm insid diameter
1	Steel Strapping (L)	12.5 cm x 1.2 cm x 0.05 cm
1	Cardboard (M)	3.5 diameter
1	Cardboard Tube (N)	15 cm long, 3.2 cm inside diameter

b. Construction

(1) Eyepiece



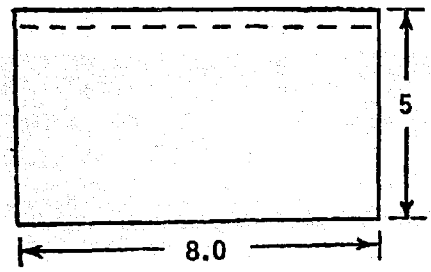
Tube (D)



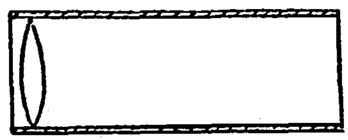
Cross Section of Tube (D)

If a cardboard tube cannot be found of the required size, one can easily be made from a piece of cardboard cut as shown. Roll the cardboard into a tube (D) 5 cm long and position the single convex lens (B) in place with the edge on the dotted line. The lens can be held in place with rubber cement or similar flexible adhesive while the tube (D) is held together with masking tape. Be certain the flat side of the lens faces the front (notched) end of the tube.

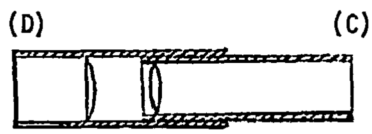
The second tube (C) may be made the same way as the first if a manufactured cardboard tube of the correct size cannot be found. Roll the cardboard into a tube and position the double convex lens (A) at one end with rubber cement. Fasten the tube securely with masking tape. This tube (C) should fit rather snugly inside tube (D), but still be able to slide easily back and forth.



Tube (C)



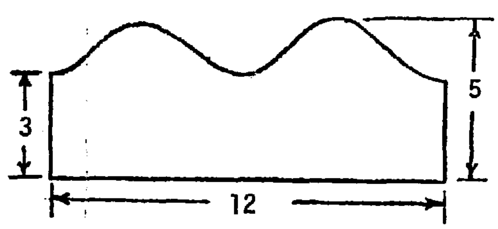
Cross Section of
Tube (C)



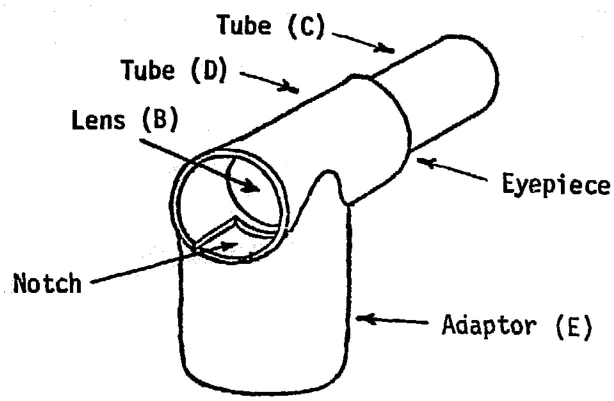
Cross Section

(2) Adaptor

The adaptor can be made from a cardboard tube (E) by notching one end so that it will interlock with the eye-piece. The adaptor and eye-piece can then be taped with masking tape. Alternatively,



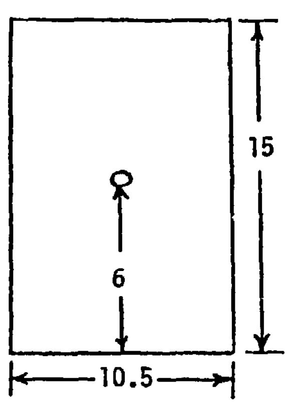
Adaptor Pattern



the pattern for the adaptor can be cut from cardboard, rolled into a cylinder, and taped. Even if the two tubes don't "mesh" exactly, they can be taped well enough to overcome inaccuracies.

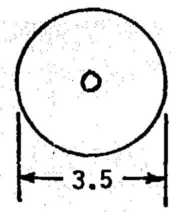
When binding the eyepiece and adaptor together with tape, be sure that the notch in the eyepiece tube (D) is directly over the adaptor tube opening.

(3) Barrel



Tube (N)

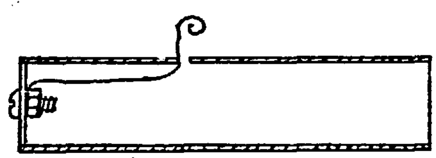
If a tube (N) of the correct size is available, simply punch a small hole (0.2 cm) about 6 cm from one end of the tube. Otherwise, a tube can be fashioned from a piece of cardboard of the indicated dimensions. Roll and tape it so that it is 15 cm long and has a 3.2 cm inside diameter.



Cardboard (M)

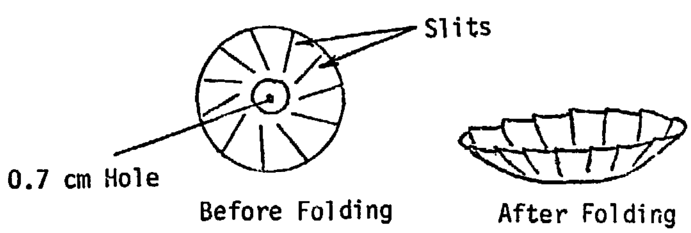
Side View

To seal off the end of tube (N), use the circular piece of cardboard (M). First, punch a hole in the center of the cardboard disc, and insert the short steel bolt (J). Fasten one of the pieces of electrical wire (H) in place with the nut (K). Pull the free end of the wire through the hole in the tube (N) and glue the disc (M) in place to seal off one end of the tube.

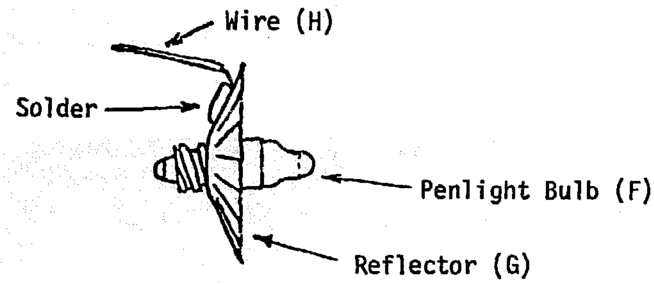


Cross Section of Tube (N)

Use the disc of tin sheeting (G) to make a reflector. First, drill a hole in the center of the disc of a diameter such that the pen-light bulb (F) will screw into it securely (approximately 0.7 cm diameter). Next, cut slits in the disc (G) as shown. Fold the resulting flaps up slightly so that

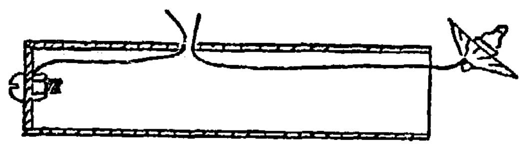


Reflector (G)



the reflector approximates a cone in appearance.

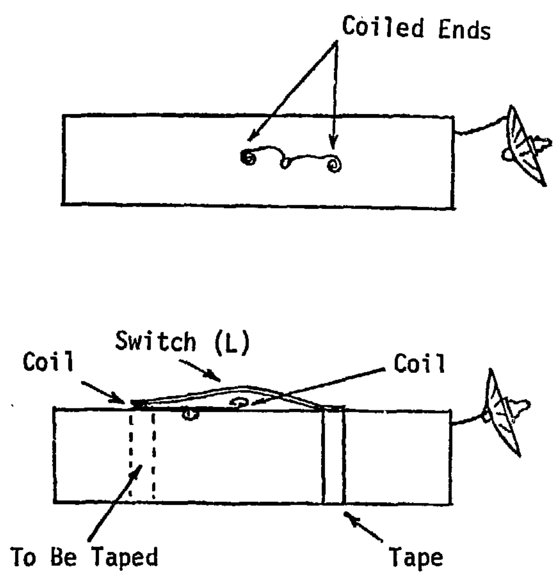
Next, screw the bulb (F) in place, and solder one end of the second piece of wire (H) to the back of the reflector. Pull the free end of the wire through the hole in the barrel tube (N) and leave the reflector assembly loose temporarily.



Cross Section

Switch (L)

The switch is made from the piece of steel strapping (L). Give it a slight bend in the middle.

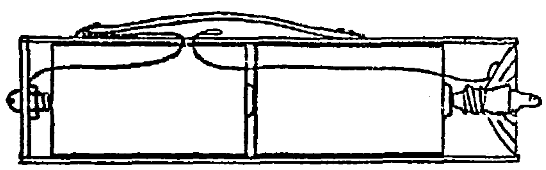


Side Views

Coil the free end of the wire which comes from the sealed end of the barrel. Do likewise for the other wire. Tape the switch to the barrel making certain that one end of the switch is taped directly over one of the wire coils and that the second coil is directly under the bent portion of the switch but not touching it. In other words, when the switch is depressed, contact will be made with the wire coil and the circuit from the bolt to the bulb will be completed.

Finally, insert two dry cells (I) into the barrel and push the reflector assembly into place.

The bulb must make contact with the battery. The reflector assembly should hold in place by tension, and require no further fastening. When the switch is pressed, the light should go on.



Cross Section of Completed Barrel

To complete the illuminated hand magnifier, insert the barrel into the adaptor.

c. Notes

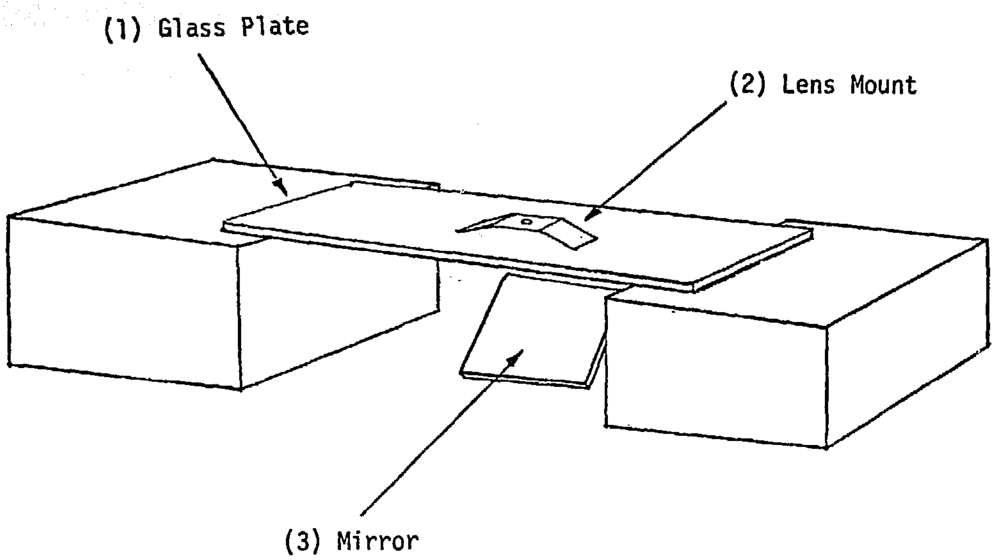
(i) The illuminated hand magnifier must be held directly over the object to be viewed. The light serves to concentrate the illumination of the object while focusing is accomplished by moving the eyepiece tube (C) up and down in relation to the second tube (D).

(ii) This magnifier is excellent for observing detail on such items as insect parts, plant surface features, crystals, etc.

(iii) Obviously, any variation in the lens diameter as given here will necessitate changes in the dimensions of the item. If a lens is slightly smaller than the cylinder into which it must be fit, it can be built up by wrapping thin pieces of tape around its edge until it will fit snugly.

B. MICROSCOPES

B1. Glass Stage Microscope



a. Materials Required

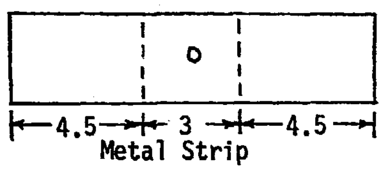
Components	Qu	Items Required	Dimensions
(1) Glass Plate	1	Window Glass (A)	20 cm x 10 cm (at least)
(2) Lens Mount	1	Metal Strip (B)	12 cm x 3 cm x 0.1 cm
(3) Mirror	1	Mirror Glass (C)	Approximately 5 cm x 5 cm

b. Construction

(1) Glass Plate

Rest the glass plate (A) on two books or other stable supports. The glass plate serves as the microscope stage.

(2) Lens Mount



Drill a hole through the center of the lens mount (B). The diameter of the hole will depend on the size and type of lens used [see Notes (ii), (iii), (iv)]. Bend the end of the lens mount down at a slight angle.

(3) Mirror

Use the mirror (C) to reflect enough light through the specimen to permit it to be seen well. If a mirror is not available, use polished metal or other reflective material.

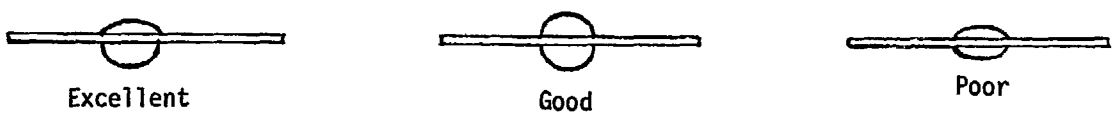
c. Notes

(i) Operating the glass stage microscope is exceptionally easy. Simply place the glass slide containing the specimen under the lens mount and reflect light through the specimen with the mirror. Focusing is accomplished by pushing on the lens mount so that the lens moves closer to or further from the specimen.

(ii) For maximum success in making water drop lenses, the hole in the lens mount must be properly prepared. First of all, this means that the hole should be as nearly circular as possible. A drill will yield best results although holes can be punched with nails, punches, or other sharp implements. Additionally, the edge of the hole should be made smooth and free from burrs. This can be done with a file or tool made especially for this purpose. The optimum size for the hole was found to be approximately 2.5 mm - 3.5 mm in diameter.

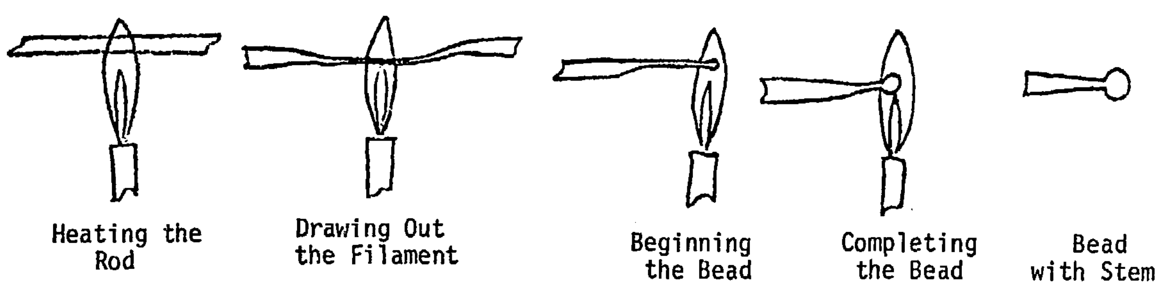
Once the hole has been made, the area around the hole should be heated and candle wax melted onto both sides of the lens mount around the hole. Be certain that no wax gets into the hole. This coating of wax prevents the water drop from spreading out and deforming.

When the hole has been prepared, the water drop lens is made simply by carefully placing a drop of water in the middle of the hole so that it is suspended from the edge. The drop is most easily handled with a dropper. It was found that a water drop with a slightly flattened side provided the best image while a drop flattened on both sides was poor.

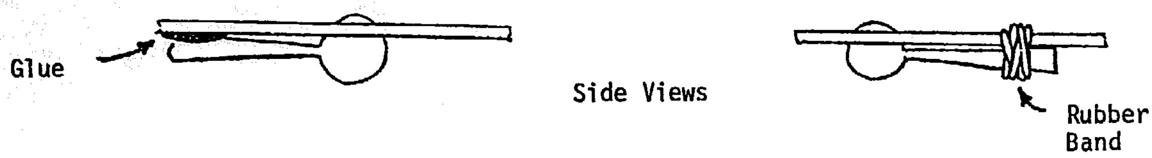


(iii) The object in making a glass bead lens is to form as nearly spherical and clear a bead as possible. This is most easily done if soft glass rods are available. If harder glass is used, extremely hot flames are needed to work it.

First, evenly heat a portion of the glass rod in a flame until it softens. When it is soft, pull the ends out until a long filament is formed and continue to pull until the filament breaks. Using the longer of the two filaments, heat the tip until a bead begins to form. Turning the filament so that the bead forms evenly, continue to heat the bead until it reaches the desired size. Allow the bead to cool and then break it off along with a portion of the stem.



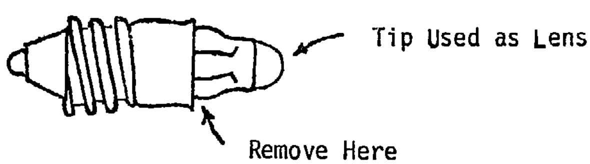
Beads can be made from approximately 2.0 mm to 5.0 mm in diameter, although those from 2.5 mm - 4.0 mm work best. Before mounting the bead on the lens mount, be certain that the hole in the mount is slightly smaller in diameter than the bead. This is extremely important. The bead can then be glued or held in place by a rubber band (see diagram).



As the diagrams show, the bead stem should be kept on the underside of the lens mount.

Although glass beads can be made from glass tubing, it is almost impossible to prevent air bubbles from forming in the bead which cause great distortion of the image. Therefore, use solid glass rods, if possible.

(iv) <u>Penlight bulb lenses</u> are made from the penlight bulbs used in small, fountain-pen sized flashlights (battery operated torches). Those commercially available in the United States are approximately 2 cm long and 1 cm in diameter at the widest point. The portion used as a microscope lens is the thickened glass at the tip of the bulb (see diagram).



The lens can be removed from the bulb by scratching the glass portion of the bulb close to the metal part. This avoids scratching the tip of the bulb itself, and is best accomplished with a small, triangular file. Once the whole glass bulb has been separated from the metal part, the lens will break off quite readily; in fact, it may fly off and be damaged unless caution is observed.

The lens may be mounted to the lens mount merely by drilling a hole the same diameter (or slightly smaller) as the lens. Then, apply a flexible glue (e.g., rubber cement) around the edge of the hole and set the lens in place (see diagram). Allow the glue to set before using the microscope.

Cross Section

The penlight bulb lens appears to work best when mounted rounded side up as shown in the diagram.

(v) Because all the microscopes described here are single lens types with small diameter lenses, the focal length is extremely small, which means that the lens must be close to the object viewed and also, the eye must be kept very close to the lens. This tends to cause a strain on the eye if the microscope is to be used for an extended period of time. In addition, it means that the depth of field is extremely limited, requiring frequent adjustments to focus.

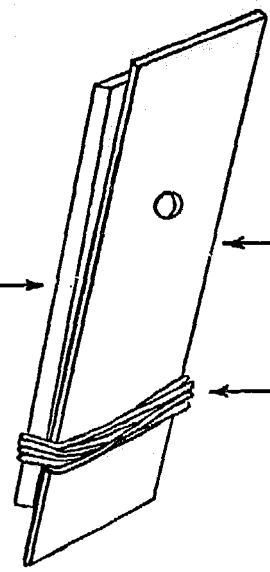
(vi) Magnification power for the different lenses is difficult to determine, but it appears that water drops and glass beads of the same diameter have the same power of magnification. Drops or beads with diameters of 2.0 mm to 4.0 mm give magnifications of approximately 40X - 60X to 20X - 30X with smaller diameter beads yielding larger magnifications. The penlight bulb lens is approximately 5 mm in diameter and 3 mm thick, and gives magnification of about 50X - 70X. With all lenses, the portion of the field in focus is rather small.

(vii) Care should be taken to keep the lenses (except water drop) clean with tissues. Also, slides, mirrors, etc., should be kept as dust free as possible.

(viii) The best material for the lens holder seems to be aluminum sheeting about 0.5 mm thick. Other types of stiff, flexible metal sheeting also work well. Cardboard or strong paper can be used, but yields poor results.

(ix) Light to illuminate the specimen should be reflected through the microscope with a mirror or other shiny surface. A strong light source is required with sunlight working as well as any.

B2. Hand-Held Microscope



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Lens Mount	1	Metal Strip (A)	8 cm x 2.5 cm x 0.1 cm
(2) Rubber Band	1	Rubber Band (B)	--

b. Construction

(1) Lens Mount

Drill a hole in the metal strip (A). The position of the hole will depend upon where on the slide the specimen has been mounted.

The dimensions given here are for a lens mount to be used with a standard 7.5 cm x 2.5 cm (3 inches x 1 inch) glass slide.

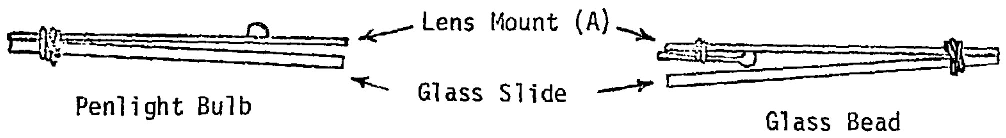
(2) Rubber Band

Wind the rubber band (B) around the slide and lens mount (A) to hold the two together so they don't slip. Be certain to position the lens directly over the specimen or portion of specimen to be viewed. Take care in moving the lens mount that the edge does not cut the rubber band.

c. Notes

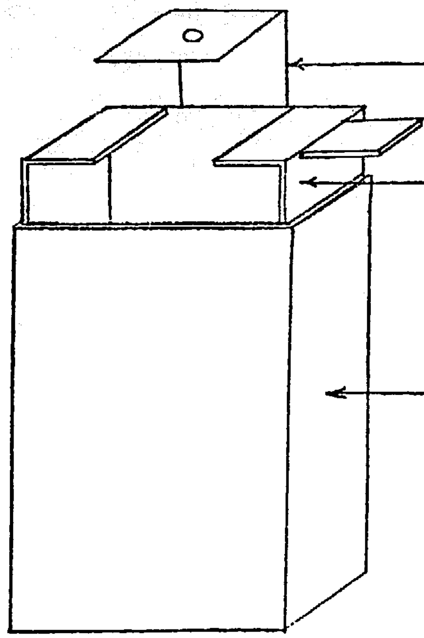
(i) This simple microscope works well with either glass bead or penlight bulb lenses [see I/B1, Notes (iii) and (iv)]. Using it with a water drop lens is quite difficult in that it is difficult to prevent the water from touching the slide. In addition, this microscope works best when held vertically rather than horizontally as is necessary with the water drop.

(ii) See the following diagrams for positioning the glass bead and penlight bulb lenses on the lens mount.



(iii) This microscope should be used primarily with permanently prepared slides as opposed to fresh mounts. Focusing is achieved simply by holding the slide with one hand and moving the lens mount back and forth with the other.

B3. Match Box Microscope *

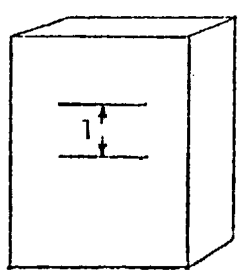


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Body	1	Match Box Cover (A)	5 cm x 3.5 cm x 1.5 cm
(2) Stage	1	Match Box Drawer (B)	5 cm x 3.5 cm x 1.5 cm
	1	Metal Strip (C)	3 cm x 1 cm x 0.1 cm
(3) Lens Holder	1	Aluminum Strip (D)	7.5 cm x 2.5 cm x 0.1 cm

b. Construction

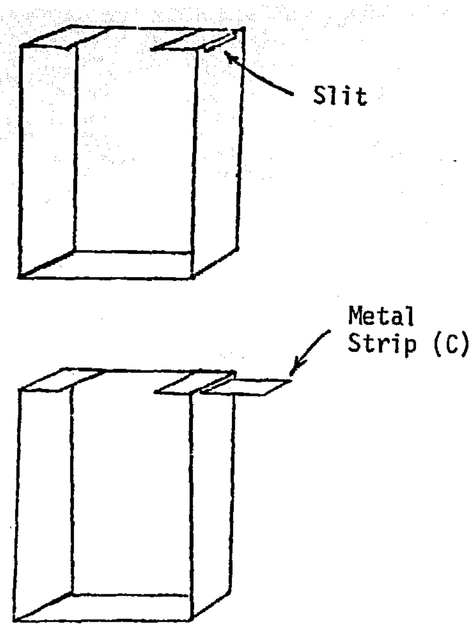
(1) Body



With a razor blade, make two slits in the back of the match box cover (A). These slits need to be slightly wider than the width of the lens holder (2.5 cm).

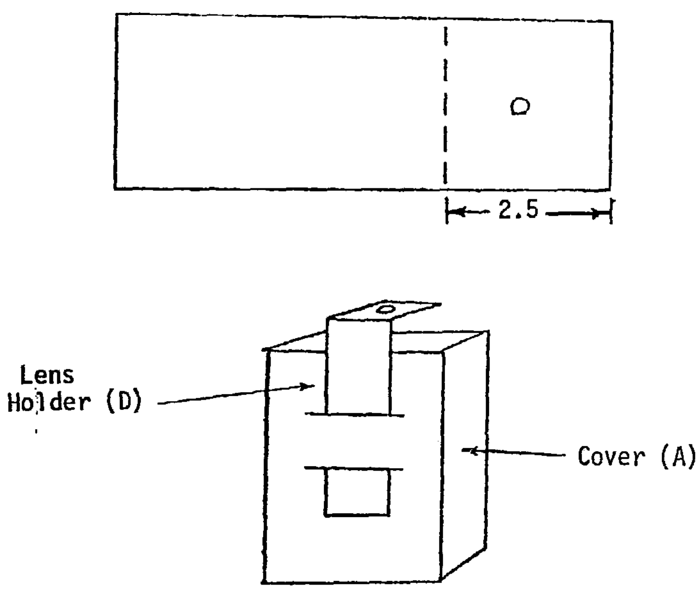
*Adapted from African Primary Science Program, Making Things Look Bigger, (Nairobi, Kenya: Curriculum Development and Research Center, 1967), pp 24-25.

(2) Stage



Cut out one end of the match box drawer (B) so that portions of the end 0.5 cm wide are left on either side. At the same end of the drawer, make a slit about 1 cm wide with a razor blade. Insert the metal strip (C) into this slit and glue it in place. Use this strip to move the stage up and down when focusing.

(3) Lens Holder



Drill a hole in one end of the aluminum strip (D), and bend it at right angles. If a drill is not available, punch a hole in the metal with a nail. Insert the metal strip through the slits in the back of the match box cover (A) to insure that it will be held in place securely. Then, remove the lens holder, slide the stage into the body, and replace the lens holder. The microscope is now ready for use.

c. Notes

(i) To use this microscope, place the slide or specimen on the stage directly under the lens. Focusing is accomplished by moving the stage up and down as the lens holder remains stationary. As with all single lens microscopes, the eye must be kept quite close to the lens in order to see the image.

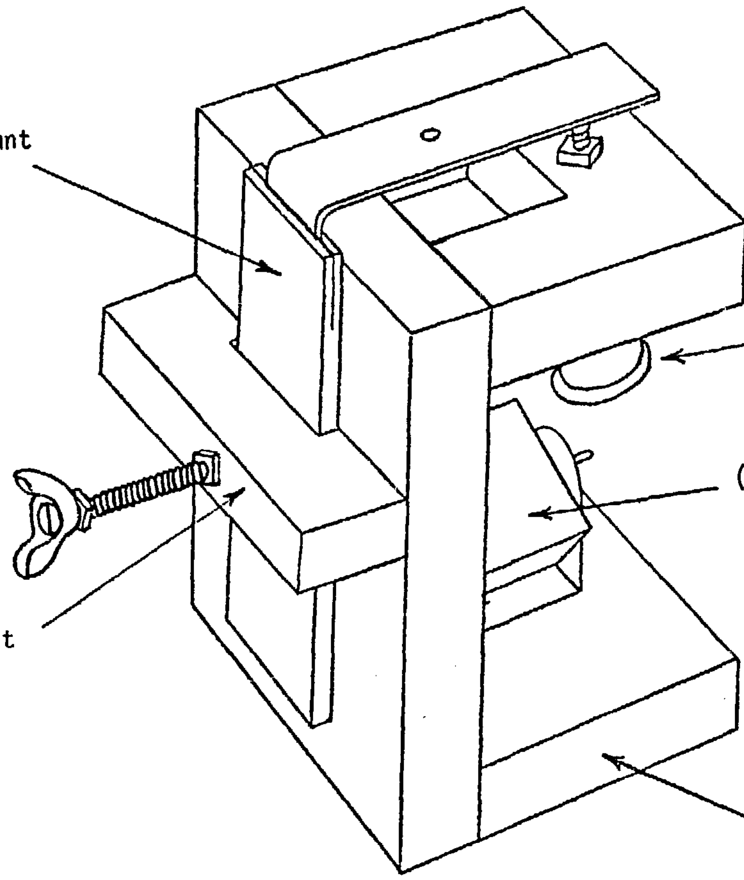
(ii) See I/B1, Notes (ii), (iii), and (iv) for complete instructions in adapting the lens holder to use either water drop, glass bead, or penlight bulb lenses.

(iii) With an item this small, it is found that there is some difficulty in keeping a glass slide on the stage, especially when the stage must be moved in focusing.

(iv) Since it is difficult to get sufficient light through the specimen, it is suggested that the inside of the match box drawer be lined with light colored paper or metal foil to increase reflected light.

(v) This microscope was found to be good for inspecting such items as coins, newsprint, insect wings, crystals, etc.

B4. Adjustable Microscope



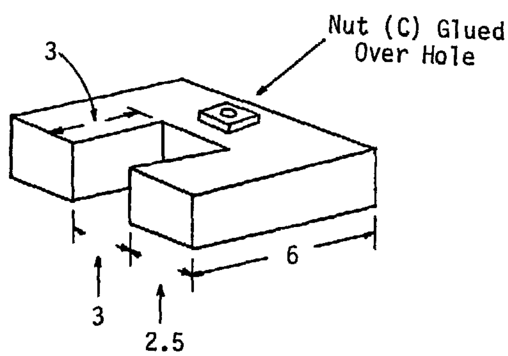
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base and Stage Assembly	1	Wood (A)	12 cm x 8 cm x 1.5 cm
	2	Wood (B)	6 cm x 8 cm x 1.5 cm
	1	Nut (C)	0.5 cm internal diameter
(2) Lens Mount Holder	1	Wood (D)	2.5 cm x 8 cm x 1.5 cm
	1	Bolt (E)	0.5 cm diameter, 6 cm long

	1	Wing Nut (F)	0.5 cm internal diameter
	2	Nuts (G)	0.5 cm internal diameter
(3) Lens Mount	1	Wood (H)	10 cm x 3.5 cm x 0.5 cm
	1	Aluminum Sheet (I)	9 cm x 2 cm x 0.1 cm
(4) Adjustment Knob	1	Wood Spool (J)	3 cm long, 2 cm diameter
	1	Bolt (K)	0.5 cm diameter, 6 cm long
	1	Nut (L)	0.5 cm internal diameter
(5) Mirror	1	Mirror Glass (M)	3 cm x 3 cm
	1	Wood (N)	3 cm x 3 cm x 0.5 cm
	1	Metal Sheet (O)	8 cm x 2 cm x 0.05 cm
	1	Nail (P)	5 cm long, 0.2 cm diameter
	1	Tack (Q)	1 cm long

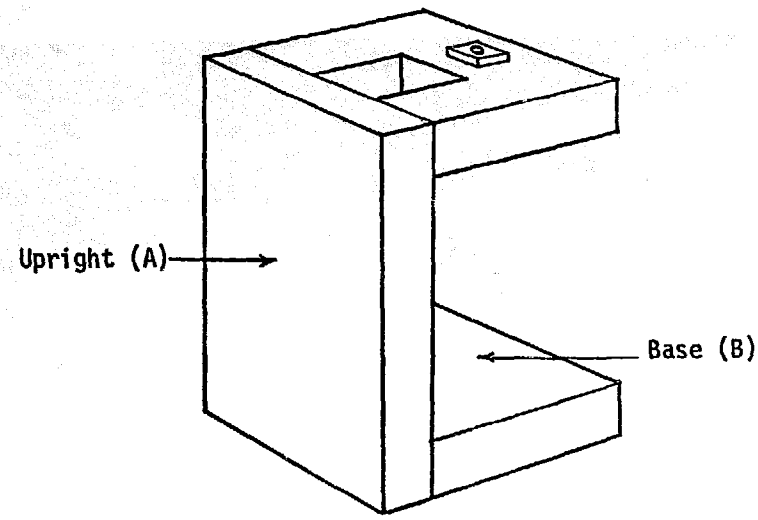
<u>b. Construction</u>

(1) Base and Stage Assembly



Stage (B)

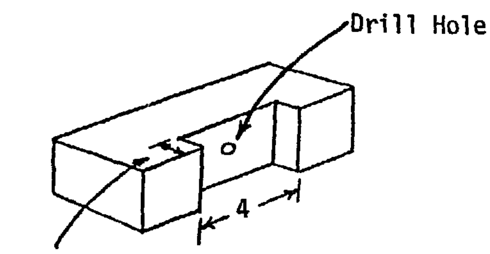
Cut a notch 3 cm square in one piece of wood (B) to make the stage. In this same piece, drill a hole through the wood. It should be centered between the edge of the notch and the edge of the stage. Make this hole slightly smaller in diameter than the bolt (K) used to make the adjustment knob. Place the nut (C) over the hole in the wood. Give it a sharp blow with a hammer so that it forms an indentation in the



Base and Stage Assembly

wood. Remove the nut, then glue it back in place taking care not to get glue in the hole or in the threads of the nut. It is best to allow the nut to dry with the bolt threaded through both it and the hole to assure proper alignment. Nail or screw this piece, the stage (B), to the upright (A). Likewise, nail or screw the base (B) to the upright.

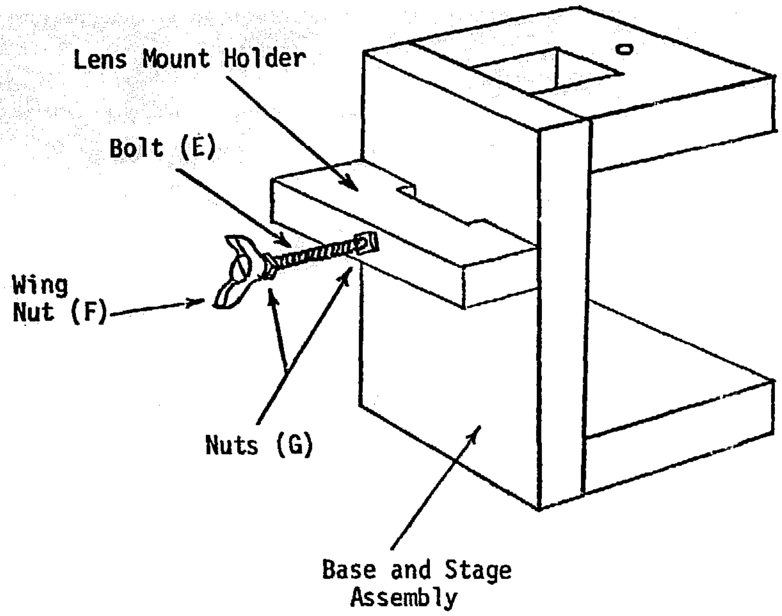
(2) Lens Mount Holder



Wood (D)

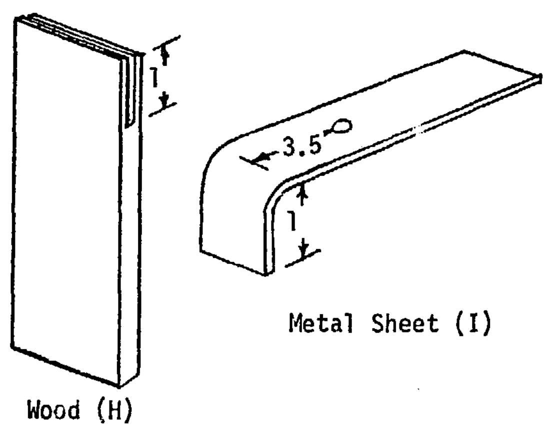
Cut a notch 0.6 cm deep and 4 cm wide in the piece of wood (D). Drill a hole in the center of the notch. This hole should be slightly smaller than the bolt (E) used to hold the lens mount in place.

Screw the wing nut (F) onto the bolt (E) and run it to the end of the bolt. Use one nut (G) to hold the wing nut tight to the end of the bolt. Place the other nut (G) over the hole in the piece of wood (D) and strike it hard with a hammer, taking care not to split the wood. Remove the

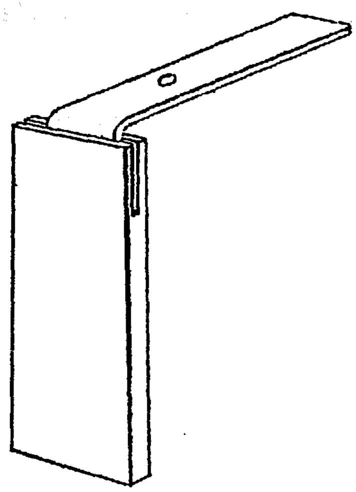


nut from the impression in the wood thus formed, and place a drop of strong glue in the impression and replace the nut. Be sure not to get glue in the threads of the nut or in the hole (this may be avoided by allowing the nut to dry with the bolt run all the way through the hole). Finally, glue, nail or screw the lens mount holder to the base and stage assembly.

(3) Lens Mount



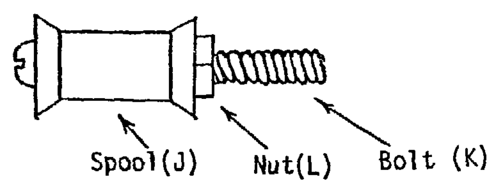
Make a slit in the end of the piece of wood (H), with a saw. This slit should be about 1 cm deep and slightly wider than the thickness of the metal sheet (I) used.



Lens Mount

Bend the aluminum sheet (I) to a right angle 1 cm from its end. Drill a hole 3.5 cm from the bend and centered. The diameter of this hole will depend upon the size of the water drop desired, the size of the glass bead used, or the size of the penlight bulb lens. [See I/B1, Notes (ii), (iii), and (iv) for instruction in making and using such lenses.] Glue the aluminum sheet (I) to the piece of wood (H).

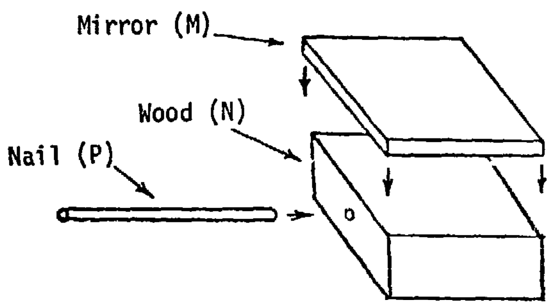
(4) Adjustment Knob



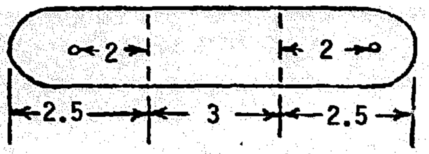
Side View

Run the bolt (K) through the hole in the wooden spool (J). Secure the spool tightly in place with the nut (L). Screw the end of the bolt through the hole and nut in the base and stage assembly.

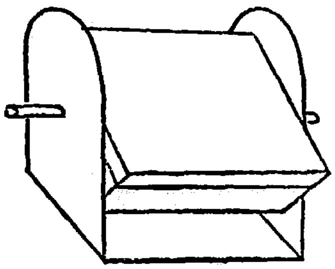
(5) Mirror



Cut the metal sheet (O) and drill two holes the same diameter as the nail (P) used. Bend the ends up at right angles along the dotted lines. Drill a hole through the wood (N) which is about the same diameter as the nail.



Metal Strip (0)


Completed Mirror

Insert the nail (P) through this hole and glue it in place. Glue the mirror (M) to the wood. Nail or screw the metal strip into position on the base directly under the notch in the stage. Insert both ends of the nail through the holes in the metal strip. There should be enough friction to keep the mirror at the desired angle.

c. Notes

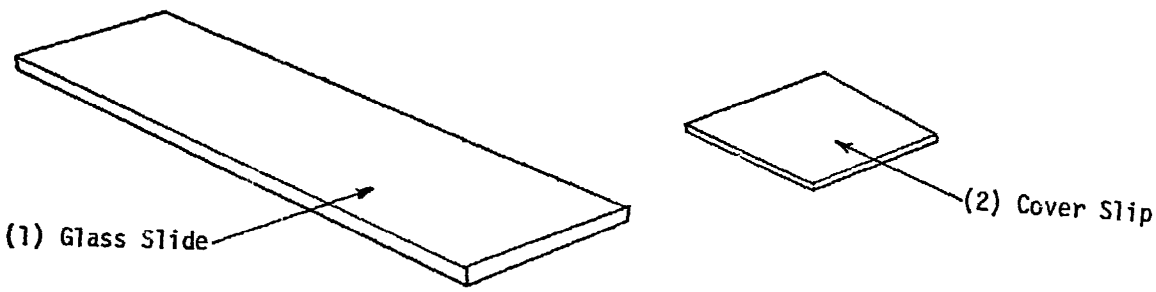
(i) The slide containing the specimen to be observed is placed over the hole in the stage. Light is reflected through the specimen and lens by means of the mirror. Coarse adjustment is obtained by varying the position of the lens mount with the lens mount holder bolt. Fine adjustment is attained by turning the adjustment knob so that it moves the metal portion of the lens mount up and down.

(ii) This microscope may be used with any of the three types of lenses: water drop, glass bead, or penlight bulb lens. See I/B1, Notes (ii), (iii), and (iv) for details in mounting each type lens on the lens mount.

(iii) Light is reflected through the lens by use of the mirror. The mirror need not be a real glass mirror - any smooth, shiny surface (e.g., polished metal) is acceptable. The source of light may be a bulb, room light, or skylight, with skylight proving most satisfactory.

C. SUPPLEMENTARY APPARATUS

C1. Glass Slide and Cover Slip



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Glass Slide	1	Glass Plate (A)	7.5 cm x 2.5 cm x 0.2 cm
(2) Cover Slip	1	Transparent Plastic (B)	2.5 cm x 2.5 cm x 0.05 cm

b. Construction

(1) Glass Slides

Glass slides may be hand cut from plate glass (A), but this is tedious and time consuming.

(2) Cover Slip

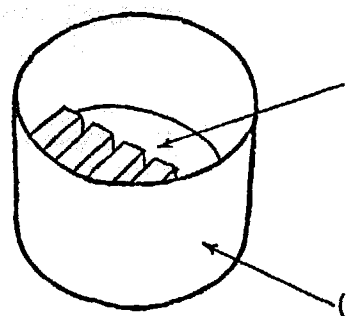
Cover slips can be cut from stiff transparent plastic sheets (B) with scissors.

c. Notes

(i) Good quality slides may be purchased almost as inexpensively as they can be handmade, or they may be obtained for free from hospital blood laboratories as they are often discarded after use.

(ii) Consult a good general biology source book for information on preparing either fresh or permanently mounted slides.

C2. Staining Vessel



a. Materials Required

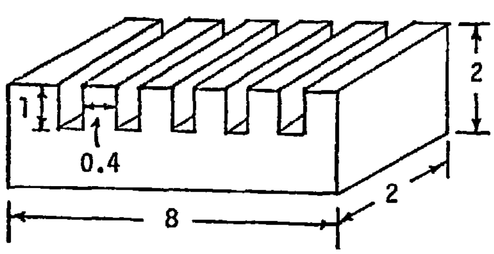
Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	8 cm high, 8 cm diameter
(2) Rack	1	Wood (B)	8 cm x 2 cm x 2 cm

b. Construction

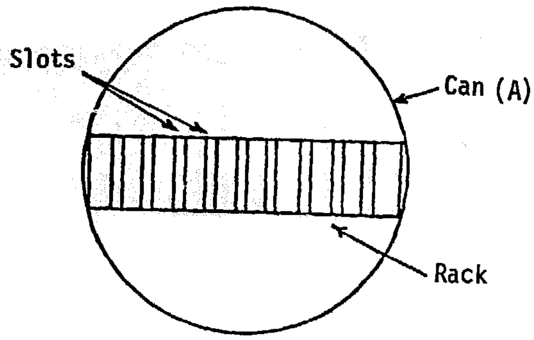
(1) Can

The diameter of the can (A) may be somewhat larger than 8 cm (it should not be much less), and the height of the can should be about the same as the length of the slides used.

(2) Rack



Cut notches in the wood (B) about 1 cm deep and just slightly wider than the slides used. Paint the wood with a sealant (e.g., varnish, shellac) to prevent the stain from soaking into it. Push the rack down into the



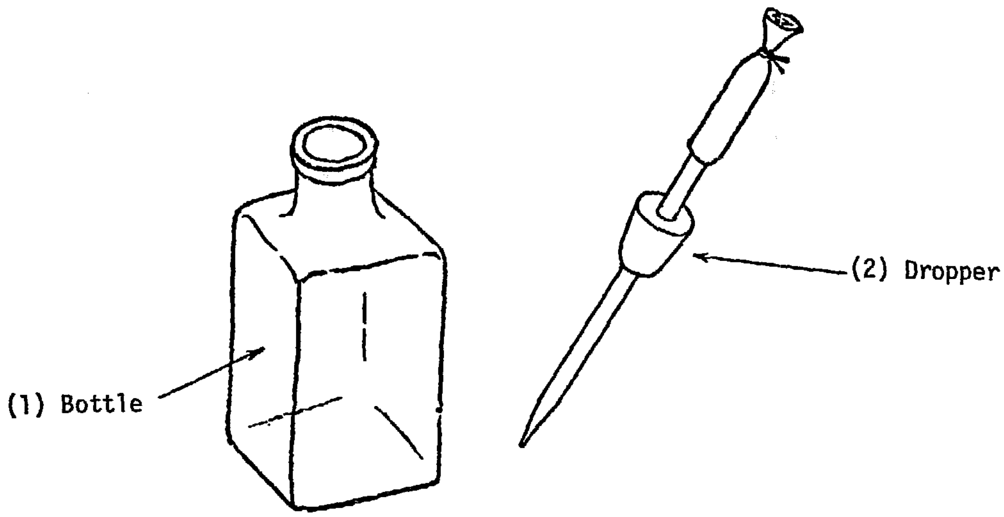
Top View

bottom of the can (A), notches up. The rack holds the slides upright and prevents them from touching each other. Always make the length of the rack equal to the diameter of the can to insure that it will fit tightly in the bottom of the can.

c. Notes

(i) Staining vessels are necessary when preparing slides for microscopic inspection. Consult a good standard biology source book for instruction in preparing slides and stains.

C3. Stain Bottle



a. Materials Required

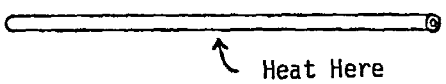
Components	Qu	Items Required	Dimensions
(1) Bottle	1	Pill Bottle (A)	25-50 ml capacity
(2) Dropper	1	Glass Tube (B)	12 cm long, 0.75 cm diameter
	1	Rubber Tube (C)	4 cm long, 1.0 cm diameter
	1	One-hole Cork Stopper (D)	To fit mouth of pill bottle
	1	Wire (E)	5 cm long

b. Construction

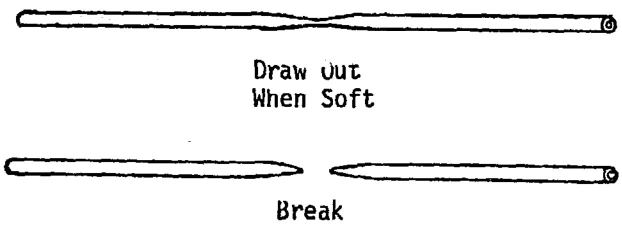
(1) Bottle

Use a clear glass pill or medicine bottle (A).

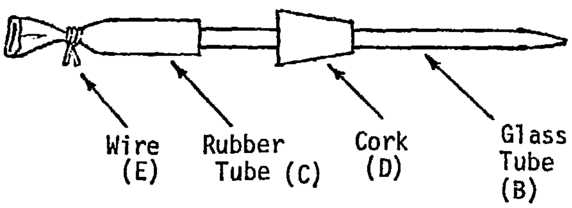
(2) Dropper



Make the tube portion of the dropper two at a time by heating a piece of glass tubing 20 cm long in the



middle and drawing it out to a narrow filament when soft. Break the tube at the most narrow part of the constriction to form two tubes (B).



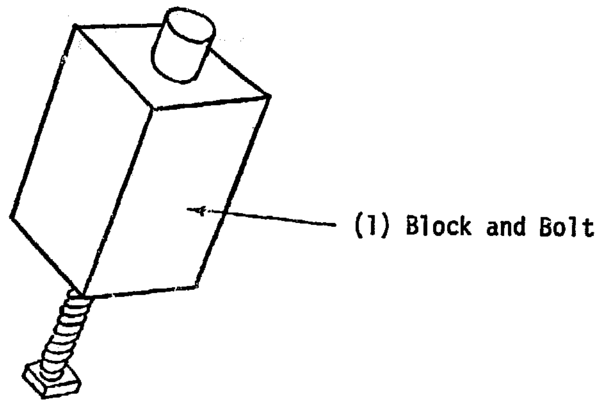
Force the glass tube through the one-hole cork stopper (D). Push the piece of rubber tubing (C) onto the wide end of the glass tubing and tie it off with the wire (E) to form the dropper's suction cap. Adjust the length of the glass tube so that when the cork is in place in the bottle, the tip of the glass tube almost touches the bottom of the bottle.

c. Notes

(i) If one-hole cork stoppers are not available, use a cork borer to make them from regular corks or use one-hole rubber stoppers.

(ii) Be sure to label the bottle with the name of the type of stain it contains.

C4. Hand Microtome

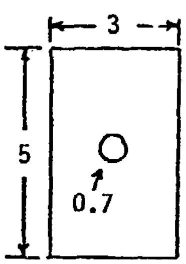


a. Materials Required

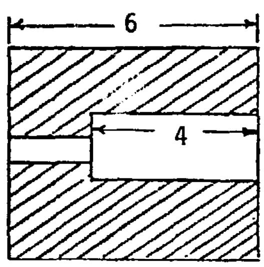
Components	Qu	Items Required	Dimensions
(1) Block and Bolt	1	Wood Block (A)	3 cm x 5 cm x 6 cm
	1	Glass Tubing (B)	5 cm long, 1 cm inside diameter
	1	Wood Dowel (C)	1 cm long, 1 cm diameter
	1	Steel Bolt (D)	9 cm long, approximately 0.7 cm diameter
	1	Nut (E)	To fit bolt

b. Construction

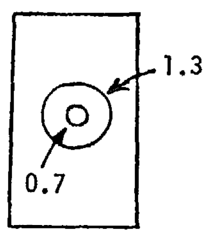
(1) Block and Bolt



End View

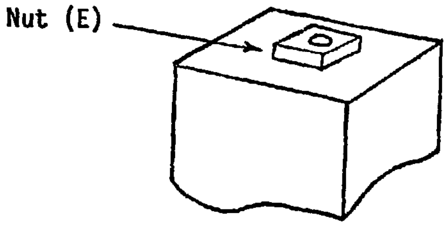


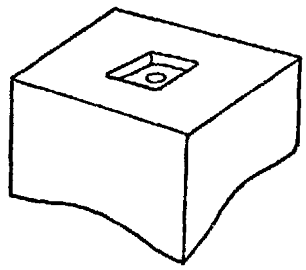
Side-View
(Cross-section)



End View

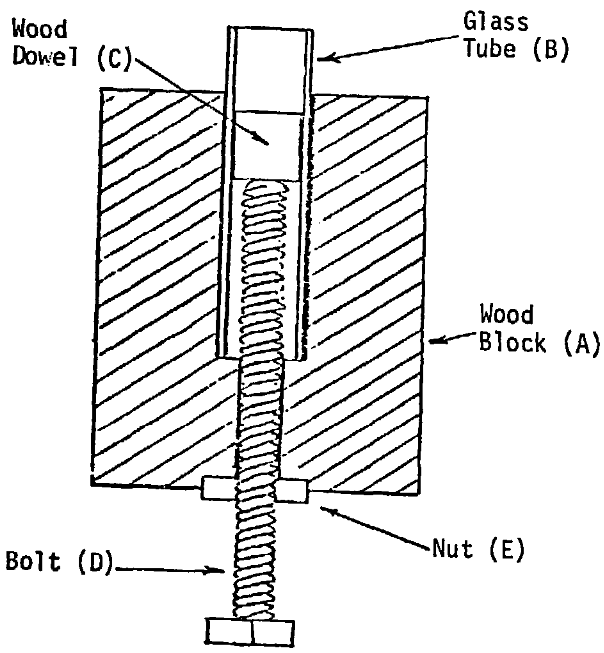
Prepare the wood block (A) by drilling or boring a hole slightly larger in diameter than the outside diameter of the glass tubing (B) 4 cm into one end of the block. Drill another hole (0.7 cm diameter) through the same end of the block. This second hole should be





Impression of Nut

centered in the bottom of the first, larger hole, and be drilled through the block. Next, lay the nut (E) on the end of the block which has the small hole in it. Strike the nut sharply with a hammer to make an impression of the nut in the wood. (Be careful not to split the wood, and also make sure the hole in the nut aligns with the hole in the wood.) After the impression has been made in the wood, glue the nut into place with epoxy resin cement.



Side View
(Cross-section)

Shove the piece of glass tubing (B) down into the large hole in the wood (A), and glue it in place. The end of the tube should stick out about 1 cm. See that this end is cut as evenly as possible and fire polish it just enough to remove any possible burrs. Insert the short wooden dowel (C) into the tube. Screw the bolt (D) through the nut until the end of the bolt touches the wooden dowel.

The microtome is now ready for use.

c. Notes

(i) To operate the hand microtome, screw out the bolt until the wood dowel drops to the bottom of the glass tube. Then, insert the section of plant stem (or whatever is to be cut for the microscope slide) into the glass tube. Fill the space which remains between the specimen and the glass tube with melted paraffin and allow it to cool. When the paraffin is hard, screw the bolt in until it begins to force the wood dowel to push the paraffin and specimen out of the glass tube. As the specimen comes out, use a single-edge razor blade to cut off sections. Practice with the microtome will eventually allow very thin sections to be sliced from specimens.

(ii) It may be desirable to substitute metal tubing for the glass as glass is easily broken. Also, painting the end of the wood dowel with shellac or varnish will prevent the paraffin from sticking to it.

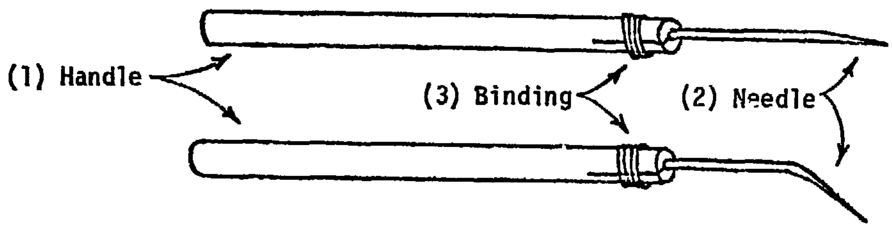
II. DISSECTING APPARATUS

A. DISSECTING APPARATUS

These items will permit the student to do many of the dissections normally done in elementary biology course work. If possible, each student should have each of the items in this section, but if cost and materials prohibit this, then enough items should be produced to permit students to work in groups of two or three.

A. DISSECTING APPARATUS

A1. Dissecting Needles

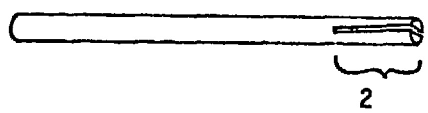


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wood Dowel (A)	10 cm long, 0.6 cm - 0.8 cm diameter
(2) Needle	1	Steel Wire (B)	5 cm long, #20 gauge wire (approximately 0.05 cm diameter)
(3) Binding	1	Iron Wire (C)	About 10 cm of #24 gauge wire (about 0.025 cm diameter)

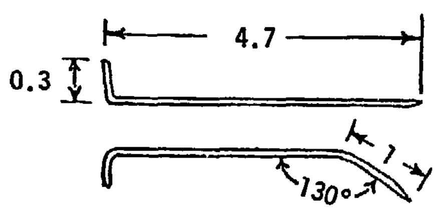
b. Construction

(1) Handle



The wood dowel (A) serves as the handle. Make a slit about 2 cm deep in one end to receive the needle. Sand the two ends to make them smooth.

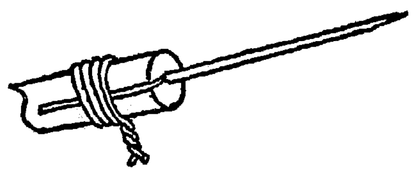
(2) Needle



Break the wire (B) by bending it back and forth instead of cutting it with wire cutters as hard steel can easily damage wire cutters. File one end to a point.

At a point 0.3 cm from the unpointed end, grasp the wire with two pliers and slowly bend until a 90° angle has been reached. If a "bent tip" dissecting needle is desired, bend the needle to an angle of 130° approximately 1 cm from the pointed end.

(3) Binding

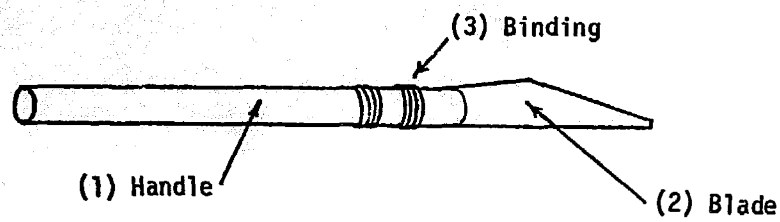


Insert the end of the needle into the handle about 1 cm deep. Wrap several turns of binding wire (C) tightly around the handle and twist the ends together.

c. Notes

(i) Iron, rather than steel, wire may be used for the needle by first making the bends where needed. Then heat the wire until it becomes dull red and immerse it in cold water to temper it. The iron wire will become hard enough so that it does not bend easily; however, it may be broken if pressed with too much force.

A2. Strapping Scalpel

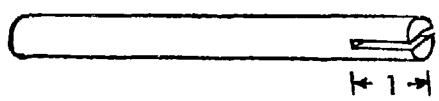


a. Materials Required

Components	Qty	Items Required	Dimensions
(1) Handle	1	Wood Dowel (A)	10 cm long, 1 cm diameter
(2) Blade	1	Steel Strapping (B)	6 cm long, 1 cm wide
(3) Binding	1	Iron Wire (C)	About 12 cm long, #24 gauge (approximately 0.025 cm diameter)

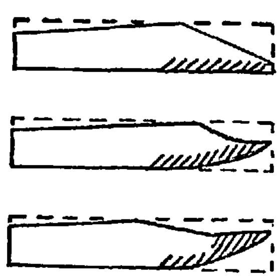
b. Construction

(1) Handle



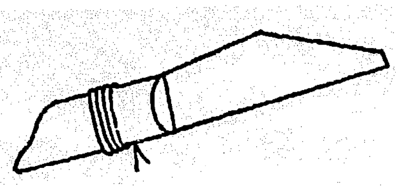
Make a slit in one end of the dowel (A) with a saw for the blade. Sand the ends to make them smooth.

(2) Blade



Cut the piece of strapping (B) into the shape of a scalpel blade (many shapes are useful for different purposes). Taper one end so it will fit the handle. File the edges (as shown by the shaded areas) to make the cutting edge.

(3) Binding



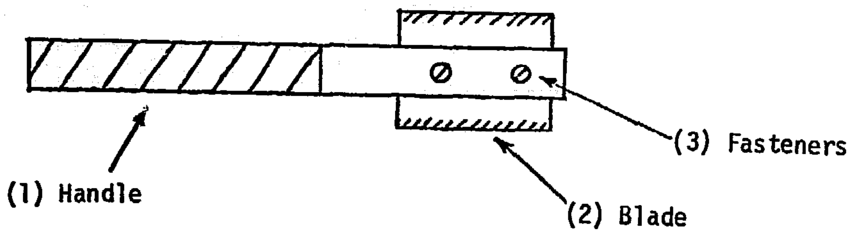
Insert the blade into the slit in the end of the handle. Wrap several turns of #24 gauge wire (C) tightly around the handle and twist the ends together. This should hold the blade firmly in place.

c. Notes

(i) The blade should be sharpened after the entire scalpel has been assembled in order to lessen the danger of being cut.

(ii) An equally good scalpel may be made from a piece of strapping about 15 cm long. Simply form a blade at one end as described above, and let the remainder act as the handle. This portion should be wrapped in tape to make it more comfortable to handle.

A3. Razor Scalpel

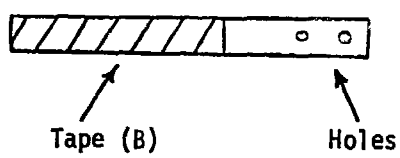


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	2	Steel Strapping (A)	15 cm long, about 1.25 cm wide
	1	Tape (B)	About 50 cm long
(2) Blade	1	Double-Edged Razor Blade (C)	2.5 cm x 3.5 cm
(3) Fasteners	2	Bolts (D)	1.0 cm long, 0.4 cm diameter
	2	Nuts (E)	0.4 cm inside diameter

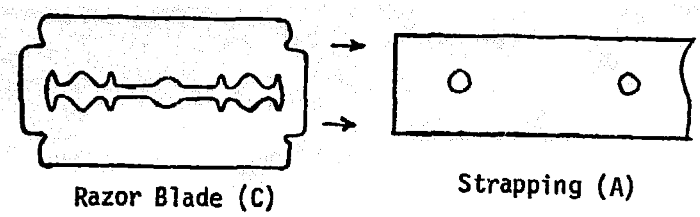
b. Construction

(1) Handle



Fasten the two pieces of strapping (A) together with tape (B). Drill two holes (0.5 cm diameter) in the other end for the bolts (D) to fit through. Locate these holes so that the razor blade (C) will be held in the desired position.

(2) Blade



Insert the blade between the two halves of the scalpel handle so that the two holes align over the holes in the razor blade.

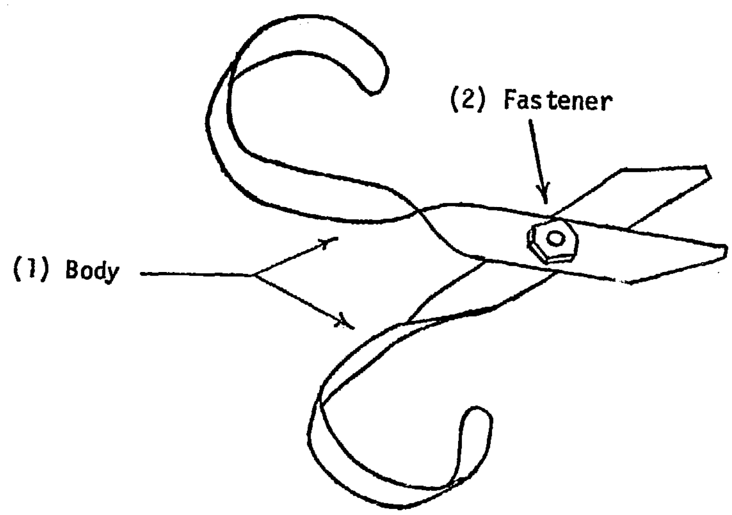
(3) Fasteners

Insert the short bolts (D) through the holes and screw on the nuts (E). This scalpel is now ready for use.

c. Notes

(i) The razor blade can easily be replaced as it becomes dull.

A4. Scissors

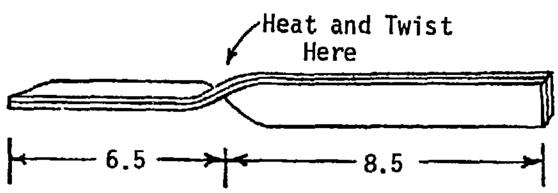


a. Materials Required

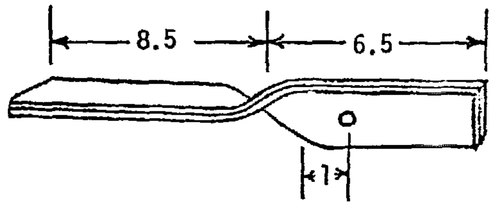
Components	Qu	Items Required	Dimensions
(1) Body	2	Steel Strapping (A)	15 cm x 1.25 cm, at least 0.05 cm thick
(2) Fastener	1	Bolt (B)	0.5 cm long, 0.5 cm diameter
	1	Nut (C)	0.5 cm inside diameter

b. Construction

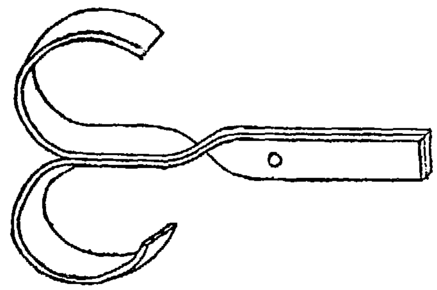
(1) Body



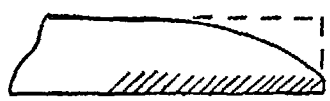
Hold the pieces of strapping (A) tightly together and heat them at a point approximately 6.5 cm from the end until they both glow dull red. Then, twist them a full quarter (90°) turn. Immediately plunge them into cold water to restore their temper.

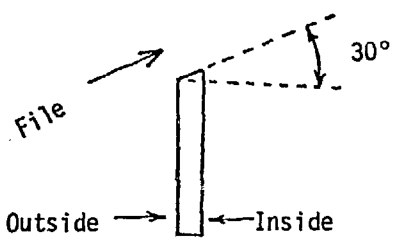


Drill a hole 0.6 cm in diameter about 1 cm from the twist on the short (6.5 cm) end of both pieces.



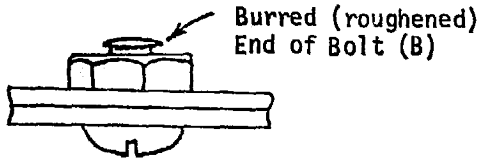
Bend the long (8.5 cm) ends up to form the handles.





Trim the tips of the strapping to the shape of blades. Sharpen the shaded area of the blade. File this area on the outside edge only, not the inside edge where the blades meet. In sharpening, file upward at an angle of 30°.

(2) Fastener

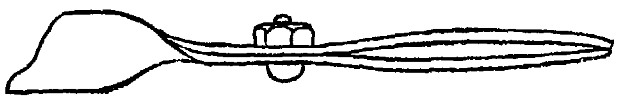


Fasten the two halves of the scissors together with the short bolt (B) (a long bolt may be cut to length) and nut (C). When the proper tightness is obtained, burr the end of the bolt to prevent the nut from loosening and falling off.

c. Notes

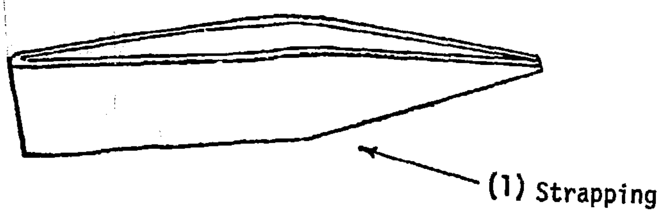
(i) Scissors constructed of strapping of 0.05 cm in thickness work fairly well in cutting tissues as long as short cuts are made, and the material being cut is kept well back between the blades.

(ii) Scissors work better if the blades are slightly curved as shown below.



Side View

A5. Forceps

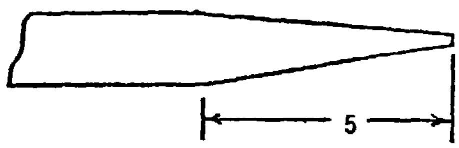


a. Materials Required

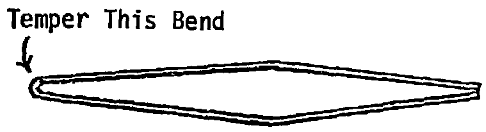
Components	Qu	Items Required	Dimensions
(1) Strapping	1	Steel Strapping (A)	20 cm long, about 1.25 cm wide

b. Construction

(1) Strapping



Cut each end of the steel strapping (A) to a taper.



Side View

Bend the strapping a full 180° at the midpoint. Make certain the tops touch and are in good alignment. Heat the bent area to dull red and plunge immediately into cold water to temper the steel. Bow the blades of the forceps slightly.

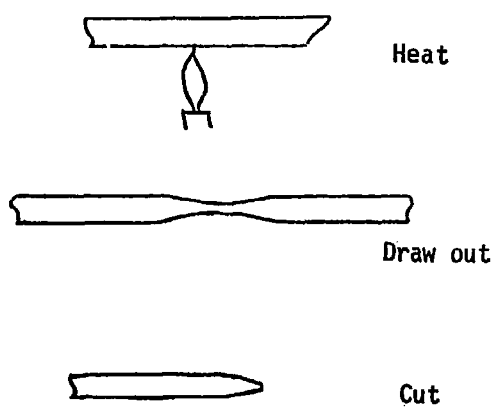
A6. Dropper

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Tube	1	Glass Tubing (A)	7 cm long, about 0.6 cm diameter
(2) Cap	1	Rubber Tubing (B)	4 cm long, 1 cm outside diameter
	2	Soft Wire (C)	4-5 cm long

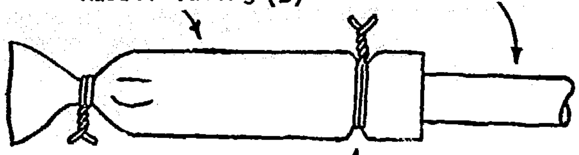
b. Construction

(1) Tube



Hold the glass tubing (A) over a hot flame, turning it to heat it evenly. When it begins to soften, draw it out until the constriction is the desired diameter, and allow it to cool. When cool, cut the tubing at the constriction with a small triangular file.

(2) Cap

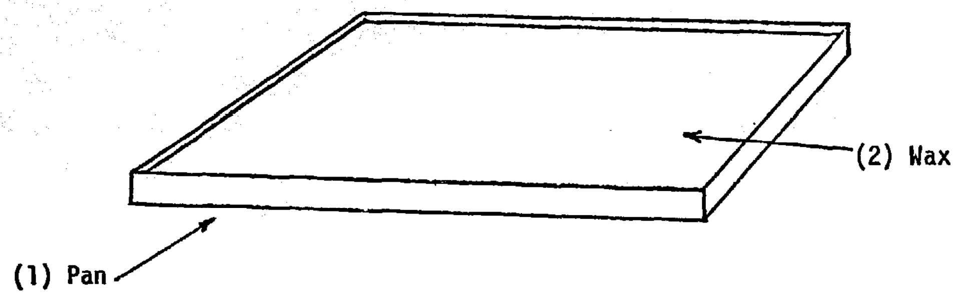


Slip the rubber tubing (B) over the end of the glass tube. Wrap a piece of wire (C) tightly around the tubing to hold it tight to the glass, and twist the end of the wire together. In a similar manner, close off the open end of the rubber tubing so that it is airtight.

c. Notes

(i) Droppers may be made in many shapes and sizes to fit the various uses for which they are needed.

A7. Dissecting Pan



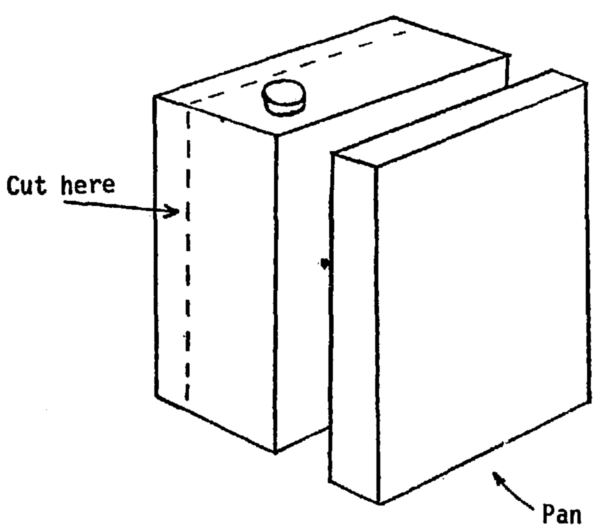
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Pan	1	Oil Can (A)	Approximately 17 cm x 25 cm x 3 cm
(2) Wax	--	Paraffin Wax (B)	Enough to partially fill the pan (about 1 liter)

b. Construction

(1) Pan

Remove the handle from a 4 liter rectangular oil can (A). Cut off the sides about 3 cm from the edge. It is best to put tape on the sharp edges of the pan to prevent students from cutting themselves.



(2) Wax

Fill the pan about two thirds full of melted paraffin wax (B), and allow the wax to harden. Be careful in heating the wax not to get it too hot or it may ignite. It is best to place the paraffin block in a glass jar, and put the glass jar in hot water until the wax melts.

c. Notes

(i) Any container like an oil can (e.g., waxed cardboard milk containers) can be used as long as a suitable pan can be made from it. Alternatively, pans can be made from sheet metal if there is sufficient technical help available.

(ii) Cases for dissecting tools can be made from heavy cloth material if it is desirable to keep each student's kit separate from the others.

III. AQUATIC COLLECTING APPARATUS

These are a wide variety of items used in collecting plant and animal specimens from the aquatic environment. Remember to use waterproof and water resistant materials wherever possible in the construction of this apparatus.

A. NETS AND DREDGES

Nets and dredges are easily made items useful in collecting both plants and animals. They are all made with some sort of netting or mesh.

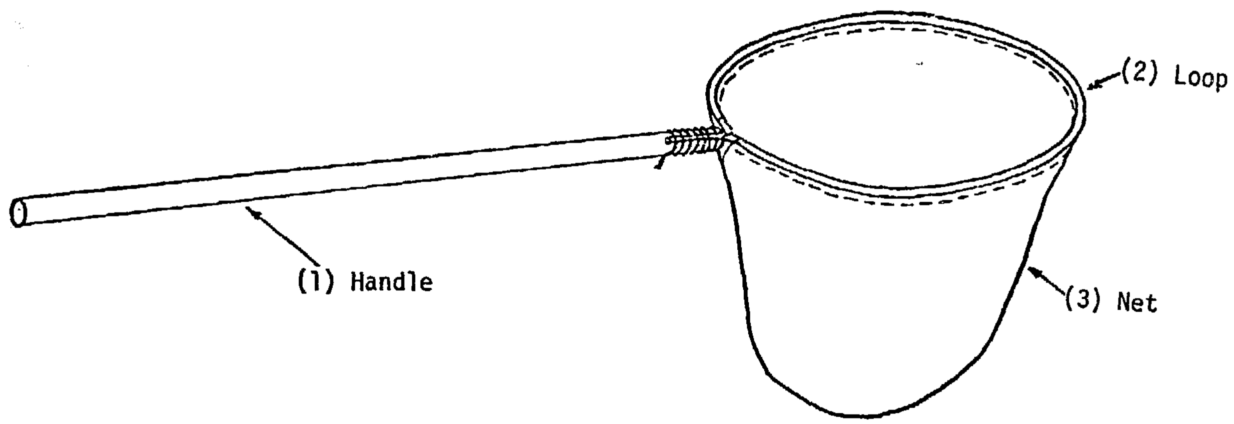
B. AQUATIC TRAPS

These two traps can be used to catch some types of aquatic animals.

C. SUPPLEMENTARY AQUATIC MATERIALS

Materials included here are less necessary, yet still useful, items in aquatic collection.

A1. Dip Net

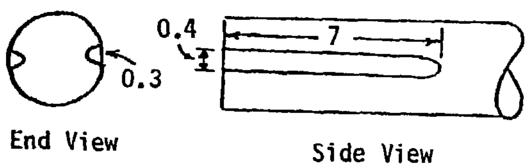


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wood Dowel (A)	100 cm long, 2 cm diameter
(2) Loop	1	Heavy Wire (B)	115 cm long, 0.3 cm diameter
	1	Stiff Wire (C)	About 80-90 cm long, 0.1 cm diameter
(3) Net	1	Nylon Bag (D)	50 cm wide, 60 cm long

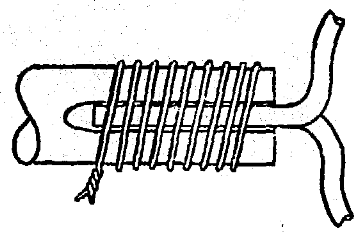
b. Construction

(1) Handle



The length of the handle may be varied according to personal preference. Cut two grooves in one end of the wood dowel (A), one opposite the other. Make these grooves about 7 cm long, 0.3 cm deep, and about 0.4 cm wide.

(2) Loop



Binding of Loop
to Handle

Form a loop 30 cm in diameter from the heavy wire (B). Leave about 7 cm of excess wire at each end which will fit into the grooves in the handle. Bend these 7 cm portions to 90° angles. Fit the wire ends into the grooves in the handle and bind them in place with the stiff wire (C).

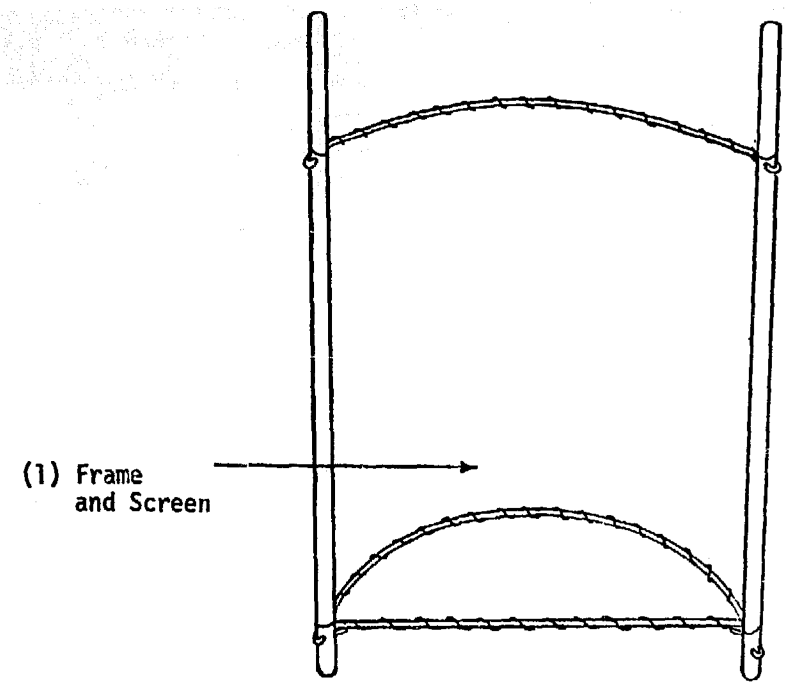
(3) Net

If a nylon laundry bag (D) of the given dimensions is used, cut it down so that it is only about 30 cm deep rather than 60. Other types of cloth or netting can also be used. Use cloth or netting through which water can easily pass, but remember that the size of the net weave determines the size of the smallest organisms which will be held by the net. Make sure the opening of the net is 5 - 10 cm greater in circumference than that of the loop. Simply sew the open portion of the net around the loop with strong thread.

c. Notes

(i) The dip net is used to collect aquatic organisms of all kinds from the shore or boat. Be sure to make its construction as sturdy as possible.

A2. Hand Screen

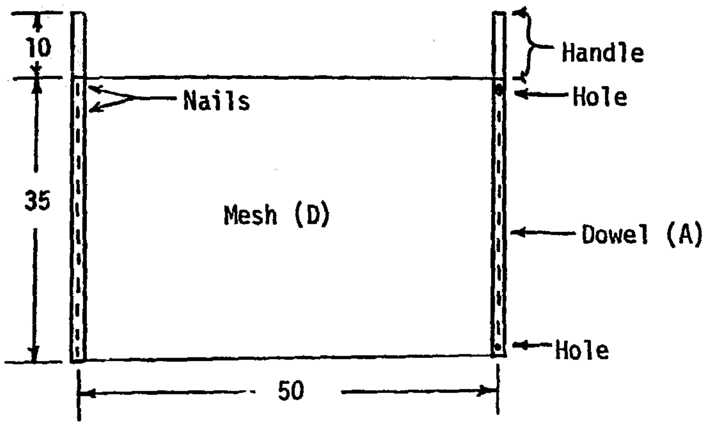


a. Materials Required

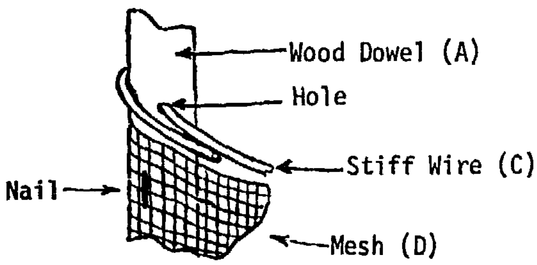
Components	Qu	Items Required	Dimensions
(1) Frame and Screen	2	Wood Dowels (A)	45 cm long, 1.5 cm diameter
	1	Stiff Wire (B)	35 cm long, 0.4 cm diameter
	2	Stiff Wire (C)	50 cm long, 0.4 cm diameter
	1	Fine Wire Mesh (D)	35 cm x 50 cm
	1	Fine Wire Mesh (E)	30 cm x 15 cm
	1	Fine Wire (F)	150 cm long, 0.05 cm diameter

b. Construction

(1) Frame and Screen



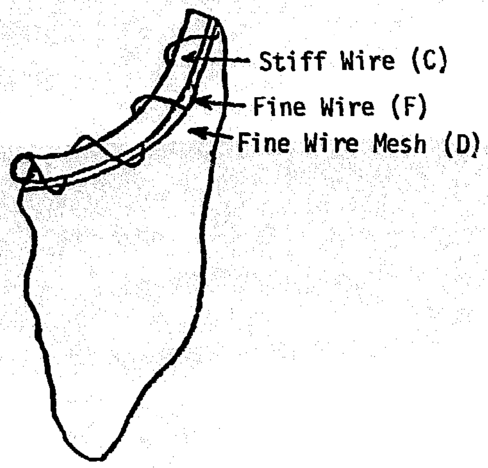
Front View



Detail

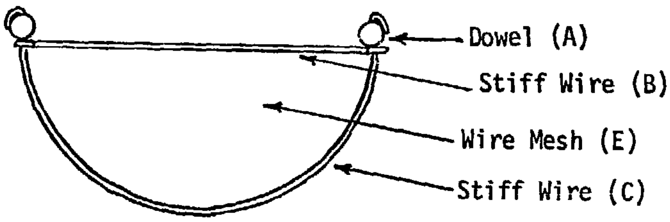
Set the two wood dowels (A) so that they are 50 cm apart. Take the wire mesh (D) and secure it to the dowels by wrapping it around each dowel once and then nailing it in place on the dowel. Be sure to leave 10 cm free at one end of each dowel to serve as handles. Drill two holes, 0.4 cm in diameter, in each dowel; drill the first 1 cm from the end with which the wire mesh is even, and the second, 12 cm from the end which is to be the handle.

Bend the two 50 cm sections of stiff wire (C) into semi-circles, each with a diameter of 30 cm. Place one end of one piece of wire into one hole of the wood dowel, so that about 5 cm of wire is protruding out of each hole. Bend these end pieces around the wood dowel until they reach the main body of wire. Follow this procedure for the other piece of wire. These two pieces of wire now form an outside frame to which the wire mesh (D) is attached.



Detail

Using the fine wire (F), in much the same way as one would use thread in sewing, wire the wire mesh (D) to the stiff wire frame, letting the edges of the wire mesh slightly overlap the wire frame.



Bottom View

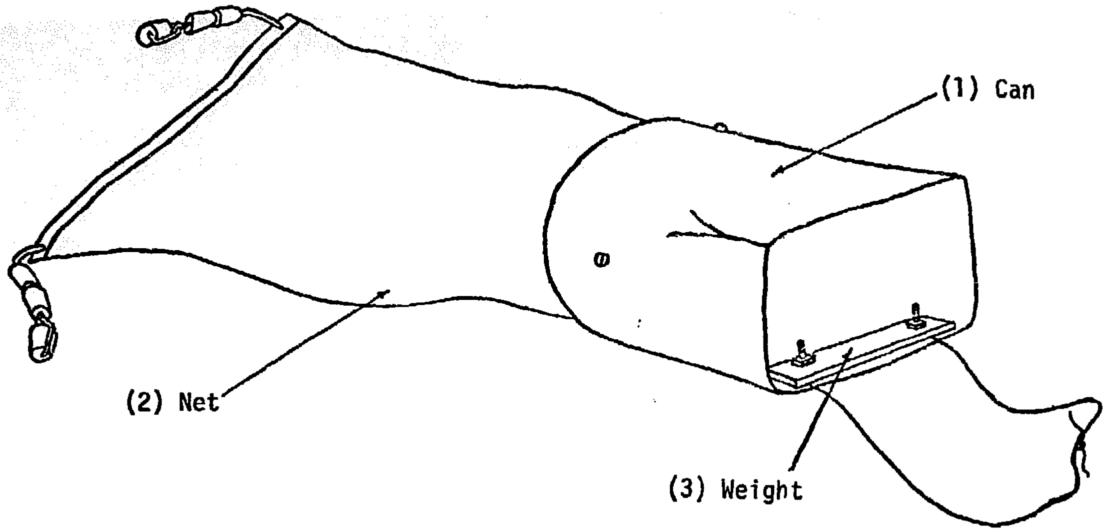
Take the last piece of stiff wire (B) and run it between the ends of the two wood dowels with which the wire mesh is flush. Secure it by bending about 3 cm of each end around the wire frame. Now, take the remaining piece of wire mesh (E) and cut it into the shape of a semi-circle. Wire this semicircle onto the bottom of the hand screen with the "sewing" method described above.

c. Notes

(i) This simple device is an effective means of collecting small plants and animals in streams. To operate, simply hold it in the water and permit the stream water to flow through the wire mesh and remove organisms as they are collected.

(ii) As an extra measure, have someone stand upstream and disturb rocks, thus chasing out underlying organisms.

A3. Dredge

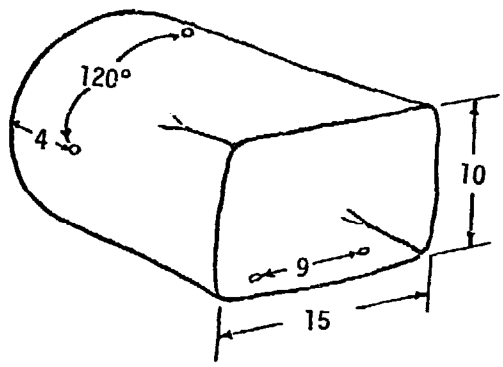


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	15 cm diameter, 18 cm long
(2) Net	1	Nylon Bag (B)	50 cm wide, 60 cm long
	1	Wire Strapping (C)	50 cm long, 1.5 cm wide, 0.05 cm thick
	3	Bolts (D)	1.5 cm long
	3	Nuts (E)	To fit bolts
	2	Cords (F)	20 cm long
	6	Corks (G)	3 cm x 3 cm
	1	Nail (H)	0.5 cm long
(3) Weight	2	Steel Bars (I)	12 cm x 3 cm x 0.3 cm
	2	Bolts (J)	1.5 cm long
	2	Nuts (K)	To fit bolts
	1	Cord (L)	100 cm long

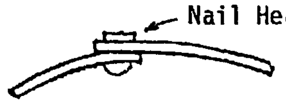
b. Construction

(1) Can



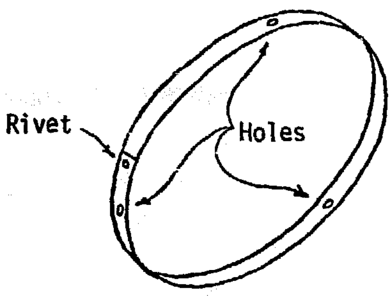
Cut both ends from the tin can (A). Flatten one end of the can to a rough rectangular shape about 15 cm x 10 cm. Drill three holes in the round end of the can, each about 4 cm from the ends. Space these holes every 120° and make them slightly larger in diameter than the bolts (D) used. Make two more holes the same diameter at the other end of the can. These holes should be about 2 cm from the edge and 9 cm apart.

(2) Net



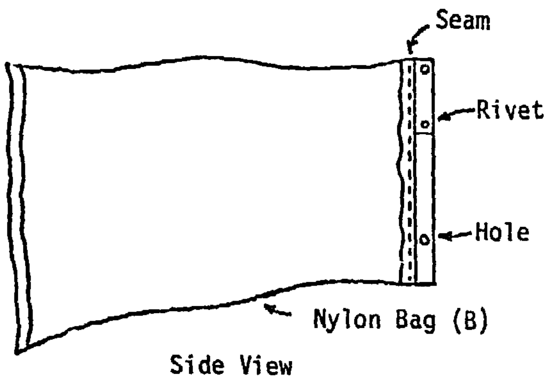
Side View of Rivet

Make a loop from the strapping (C) that will fit inside the can (i.e., slightly smaller than 15 cm in diameter). To do this easily, drill a small hole near each end of the strapping. Cut the head off a flat-headed nail (H) and insert this nail through the holes in the strapping. Flatten the nail down like a rivet to hold the loop together.



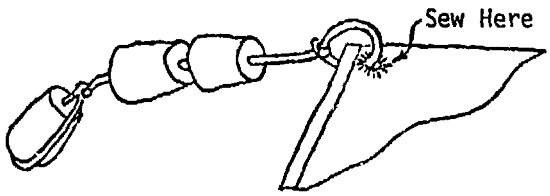
Strapping Loop (C)

Drill holes in the strapping which will align with the holes in the round end of the can. One might wish to drill these holes before riveting the loop together. These holes should be the same diameter as the holes in the can.



Side View

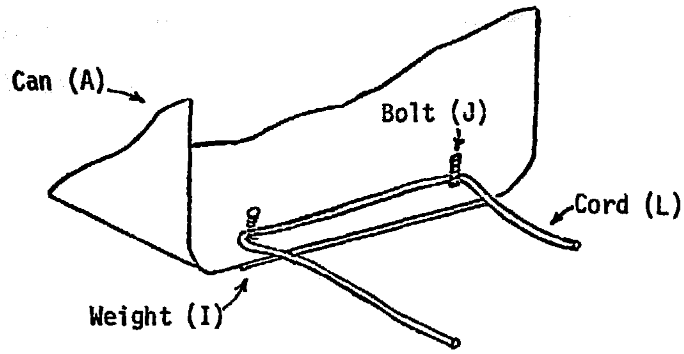
Sew the open end of the nylon bag (B) around the strapping loop with stout thread. The net may also be made from nylon netting if ready-made bags are unavailable. Punch holes through the nylon bag to correspond to the holes in the strapping loop. Fasten the net and loop to the can with the three nuts (E) and bolts (D).

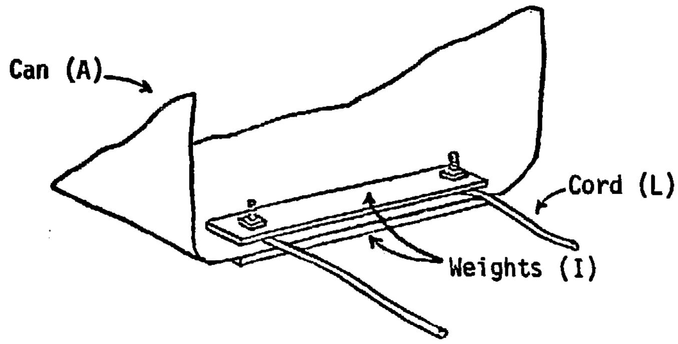


Detail of Cork (G) Attachment

Punch holes through the six corks (G) and tie one of them to each of the two cords (F). Run each of the cords through two of the remaining corks and tie one cord to each corner of the net (B). It may be necessary to sew around each connection to prevent the nylon from tearing.

(3) Weight





Detail

Drill two holes slightly larger than the bolts (J) used in each steel bar (I). Make these holes 9 cm apart so they will align with the holes already drilled in the can. Insert the two bolts (J) through the holes in one of the steel bars and then put the bolts through the holes in the can so that the steel bar weight is on the outside of the can. Stretch the cord (L) around the two bolts.

Place the second steel bar (I) over the two bolts and fasten with the nuts (K). The cord (L) should be firmly held between the can and bar. Tie the loose end of the cord together to form a loop.

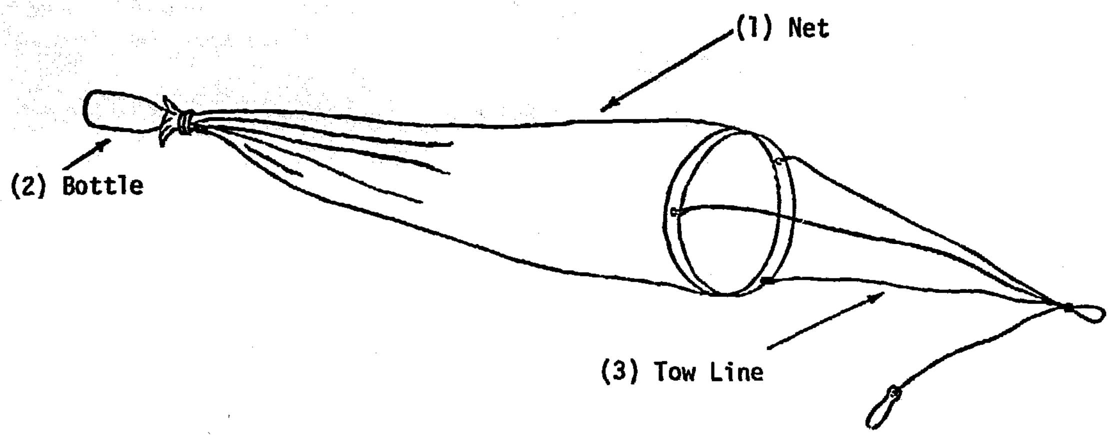
c. Notes

(i) In use, the dredge is tied to a long rope and dragged along the bottom of a body of water. Organisms living on or near the bottom are collected in the net.

(ii) The weights insure that the dredge will stay in the correct position on the bottom. The corks are to help keep the net off the bottom until it is filled with collected material. This prevents it from being torn.

(iii) Use water resistant materials wherever possible in construction of this and all aquatic apparatus.

A4. Plankton Net *

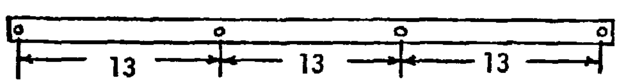


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Net	1	Nylon or Silk Stocking (A)	About 50 cm long
	1	Metal Strapping (B)	40 cm long, 1.5 cm wide, 0.05 cm thick, 2.5 cm diameter
(2) Bottle	1	Glass Bottle (C)	2.5 cm diameter, 6 cm long
	1	Rubber Band (D)	--
(3) Tow Line	2	Cords (E)	60 cm long
	1	Lead Weight (F)	Weight is variable

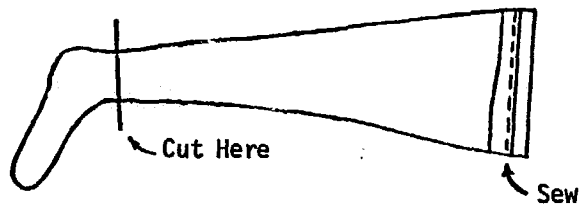
b. Construction

(1) Net



Drill four holes into the metal strapping (A) at 13 cm intervals. Make the holes about 0.3 cm in diameter.

*Adapted from Biological Sciences Curriculum Study, High School Biology: Student's Manual, (Chicago: Rand McNally and Company, 1963), p 157.

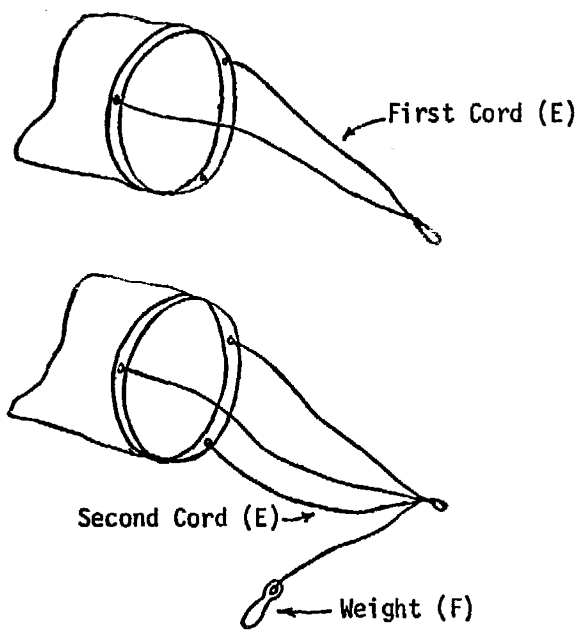


Hold the strapping in a ring shape and sew the open end of the stocking (A) to this ring. Cut off the foot of the stocking.

(2) Bottle

Attach the glass bottle (C) to the end of the net by wrapping the rubber band (D) tightly around it. Be sure the opening to the bottle is not clogged by material from the net.

(3) Tow Line



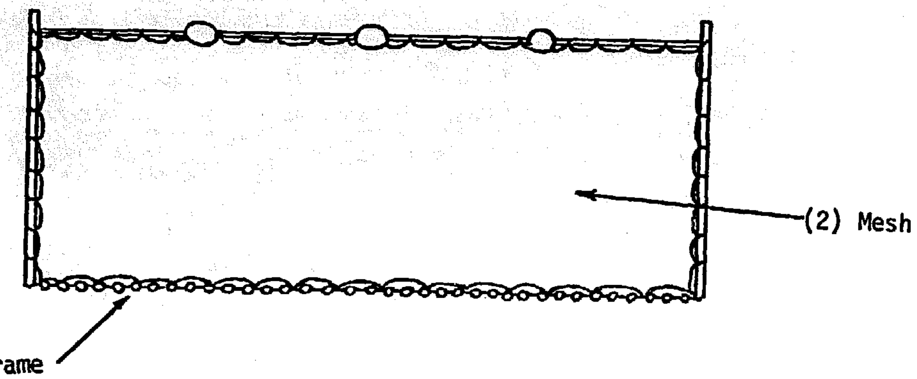
Punch small holes in the net to correspond to the three holes in the strapping ring. Tie one end of one cord (E) to one of these holes, make a loop in the middle of the cord, and tie the other end to the hole formed where the two ends of the strapping overlap. Next, tie the other cord (E) to the remaining hole in the ring. Tie the middle of this cord to the knot in the other cord, and tie the free end to a lead fishing weight (F).

c. Notes

(i) The plankton net is best used by dragging it behind a boat near the surface of the water. Organisms are trapped in the bottle as the water washes through the net.

(ii) Use netting with as fine a mesh as possible. An old parachute is an excellent source of material for the net.

A5. Two-Man Seine*

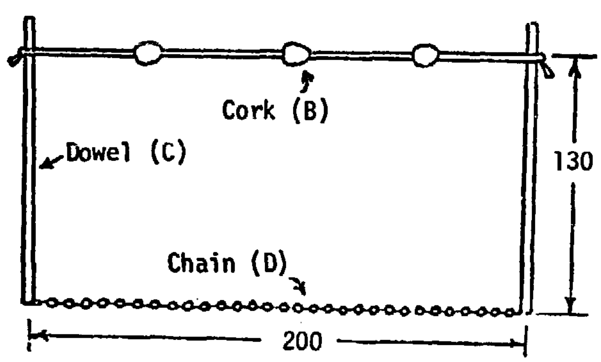


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Nylon Rope (A)	250 cm long, 0.5 cm diameter
	3	Cork Floats (B)	15 cm long, 10 cm diameter
	2	Wood Dowels (C)	150 cm long, 3 cm diameter
	1	Galvanized Chain (D)	200 cm long
(2) Mesh	1	Nylon Cord (E)	About 1000 cm long, 0.2 cm diameter
	1	Nylon Seine Net (F)	130 cm x 200 cm

b. Construction

(1) Frame



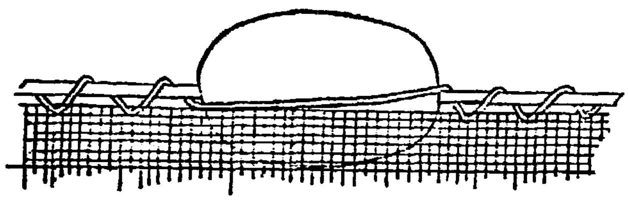
Fasten the ends of the chain (D) to the bottoms of the wooden dowels (C). Tie one end of the nylon rope (A) to the top of one dowel about 20 cm from the end. Run the free end of the rope through the holes in the cork floats (B) and tie it to the other

*Adapted from Jens W. Knudsen, Biological Techniques, (New York: Harper and Row, 1966), p 326.

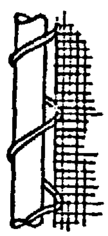
dowel so that the distance between the two dowels when the rope is stretched out is 200 cm.

(2) Mesh

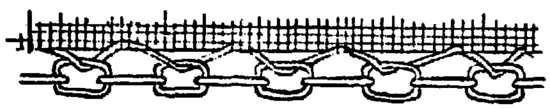
Use a mesh (F) from 0.25 to 0.50 cm square. Fasten it to the dowel (C), chain (D), and rope (A) as shown by using the small diameter nylon cord (E).



Attachment of Mesh (F) to Rope (A)



Attachment of Mesh (F) to Dowel (C)



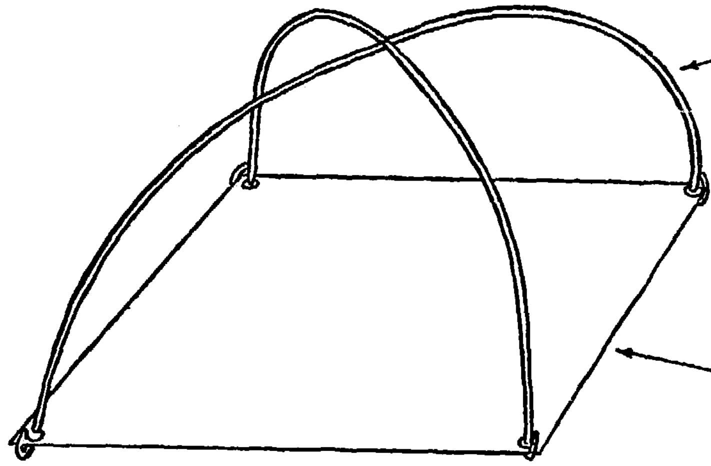
Attachment of Mesh (F) to Chain (D)

c. Notes

(i) Two persons are required to use the seine net. Each holds one of the poles upright in the water and they both walk slowly toward the shore. A great variety of organisms can be collected in this manner.

(ii) Wherever possible, use corrosion and rot resistant materials for the seine such as nylon rope, cord and mesh and galvanized chain.

A6. Lift Net *

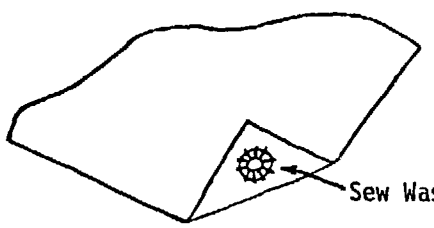


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Net	1	Nylon Mesh (A)	50 cm x 50 cm
	4	Metal Washers (B)	1.5 cm diameter
(2) Spreaders	2	Heavy Wires (C)	100 cm long, 0.3 cm diameter

b. Construction

(1) Net



Corner Detail

Construction of the lift net is quite simple. Simply fold over each corner of the nylon mesh (A) and sew a washer (B) to the double thickness of material. Punch a hole through the center of each washer and through the double layer of nylon.

*Adapted from Jens W. Knudsen, Biological Techniques, (New York: Harper and Row, 1966), p 283.

(2) Spreaders

Roll each wire (C) to a roughly semicircular shape. Insert one end of each wire through adjacent corners of the net and bend up the ends. Insert the other end of each wire through the corner diagonally opposite the first corner and bend up the ends again. Use a small piece of wire to bind the spreaders together where they cross.

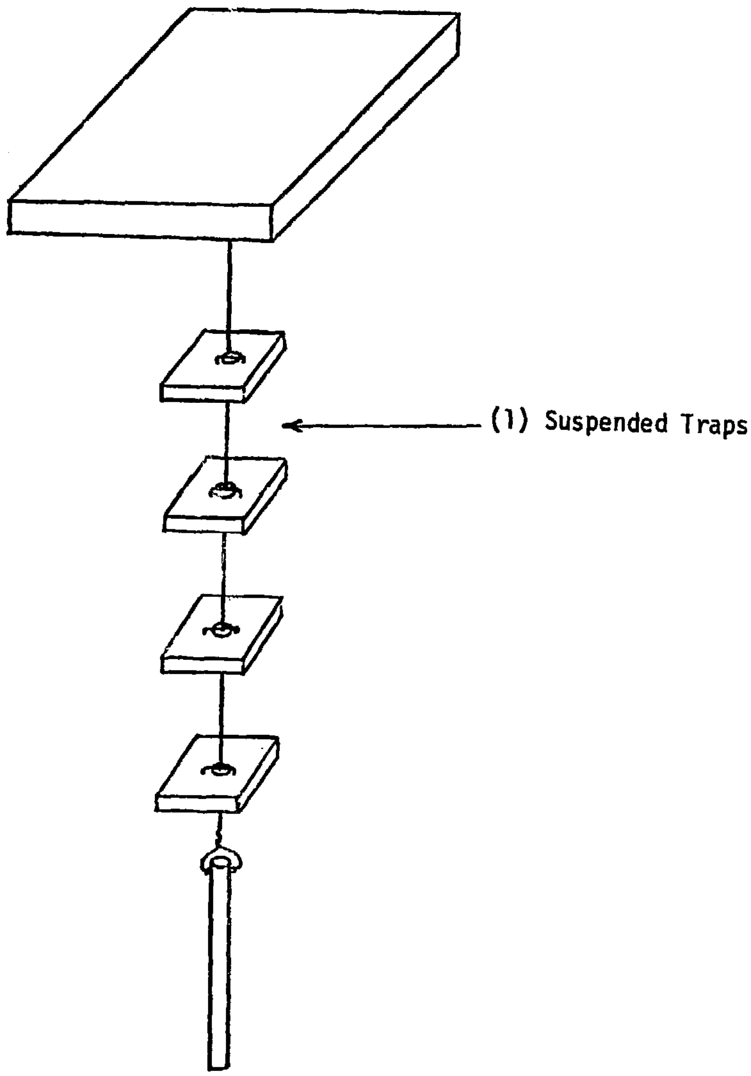
c. Notes

(i) Use the lift net to catch small fish and crustaceans. Place a suitable bait firmly tied to a weight in the center of the net. Tie a line to the lift net where the spreaders cross and lower the net into the water. If the water is clear, watch for fish or crustaceans to near the center of the net, and when they do, quickly lift the net to trap them. If the water is not clear, simply wait for one or two minute intervals before quickly raising the net.

(ii) Small fish may be collected by floating food on the surface of the water. As small fish come to the food, the net may be raised, and the fish collected.

B. AQUATIC TRAPS

B1. Piling Trap



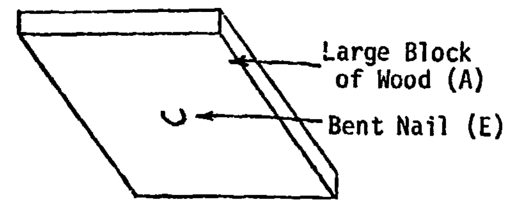
a. Materials Required

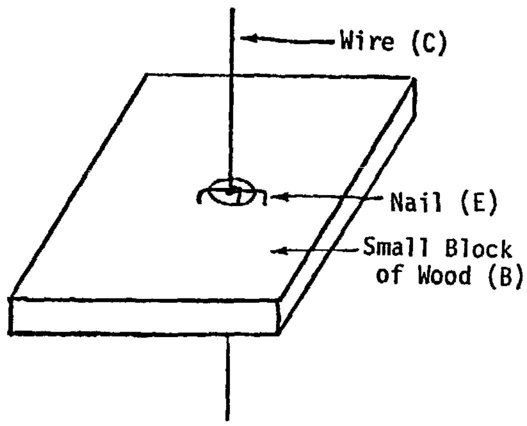
Components	Qu	Items Required	Dimensions
(1) Suspended Traps	1	Wood (A)	24 cm x 24 cm x 4 cm

4	Wood (B)	10 cm x 10 cm x 2 cm
1	Wire (C)	120 cm long, 0.1 cm diameter
1	Metal Rod (D)	26 cm long, 1.5 cm diameter
5	Nails (E)	2.5 cm long, 0.3 cm diameter

<u>b. Construction</u>

(1) Suspended Traps





Place a heavy staple or bent nail (E) in the center of the large block of wood (A). Drill a hole 0.4 cm in diameter through the center of each of the small blocks of wood (B). Place a nail (E) near each of the holes and wrap the wire (C) around these nails as it is passed through the holes. Bend the nails down across the holes. The small blocks should be spaced about 20 cm apart, with the first block about 30 cm from the large wood block (A), and the metal rod (D) about 30 cm from the last block. Drill a hole in the metal rod through which the wire is run, and connect the rod to the wire. Finally, attach the upper end of the wire to the staple or bent nail on the underside of the large block of wood.

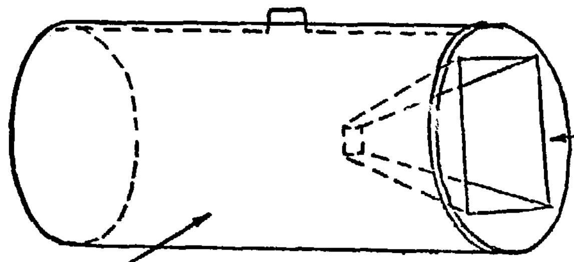
c. Notes

(i) Many aquatic animals attach themselves to the bottom of boats and piers. This trap utilizes this principle in capturing these organisms. To operate, simply place the apparatus in the water and remove approximately every 30 days and collect the organisms which have attached themselves to the blocks of wood.

(ii) The large wood block may be substituted for by some other type of float. A watertight plastic container (e.g., an empty plastic bottle of bleach) can be used. This float can be painted a bright color, thus making it easy to see.

(iii) Any type of weight may be used provided that it is not heavy enough to submerge the large block of wood while still keeping the small blocks of wood under water.

B2. Funnel Trap

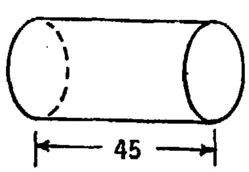


a. Materials Required

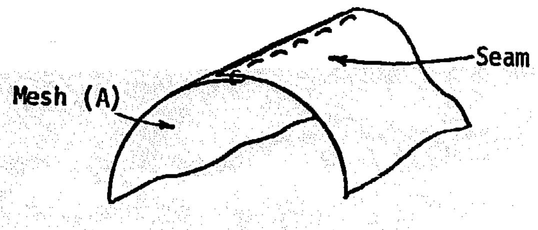
Components	Qu	Items Required	Dimensions
(1) Body	1	Wire Mesh (A)	45 cm x 80 cm
	1	Wire Mesh (B)	25 cm diameter
	1	Stiff Wire (C)	85 cm long, 0.2 cm diameter
	1	Stiff Wire (D)	50 cm long, 0.2 cm diameter
	1	Fine Wire (E)	0.05 cm diameter, about 300 cm long
(2) Funnel	1	Stiff Wire (F)	85 cm long, 0.2 cm diameter
	1	Spring (G)	2 cm long
	1	Wire Mesh (H)	30 cm diameter
	4	Wire Mesh (I)	17 cm x 17 cm
	1	Fine Wire (J)	0.05 cm diameter, about 300 cm long

b. Construction

(1) Body

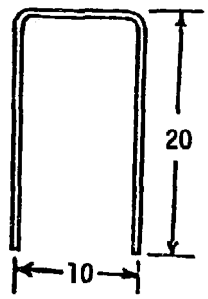


Make a cylinder 45 cm long and 25 cm in diameter from the rectangular piece of wire mesh (A). Wire the 45 cm sides together with the fine



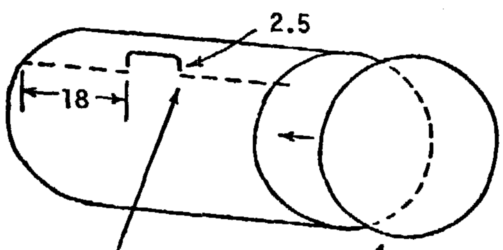
Detail

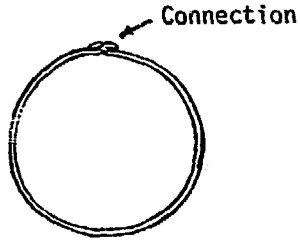
wire (E) in much the same way as one would sew a cloth seam. Let the edges of the mesh overlap about 1 cm to facilitate "sewing" them together with the wire.



Wire (D)

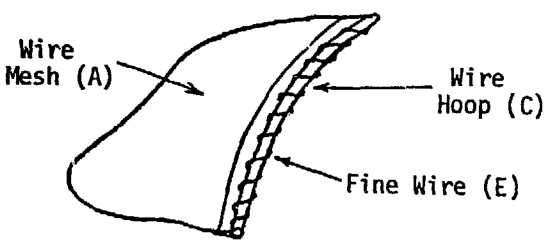
Next, bend the stiff wire (D) to the shape of a "U". Make two small holes 10 cm apart in the cylinder. Insert the U-shaped wire through these two holes, and bend up the ends leaving about 2.5 cm of the wire extending out of the cylinder as a handle. Take the 25 cm diameter piece of wire mesh (B) and "sew" it to one end of the cylinder with a piece of fine wire (E) to seal it off.





Hoop Made
from Wire (C)

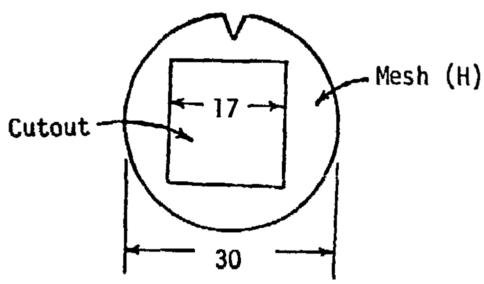
Detail of
Connection



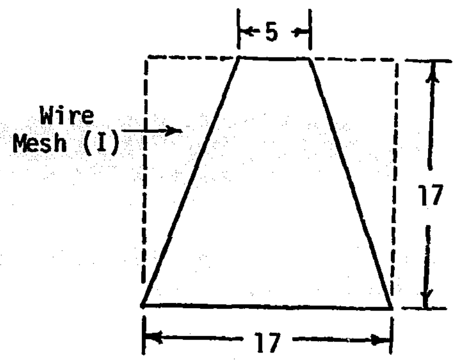
Detail

Finally, make a 25 cm diameter "hoop" from the stiff wire (C) by hooking the ends together. Connect the wire hoop to the open end of the cylinder with fine wire to stiffen the cylinder. This is best done by folding about 2 cm of the end of the cylinder back over the hoop and sewing the hoop inside this flap for the full circumference of the hoop.

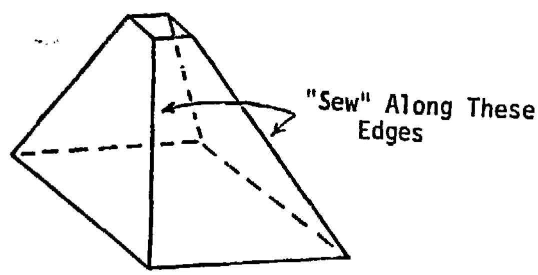
(2) Funnel



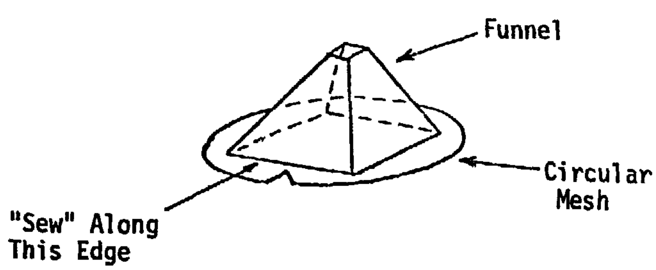
Cut a square 17 cm on a side from the center of the circular piece of wire mesh (H). Also, cut a V-shaped notch 2.5 cm deep in one edge of the piece of mesh.



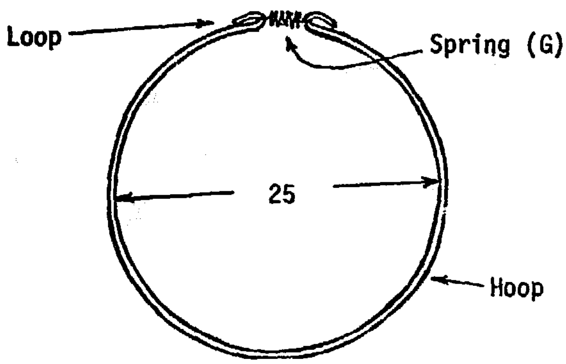
Cut the four pieces of wire mesh (I) into triangular-shaped pieces 17 cm at the base and 5 cm at the apex. Sew the four pieces together along their long edges with fine wire (J) to form a pyramid-shaped funnel.



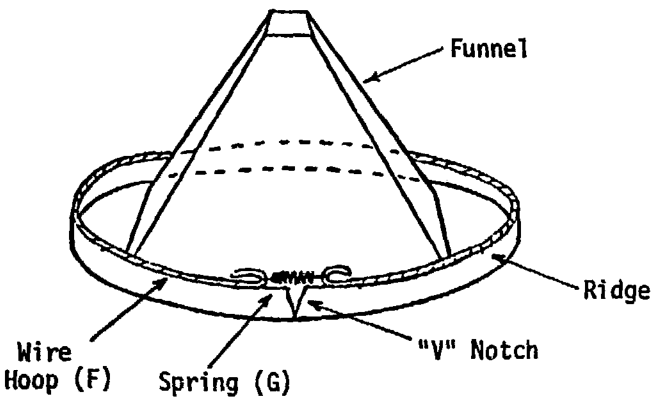
Mesh Funnel



Sew the funnel to the circular piece of mesh (H) with the square cutout.



Form a hoop from the stiff wire (F) 25 cm in diameter with small loops at both ends. Connect these two ends of the hoop with the spring (G). (Springs can easily be made by wrapping stiff wire around a pencil or other round object.)

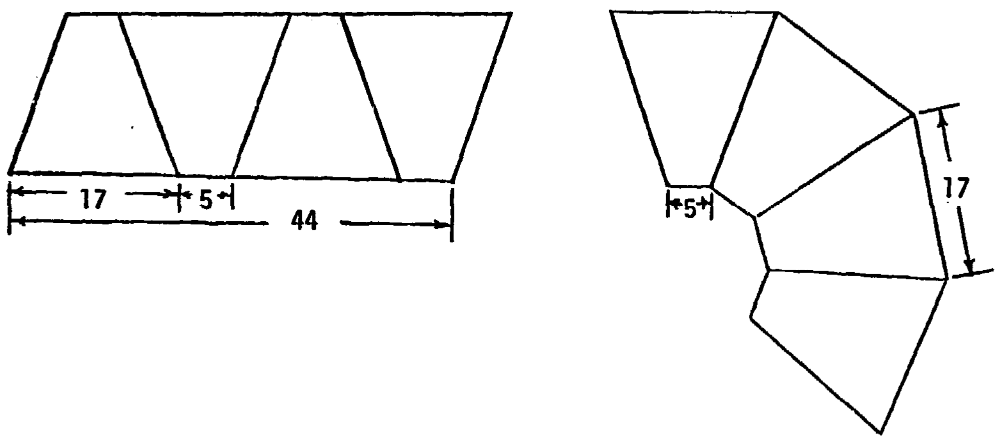


Now, fold up a ridge 2.5 cm high all around the circumference of the circular piece of mesh (H). Wire the hoop (F) to this ridge making certain the spring (G) on the hoop aligns with the "V" notch in the mesh. Fit this funnel assembly over the end of the cylindrical body by pulling the spring open slightly. Slip the funnel over the end of the cylinder and let the spring snap back. The tension of the spring should hold the funnel assembly to the cylinder relatively tightly.

c. Notes

(i) Use of the funnel trap is simple. Just remove the funnel portion of the trap by spreading open the spring slightly and pulling the funnel off the cylinder. Place some rocks or other weights in the trap to hold it down in the water, and place a suitable bait (e.g., pieces of fish, old cheese wrapped in a cloth bag) in the cylinder. Replace the funnel, and tie a length of rope to the handle. Drop the trap into a stream or pond, and tie the other end of the rope to an object on the bank or a float (a plastic bottle makes an excellent float). Check the trap periodically to remove captured animals and replace baits.

(ii) The following two patterns can also be used for the funnel:



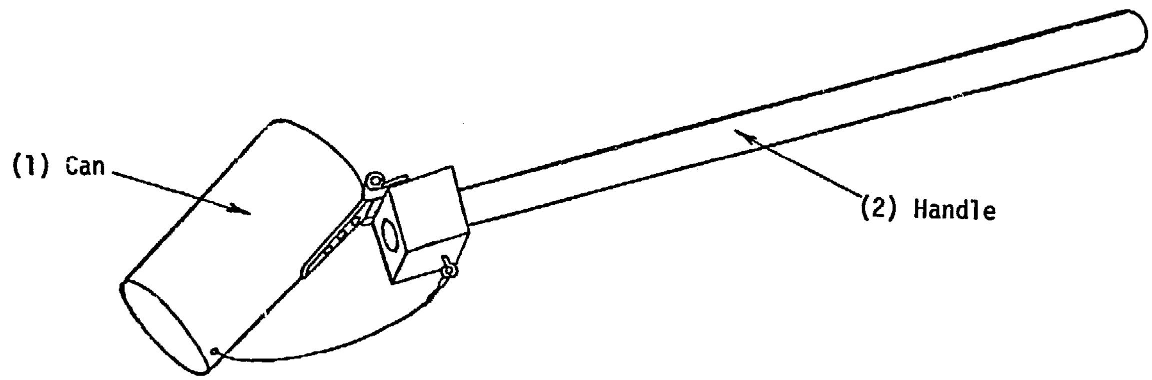
The first pattern is used because it wastes less material while the second is good because only one seam needs to be sewn while the others are merely folded.

(iii) Wherever possible, use rustproof materials like aluminum screening in the construction of this item.

(iv) The circular and other shapes can more easily be cut from the wire mesh if a pattern is first cut from paper and taped to the mesh. Then cut around the paper rather than attempting to draw a pattern on the mesh as this is extremely difficult to do.

C. SUPPLEMENTARY AQUATIC MATERIALS

C1. Bottom Sampler

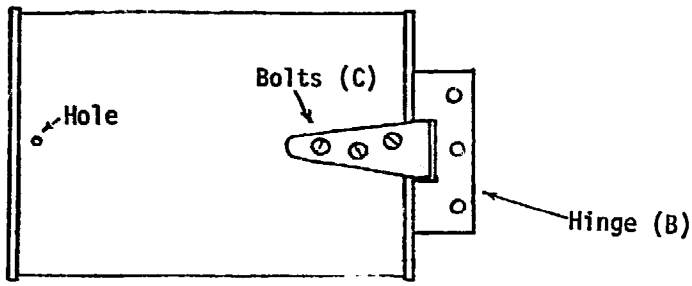


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	12 cm long, 8 cm diameter
	1	Hinge (B)	--
	3	Bolts (C)	1.0 cm long
	2	Nuts (D)	To fit bolts
	3	Wood Screws (E)	1.0 cm long
(2) Handle	1	Wood (F)	5 cm x 4 cm x 4 cm
	1	Wood Dowel (G)	2.5 cm diameter, length variable
	1	Eyed Screw (H)	--
	1	Wire (I)	18 cm long

b. Construction

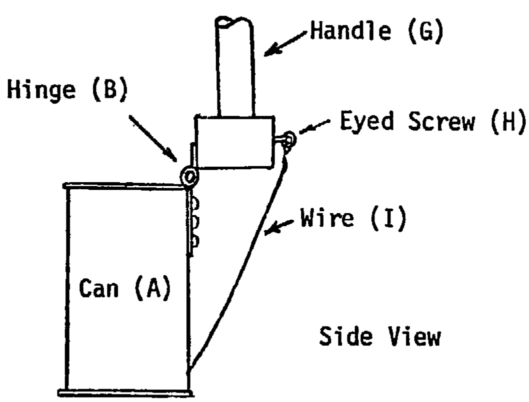
(1) Can



Top View

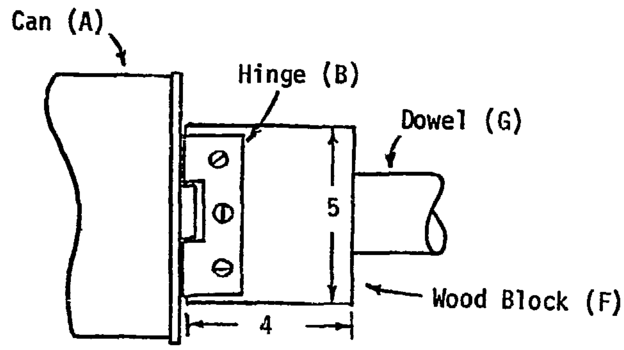
Remove one end of the tin can (A). Punch a small hole near the bottom of the can. At the open end of the can fasten one plate of the hinge (B) to the can with the bolts (C) and nuts (D). Holes will have to be drilled or punched through the can for the bolts to go through. The hinge may be fastened to the can with sheet metal screws if these are available.

(2) Handle



Side View

Drill or bore a hole the same diameter as the wood dowel (G) through the middle of the wood block (F). Insert one end of the dowel into the block and screw or glue them together. With screws (E), fasten the plate of the hinge (B) to the bottom of the block. Screw the eyed screw (H) into the other side of the wood block. Finally, make a knot in the end of the wire (I) and pass the free end through the hole in the bottom of the can (the knot must be inside the can) and tie the free end to the eyed screw.



Bottom View

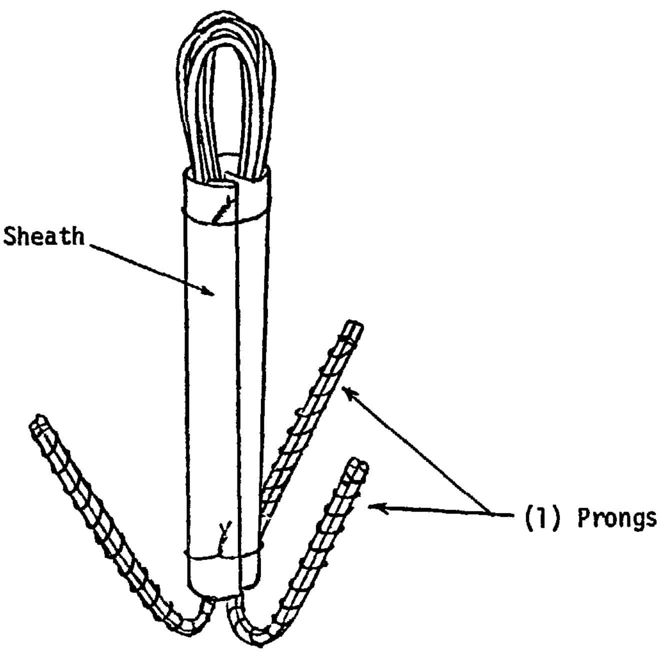
c. Notes

(i) To operate, simply lower the sampler into the water until the can hits bottom. Drag the can back and forth until it feels heavy, then pull it out of the water and remove the bottom sediment. The wire prevents the can from hitting bottom with the open end pushed against the handle so that no sediment can enter it. Collect bottom samples in different ponds and streams to check the sediment for the various organisms living in each.

(ii) The length of the handle will vary according to the depth of the water where the sample is to be taken.

(iii) The details of design of this item depend mainly on the type of hinge used.

C2. Grappling Hook

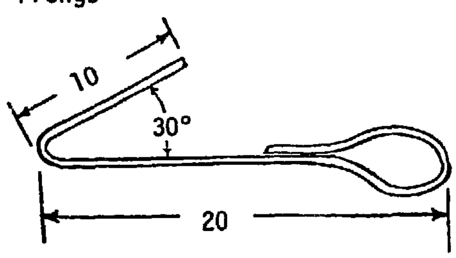


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Prongs	6	Stiff Wire (A)	40 cm long, 0.25 cm diameter
	1	Soft Wire (B)	About 100 cm long, 0.05 cm diameter
(2) Sheath	1	Sheet Metal (C)	12 cm x 8 cm x 0.05 cm
	2	Soft Wire (D)	8 cm long, 0.1 cm diameter

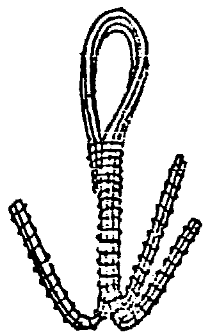
b. Construction

(1) Prongs



Bend each piece of stiff wire (A) to the shape of a hook with a loop at one end. Group the prongs together by twos and bind them together with the soft wire (B).

Then place the three resulting double prongs together and bind them so that the prongs are about at angles of 120° to each other.



(2) Sheath

To finish the grappling hook simply wrap the piece of metal sheet (C) around the middle of the hook and bind it in place with the soft wire (D).

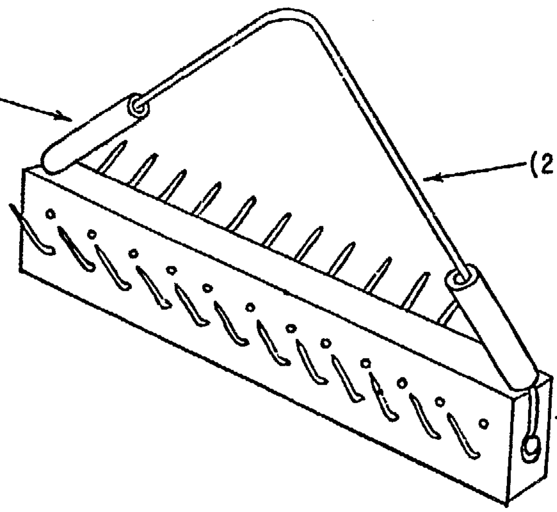
c. Notes

(i) To use the hook, just tie it to the end of a rope or cord, drop it into the water, and pull it up when it becomes entangled in vegetation.

(ii) Be careful when handling this item of the sharp edges of the sheet metal and the points of the wire used in binding it together.

(iii) If heavy steel wire is available, only one piece is needed per hook rather than two.

C3. Grappling Bar

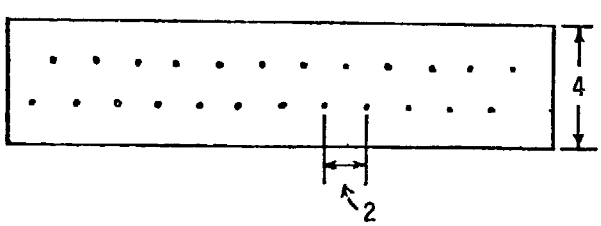


a. Materials Required

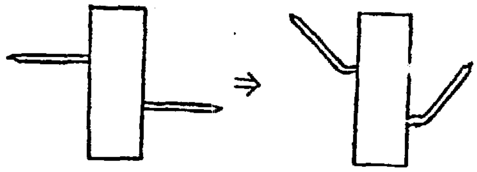
Components	Qu	Items Required	Dimensions
(1) Body	1	Wood (A)	25 cm x 4 cm x 2 cm
	24	Nails (B)	5 cm long, 0.2 cm diameter
(2) Handle	1	Soft Wire (C)	50 cm long, 0.2 cm diameter
	2	Nails (D)	3 cm long
(3) Weight	2	Lead Pipe (E)	8 cm long, 1.5 cm diameter

b. Construction

(1) Body



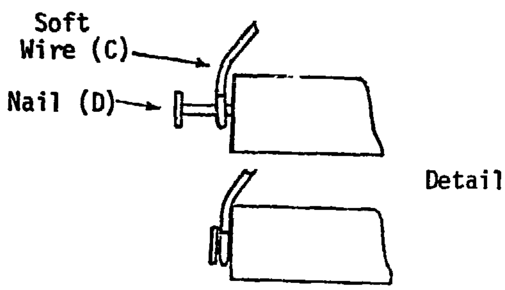
Drive the nails (B) through the wood (A) in two rows, staggering them so that they don't align directly above one another. One row of nails is nailed through from one side while the other row is nailed through the opposite side.



Side Views

Where the nails have been driven through the wood, bend them upwards at approximately 45° angles as close to the base as possible.

(2) Handle



Hammer one of the nails (D) into the end of the body and let it protrude about 1 cm. Twist one end of the soft wire (C) around the nail, then hammer it down completely.

(3) Weight

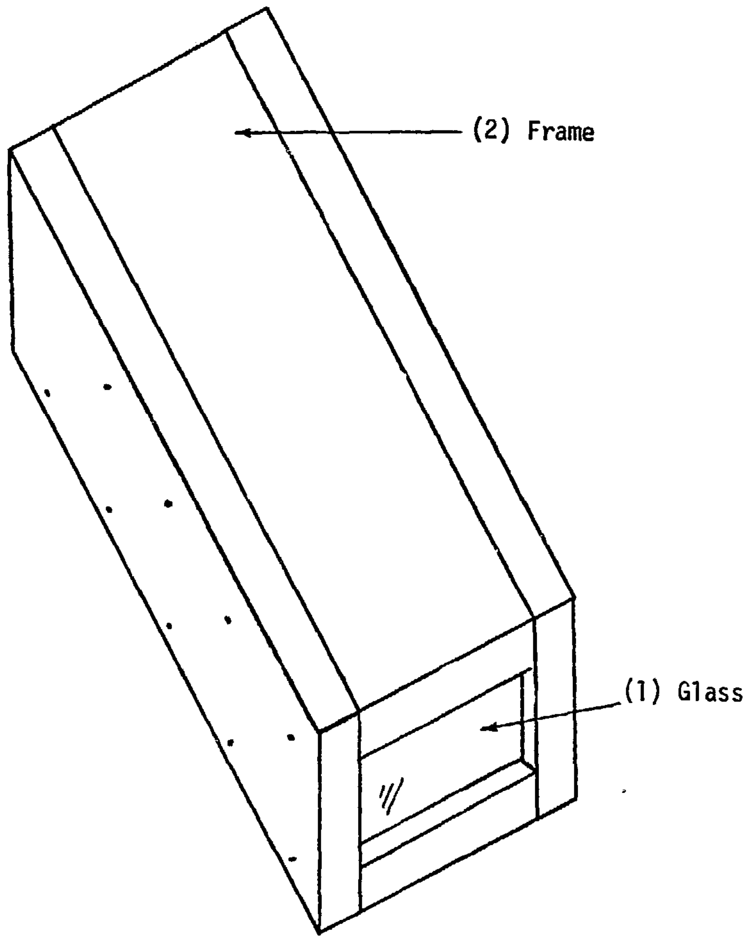
Slip the two pieces of lead pipe (E) over the free end of the handle, and fasten the free end to the opposite end of the body. Bend the handle at its middle allowing one weight to slide down each arm of the handle.

c. Notes

(i) To use the grappling bar, tie the end of a long, stout rope or cord to the handle. Drop the bar in water, allow it to reach bottom, and drag it along until resistance is felt, then haul it up The bar works well for retrieving plant specimens from pond and river bottoms.

(ii) Be certain the weights are sufficient to sink the bar easily, as wood can be extremely buoyant.

C4. Water Glass



a. Materials Required

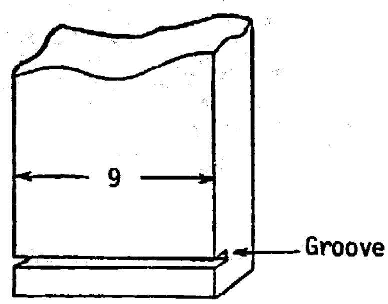
Components	Qu	Items Required	Dimensions
(1) Glass	1	Glass Plate (A)	6.3 cm x 10.3 cm x 0.3 cm
(2) Frame	4	Wood (B)	20 cm x 9 cm x 2 cm

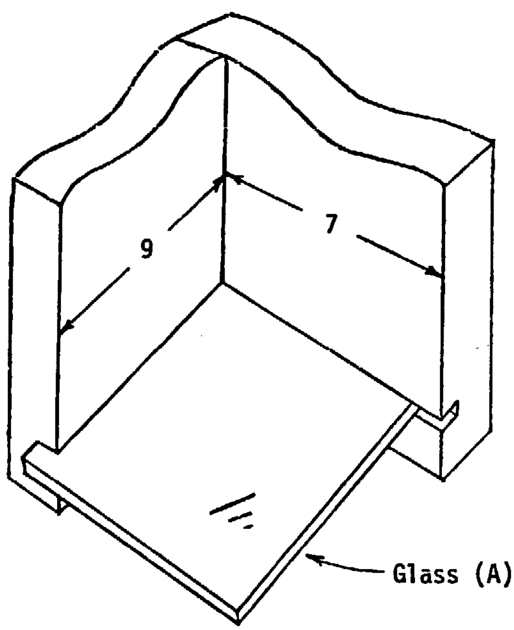
b. Construction

(1) Glass Plate

Cut the piece of glass (A) to the specified dimensions, making sure that all the edges are smooth and free of burrs.

(2) Frame





Cut a groove, 0.3 cm wide and 0.7 cm deep, across the width of each piece of wood (B), 1.2 cm from one end. Fasten two of the pieces of wood together at right angles using waterproof cement along the point of contact. Be sure that the grooves are lined up and that they face to the inside. Use nails or screws to reinforce this joint. Glue two sides of the glass plate with waterproof cement into the two grooves, placing the long side of the glass plate into the groove in the piece of wood with a width of 9 cm. The next piece of wood should be placed so that the groove holds the larger of the two free sides remaining on the glass plate. The last piece of wood then fits over the final free end. These last two pieces of wood should be glued and nailed to the previously assembled structure as they are put into place. Seal the ends of the grooves on the outside of the water glass with waterproof cement. Make certain all seams are waterproof.

c. Notes

(i) The water glass is designed to view the bottom organisms of a body of water. When the end with the glass plate is inserted into the water, glare from the sun as well as surface ripples are eliminated.

IV. TERRESTRIAL COLLECTING APPARATUS

These items are designed for use in collecting land invertebrates, vertebrates, and plants. Instructions for killing, preserving, and storing these organisms can be found in a variety of books and journals.

A. INSECT COLLECTING APPARATUS

Insects are the most common, familiar organisms everywhere in the world. Items described in this section are used in collecting and treating them.

B. SOIL ORGANISM COLLECTING APPARATUS

These pieces of equipment enable students to discover the multitude and diversity of living things in the soil.

C. SMALL VERTEBRATE COLLECTING APPARATUS

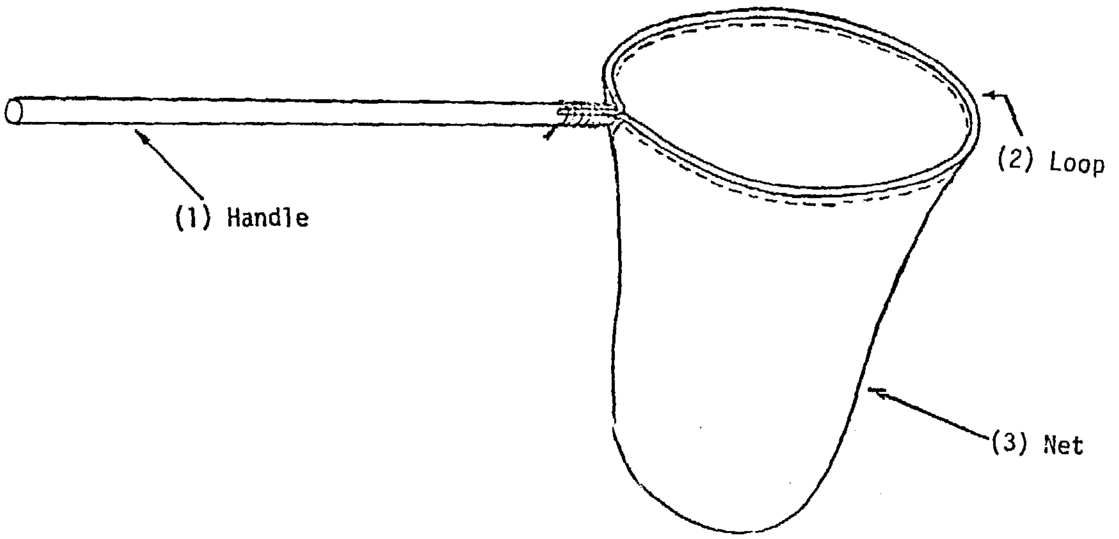
Small lizards, snakes, birds and mammals may be captured alive using these devices.

D. PLANT COLLECTING APPARATUS

The vasculum and plant presses in this section are used in collecting and preserving plant materials.

A. INSECT COLLECTING APPARATUS

A1. Butterfly Net

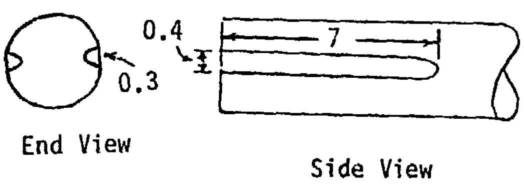


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wood Dowel (A)	100 cm long, 2 cm diameter
(2) Loop	1	Heavy Wire (B)	115 cm long, 0.3 cm diameter
	1	Stiff Wire (C)	About 80-90 cm long, 0.1 cm diameter
(3) Net	1	Nylon Bag (D)	50 cm wide, 60 cm long

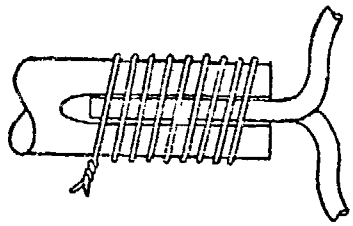
b. Construction

(1) Handle



The length of the dowel (A) from which the handle is made may be varied according to personal preference. Cut two grooves in one end of the handle, one opposite the other. Make these grooves about 7 cm long, 0.3 cm deep, and about 0.4 cm wide.

(2) Loop



Binding of Loop to Handle

Form a loop 30 cm in diameter from the heavy wire (B). Leave about 7 cm of excess wire at each end which will fit into the grooves in the handle. Bend these 7 cm portions to 90° angles. Fit the wire ends into the grooves in the handle and bind them in place with the stiff wire (C).

(3) Net

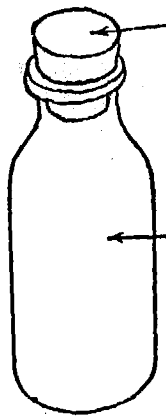
Select a finely meshed nylon laundry bag (D) or sew a net from a piece of nylon cloth or similar sturdy cloth with a relatively open weave. Whether a bag is used or a net sewn specifically for the butterfly net, make sure the opening of the net is 5 - 10 cm greater in circumference than that of the loop. Simply sew the open portion of the net around the loop with strong thread.

c. Notes

(i) Use the butterfly net to collect flying insects of all kinds. If it is sturdily made, it can also be swept through high grass to collect insects living in the grass. Consult a good source book for information on preserving, mounting, and storing collected insects.

(ii) The material used for the net must have a fine mesh through which insects cannot escape. At the same time, the mesh must be open enough to permit air to easily pass through it with little resistance. Parachute nylon is especially good for this purpose.

A2. Killing Jars



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Stopper	1	Stopper (A)	To fit bottle
(2) Bottle	1	Glass Pill Bottle (B)	Approximately 10 cm long, 4 cm diameter

b. Construction

(1) Stopper

Select a cork or rubber stopper (A) which will effectively seal the bottle airtight.

(2) Bottle

Use a glass bottle (B) with a wide mouth.

c. Notes

(i) Killing bottles for insects can be made in several ways. Some are exceptionally dangerous and should only be used by the instructor. Be certain to label all jars as to their contents.

(ii) The following are methods of preparing killing jars:

(A) Cyanide Killing Jar - This is extremely dangerous and should only be used by the instructor. First, put a thin layer (0.5 cm) of potassium or sodium cyanide crystals in the bottom of the bottle. Cover this with a similar layer of fine sawdust or dry plaster of Paris. Finally, cover both layers with a layer of wet plaster of Paris. The jar is ready to use when the plaster hardens. Be sure to keep it tightly stoppered except to kill insects. Use only rubber stoppers.

(B) Ethyl Acetate Killing Jar - Put a thin (0.5 cm) layer of wet plaster of Paris in the bottom of the jar. When it has dried, put some ethyl acetate over the plaster and cover it with a small amount of tissue paper. This is also especially dangerous and should be kept tightly stoppered.

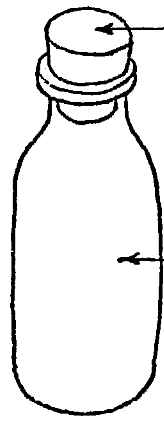
(C) Carbon Tetrachloride Killing Jar (1) - Pin a small piece of blotting paper or cotton to the bottom of the stopper. Saturate this with carbon tetrachloride just before putting the insects in the jar. This is a much safer jar for student use as the carbon tetrachloride quickly evaporates.

(D) Carbon Tetrachloride Killing Jar (2) - Use a one-hole stopper for the jar with a short piece of glass tubing extending through the hole. Plug one end of the tube with cotton. Place the insect in the jar, and replace the stopper. Then, carbon tetrachloride can be dripped through the tube onto the cotton plug where the fumes will kill the insect.

(E) Carbon Tetrachloride Killing Jar (3) - Place several rubber bands in the bottom of the jar and soak them overnight in carbon tetrachloride. Pour off the excess liquid and put a tight-fitting piece of blotting paper over the bands to keep them in place. This jar is relatively long lasting in its killing power.

(iii) The cork or rubber stoppers may absorb the toxic fumes from the jar so be sure to destroy them when the jars are discarded. Be absolutely certain that no fumes escape through the cork. It may be necessary to dip cork stoppers in melted paraffin wax to seal them completely.

A3. Relaxing Jar



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Stopper	1	Cork Stopper (A)	To fit bottle
(2) Bottle	1	Glass Pill Bottle (B)	Approximately 10 cm long, 4 cm diameter

b. Construction

(1) Stopper — Select a cork or rubber stopper (A) which will effectively seal the bottle airtight.

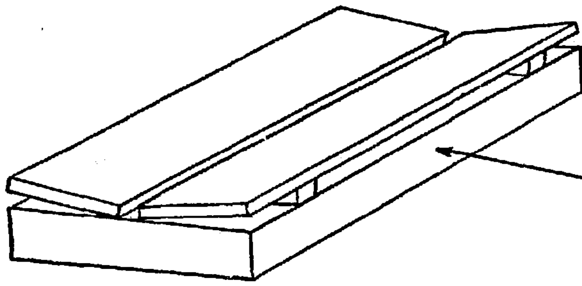
(2) Bottle — Use a glass bottle (B) with a wide mouth.

c. Notes

(i) Relaxing bottles are used to make dead insects more flexible so that they can be manipulated into a desirable mounting position.

(ii) The following is a method for preparing a relaxing jar: Place some moist sand in the bottom of the jar and add a few drops of carbolic acid to inhibit mold growth. Cover the sand with a piece of moist blotter paper. Leave the insects in the jar overnight to relax them.

A4. Insect Spreading Board

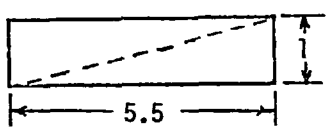


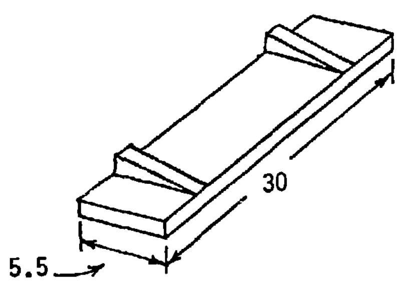
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Platform	1	Wood (A)	12 cm x 30 cm x 1.0 cm
	2	Wood (B)	5.5 cm x 30 cm x 0.5 cm
	2	Wood (C)	5.5 cm x 1 cm x 2 cm

b. Construction

(1) Platform



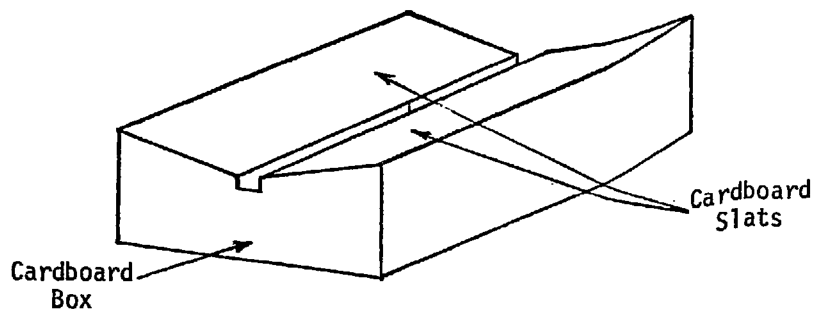


Cut the two small pieces of wood (C) in half diagonally, yielding four wedge-shaped pieces. Glue two of the wedges to the backs of each of the two slats (B). Turn the two slats over and glue them to the base (A). Leave a 1.0 cm gap between the two slats.

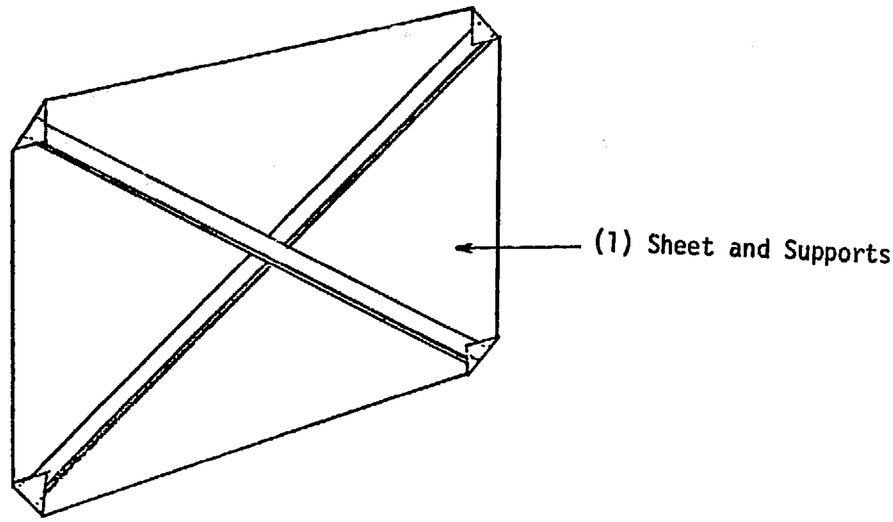
c. Notes

(i) Make the slats (B) from the softest wood available (e.g., balsa). Consult a good biological source book for details on preparing insects to be pinned and prepared on the spreading board.

(ii) A simple, inexpensive spreading board can be made from a cardboard box. Remove the top and cut the ends as shown in the illustration. Then glue two pieces of cardboard to the box to complete the spreading board.



A5. Beating Sheet *



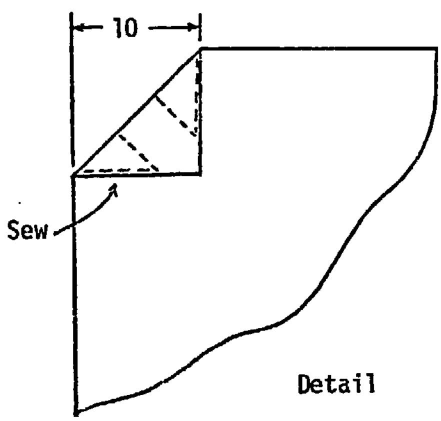
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Sheet and Supports	1	Heavy Cloth (A)	100 cm x 100 cm
	2	Wooden Slats (B)	125 cm x 4 cm x 1.0 cm

b. Construction

(1) Sheet and Supports

Fold back about 10 cm of the heavy cloth (A) (muslin will work) at each corner and sew a pocket into each such that the tips of the wooden slats (B) will fit into them.



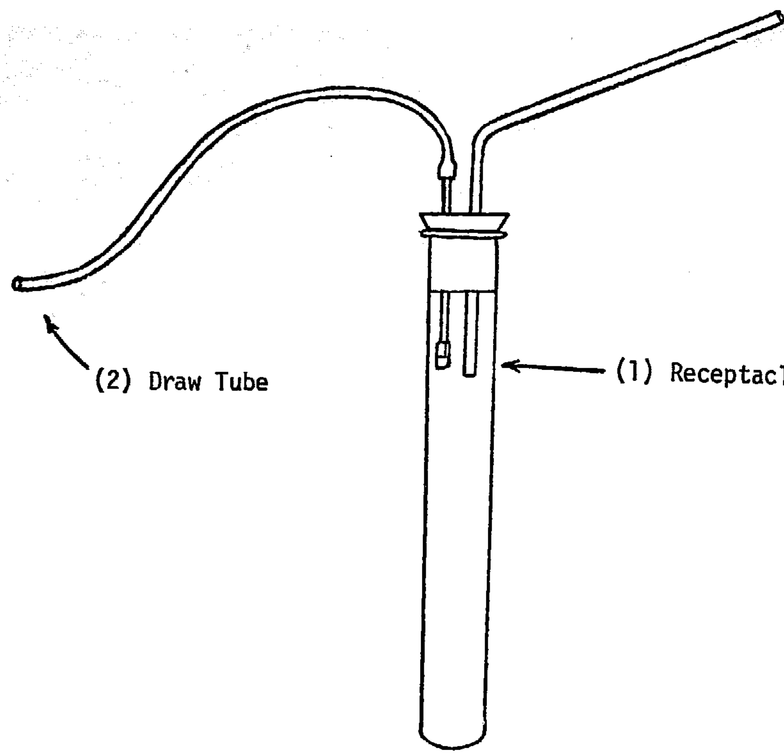
*Adapted from Jens W. Knudsen, Biological Techniques, (New York: Harper and Row, 1966), p 209.

c. Notes

(i) The sheet is held under shrubbery and insects are shaken off onto it where they can easily be captured.

(ii) Bamboo, wooden dowels, broom handles, etc. can be substituted for the wooden slats. In any case, the crosspieces can be removed after use to permit compact storage.

A6. Aspirator



a. Materials Required

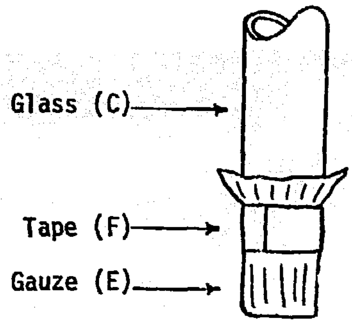
Components	Qu	Items Required	Dimensions
(1) Receptacle	1	Test Tube (A)	15 cm long, 1.6 cm inside diameter
	1	2-Hole Stopper (B)	To fit test tube
(2) Draw Tube	1	Glass Tube (C)	6 cm long, 0.2 cm inside diameter
	1	Rubber Tube (D)	35 cm long, 0.3 cm inside diameter
	1	Gauze (E)	1 cm x 2 cm
	1	Tape (F)	2 cm long
(3) Intake Tube	1	Glass Tubing (G)	16 cm long, 0.3 cm inside diameter

b. Construction

(1) Receptacle

Plug the end of the test tube (A) with a two-hole stopper (B).

(2) Draw Tube



Detail

Use the tape (F) to hold the gauze (E) in place over the end of the glass tube (C). Be certain air still flows freely through the end of the tube. Insert the end of the tube through one of the holes in the stopper. Attach the end of the rubber tube (D) to the glass tube (C).

(3) Intake Tube

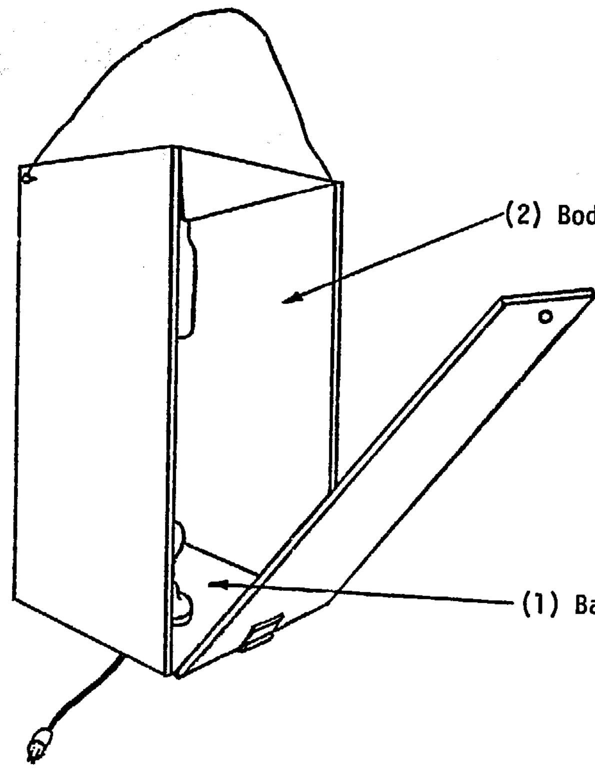
Bend the glass tube (G) to an 120° angle about 6 cm from one end, and insert this end into the remaining hole in the stopper.

c. Notes

(i) The aspirator is a useful instrument when collecting insects which are too small or too fragile to be collected by hand. To operate, place the draw tube between one's teeth and the intake tube near the insect to be collected. The collector then sucks in and the insect is captured. The gauze prevents the insect from entering the draw tube.

(ii) A glass bottle or vial may be used in place of a test tube, but in any case a tight-fitting stopper is required. The stopper may be either rubber or cork, and cotton may be used in place of the gauze.

A7. Night Flying Insect Collector



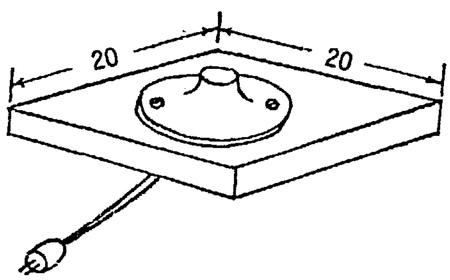
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	20 cm x 20 cm x 2 cm
	1	Electric Lightbulb Socket (Porcelain) (B)	12 cm diameter
	2	Electrical Wire (C)	50 cm long, 0.3 cm diameter
	1	Electrical Plug (D)	--
(2) Body	2	Wood (E)	22 cm x 50 cm x 1.0 cm
	2	Wood (F)	20 cm x 50 cm x 1.0 cm
	1	Hinge (G)	--
	4	Fine Wire Mesh (H)	20 cm x 17 cm
	1	Thick Rubber Band (I)	--
	1	Glass Container with Lip (J)	500 ml
	1	Light Bulb (K)	100 watts
	2	Screw Eyes (L)	2.5 cm long, 0.2 cm diameter
	1	Wire (M)	60 cm long, 0.1 cm diameter

1	Thin Sheet Metal (N)	10 cm x 10 cm
1	Wire (O)	10 cm long, 0.1 cm diameter
2	Wood Screws (P)	1 cm long

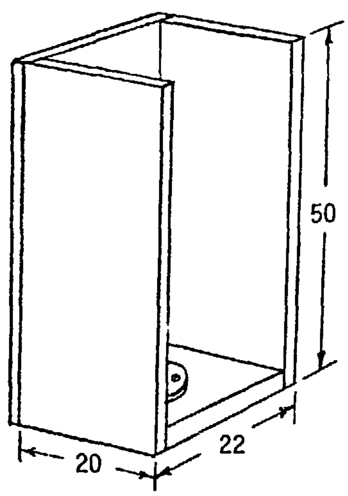
b. Construction

(1) Base

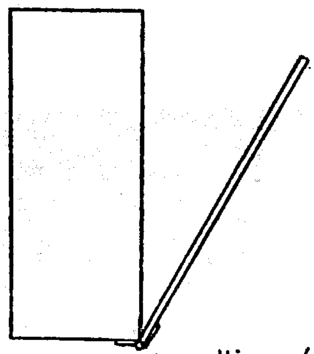


The electric light bulb socket (B) is centered on the base (A) and two holes are drilled through the base for the attachment of the electrical wires (C) to the terminals on the electric light socket. Attach the electrical wires to these terminals and extend them through the base. The socket is then screwed into place on the base using wood screws. Attach the electrical plug (D) to the wires to complete the base.

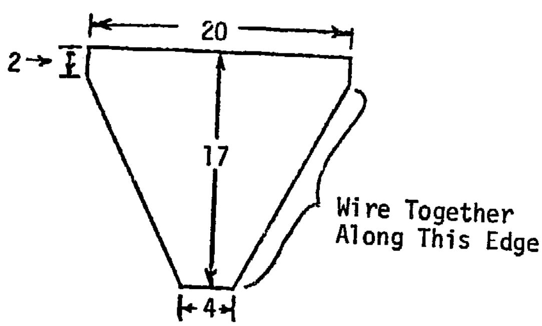
(2) Body



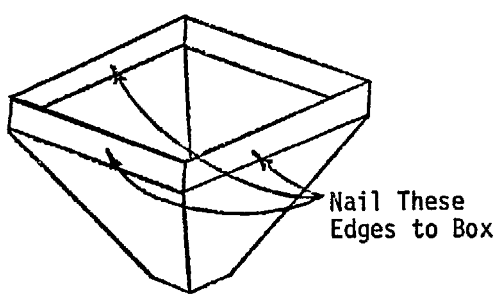
The two pieces of wood (F) are nailed into place on opposite sides of the base. One of the pieces of wood (E) is nailed onto the third side of the base where it overlaps the two ends of the sides already attached. It is then nailed to the other two sides. Take the last piece of wood (E) and attach the hinge (G) to the bottom of it and to the bottom of the base so that it forms a door which opens downward.



Side View

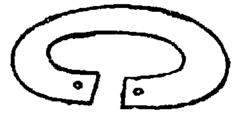


Pattern

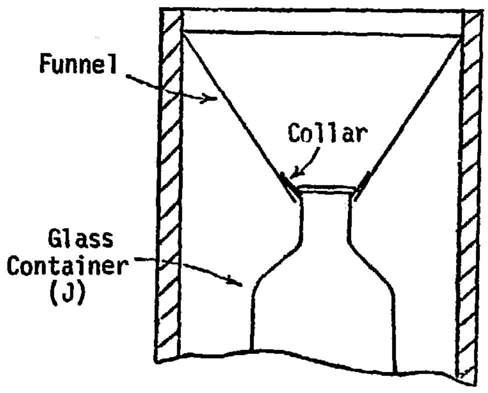


Completed Funnel

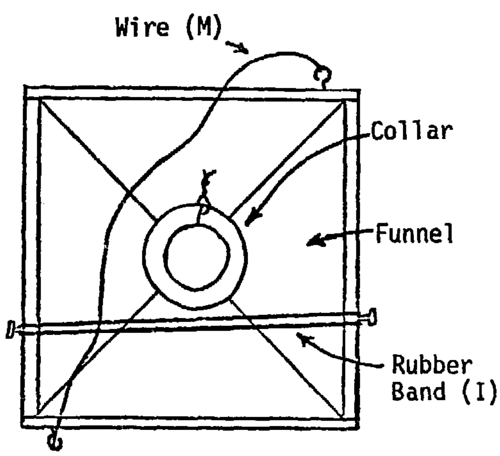
Take the four pieces of wire mesh (H) and cut them to the pattern shown, then wire them together along their edges to form a square funnel. The opening at the bottom of the funnel (4 cm square) should be the same width as the diameter of the neck of the collecting bottle (J) used. Nail three of the edges of the funnel along the top edges of the fixed sides of the trap. Of course, do not nail the fourth edge to the door or the door will not open.


Collar

Next, cut a collar from the piece of sheet metal (N) so that it will fit under the lip on the glass container (J). Cut this collar in such a way so that it



Side View



Top View

does not form a continuous circle, but instead has a break in it. Now, wrap the collar tightly around the neck of the glass container just under the lip. Pull the two free ends together and overlap them. Then punch a hole through the ends and place the piece of wire (O) through the holes and bend it so that it holds the collar tightly closed. The glass container can now be picked up by the collar without falling through it. Remove the collar, force the mouth of the glass container up through the bottom of the hole in the funnel, and replace the collar so that it holds the glass container in place.

Place two screws (P), one on the outside of the door about 2 cm down from the top, and the other in the same position on the side opposite the door. Then, close the door and stretch the rubber band (I) from one screw to the other over the top to hold the door closed. Finally, attach the two screw eyes (L) to opposite corners on the sides of the top and secure the wire (M) to them, and screw the light bulb (K) into the socket.

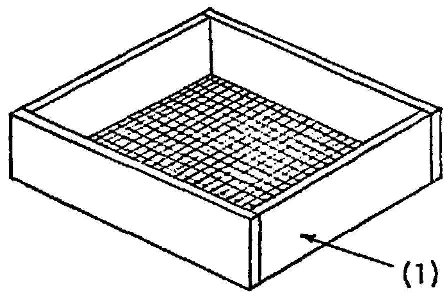
c. Notes

(i) To operate, simply hang the trap at night outside from a fixture (e.g., a tree limb), and attach the electrical wires to a power supply. Be sure to hang it in an area where there are a large number of night-flying insects. The light will attract the insects and they will fall into the glass container. When a sufficient number have become trapped in the container, place a wad of cotton soaked in carbon tetrachloride over the opening, thus killing the insects.

(ii) By placing two hinges on the side of the door, it can be opened to the side if so desired.

B. SOIL ORGANISM COLLECTING APPARATUS

B1. Soil Organism Sieve

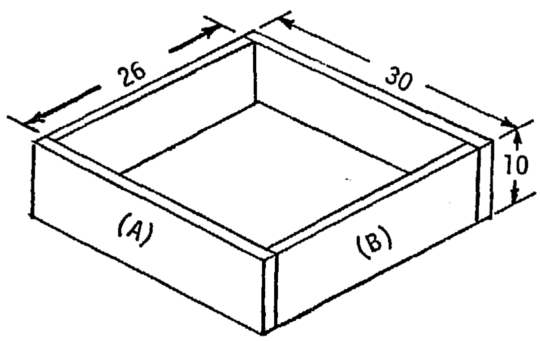


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Sieve	2	Wood (A)	30 cm x 10 cm x 2 cm
	2	Wood (B)	26 cm x 10 cm x 2 cm
	1	Wire Screen (C)	30 cm x 30 cm

b. Construction

(1) Sieve



Frame

Simply nail or screw the four wood boards (A,B) together to form a frame and nail the piece of screen (C) to the bottom of the frame.

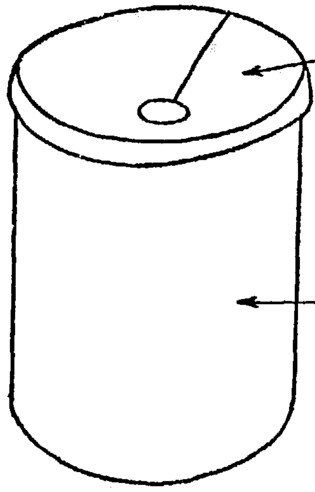
c. Notes

(i) Use the sieve to separate out soil organisms such as worms, grubs, etc., from the material in which they are living.

(ii) Carefully choose the size of wire mesh used in the sieve. A mesh or screen with too fine a weave will become clogged with soil and rendered useless. A relatively wide mesh will work well if the soil is coarse, allowing the organisms to fall through the mesh while holding back the soil.

(iii) A frame for the sieve can also be made by knocking out the bottom from an old drawer or wooden box.

B2. Soil Insect Trap



a. Materials Required

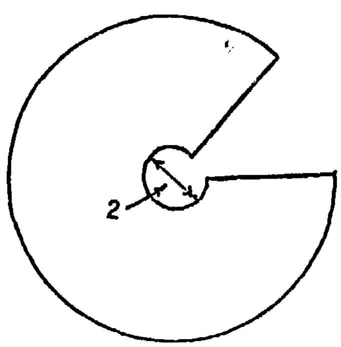
Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	0.5 liter capacity
(2) Funnel	1	Wire Mesh (B)	About 15 cm x 15 cm

b. Construction

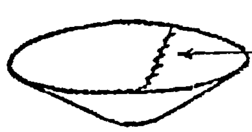
(1) Can

Remove one end from a tin can (A).

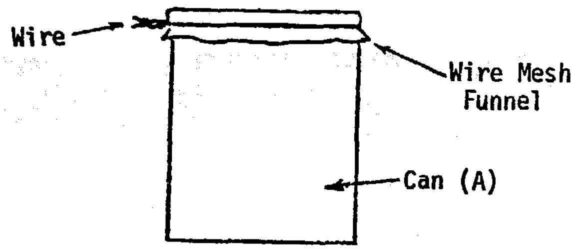
(2) Funnel



Cut a pattern for the funnel from the wire mesh (B). The outside diameter of the pattern should be approximately 2 cm wider than the diameter of the can (A) used.



Connect the two edges of the cutout portion of the pattern by "sewing" them together with wire. This will result in a cone with a hole at the apex. Complete the soil insect trap



Side View

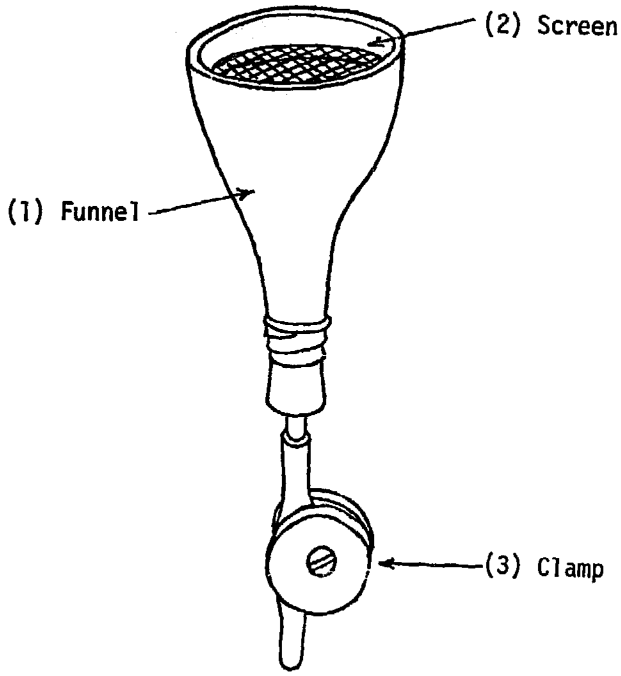
by inserting the funnel in the open end of the can and folding the excess wire mesh down around the outside of the can to hold it in place. If necessary, a piece of wire wrapped around the outside of the can and twisted tightly will help hold the funnel in place too.

c. Notes

(i) Place the trap in a hole in the ground so that the top edge of the trap is even with the soil level. Thus, small insects and other ground organisms crawling across the trap will fall through the hole in the funnel into the can. Check the can periodically for captured organisms.

(ii) The trap can be varied by making the funnel portion from aluminum foil, waxed paper, or other materials which are smooth and will help prevent the organisms from crawling out of the trap. Also, dusting the inside walls of the can with fine powder (e.g., talcum powder) will prevent organisms from crawling up the walls and out of the cage.

B3. Baermann Funnel

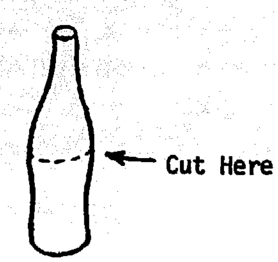


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	About 7 cm diameter, 20 cm long
	1	Glass Tube (B)	5 cm long, 0.5 cm inside diameter
	1	1-Hole Stopper (C)	To fit bottle opening
	1	Rubber Tube (D)	12 cm long
(2) Screen	1	Fine Wire Mesh (E)	7 cm diameter
	1	Stiff Wire (F)	16 cm long, 0.3 cm diameter
(3) Clamp	1	Screw Clamp (G)	CHEM/IV/A4

b. Construction

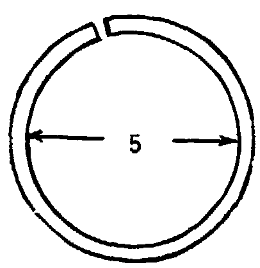
(1) Funnel



Soda Pop Bottle

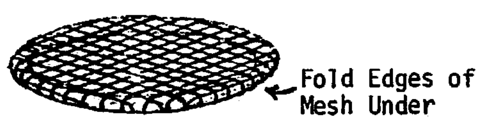
Cut the top of a glass soda pop bottle (A) off (See CHEM/I/F2). Force a short piece of glass tubing (B) through the one-hole stopper (C) and seal the opening with the stopper. Next, attach the rubber tube (D) to the glass tube.

(2) Screen



Ring

Make a ring slightly smaller in diameter (i.e., about 5 cm diameter) than the bottle with the stiff wire (F). Fold the edge of the circular piece of wire mesh (E) under the wire ring. The wire mesh will probably be stiff enough to hold itself in place without being wired to the ring.

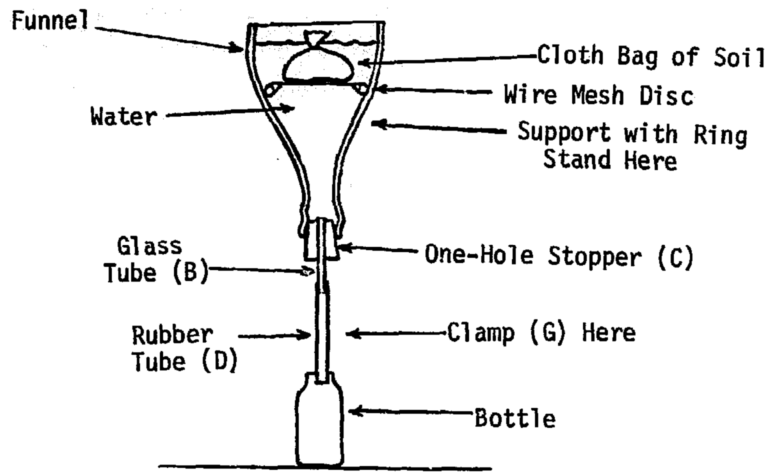


(3) Clamp

Use the clamp (G) to seal the rubber tube airtight.

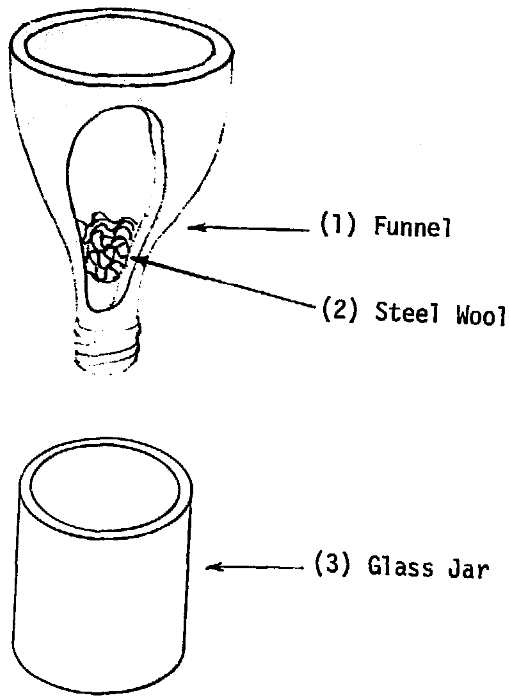
c. Notes

(i) The Baermann funnel is designed to extract soil nematodes from soil. To use it, it must be supported by a ring stand. Clamp off the tubing, and let the end of the tube extend into a small vial or bottle. Set the wire mesh disc into the funnel, put a small cloth bag of soil on the disc, and fill the apparatus with water. After an hour or so, release the clamp to collect a small sample of water which can be examined for soil nematodes. (See illustration on next page.)



(ii) If commercial funnels of the correct size are available and inexpensive, they can be substituted for the bottle funnel. Also, the end of the rubber tube can be sealed off with a pencil stub or piece of wooden dowel if a good clamp is not available.

B4. Berlese Funnel

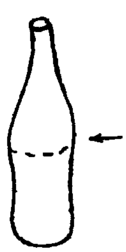


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	About 7 cm diameter, 20 cm long
(2) Steel Wool	1	Steel Wool (B)	30 g
(3) Glass Jar	1	Glass Jar (C)	50 ml capacity

b. Construction

(1) Funnel



Cut the top of a soda pop bottle (A) off (See CHEM/I/F2) to make the funnel. Alternately, use a commercial glass or metal funnel, or make one using metal foil or heavy paper.

(2) Steel Wool

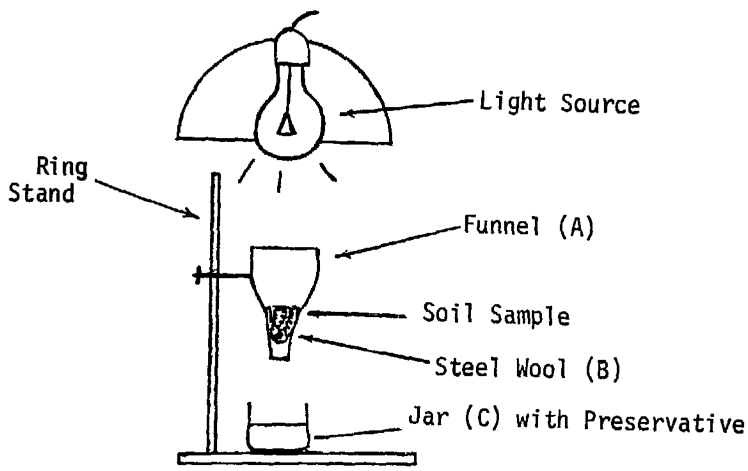
Place the steel wool (B) inside the funnel so that it blocks off the opening.

(3) Glass Jar

Fill the jar (C) about 1/2 full of alcohol or formalin and place it directly under the funnel.

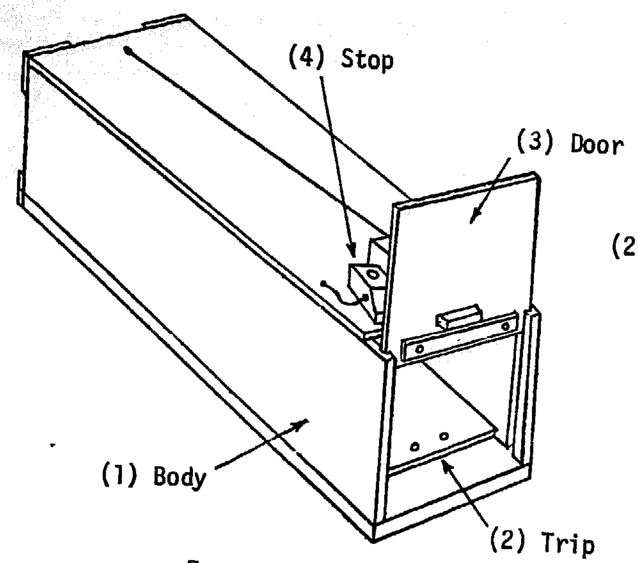
c. Notes

(i) To use the Berlese funnel, a ring stand and light source are needed. Support the funnel with the ring stand so that the neck of the funnel is directly over the glass jar. Place a 25 watt light directly above the funnel and close enough to the funnel that the heat from the bulb will warm the contents of the funnel. Place the soil sample in the funnel so that it rests on the steel wool. Pick out the larger soil organisms with forceps. The smaller organisms will be driven down by the light and heat of the bulb until they drop through the steel wool into the preservative in the jar. The apparatus should be left in place several days to insure that most of the organisms are collected.

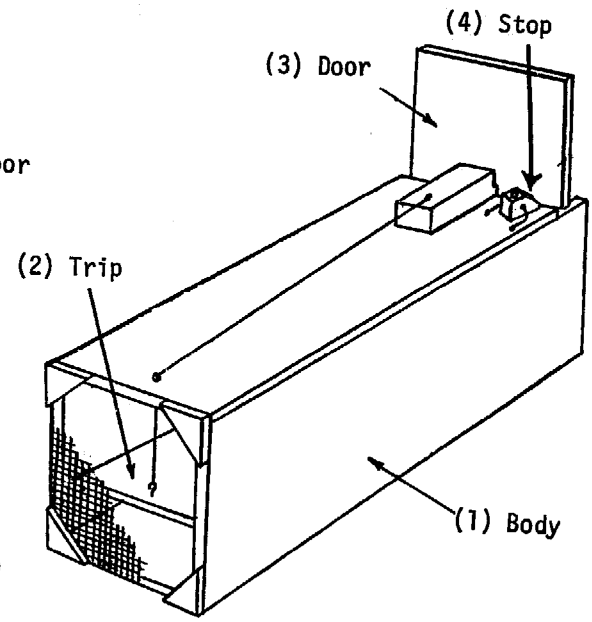


C. SMALL VERTEBRATE COLLECTING APPARATUS

C1. Simple Box Trap



Front View



Back View

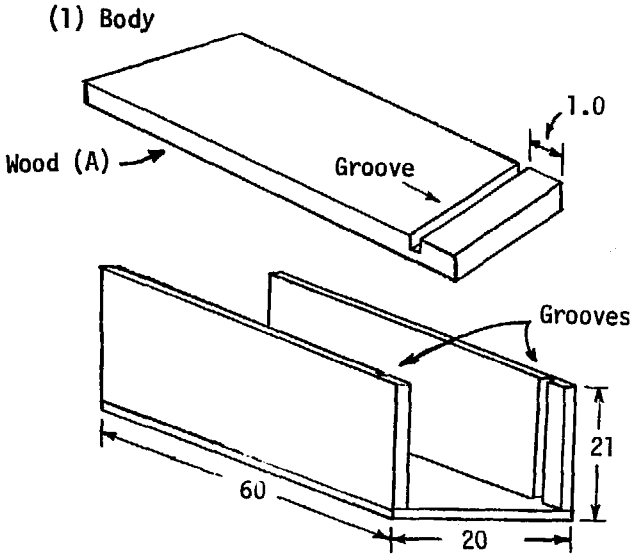
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Body	3	Wood (A)	60 cm x 20 cm x 1.0 cm
	1	Wood (B)	58 cm x 20 cm x 1.0 cm
	2	Wood (C)	5 cm x 5 cm x 0.5 cm
	1	Wire Mesh (D)	20 cm x 22 cm
(2) Trip	1	Wood (E)	17.5 cm x 55 cm x 0.5 cm
	1	Metal Hinge (F)	5 cm x 5 cm
	1	Eyed Screw (G)	2 cm long
	1	String (H)	85 cm
	1	Wood (I)	10 cm x 4 cm x 1.5 cm
	4	Round-headed Screws (J)	Approximately 1.0 cm long
(3) Door	1	Construction Board (K)	19 cm x 20.5 cm x 0.25 cm
	1	Flat Metal (L)	15 cm x 1.5 cm x 0.5 cm

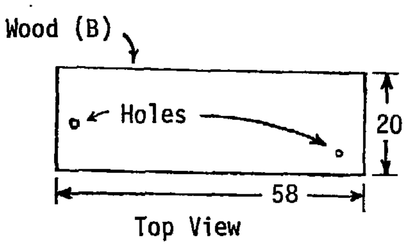
	2	Bolts (M)	1.25 cm long
	2	Nuts (N)	To fit bolts
(4) Stop	4	Tacks (O)	1.0 cm long
	1	String (P)	7 cm
	1	Rubber Band (Q)	--
	1	Wood (R)	6 cm x 2 cm x 2 cm
	1	Bolt (S)	5 cm long
	1	Nut (T)	To fit bolt

b. Construction

(1) Body

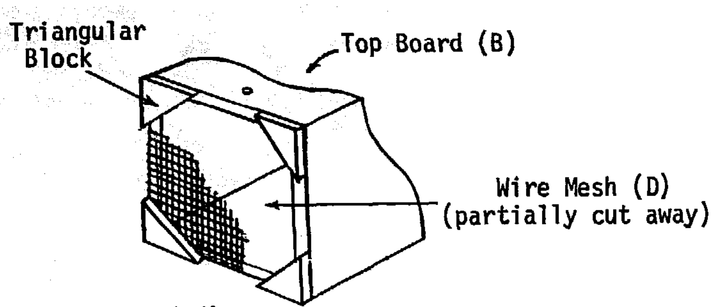


Begin the body by cutting a goove 0.3 cm wide and 0.5 cm deep parallel to the end of two of the pieces of wood (A). This groove is 1.0 cm from the end. Nail or screw these two boards to the third board (A).

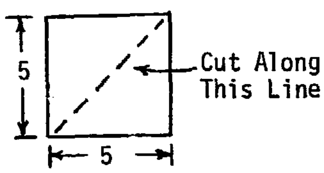


In the corner of the board (B) to be used as the top, drill a hole 0.7 cm in diameter about 3 cm from each edge, and drill a hole about 0.5 cm in diameter through the other end of the top, 1.0 cm from the edge and centered. Set this board (B) aside until the trip (2) is completed.

Seal off one end of the body by nailing the wire mesh (D) to it. Reinforce the corners with triangular pieces of wood gotten by cutting the wood pieces (C) in half diagonally. Again, do not seal the end until the trip (2) and top board (B) are in place.

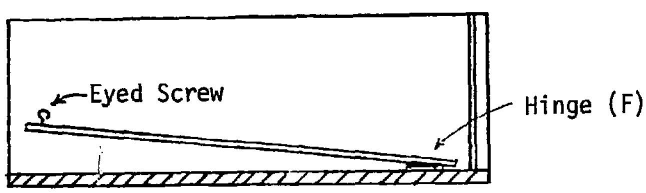


End View

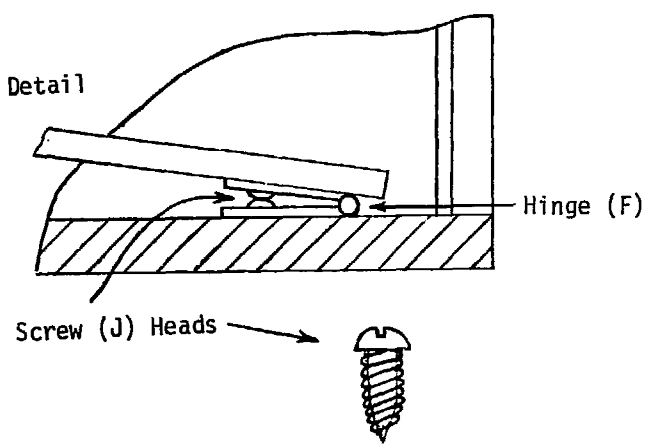


(2) Trip

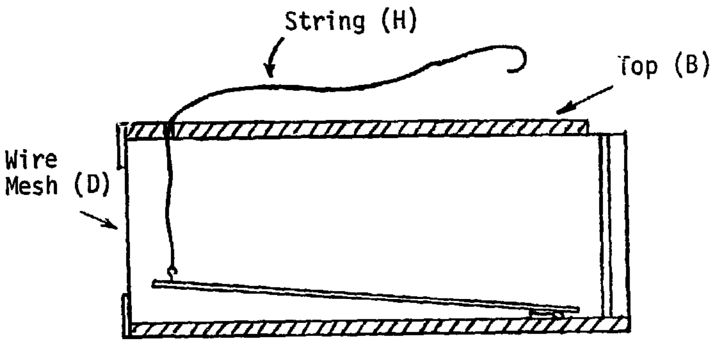
Screw the eyed screw (G) into one end of the wood (E) about 1.0 cm from the edge and centered. To the back of this board, fasten the hinge (F) which also should be about 1.0 cm from the edge and centered. Next, fasten the other half of the hinge to the bottom of the body so that the board is centered in the bottom of the body (i.e., it should be 2.5 cm from each end and 0.25 cm from each side of the body). Use round-headed screws (J) so that the hinge cannot close completely flat. In this way, the trip will be held up at a slight angle, which is needed in the design of this trap. Alternately, the length and tension of the trip string (N) can be adjusted to hold the trip in



Side View (Cross-section)



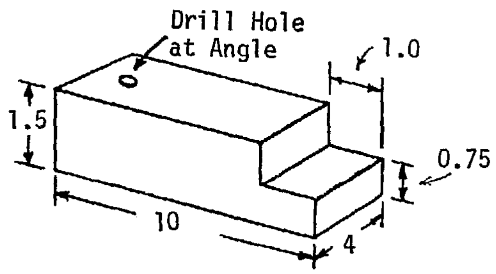
the desired position without the necessity of using this type of hinge and screws.

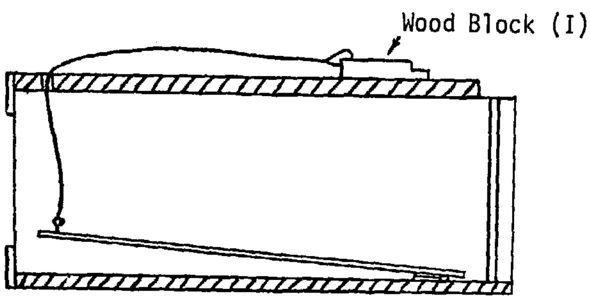


Side View (Cross-section)

Now tie one end of the string to the eyed screw (G) in the trip (H). Run the other end of the string through the hole in the top board (B) of the body which may now be nailed or screwed into place. Also, the wire mesh (D) for the end of the body may be fastened in place after the top is finished.

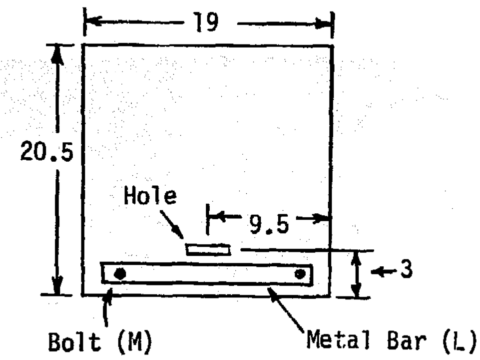
To complete the trip, cut a notch from the block of wood (I) and attach the free end of the string to the block by tying it through a hole drilled in the block.

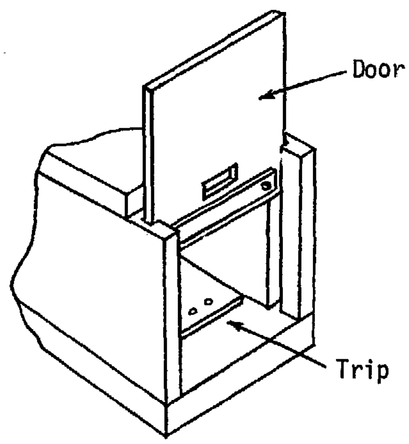




Side View (Cross-section)

(3) Door

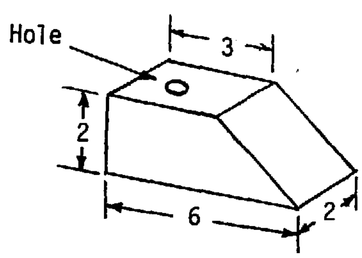




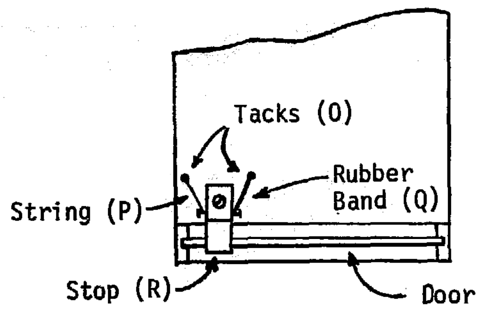
Detail

Cut a hole 4.25 x 1.0 cm in the construction board (K) 3 cm from the end of the board and centered. Next, using the nuts (N) and the bolts (M), bolt the flat metal bar (L) into position just under the hole. Holes will have to be drilled through the board for the bolt to go through. The door is now finished and should slide easily up and down in the notches in the sides of the body.

(4) Stop



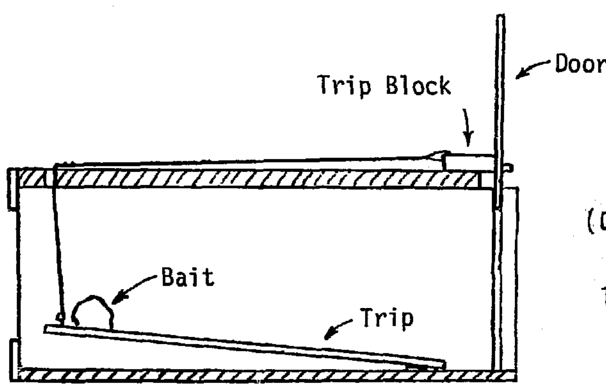
Cut the piece of wood (R) as shown and drill a hole in the wood slightly larger in diameter than the bolt (S) used.



Hammer a tack (O) into each side of the stop (R), and run a bolt (S) through the stop and the hole in the corner of the top. Screw the nut (T) loosely onto the bolt. Hammer two other tacks (O) into the top of the body, one to either side of the stop and slightly behind it. Finally, tie the piece of string (P) between the tack in the left side of the stop and the tack to the left in the top, and similarly attach the rubber band (Q) on the right side. Fix the tension in the rubber band so that the stop will be held out over the door when the door is closed, thus preventing the door from being raised after the trap has been sprung.

c. Notes

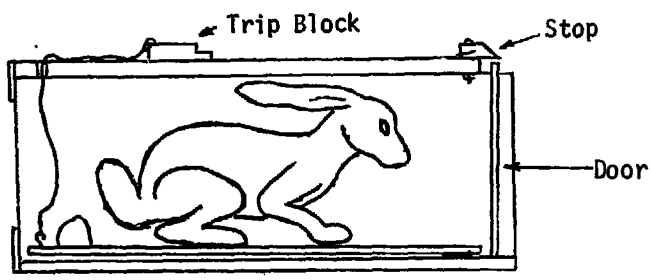
(i) To set the trap up, place it where small animals are likely to be found. Push the stop out of the way and put the door between the grooves in a raised position. Next, push the notched portion of the trip block through the hole in the door to hold the door up. Release the stop, allowing the rubber band to pull it against the door. At this point, the string attaching the trip block to the trip should be taut. Finally, place a suitable bait in the extreme rear of the cage on the trip.



Side View
(Cross-section)

Trap in "Set" Position

Because the round heads of the hinge screws hold the trip up at a slight angle, the animal entering the trap must move to the rear of the trap before the combination of its (the animal's) weight and leverage causes the rear of the trip to drop down, pulling the trip block back out of the hole in the door. The door then drops down in the grooves, the metal bar aiding in a faster drop. Finally, the stop is pulled out over the top of the door once the door is out of its way, and is held over the door because the rubber band pulls against the string.



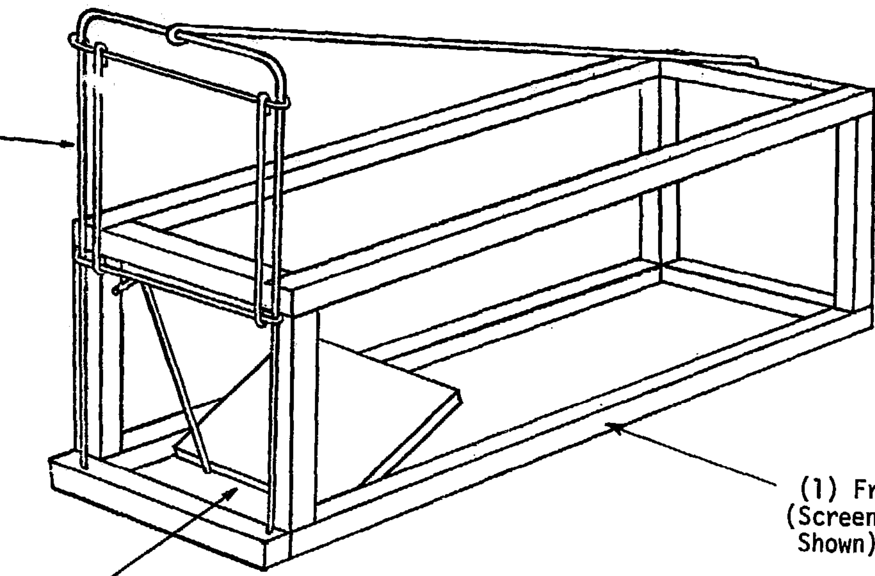
Side View
(Cross-section)

Trap in "Sprung"
Position

(ii) It may be desirable to modify the construction of this trap by making it with wire mesh sides as many animals are difficult to entice into enclosed spaces.

(iii) This design can be altered in many ways, especially with respect to proportion, dimensions, and materials used, including plywood or other thin but strong construction materials.

C2. Potter Bird Trap *



a. Materials Required

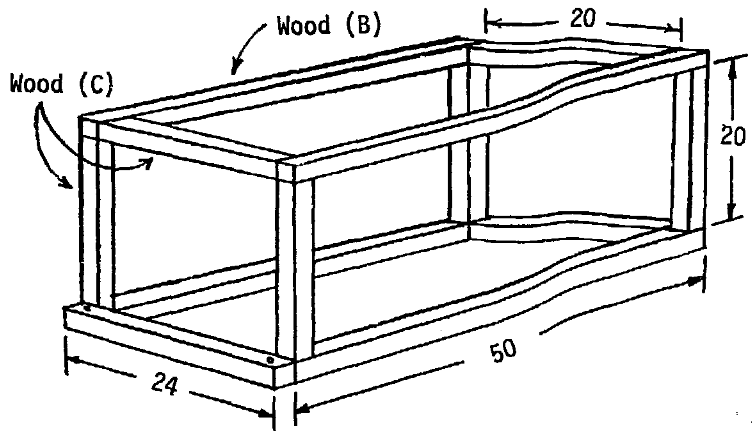
Components	Qu	Items Required	Dimensions
(1) Frame	1	Wood (A)	24 cm x 2 cm x 2 cm
	4	Wood (B)	50 cm x 2 cm x 2 cm
	7	Wood (C)	20 cm x 2 cm x 2 cm
	4	Wire Screen (D)	23 cm x 49 cm
	1	Wire Screen (E)	23 cm x 23 cm
(2) Door	1	Stiff Wire (F)	125 cm long, 0.3 cm diameter
	1	Stiff Wire (G)	60 cm long, 0.3 cm diameter
	4	Stiff Wire (H)	27 cm long, 0.3 cm diameter
	1	Wire Screen (I)	22 cm x 22 cm
(3) Trip	1	"U" Tack (J)	1 cm long
	1	Stiff Wire (K)	25 cm long, 0.3 cm diameter

*Adapted from Nuffield Foundation, Teacher's Guide III: The Maintenance of Life, (England: Longmans/Penguin Books, 1966), p 201.

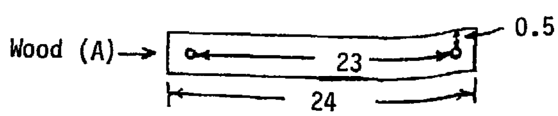
3	"U" Tacks (L)	1 cm long
1	Wood (M)	19 cm x 12 cm x 1.0 cm

b. Construction

(1) Frame



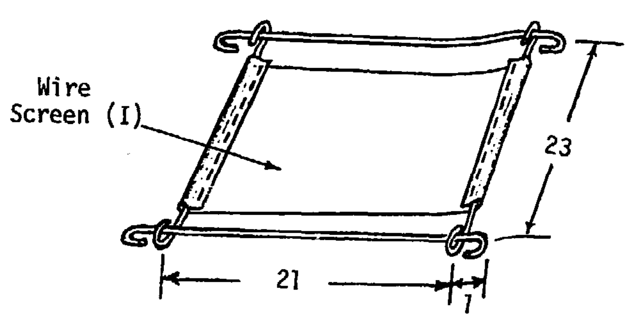
Nail and glue the basic framework together as shown. Begin by nailing one piece of wood (C) to the ends of two long pieces (B). Nail four of the remaining short pieces (C) to the U-shaped piece already made. Nail one in an upright position at each end of each long piece (B) to form the corners of the trap. Next, nail the two remaining pieces of both the short (C) and long (D) wood to the ends of the four upright pieces to complete the basic trap framework.



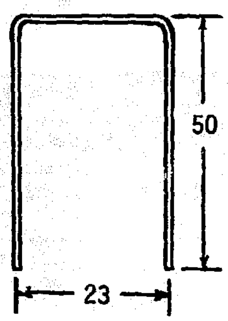
Top View

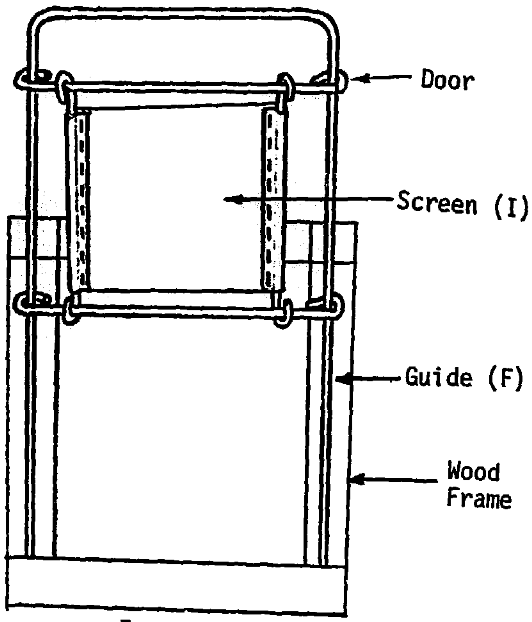
Drill holes the same diameter (0.3 cm) as the stiff wire (F) used for the door in the piece of wood (A) to act as "seats" for the door frame. Drill these holes 1.5 cm deep. Nail the four long pieces of screen (D) to the sides, bottom and top of the trap and nail the square piece (E) to the rear end to enclose all but the front of the trap in screening.

(2) Door



Bend the ends of two pieces of wire (H) over about 2 cm from each end. Bend the ends of the other two pieces (H) around the first two pieces to form a square framework. Fold two edges of the wire screen (I) around two sides of the frame

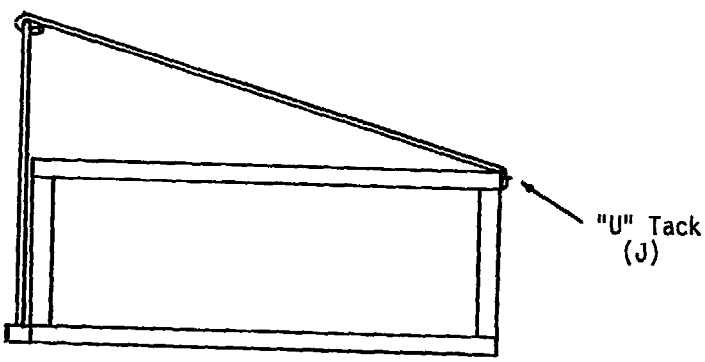




Front View

and "sew" the screen together with wire.

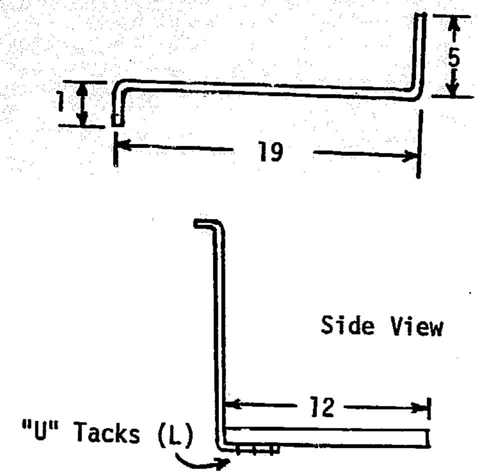
Bend the piece of wire (F) to a "U" shape. Slip the ends of this wire through the open ends of the wires in the door frame. The door should slide up and down easily with the U-shaped wire acting as a guide. Next, imbed the ends of the "U" into the holes in the front piece (A) of the wooden frame. They may be glued in place if necessary. When the door slides down the guide, it should effectively block the entrance of the trap with little or no gap.



Side View

Tack the end of the piece of wire (G) to the rear of the cage with a "U" tack (J) and bend it down until it touches the top of the door frame. Bend the remaining end around the wire (F) to help stabilize and support the door frame.

(3) Trip



Bend up 5 cm of the wire (K) to a right (90°) angle and bend 1.0 cm of the other end of the wire to a right angle in the opposite direction. Tack the wire to the wood (M) with the three "U" tacks (L) as near to one of the 12 cm edges as possible.

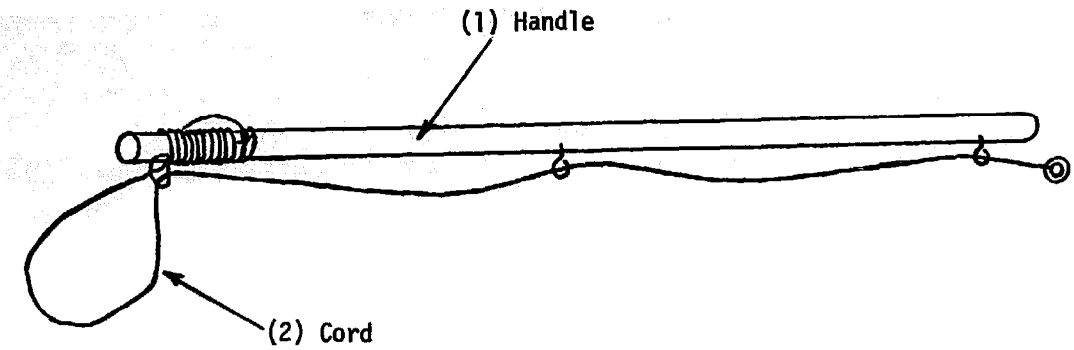
c. Notes

(i) To use the Potter bird trap, place it in a place where the desired type of bird is known to congregate. It may be necessary to anchor the trap in some manner in order to prevent it from being disturbed. The trap is set by pulling the sliding door all the way up and placing the trip inside the trap at such an angle that, when the door is lowered, the lower cross wire of the door rests on the bent portion of the trip wire. The slight pressure of the door on the trip should both hold the door up (and open) and keep the trip at a slight angle. Finally, bait the trap with a suitable attractant for the particular type of birds desired. A bird entering the trap for the bait will hop on the wooden part of the trip causing the wire to be pulled out from under the door which will drop down in place and trap the bird.

(ii) This trap, unlike others, doesn't require the hunter to hide in a blind waiting for a bird to enter.

(iii) The dimensions of this trap can be altered according to the size of the birds being trapped. Also, the trap may be baited in such a way as to attract other animals besides birds.

C3. Snare

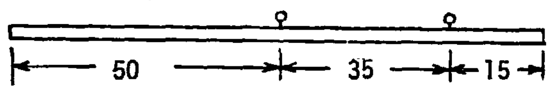


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wooden Rod (A)	100 cm long, 2 cm diameter
	2	Eyed Screws (B)	1 cm diameter opening
(2) Cord	1	Insulated Copper Wire (C)	250 cm long, 0.3 cm diameter
	1	Washer (D)	3 cm diameter
	1	"U" Tack (E)	1 cm long

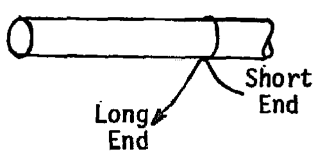
b. Construction

(1) Handle

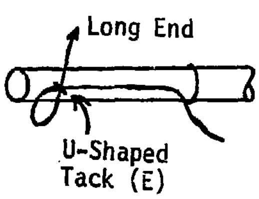


Screw one eyed screw (B) 15 cm from the end of the wooden rod (A) and screw the second screw (B) 50 cm from the other end.

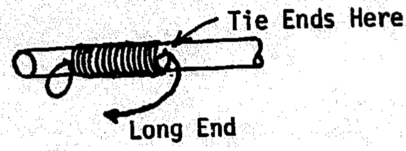
(2) Cord



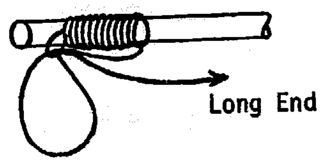
Tie the cord (C) securely to the rod at a point approximately 10 - 15 cm from the end. The short end should be at least 10 cm long as it will be used again to be tied to the long end.



Run the long end of the cord up to the end of the rod and form a loop. Hold the loop in place with a U-shaped tack (E).



At the end of the loop, begin wrapping the long end of the cord tightly around the rod until the short end has been reached. At that point, tie the long and short ends securely.



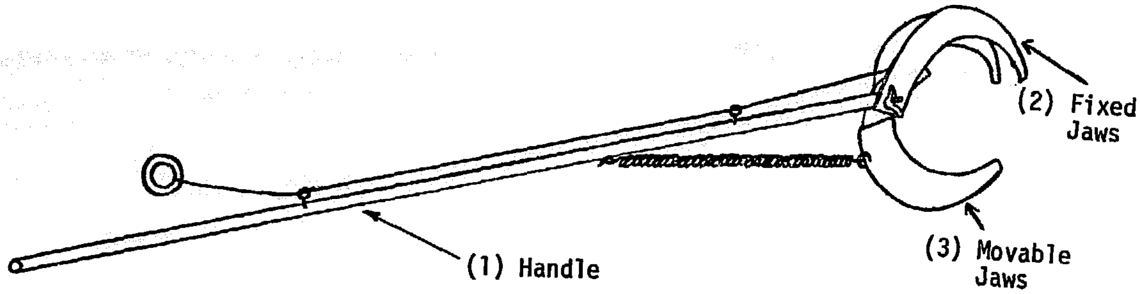
Extend the long end through the loop and then extend it back to form the snare. The long end is kept in position by extending the ends through the eyes on the rod. When the long end of the cord extends through the second eyed screw, tie the large metal washer (D) to it to make a pull ring.

c. Notes

(i) Use the snare to capture snakes, lizards, and other small animals which are difficult or dangerous to capture by hand. The loop must be placed over the animal's head, then pulled tight to hold it fast.

(ii) Bamboo or other materials may be used instead of wood for the rod. Rope can be used instead of insulated wire, but the wire is better since it is stiff and this helps keep the snare loop open instead of hanging limp.

C4. Reptile Hook

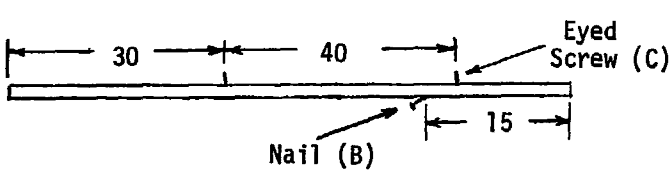


a. Materials Required

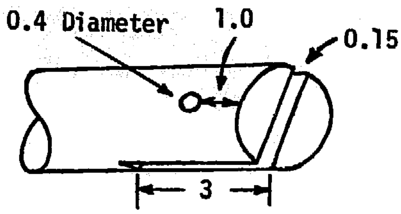
Components	Qu	Items Required	Dimensions
(1) Handle	1	Wooden Dowel (A)	100 cm long, 1.5 cm diameter
	1	Nail (B)	1.5 cm long, about 0.2 cm diameter
	2	Eyed Screws (C)	2 cm long, 1 cm diameter opening
(2) Fixed Jaws	2	Sheet Metal (D)	10 cm x 6 cm x 0.1 cm
	2	Tape (E)	About 50 cm
(3) Movable Jaw	1	Sheet Metal (F)	10 cm x 9 cm x 0.1 cm
	1	Spring (G)	12 cm x 0.5 cm
	1	Steel Wire (H)	100 cm long
	1	Washer (I)	3 cm diameter
	1	Bolt (J)	0.4 cm diameter, 2.5 cm long
	1	Wing Nut (K)	0.4 cm internal diameter
	1	Tape (L)	About 50 cm
	1	Rubber Tubing (M)	7 cm long, 1.0 cm diameter

b. Construction

(1) Handle

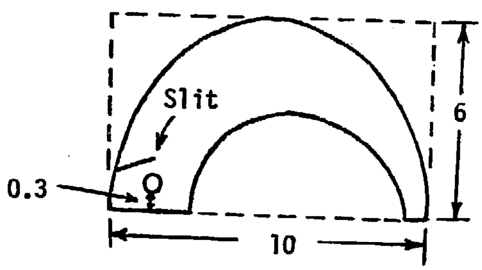


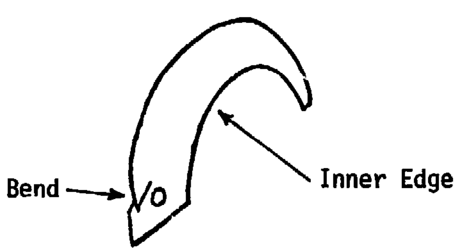
Screw the two eyed screws (C) into the wooden dowel (A) so that the opening of the "eye" faces the ends of the dowel. Hammer the nail (B) into the opposite side of the dowel at the angle indicated.



Cut a notch into the end of the dowel nearest the nail. This notch needs to be 3 cm deep and about 0.15 cm wide (i.e., slightly wider than the sheet metal (F) used for the movable jaw). Finally, drill a hole 0.4 cm in diameter 1 cm from the end, and perpendicular to the notch.

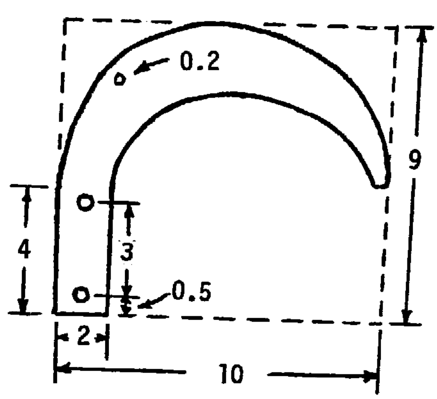
(2) Fixed Jaws



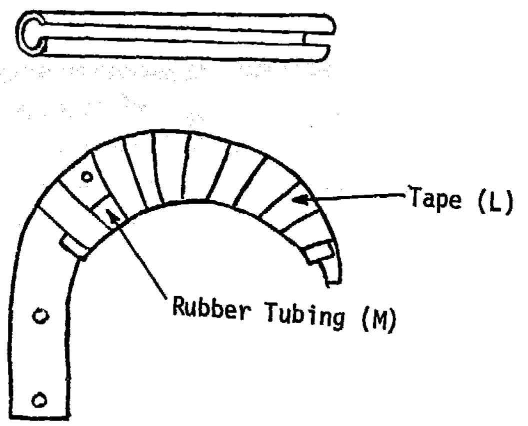


Cut the two fixed jaws to shape from the sheet metal (D). Drill or punch a hole 0.5 cm in diameter through the wide portion of each jaw, centered, and 0.3 cm from the flat edge. Cut a slit into each jaw about 0.7 cm long and in approximately the position indicated. Bend the resulting point of metal in on one jaw and out on the other (i.e., in opposite directions). To complete the jaws, cover at least the inner edge with tape (E), cloth, etc., to protect the animals being collected from cuts.

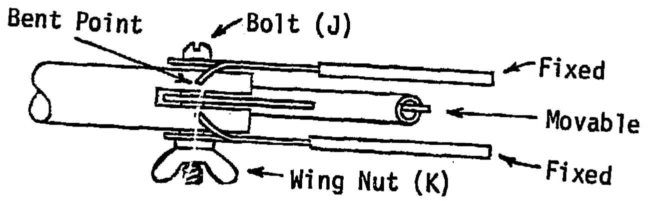
(3) Movable Jaw



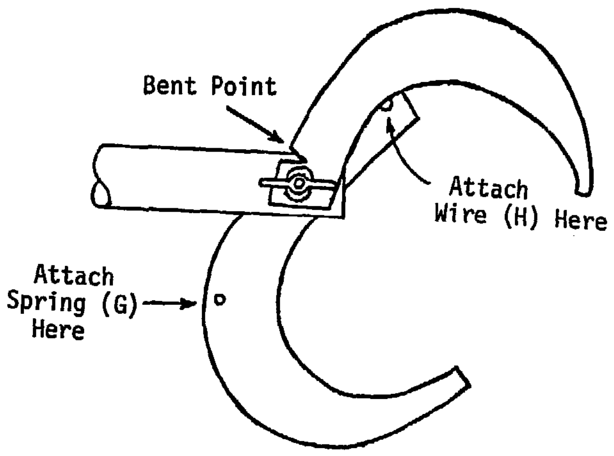
The movable jaw, made from sheet metal (F), is identical in shape to the fixed jaws except that one arm is extended for 4 cm. Three holes must be drilled or punched in the jaw. The two lower holes need to be 0.5 cm in diameter while the third need only be about 0.2 cm in diameter. Pad the inner edge of the movable jaw by slitting one



side of a 7 cm long piece of rubber tubing (M), and slipping it over the edge of the jaw. Use tape (L) to hold the tubing in place. Alternatively, the jaw may simply be padded with cloth and tape or other materials.



Top View



Side View

Attach the jaws to the handle in this order: Run the bolt (J) through one fixed jaw, halfway through the handle, through the middle hole of the movable jaw, through the rest of the handle and through the second fixed jaw. Screw on the wing nut (K) to secure the whole assembly. Be certain that the "bent points" of the fixed jaws both point in, rather than out. Fix tension on the wing nut such that the jaws are not loose, but the movable jaw still can be freely moved. The "bent points" of the fixed jaws prevent them from rotating backwards about the bolt.

Next, attach the steel wire (H) to the upper hole of the movable jaw and run the free end through both eyed screws (C). Fasten the free end to the washer (I). Fasten one end of the spring (G) to the remaining hole in the movable jaw, stretch out the spring, and fasten the free end to the nail (B). The movable jaw should be held wide open, and the reptile hook is ready for use. [Note: If a spring of the correct size and tension is not available, one can easily be made by winding steel wire (about 0.08 cm diameter) around a pencil or other cylindrical rod.]

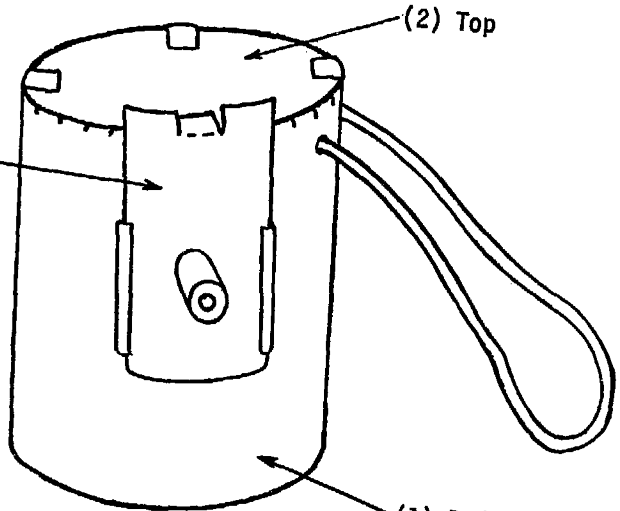
c. Notes

(i) Other materials such as bamboo, broom handles, etc., may be used for the handle. Also, a strong rubber band may be substituted for the spring.

(ii) If the sheet metal used for the jaws is sufficiently stiff and strong, only one fixed jaw may be required instead of two.

D. PLANT COLLECTING APPARATUS

D1. Vasculum

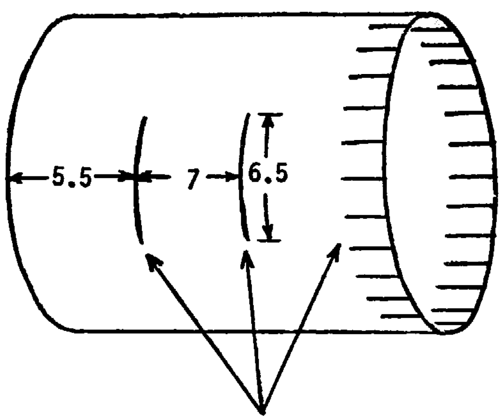


a. Materials Required

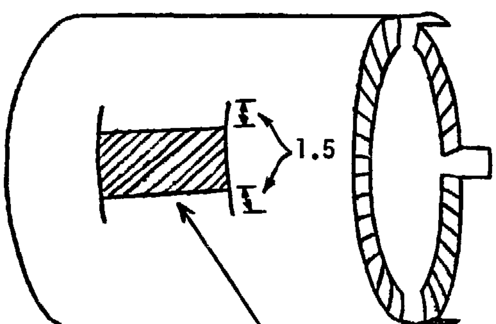
Components	Qu	Items Required	Dimensions
(1) Body	1	Tin Can (A)	4 liter capacity (about 18 cm long by 15 cm diameter) or larger
	1	Rope (B)	50 cm x 0.5 cm
(2) Top	1	Tin Sheet (C)	15 cm diameter, 0.05 cm thick
(3) Door	1	Tin Sheet (D)	14 cm x 8 cm x 0.05 cm
	1	Wood Dowel (E)	2.5 cm long, 2.5 cm diameter
	1	Nail (F)	3 cm long, 0.3 cm diameter

b. Construction

(1) Body

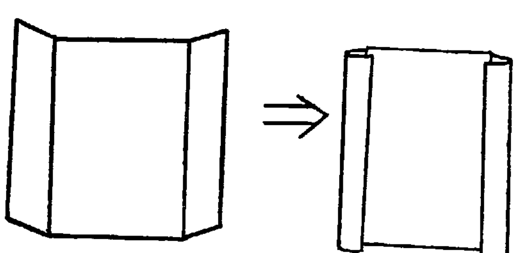


Use a hacksaw to make two slits in the side of the can (A). Each slit is 6.5 cm wide. The first slit is 5.5 cm from the bottom of the can, and the second slit is 7.0 cm from the first. Also, around the top edge (the top being the end which has been removed) make a series of slits approximately 2 cm deep and 2 cm apart.



Remove Shaded Portion

After these initial slits have been made, remove part of the can between the two slits leaving about 1.5 cm of metal to either side of the opening. Further, bend down all of the flaps made in the top edge of the can except for three, specifically those three which are 90°, 180°, and 270° from a point directly above the door.

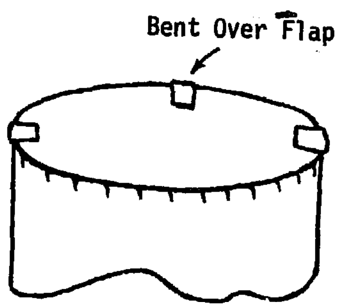


Detail of Door Guides

To make the guides for the door, first bend the 1.5 cm flaps out until they touch the can, then double them over so that the door will slide between them without falling out. This second step is best done by holding the door in place and bending the flaps over it.

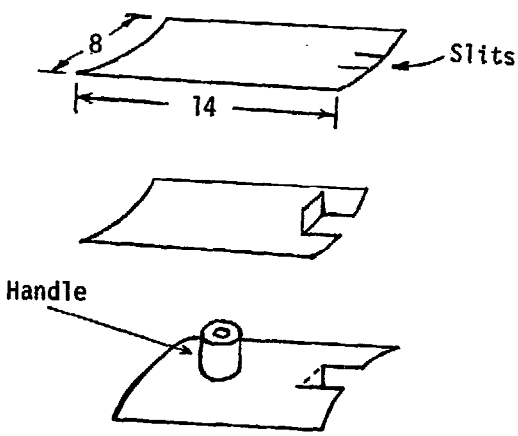
Finally, drill or punch two holes (about 1 cm diameter) in one side of the can. Pass an end of the rope (B) through each hole and knot the ends inside the can so that the rope cannot pull out.

(2) Top



Merely cut out a circular piece of tin sheet (C) the same size as the end of the can. Place this piece on top of the bent down flaps and bend down the remaining three flaps. The top should slide in and out easily.

(3) Door



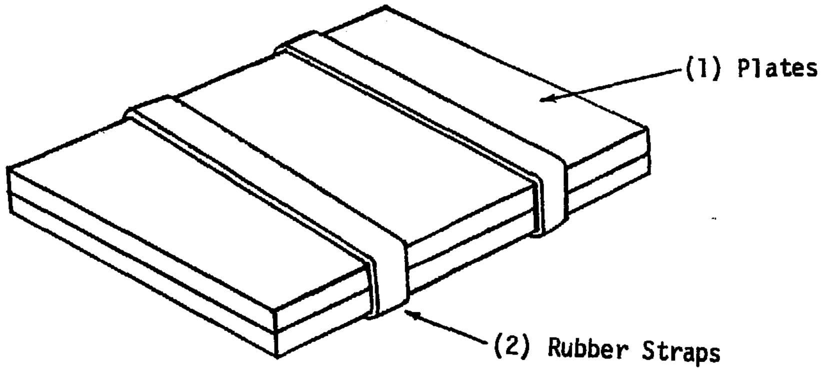
Roll the sheet metal (D) slightly until the slight curvature conforms to the side of the can. Make two slits 2 cm deep and 2 cm wide in one end, and bend the flap down. Make the door handle from the dowel (E) and nail (F). Simply drive the nail through the end of the dowel and through the door itself. Flatten the point of the nail like a rivet to hold the handle in place. When finished, the door should slide easily between the guides on the side of the can. The flap on the end of the door serves to help hold down the top as well as preventing the top from sliding out by accident.

c. Notes

(i) The vasculum is used to keep plant materials from excessively drying out when collecting in the field. Put the plants in the vasculum through the door when collecting, and remove them by removing the top.

(ii) If large tin cans with replacable lids are available, these will do nicely and will eliminate the need for cutting out the door and lid. Also, see VII/A2 (Sterilizer) for an alternate method of making the lid for a tin can of this type.

D2(1). Plant Press (Field Type)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Plates	2	Wood (or Plywood) (A)	25 cm x 20 cm x 1.0 cm
(2) Rubber Straps	2	Heavy Rubber Bands (B)	2.5 cm wide, 15 cm diameter

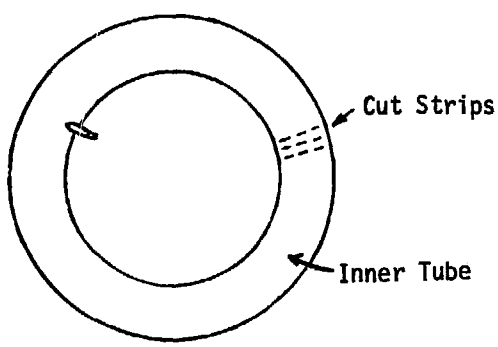
b. Construction

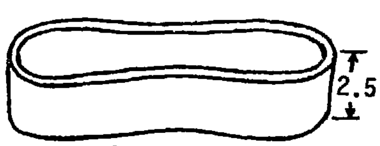
(1) Plates

Cut the wood (A) to size. Smaller or larger sizes may be made according to personal preference.

(2) Rubber Straps

Cut the rubber straps (B) from old automobile tire inner tubes.





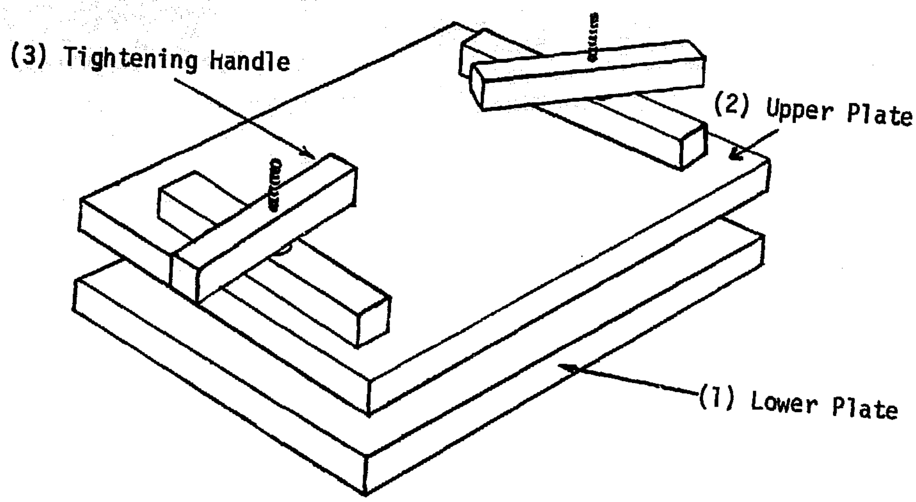
Section of
Inner Tube

c. Notes

(i) Use the field plant press to hold plant materials until they can be returned to the laboratory. Place the plants between several layers of newspaper, and place the newspapers between the press plates. Wrap the rubber straps around the plates and newspapers to hold them securely until they are returned to the laboratory.

(ii) Lengths of rope or belt-like straps can be used to tighten the press rather than the rubber straps.

D2(2). Plant Press (Laboratory Type)

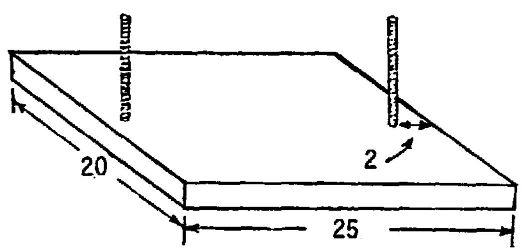


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Lower Plate	1	Plywood (A)	25 cm x 20 cm x 1.25 cm
	2	Bolts (B)	15 cm long, 0.7 cm diameter
(2) Upper Plate	1	Plywood (C)	25 cm x 20 cm x 1.25 cm
	2	Wood (D)	15 cm x 1.75 cm x 1.75 cm
(3) Tightening Handles	2	Nuts (E)	0.7 cm inside diameter
	2	Wood (F)	15 cm x 1.75 cm x 1.75 cm
	2	Washers (G)	1 cm inside diameter, 2 cm outside diameter

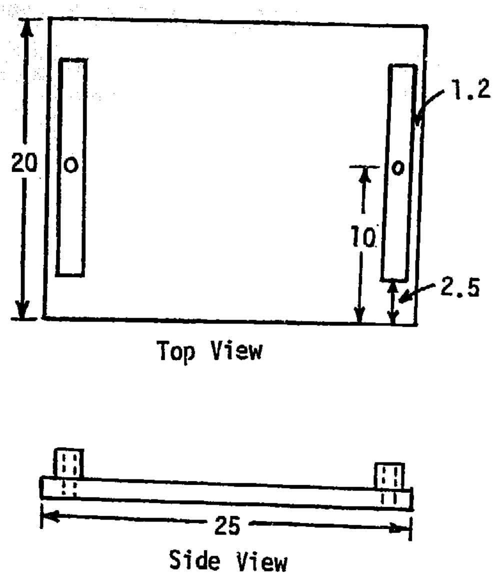
b. Construction

(1) Lower Plate



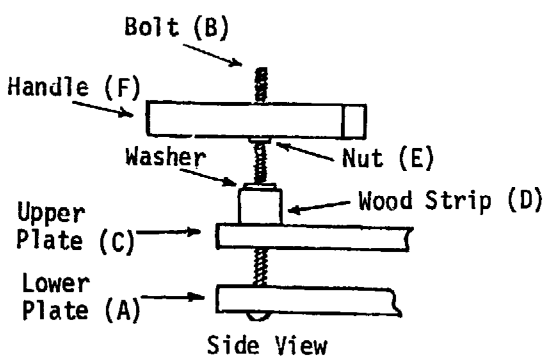
Drill a hole through each end of the plywood (A) (regular wood may be used as well) 2 cm from the end and centered. The holes should be 0.8 cm in diameter. Pass the bolts (B) through these holes as far as they will go.

(2) Upper Plate



Nail or glue the two wood strips (D) to the plywood (C) 1.2 cm from the ends and parallel to the edge. Drill a hole 0.8 cm in diameter through the wood strip and plywood at each end. Put the upper plate into position by running the two bolts (B) in the lower plate through the holes in it (the upper plate).

(3) Tightening Handles



Drill a hole 0.8 cm in diameter through the center of each strip of wood (F). Then, place a nut (E) directly over the hole in the wood and give it a sharp rap with a hammer. Remove the nut from the depression thus formed, put some epoxy resin cement in the depression and glue the nut in place in the depression. When the glue has hardened, place a washer (G) over each bolt, and screw on the tightening handles. The laboratory plant press is now ready for use.

c. Notes

(i) To use the laboratory plant press, place collected specimens between several layers of newspaper and tighten the two plates of the press together very tightly. Leave the plants in the press until they are thoroughly dried out.

V. AQUARIA AND TERRARIA

A. CLASSROOM DEMONSTRATION AQUARIA

This is the most common type of aquarium and is used for student observation of the various relationships demonstrated by an ecosystem. Therefore, this type of aquarium is characterized by the use of glass.

B. BREEDING AQUARIUM

This is used to provide places for maintaining and growing a supply of aquatic organisms. Since the purpose is not primarily that of student observation, glass sides are not necessary.

C. TEMPORARY AQUARIUM

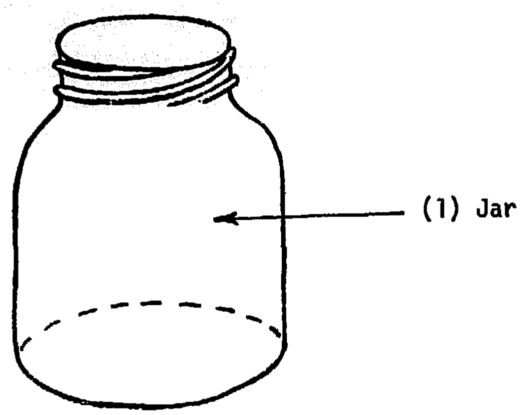
This is useful for short-term storage of fish and aquatic plants. Depending on the materials used, the temporary aquarium will suffice to hold plants and animals for approximately one to seven days, or much longer if care is taken in its construction.

D. TERRARIA

Any container in which plants can be grown will serve as a terrarium. The chief criterion for such a structure is that it be large enough to give the desired plants room to grow without crowding.

A. CLASSROOM DEMONSTRATION AQUARIA

A1. Quickly Made Demonstration Aquarium



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Glass Jar (A)	2 liters or larger

b. Construction

(1) Jar

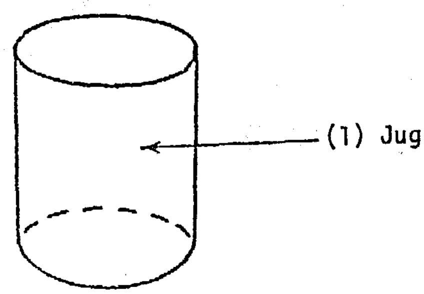
Simply clean out the jar (A), add water and fish. Sand and small plants may also be added.

c. Notes

(i) The number and size of fish which can be kept in a non-aerated aquarium varies, but a general rule is at least 2 liters of water per each centimeter of fish. Remember that the amount of oxygen available to the fish depends on the surface area of the water so that jars with narrow necks should be filled only to the point where the neck begins to narrow.

(ii) This or any aquarium may be covered to prevent fish from jumping out, but remember to allow some air flow under the cover to insure that oxygen will dissolve from the air into the water.

A2. Jug or Carboy Aquarium

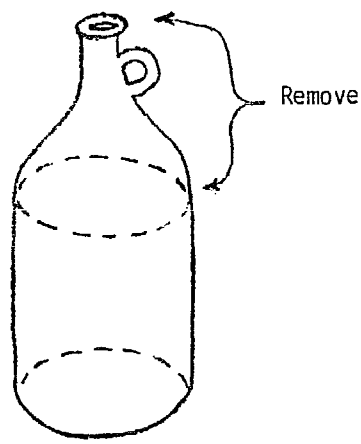


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jug	1	Glass Jug or Carboy (A)	3-4 liters or larger

b. Construction

(1) Jug



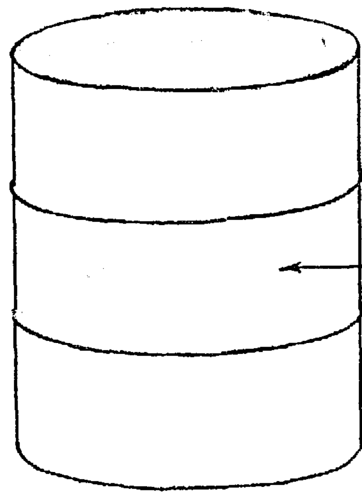
Remove the top portion of a jug or carboy (A) by either method described under item CHEM/I/F2.

c. Notes

(i) When the neck is removed, add water, sand, plants and fish. Remember, at least 2 liters of water is required for each centimeter of fish.

B. BREEDING AQUARIUM

B1. Breeding Aquarium



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Drum	1	Oil Drum (A)	100 liters or larger

b. Construction

(1) Drum

Remove the top from a large oil drum (A) or any similar container. Clean the drum thoroughly before adding water, plants, sand and fish.

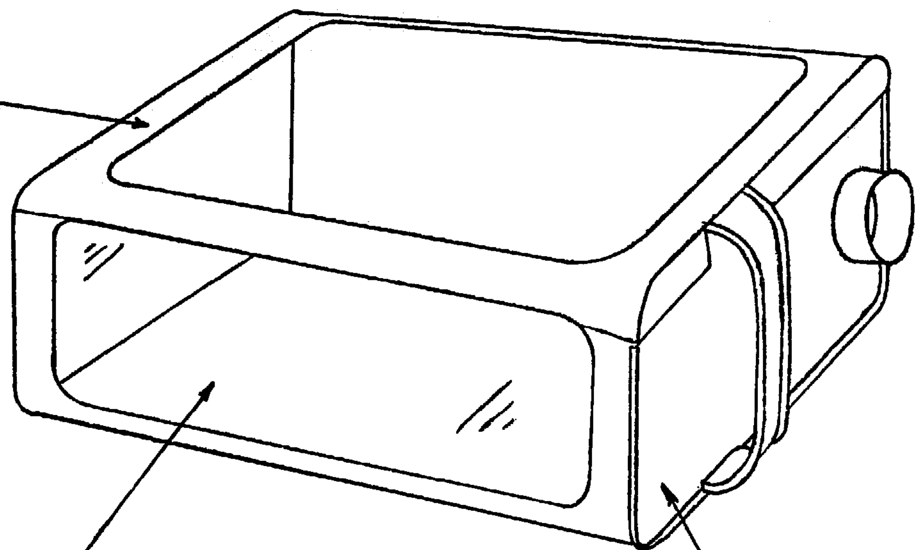
c. Notes

(i) Since many fish breed best or only when plants are present in the aquarium, a light source may have to be placed over the top of the drum to provide for healthy plants.

(ii) Most fish are extremely sensitive to water containing a high concentration of metallic ions, so the drum should be lined with a plastic bag, or the inside painted with non-leaded paint or other non-toxic coating.

C. TEMPORARY AQUARIUM

C1. Plastic Bag Aquarium



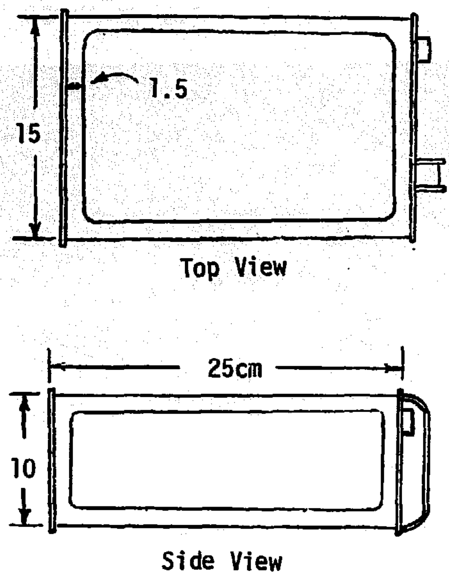
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Rectangular Tin Can (A)	4 liter capacity or larger (at least 10 cm x 15 cm x 25 cm)
(2) Plastic Bag	1	Plastic Bag (or Sheeting) (B)	50 cm x 60 cm
(3) Tape	2	Masking Tape (C)	30 cm
	2	Masking Tape (D)	20 cm

b. Construction

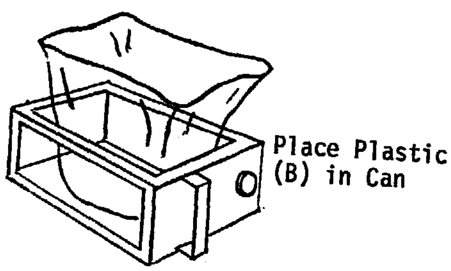
(1) Can

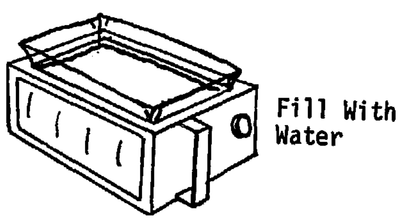
Cut the top and one side out of a four liter rectangular tin can (A) leaving about 1.5 cm of metal remaining to provide rigidity. Such cans can easily be cut with metal snips or shears. Begin each hole by



holding the can firmly, placing the edge of a screwdriver against the side, and striking the screwdriver sharply with a hammer. The sharp edges of the metal should be taped to prevent them from cutting the plastic.

(2) Plastic Bag





Use a large clear plastic bag or piece of plastic sheeting (B). Carefully place the middle of the plastic on the bottom of the inside of the can (A) and spread the plastic out so it fills up the inside. Let the excess plastic extend above the can. Next, carefully pour water into the center of the plastic until the can is filled to the level desired.

(3) Tape

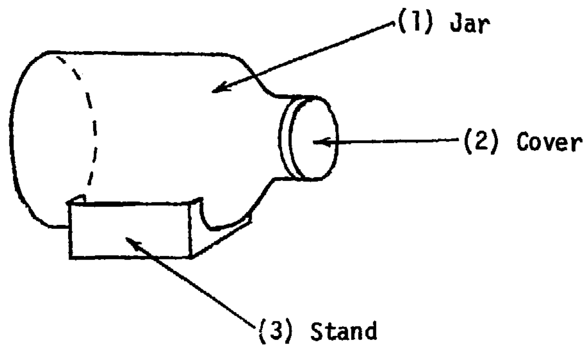
Use the four pieces of masking tape (C,D) that hold down the excess plastic sheeting. Waterproof plastic tape is recommended instead of masking tape if it is available.

c. Notes

(i) With this design, fish and other aquatic organisms can be easily viewed while the three sides of the can provide excellent rigidity. Gravel, plants, rocks, etc., may be placed in the aquarium to provide a more natural environment.

D. TERRARIA

D1. Simple Terrarium



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Glass Jar (A)	4 liters or larger
(2) Cover	1	Plastic Sheeting (B)	Approximately 12 cm diameter
	1	Adhesive Tape (C)	40 cm long
(3) Stand	1	Cardboard Box (D)	15 cm x 15 cm x 10 cm

b. Construction

(1) Jar

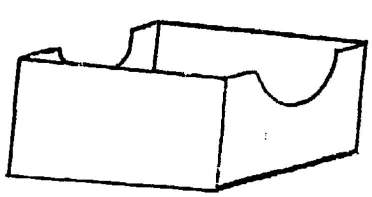
Select a wide-mouthed glass jar (A), the larger the jar and the wider the mouth, the better.

(2) Cover

Tape a circular piece of plastic sheeting (B) over the mouth of the jar with the tape (C) to make it fairly airtight.

(3) Stand

Cut two semicircular pieces from the cardboard box (D) so the terrarium can be set on it without rolling off.

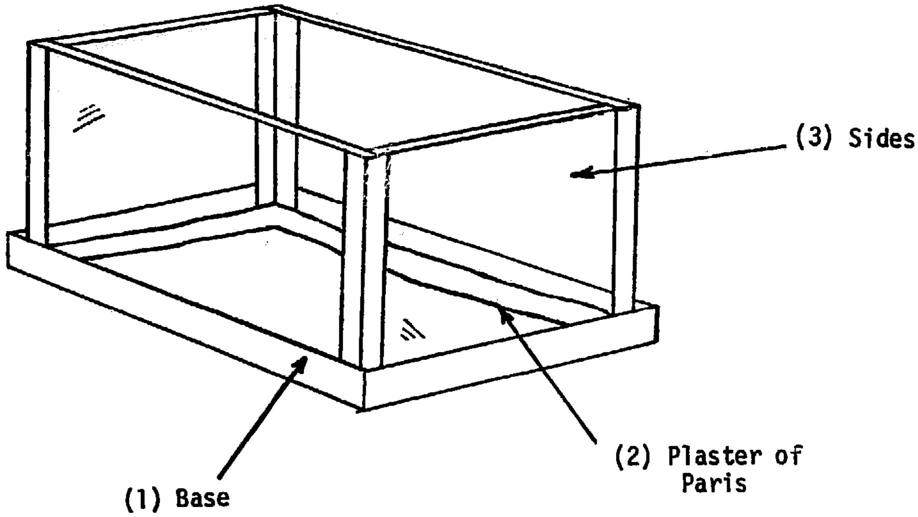


c. Notes

(i) Fill the bottom of the terrarium with rich soil and add plants or seeds. The plastic cover will prevent moisture loss and permit some gas exchange. The jar lid may be used instead, but it has a tendency to rust.

(ii) More durable stands made from metal or wood may be constructed if desired.

D2. Glass Terrarium

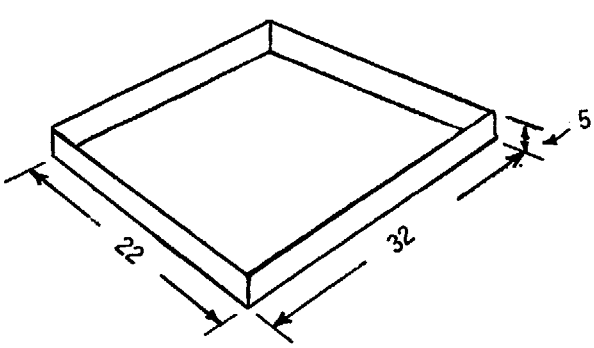


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Tin Can (A)	32 cm x 22 cm x 5 cm
(2) Plaster of Paris	--	Plaster of Paris (B)	--
(3) Sides	2	Glass Plates (C)	30 cm x 20 cm x 0.3 cm
	2	Glass Plates (D)	20 cm x 20 cm x 0.3 cm
	1	Plastic Sheet (E)	35 cm x 25 cm
	4	Tape (F)	--

b. Construction

(1) Base

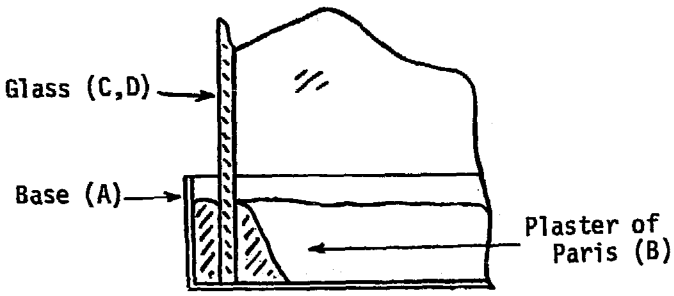


Cut the base from a rectangular tin can (A) to the approximate dimensions given. Adequate bases can also be made from wood, cardboard, sheet metal, etc.

(2) Plaster of Paris

Mix about 1 liter of dry plaster of Paris (B) with enough water to make it workable but stiff.

(3) Sides



Partial Cross-Section

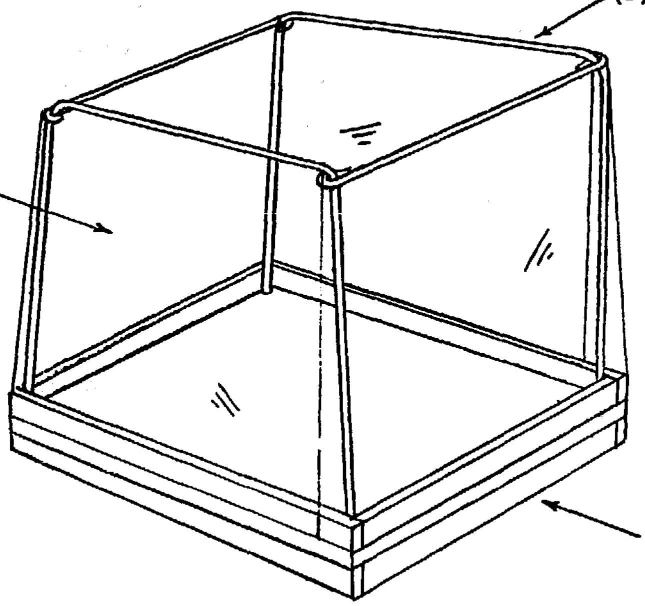
Spread the plaster of Paris (B) thickly around the sides of the base (A). Set the plates of glass (C,D) in the plaster while it is wet. Tape the corners where the glass plates come together with tape (F) to hold the sides upright while the plaster is drying. Cover the terrarium with the plastic sheet (E) when plants are kept in it to prevent moisture loss.

c. Notes

(i) The dimensions of this terrarium may be varied in order to meet special needs or to fit materials available.

(ii) Plants may be placed in the terrarium in pots or planted in soil. If they are planted in soil, be certain that the plaster used is impervious to water.

D3. Plant Growth Chamber

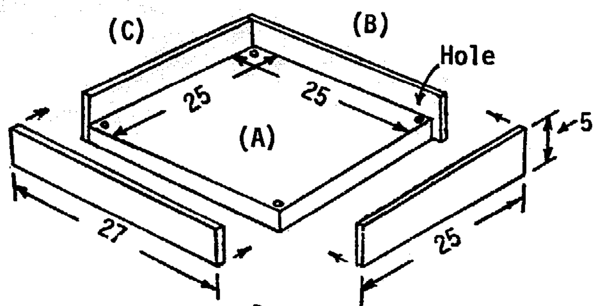


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	25 cm x 25 cm x 2 cm
	2	Wood (B)	27 cm x 5 cm x 1.0 cm
	2	Wood (C)	25 cm x 5 cm x 1.0 cm
(2) Frame	2	Soft Wire (D)	75 cm long, 0.2 cm diameter
	2	Soft Wire (E)	25 cm long, 0.2 cm diameter
	4	Wire (F)	10 cm long, 0.1 cm diameter
(3) Plastic Cover	5	Transparent Plastic Sheeting (G)	30 cm x 30 cm
	--	Tape (H)	--

b. Construction

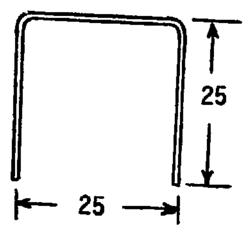
(1) Base

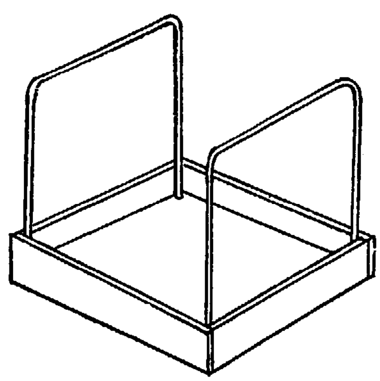


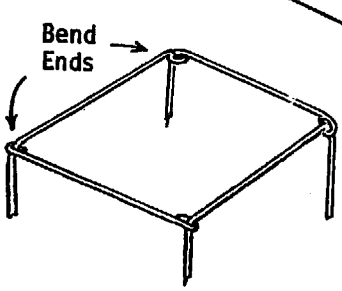
Base

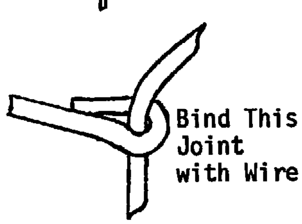
Nail or glue the four rectangular pieces of wood (B,C) to the square piece (A). Drill four holes, 0.2 cm diameter, in the square piece (A), one hole near each corner of the wood.

(2) Frame





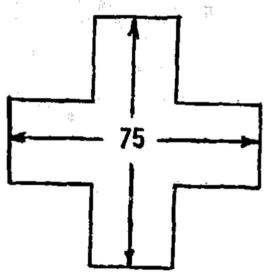




Detail

Bend the two longest pieces of soft wire (D) into a "U" shape, and insert the ends into the holes in the base. Fasten the shorter pieces of soft wire (E) to the frame by bending about 1 cm of each end around the bends in the longer wires (D). Bind the joints together with the short, thinner wires (F).

(3) Plastic Cover



Cut a piece of transparent plastic sheeting (G) to the pattern shown or use five separate pieces of sheeting. Whether using the single or separate sheets, cover the frame with plastic and seal the joints between the sheeting with tape (H). Leave one side of the sheeting loose to be used as a "door" in order to easily remove the plants.

c. Notes

(i) Plants may be placed in the chamber in pots or soil may be placed in the base in order to hold the plants.

(ii) Dimensions for the plant growth chamber may be altered in any way depending upon the purposes to which it will be put. Especially, the base needs to have more depth than 3 cm if plants are to be grown in soil rather than pots.

VI. CAGES

A. GLASS CAGES

These cages, made wholly or largely of glass, can be used to house a large variety of small animals, from insects to small mammals.

B. WOODEN CAGES

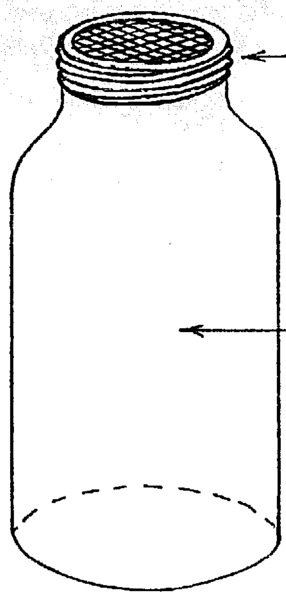
Two wooden cages are offered, one to house insects and the other designed for small mammals or birds. Both are somewhat more elaborate and permanent than their equivalent glass cages.

C. TEMPERATURE CONTROLLED CAGES

The vivarium and egg incubator are heated with light bulbs to serve the needs of animals and eggs which require relatively higher temperatures to live or hatch, respectively. Use a thermostat to control the internal temperature of heated cages and incubators, especially in classrooms which are not themselves thermostatically temperature controlled.

A. GLASS CAGES

A1. Glass Jar Cage



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Glass Jar (A)	4 liters capacity or larger
(2) Top	1	Glass Jar Top (B)	To fit jar
	1	Wire Screening (C)	Same diameter as jar top

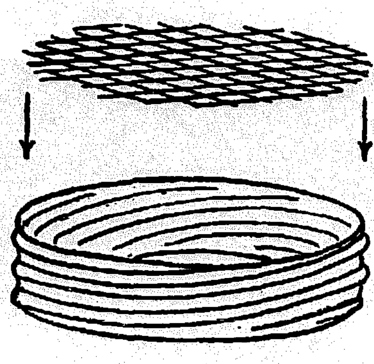
b. Construction

(1) Jar

Thoroughly clean the large glass jar (A). Select one with as large a mouth as possible.

(2) Top

Cut out a circular piece from the metal top (B) of the gl ss jar. The diameter of the hole in the top should be about 1 cm less than that of the top itself.



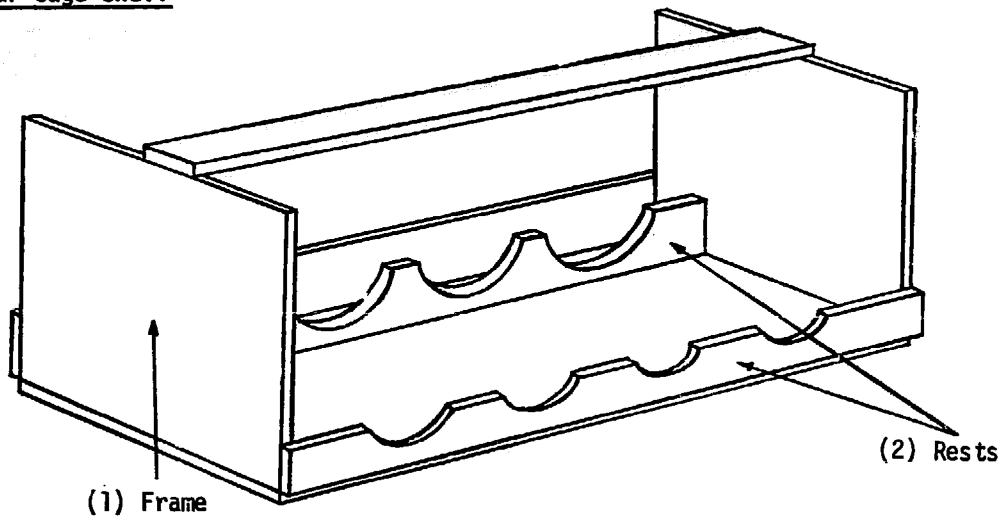
Next, cut out a circular piece of wire screen (C) the same diameter as the top. Insert this wire screen inside the top and glue it in place if it does not stay in place by itself.

c. Notes

(i) If the wire screening is cut to a diameter very slightly larger than that of the metal top, it will tend to stay in place within the top, and doesn't need to be cemented. In fact, once the top is screwed to the jar, the screen will be held tightly between the glass and top, and no cement is necessary.

(ii) Grass, sand, soil, twigs, etc., can be added to this cage depending on what type of animal is to be kept. If small amphibians are housed in it, lay it on its side and partially fill it with water. Most amphibians are best housed in shallow aquaria, however.

A2. Jar Cage Shelf *

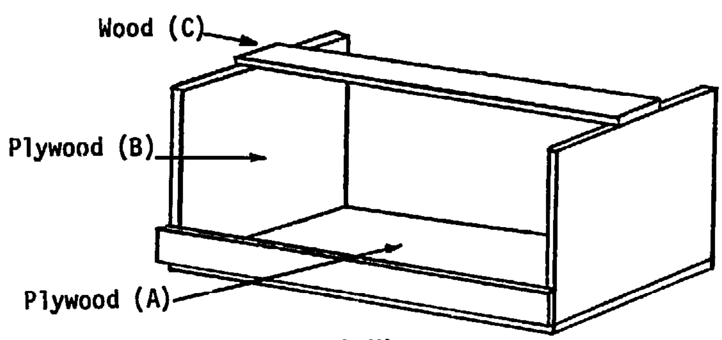


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Plywood (A)	18 cm x 47 cm x 1.0 cm
	2	Plywood (B)	18 cm x 15 cm x 1.0 cm
	2	Wood (C)	4 cm x 47 cm x 1.0 cm
(2) Rests	1	Wood (D)	4 cm x 45 cm x 1.0 cm
	1	Wood (E)	2 cm x 47 cm x 1.0 cm

b. Construction

(1) Frame

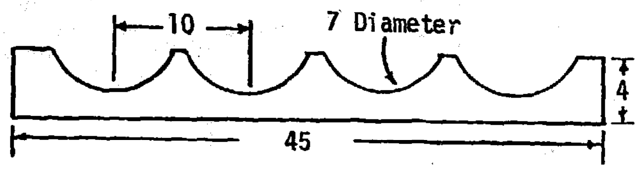


Back View

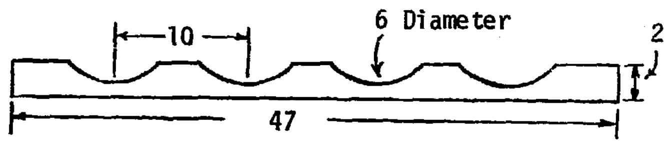
Nail or screw the two small pieces of plywood (B) to the ends of the large piece (A). Nail one of the wood strips (C) to the back with the lower edge even with the back. Screw the other strip (C) to the top to act as a carrying handle.

*Adapted from Richard E. Barthelemy, et. al., Innovations in Equipment and Techniques for the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964), p 28.

(2) Rests

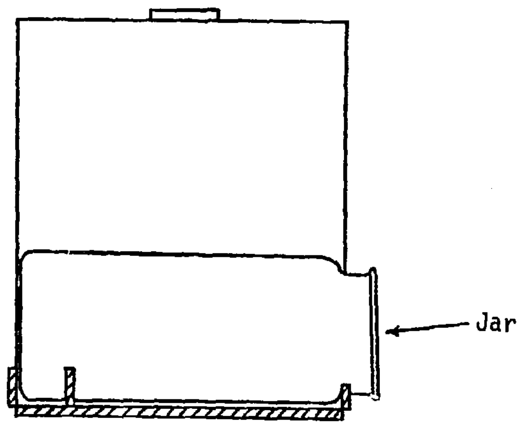


Wood Strip (D)



Wood Strip (E)

Wooden rests are needed to prevent the jar cages from rolling. Cut four arcs spaced 10 cm on center from the wide piece of wood (D). The diameter of the arcs should be the same as that of the body of the jar cages (in this description, the jars used had a body diameter of 7 cm and a neck diameter of 6 cm).



Side View
(Cross-section)

Similarly, cut four arcs of the same diameter as the neck of the bottle (in this case, 6 cm) from the narrow strip (E), also 10 cm on center. Nail the wide strip (D) to the sides and base about 3 cm from the back strip. Nail the narrow strip (E) to the front with its lower edge even with the base.

c. Notes

(i) Use this item as a storage rack for several jar cages (VI/A1). The handle permits several cages to be carried with little disturbance.

(ii) All dimensions given here are subject to change depending on the size, shape, and number of jar cages to be stored.

A3. Cockroach Cage *

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cage	1	Glass Jar Cage (VI/A1) (A)	At least 1.0 liter capacity
(2) Food Container	1	Jar Top (B)	2-3 cm diameter, 1 cm deep
(3) Watering Device	1	Glass Vial (C)	4 cm long, 2 cm diameter
	1	Cotton (D)	Small plug

b. Construction

(1) Cage — Use the Glass Jar Cage (VI/A1) (A) as is.

(2) Food Container — A small jar top (B) will hold the small amount of food necessary for small insects like cockroaches.

(3) Watering Device — Insert the cotton plug (D) into the open end of the vial (C) containing a small amount of water. The cotton will stay

*Adapted from Richard E. Barthelemy, et. al., Innovations in Equipment and Techniques for the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964), p 22-23.

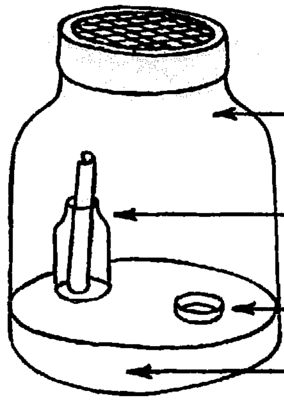
damp and provide water for the insects.

c. Notes

(i) If desired, the upper portion of the jar can be coated with talcum powder to prevent the insects from crawling out when the jar is open.

(ii) Providing small objects which the insects can climb on or conceal themselves in is recommended.

A4. Housefly Cage *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cage	1	Glass Jar Cage (VI/A1) (A)	4 liters or larger
(2) Watering Device	1	Glass Jar (B)	Approximately 25 ml
	1	Absorbent Paper (C)	Approximately 10 cm x 3 cm
(3) Food Container	1	Jar Top (D)	4 cm long, 2 cm diameter
(4) Culture Medium	1	Culture Medium (E)	50 ml or enough to fill the cage to a depth of approximately 2 cm

b. Construction

(1) Cage

Use the Glass Jar Cage (VI/A1) (A) as is. Be sure to select a glass jar with as wide a mouth as possible.

(2) Water Device

This is merely a small glass jar (B) or other small container which holds a "wick" of absorbent paper (C). Water in the jar will soak into the paper

*Adapted from Richard E. Barthelemy, et. al., Innovations in Equipment and Techniques in the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964), p 23.

where it can be obtained by flies and other flying insects.

(3) Food Container

A small jar top (D) will suffice as a container for food for the flies.

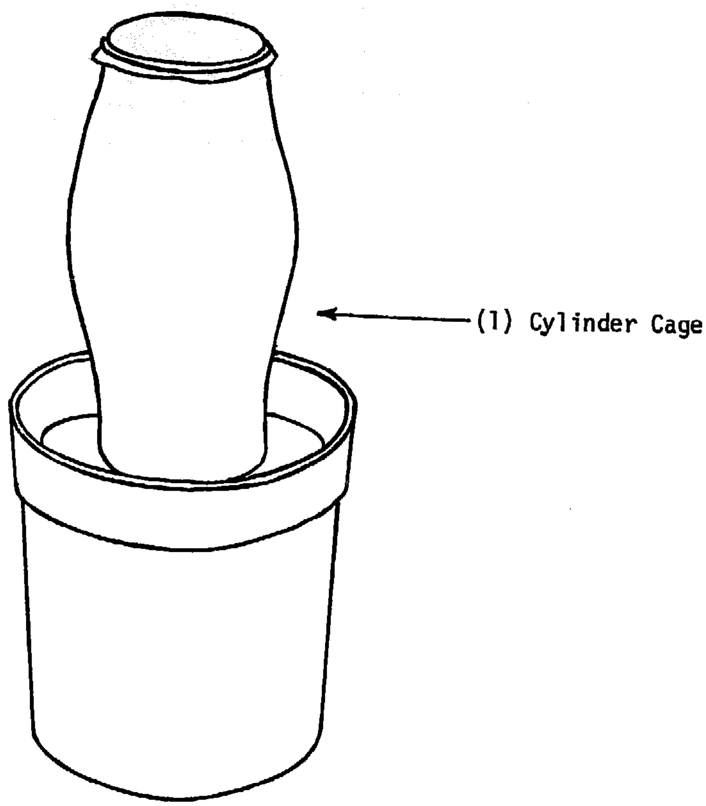
(4) Culture Medium

This is a growth medium (E) for the insect larvae, and should contain all the necessary growth ingredients.

c. Notes

(i) For suitable growth media for houseflies, see the following BSCS publications: Barthelemy et. al., Innovations in Equipment and Techniques for the Biology Teaching Laboratory; and Glenn, The Complementarity of Structure and Function (BSCS Laboratory Block).

A5. Cylinder Cage



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cylinder Cage	1	Potted Plant (A)	--
	1	Lamp Chimney (B)	8 cm diameter, 30 cm long
	1	Cloth Mesh (C)	10 cm diameter
	1	Rubber Band (D)	--

b. Construction

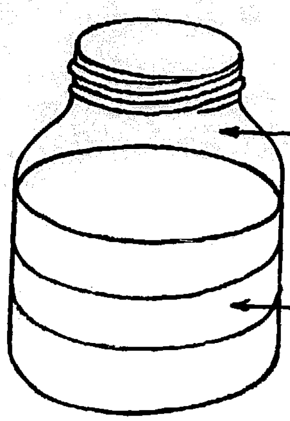
(1) Cylinder Cage

This is a quickly made cage. Simply put the lamp chimney (B) or other large diameter glass tube over the potted plant (A). Add the insects, and cover the top with cloth mesh (C) or gauze held in place with the rubber band (D).

c. Notes

(i) This is a good, simple cage in which to rear insects which feed on plants.

A6. Jar Wormery



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Glass Jar (A)	1-4 liters
(2) Medium	1	Sand (B)	1/4-1 liter
	1	Leaf Mold (C)	1/4-1 liter
	1	Loam (D)	1/4-1 liter

b. Construction

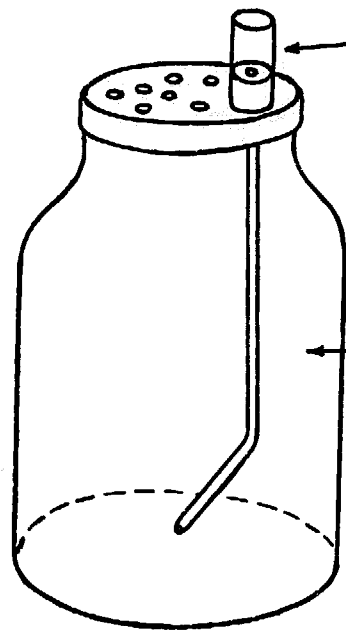
(1) Jar — Thoroughly clean the glass jar (A).

(2) Medium — Each layer of the medium should have a volume approximately one fourth that of the total for the jar. The bottom layer is sand (B), the middle is leaf mold (C), and the top layer is loam (D).

c. Notes

(i) Place the worms in the wormery along with some dead leaves, lettuce, carrots, etc. Keep the contents damp.

A7. Jar Cage



a. Materials Required

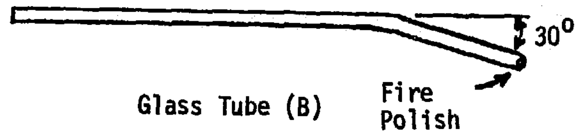
Components	Qu	Items Required	Dimensions
(1) Jar	1	Large Glass Jar (A)	4 liter capacity
(2) Water Bottle	1	Glass Tube (B)	25 cm long, 0.5 cm outside diameter
	1	Vial (C)	50-100 ml capacity
	1	1-Hole Stopper (D)	To fit vial

b. Construction

(1) Jar

Use a large capacity glass jar (A) with a metal or plastic lid. Punch several holes in the lid for ventilation. Make certain one of the holes is slightly larger in diameter than the glass tube (B) used in the water bottle.

(2) Water Bottle



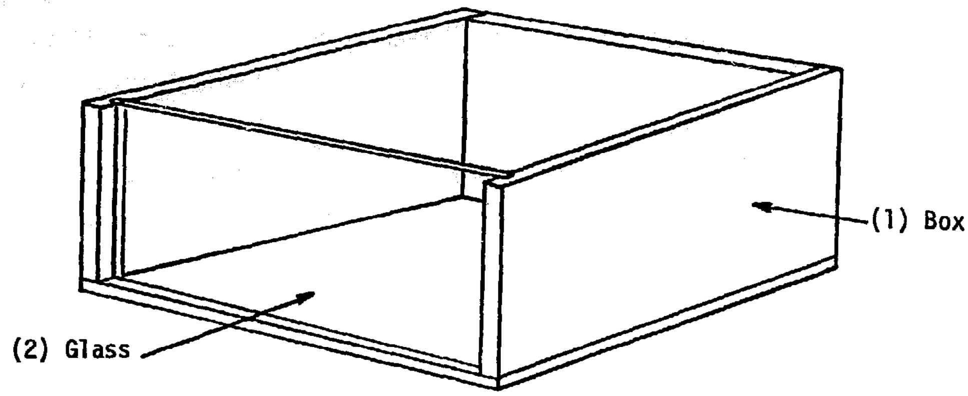
Heat the glass tube (B) about 7 cm from one end and make a slight bend in it (about 30°). Fire polish this end until the opening constricts very slightly. Insert the other end of the tube through the one-hole stopper (D), and plug the vial (C) with the stopper. Insert the completed water bottle through a hole in the lid of the jar. Be sure the tip of the glass tube is low enough for the animals to reach.

c. Notes

(i) This cage is designed for small mammals like mice or gerbils. Spread a layer of sawdust or newspaper shreds on the bottom to absorb wastes. Fill the water bottle and the animals soon learn to lick water from the end of the tube. Pieces of food can be dropped through the holes in the lid.

(ii) This cage is meant to be a temporary, not permanent, container for small mammals. Large jars of 4 liter capacity may be obtained from restaurants and other places which buy food in large quantities.

A8. Box Wormery

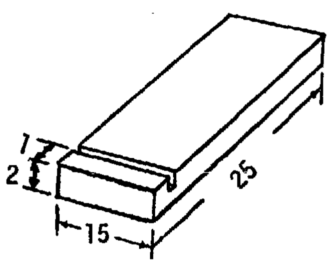


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Box	1	Wood (A)	25 cm x 25 cm x 1 cm
	2	Wood (B)	25 cm x 2 cm x 15 cm
	1	Wood (C)	21 cm x 2 cm x 15 cm
(2) Glass	1	Window Glass (D)	23 cm x 15 cm x 0.3 cm

b. Construction

(1) Box



With a saw, cut a groove 1.0 cm deep and 1.0 cm from the end of the two pieces of wood (B). These grooves should be slightly wider (about 0.4 cm) than the glass (D) used. Nail these two pieces and the piece (C) to the base (D) to form an open-ended box with the two grooves facing each other.

(2) Glass

Insert the glass (D) into the grooves in the sides of the box. The box wormery is now complete.

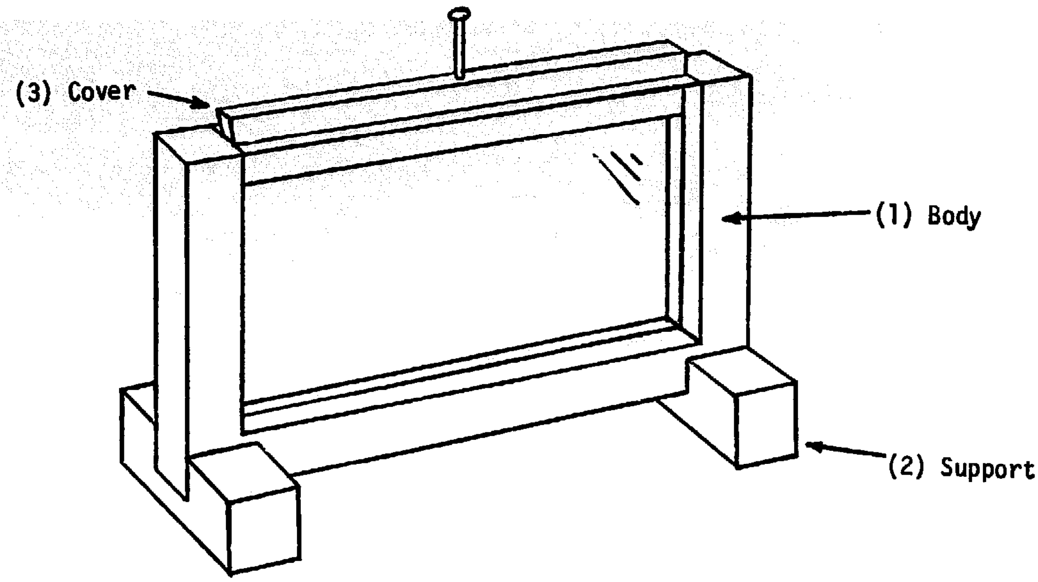
c. Notes

(i) Put a 5 cm deep layer of sand in the box, cover this with 5 cm of leaf mold, and finally cover this with about 5 cm of loam. Add worms, dead leaves, pieces of lettuce and carrots to the top. Cover the glass front with dark paper or cloth and keep the soil damp. After several days, worms and tunnels should be visible when the paper or cloth is removed.

(ii) There is no real need for the glass plate to be removable so all the joints between the wood and glass can be sealed with waterproof sealant (e.g., pitch, caulk).

(iii) If it is desired to simply raise worms rather than observe them, then the glass may be omitted and any suitable box can be used for the wormery.

A9. Ant Observation Cage

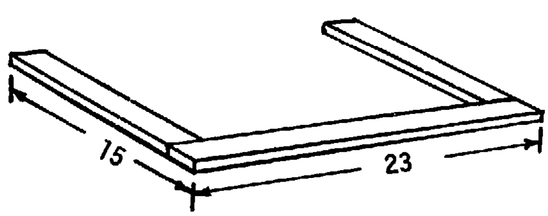


a. Materials Required

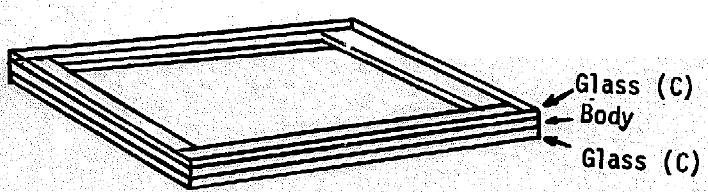
Components	Qu	Items Required	Dimensions
(1) Body	2	Wood (A)	13 cm x 2 cm x 0.7 cm
	1	Wood (B)	23 cm x 2 cm x 0.7 cm
	2	Glass Plates (C)	23 cm x 15 cm x 0.3 cm
	6	Tape (D)	19 cm x 2 cm
	3	Tape (E)	27 cm x 2 cm
(2) Support	2	Wood (F)	7 cm x 2 cm x 2 cm
(3) Cover	1	Wood (G)	19 cm x 2 cm x 0.7 cm
	1	Nail (H)	4 cm long, 0.3 cm diameter

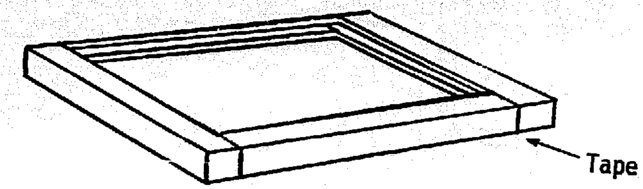
b. Construction

(1) Body

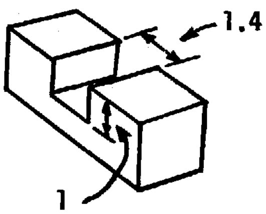


Glue, nail, screw or otherwise fasten the two short pieces of wood (A) to the ends of the longer piece (B). When the glue has dried, place the wood frame between the two pieces of glass (C) forming a "sandwich". Use the six short pieces of tape (D) to tape each end together and use the three long pieces of tape (E) to tape the bottom.





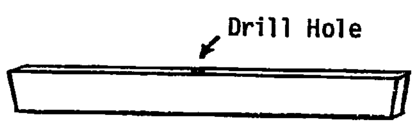
(2) Support

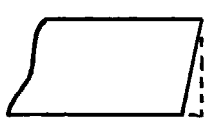


Cut a notch 1.4 cm wide and 1.0 cm deep into the center of each wooden support (F). Set the body into place.

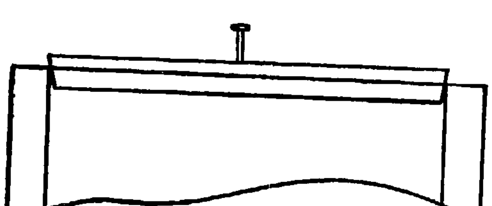
(3) Cover

Drill a hole approximately 0.3 cm in diameter through the middle of the piece of wood (G). Cut off a small portion of each end so that the ends are slightly tapered. This cover should now effectively seal the body, and the wedge shape of the cover insures that it need not be perfectly accurate in order to seal the cage. Complete the ant observation cage by sticking the nail (H) in the hole.





Detail



Detail

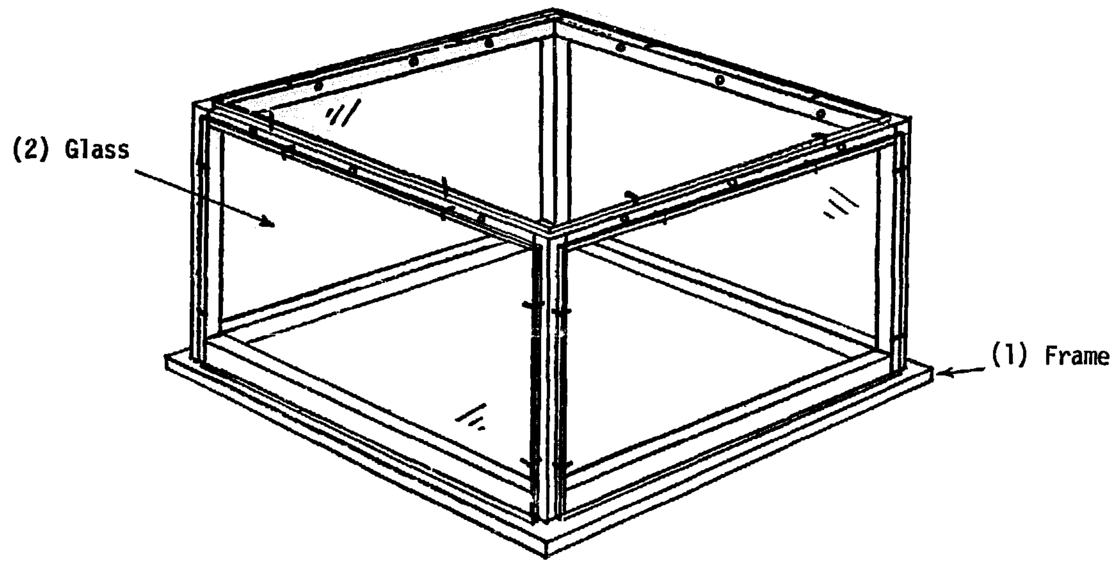
c. Notes

(i) Prepare the cage for use by filling it to within 2 - 3 cm of the top with soil. The soil should be firm, but not tightly packed. Add the ants (include a "queen" ant), and feed them by dropping moistened sugar, bread crumbs, etc., through the hole in the cover. Keep the cage covered when not actually observing the ants as this will encourage their tunneling activity.

(ii) The soil ought to be kept moist, so the cage should be taped with waterproof tape. Taping allows the cage to be easily dismantled, cleaned and reassembled.

(iii) Ant observation cages of different dimensions from those given here can be made, but the basic design need not be altered.

A10. Glass Cage

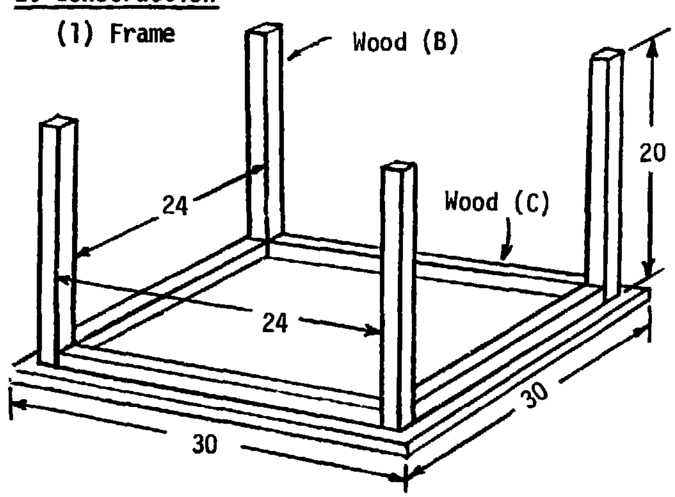


a. Materials Required

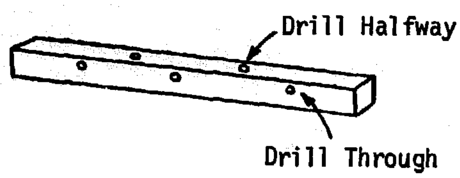
Components	Qu	Items Required	Dimensions
(1) Frame	1	Plywood (A)	30 cm x 30 cm x 1.0 cm
	4	Wood (B)	20 cm x 2 cm x 2 cm
	8	Wood (C)	24 cm x 2 cm x 2 cm
(2) Glass	32	Nails (D)	2.5 cm long
	4	Glass (E)	25.5 cm x 18.75 cm x 0.3 cm
	1	Glass (F)	25.5 cm x 25.5 cm x 0.3 cm

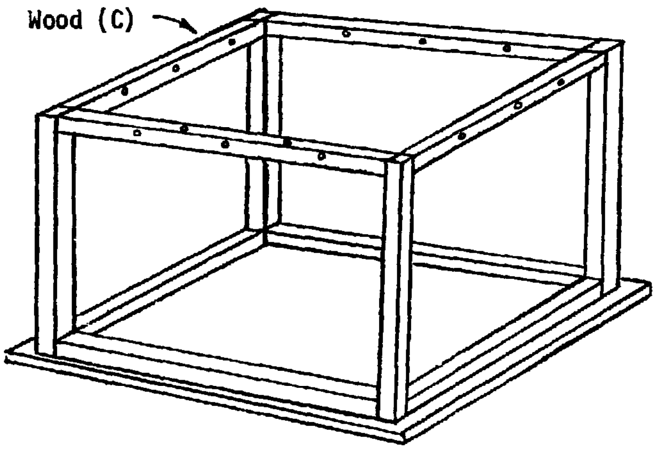
b. Construction

(1) Frame



Use the plywood (A) as the cage base. Screw the four short pieces of wood (B) to the base from the back side of the base so that each of their edges is 1.0 cm from the edge of the base. Nail four of the remaining pieces (C) to the base (A) and uprights (B), between the uprights and 1.0 cm from the edge of the base.

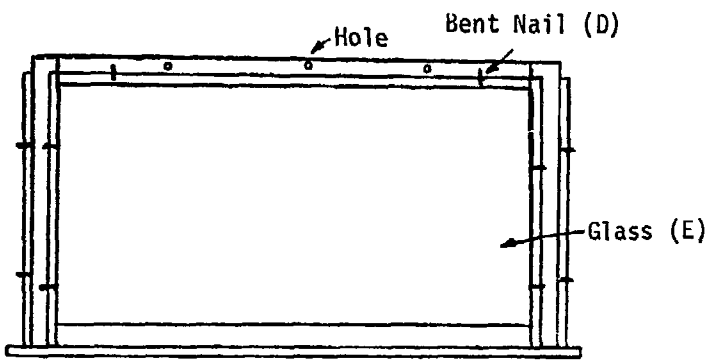




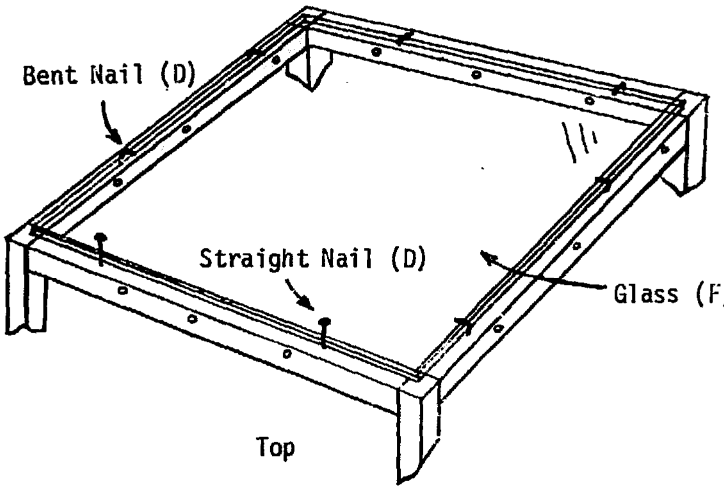
Drill three holes (0.2 cm in diameter) through each of the four remaining pieces of wood (C). Space the three holes about 6 cm apart and 0.5 cm from one edge. In one of these pieces of wood, drill two additional holes 0.2 cm in diameter. Drill them 0.5 cm from the same edge the other three holes are near, but only drill them halfway through the wood. Nail these four pieces to the uprights so that the holes are parallel to the base, and the holes must be closest to the top edge of the wood rather than the bottom. These three holes serve to ventilate the cage.

(2) Glass

Position one of the glass pieces (E) against the side of the frame so that it overlaps the edges of the frame by about 0.75 cm on all three sides. Drive four nails (D), two per vertical side, into the frame as close to the glass as possible. Only drive them in about halfway and remove the glass. Bend each nail over at right angles, and replace the glass. The nails should overlap the glass and hold it upright against the frame. Nail two more nails (D) above the glass and bend them down in a similar manner to keep the glass side firmly in place. Be



Side View



careful not to break the glass.

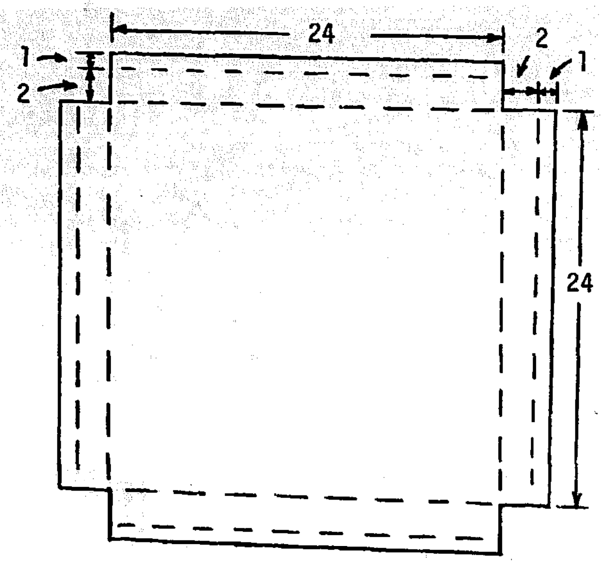
Fasten the remaining piece of glass (F) to the top in a similar manner as was done with the sides. Nail six nails (D), two per side, and bend them over to hold the glass in place. Put two nails in the holes in the remaining side of the frame. These two nails should slip easily in and out the holes so that they can be removed and the top glass plate removed by sliding it out from under the bent nails. Do not bend these last two nails.

c. Notes

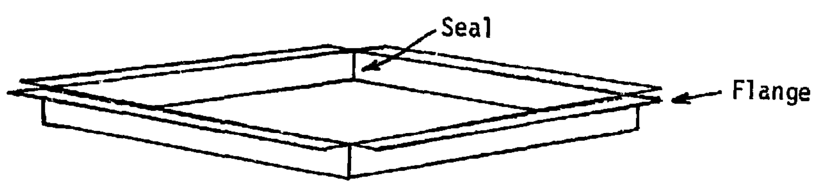
(i) This cage is designed primarily to house small reptiles (especially lizards and snakes) and other small, non-gnawing animals. The bottom of the cage can be filled with 1.5 - 2 cm of clean sand or gravel. If burrowing animals are to be kept, build the bottom of the frame higher so that the sand or gravel may be made deeper. Water may be provided in a jar lid and food simply dropped in from the top.

(ii) The dimensions of this cage can easily be altered depending on the number, size, and habits of the animals to be housed in it.

(iii) If it is so desired, a metal tray can be fashioned for the bottom of the cage to hold the sand or gravel. This makes the cage much easier to clean as the tray can simply be lifted out of the cage, the sand or gravel cleaned by running it through a seive, and replacing it. The tray prevents the wood from absorbing liquid wastes and spilled water and food. The pattern given here will fit the cage as described above. (See illustration on next page.)



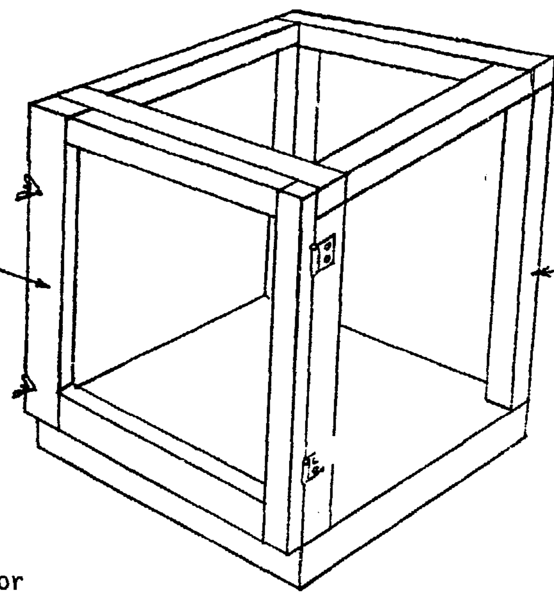
Fold the pattern along the dotted lines to the following shape.



Seal the inside corner joints with a waterproof sealant (e.g., pitch) and set the tray in place in the bottom of the cage. The flanges should overlap the bottom portion of the frame.

B. WOODEN CAGES

B1. Wooden Frame Cage



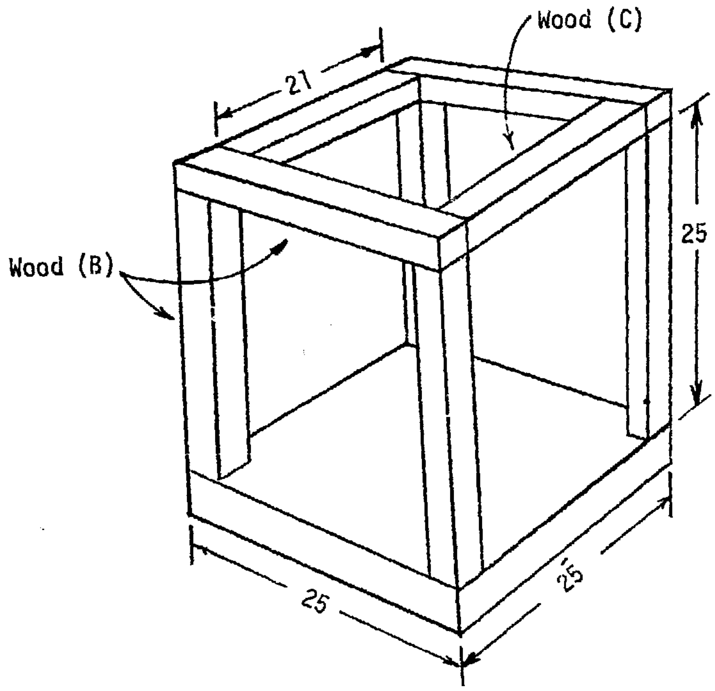
(3) Screening (Omitted for clarity)

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Wood (A)	25 cm x 25 cm x 1.0 cm
	6	Wood (B)	25 cm x 2 cm x 2 cm
	2	Wood (C)	21 cm x 2 cm x 2 cm
(2) Door	2	Wood (D)	27 cm x 3 cm x 1.0 cm
	2	Wood (E)	19 cm x 3 cm x 1.0 cm
	2	Hinges (F)	About 3 cm x 2 cm
	4	Nails (G)	2 cm long
	2	Rubber Bands (H)	--
(3) Screening	1	Wire Mesh (I)	24 cm x 24 cm
	3	Wire Mesh (J)	26 cm x 24 cm
	1	Cloth (K)	85 cm x 25 cm
	1	Rubber Band (L)	--

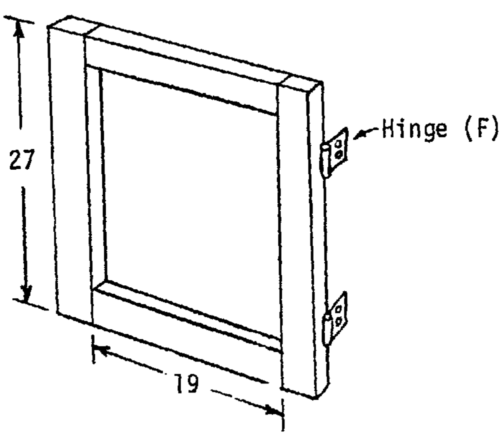
b. Construction

(1) Frame

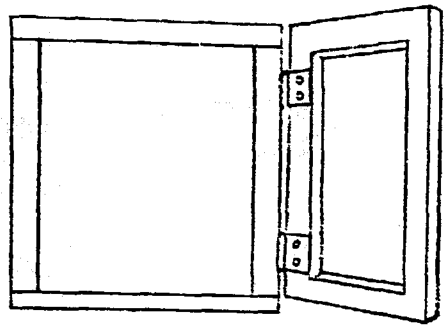


Glue, nail, or screw four of the long pieces of wood (B) to the four corners of the square piece (A) to form the uprights of the cage. Nail the two remaining long wooden pieces (B) to the tops of adjacent uprights. Then, nail the two short pieces (C) into place to complete the basic cage frame.

(2) Door

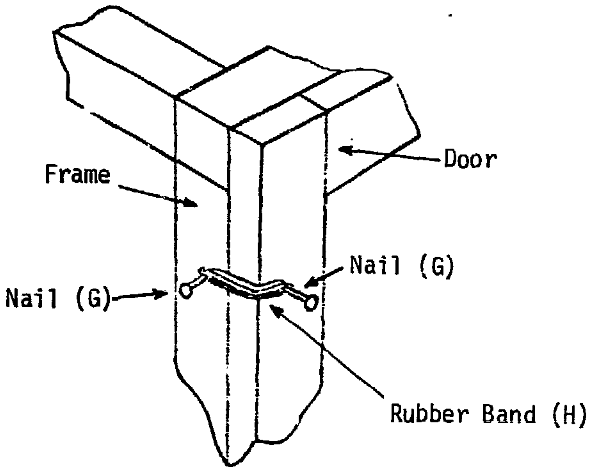


Glue, nail, or screw the short pieces of wood (E) between the long pieces (D) to form the frame for the door. Attach two small hinges (F) to the back of the door.



Front View

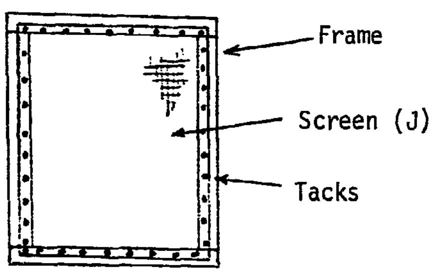
Next, fasten the door to the frame by use of the two hinges.



Detail

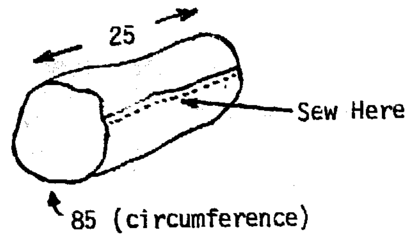
To keep the door shut, hammer nails (G) at both top and bottom of the door and frame. When the door is shut, wrap a strong rubber band (H) around each set of nails to keep the door shut.

(3) Screening

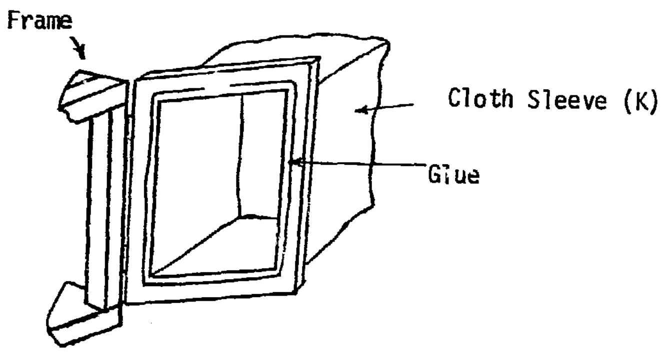


Side View

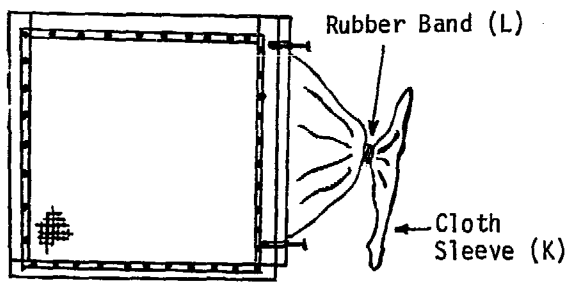
Attach the three pieces of screening (J) (cloth mesh may also be used) to the three sides and the fourth (I) to the top of the frame by gluing or tacking them in place. Liberal use of glue helps seal the joint between the screen and wood, especially if cloth mesh is used instead of wire mesh.



Sew the piece of cloth (K) along the short (25 cm) edge to make a kind of tube or "sleeve". Then, glue one end all around the inside edge of the door, making certain there are no gaps in the glue seam.



Detail



Side View

To complete the cage, close and latch the door, twist the protruding end of the cloth tube tight, and close it off with the rubber band (L).

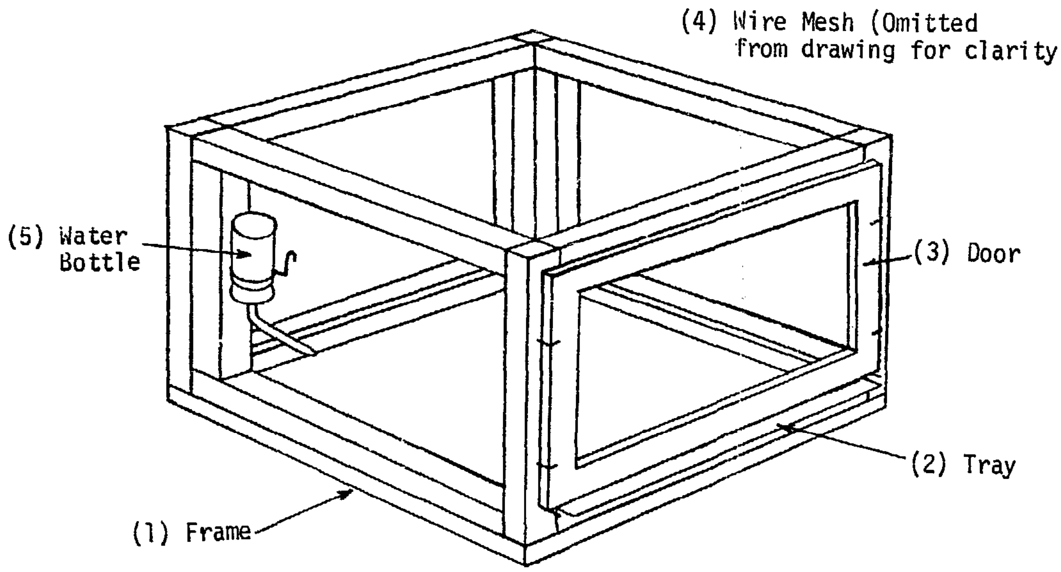
c. Notes

(i) The door can be opened to allow the cage to be cleaned, rearranged, etc. However, when the cage contains insects, items such as food, water, and the insects themselves can be put into and taken out of the cage by undoing the rubber band, slipping one hand through the cloth sleeve into the cage, and holding the cloth tightly around the arm in the sleeve with the other hand; this method prevents the insects from escaping.

(ii) See insect cages VI/A3 and VI/A4 for making watering and feeding devices for insects.

(iii) Since cloth is used for the sleeve and may be used for the sides, keep only insects or other small animals which are unable to chew their way through cloth in this cage.

B2. Wire Cage



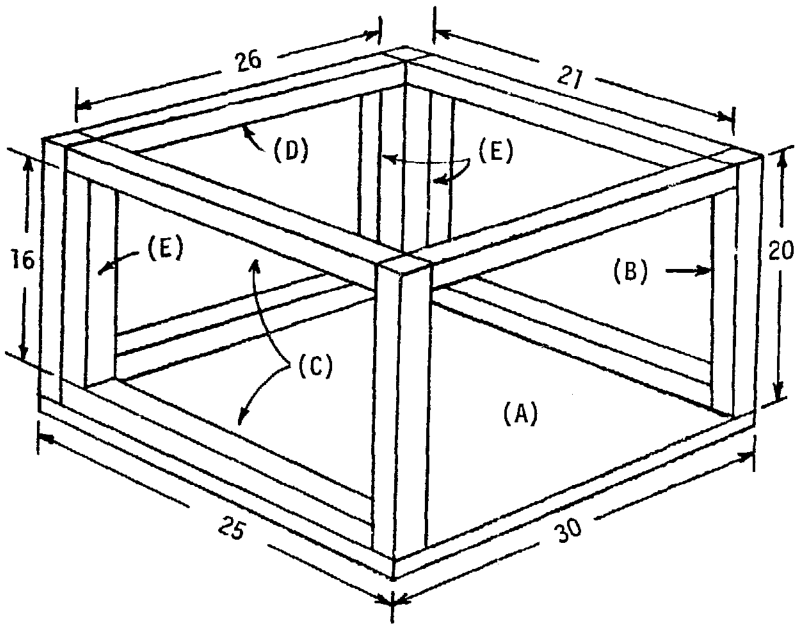
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Plywood (A)	25 cm x 30 cm x 0.5 cm
	4	Wood (B)	20 cm x 2 cm x 2 cm
	4	Wood (C)	21 cm x 2 cm x 2 cm
	3	Wood (D)	26 cm x 2 cm x 2 cm
	4	Wood (E)	16 cm x 2 cm x 2 cm
(2) Tray	1	Sheet Metal (F)	30 cm x 30 cm x 0.05 cm
(3) Door	2	Wood (G)	28 cm x 3 cm x 1.0 cm
	2	Wood (H)	18 cm x 3 cm x 1.0 cm
	1	Wire Mesh (I)	28 cm x 18 cm
	6	Nails (J)	2.5 cm long
(4) Wire Mesh	1	Wire Mesh (K)	23 cm x 62 cm
	1	Wire Mesh (L)	23 cm x 28 cm
	1	Wire Mesh (M)	20 cm x 26 cm
(5) Water Bottle	1	Vial (N)	50-100 ml capacity
	1	1-Hole Stopper (O)	To fit vial

1	Glass Tube (P)	10 cm long, 0.7 cm outside diameter, 0.5 cm inside diameter
1	Stiff Wire (Q)	About 20 cm long

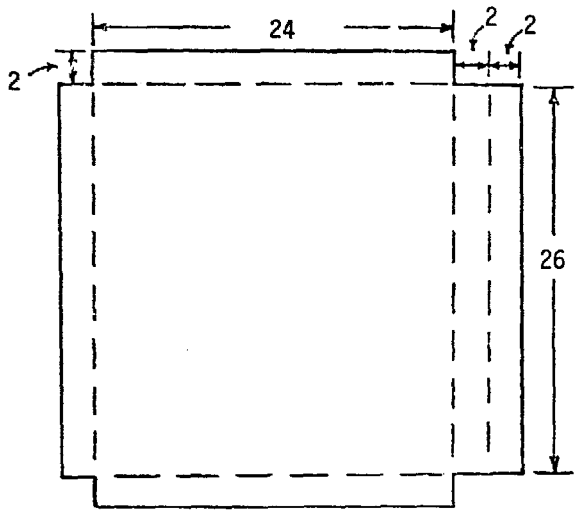
b. Construction

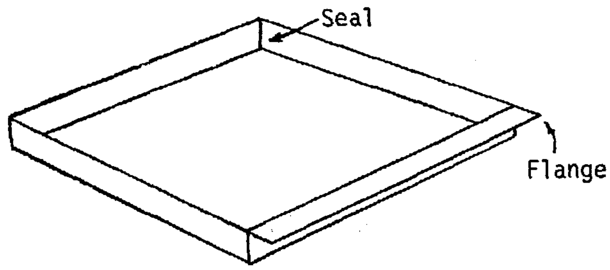
(1) Frame



Nail or screw the four 20 cm pieces of wood (B) onto the four corners of the piece of plywood (A) used as the base. Make certain they are even with the edges of the base. Next, nail the four 21 cm pieces (C) into position between the upright pieces, two at each side of the cage. Nail the lower ones to both the base and uprights. Nail the three 26 cm pieces (D) between the uprights, one at the top front, and two in the rear, top and bottom. Finally, nail the four 16 cm pieces (E) into position at the two back corners of the cage, one on each side of each upright.

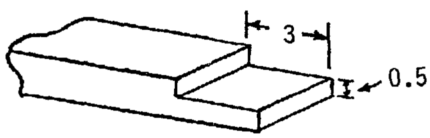
(2) Tray



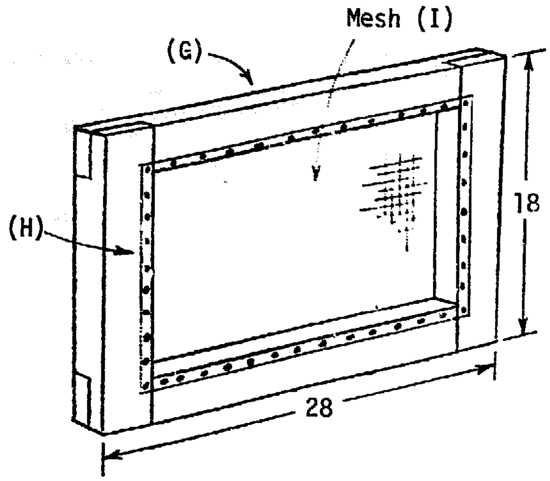


Cut the sheet metal (F) to the given pattern. Bend up the sides along the dotted lines and bend down the flange at the front. Seal the corners with a waterproof sealant (e.g., pitch). The tray should slide easily into the cage and protrude from the front for 1.0 cm.

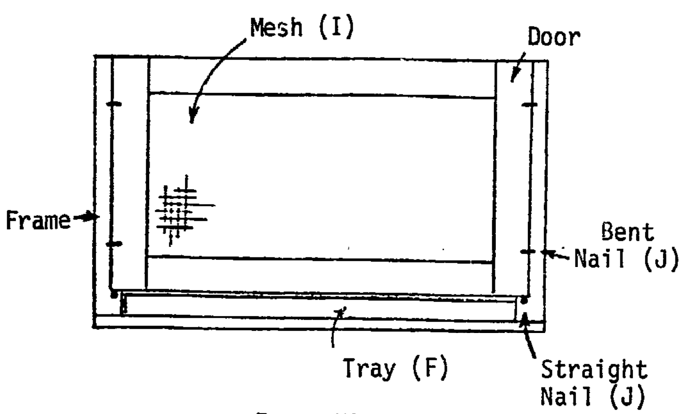
(3) Door



Make the door from the four pieces of wood (G,H) by using half-lap joints. This simply involves cutting away half the piece of wood where the two pieces to be joined overlap.



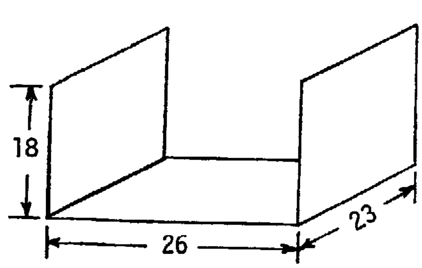
Nail the wire mesh (I) to the back of the door making certain that it covers all wood portions completely to discourage gnawing animals like mice. If possible, use mesh with openings about 0.5 cm square rather than regular wire screening that is used in house screens.



Front View

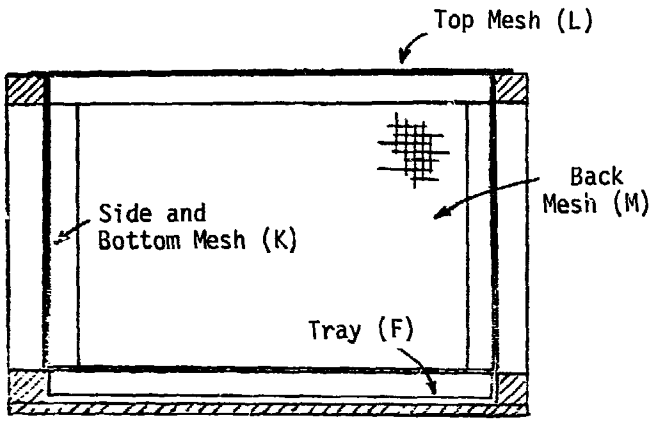
To form a holder for the door, first hammer two nails (J) into the front of the frame at a level even with the top of the tray. Drive them in 1 - 1.5 cm but do not bend them. Set the door on these two nails and be certain that it completely covers the opening. Nail two nails (J) on each side of the door as close to it as possible and bend them over so that they hold the door in an upright position. The door should slide easily in and out of position. Remove the door while completing the cage construction.

(4) Wire Mesh



Mesh (K)

Fold the long piece of wire mesh (K) (again, use the 0.5 cm square size if possible) to the shape shown. Then, nail the 20 cm piece (M) into position to seal off the rear of the cage. Next, nail the folded piece (K) into position so that



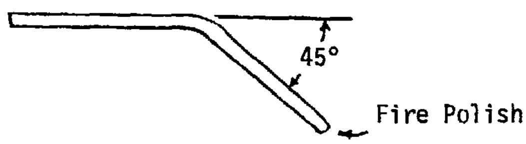
Cross Section View

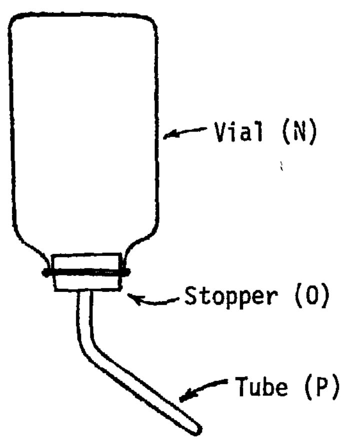
the sidepieces cover the sides of the cage completely. The bottom of the screen will be 2 cm above the floor of the cage (actually, it will be level with the top edge of the tray). Properly done, wire mesh should cover the inside of the cage so that no wood is exposed. Finally, nail the remaining piece of mesh (L) onto the top of the cage.

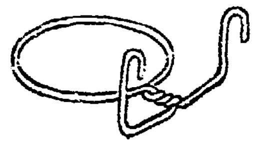
(5) Water Bottle

Begin the water bottle by bending the glass tube (P) in the middle to about a 45° angle. Fire polish one end until the opening constricts very slightly. Insert the other end of the tube into the stopper (O). Fill the vial (N) with water and seal the opening with the stopper.

When the vial is upside down water should flow down into the tube and stop at the end. One may have to tap the tube lightly with a finger to break up air bubbles in the tube.







Hanger (Q)
(Vial not shown
for clarity)

To make a hanger for the water bottle, use the piece of stiff wire (Q). Twist the wire around the stopper, then bend the loose ends as shown. The water bottle can then be hung on the outside of the cage with the glass tube sticking through the wire mesh. Animals such as mice and gerbils soon learn to lick the end of the tube to obtain water.

c. Notes

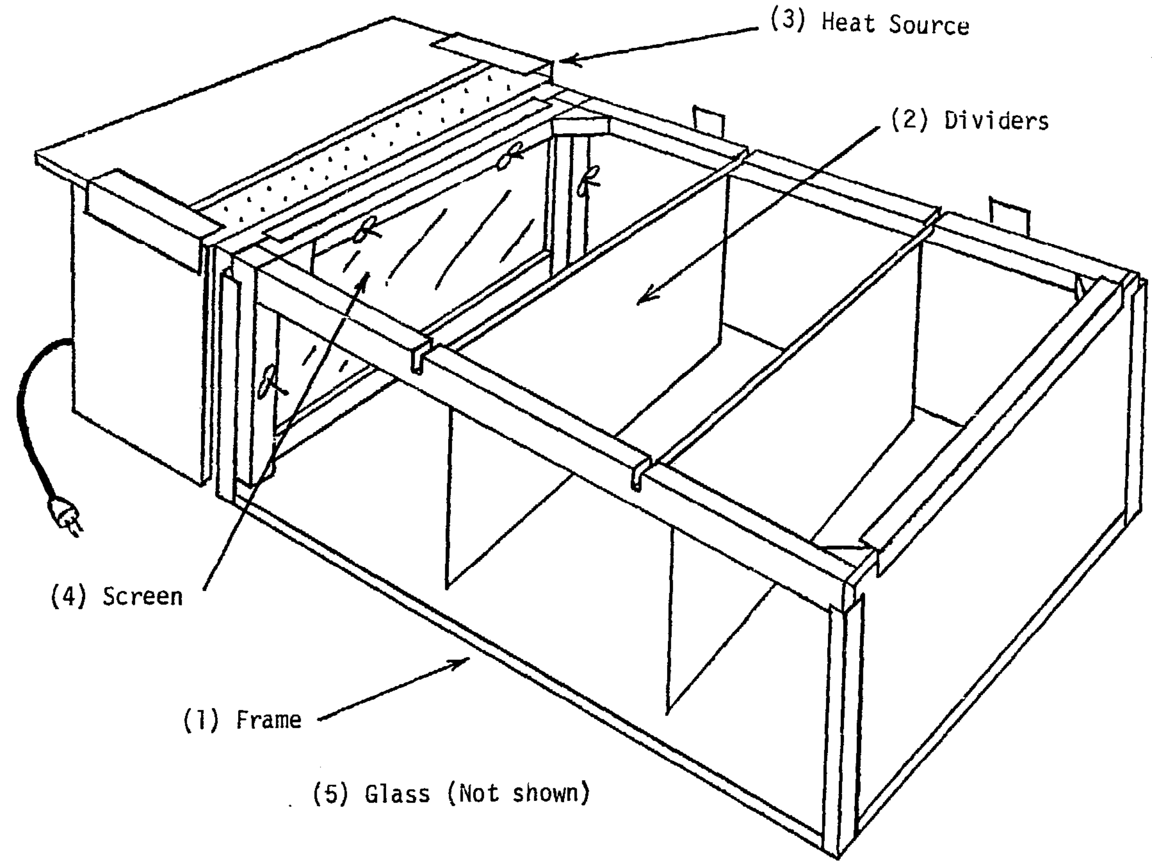
(i) This cage is intended for long-term housing of small mammals. Cover the screen floor with shredded newspaper or sawdust. Wastes fall through the screen floor onto the tray so they can easily be removed. Food can be simply put into a jar lid or shallow tin can.

(ii) The basic design of this cage can be retained and the dimensions altered to accommodate other animals, especially birds. Remember to provide the basic requirements for each different type of animal (e.g., perches for birds).

(iii) If space is limited, these cages will stack one upon the other. However, the door must be hinged to swing open if it is undesirable to unstack them each time a lower cage is to be opened.

C. TEMPERATURE CONTROLLED CAGES

C1. Vivarium



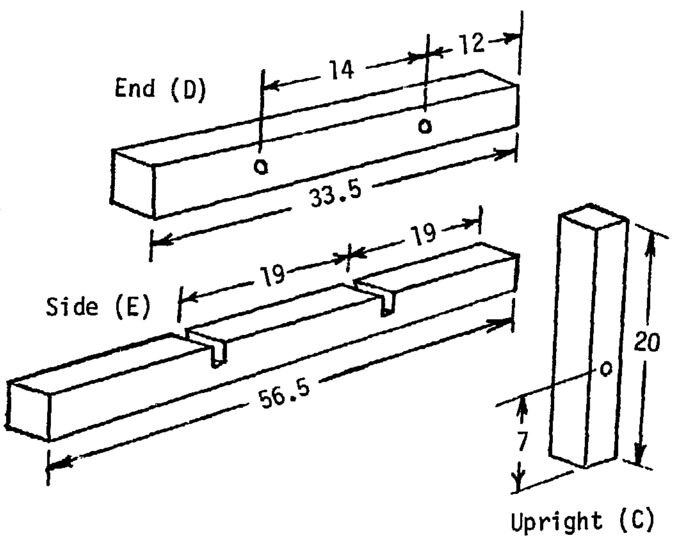
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	1	Plywood (A)	60 cm x 45 cm x 1.0 cm
	1	Plywood (B)	43.5 cm x 20 cm x 1.0 cm
	2	Wood (C)	20 cm x 2.5 cm x 2.5 cm
	1	Wood (D)	38.5 cm x 2.5 cm x 2.5 cm
	2	Wood (E)	55.5 cm x 2.5 cm x 2.5 cm
	2	Wood (F)	4 cm x 4 cm x 2 cm
	4	Sheet Metal (G)	5 cm x 21 cm x 0.05 cm
	2	Sheet Metal (H)	40 cm x 5 cm x 0.05 cm
(2) Dividers	2	Wood Dowels (I)	42 cm long, 0.75 cm diameter
	2	Cloth (Cotton) (J)	38 cm x 25 cm

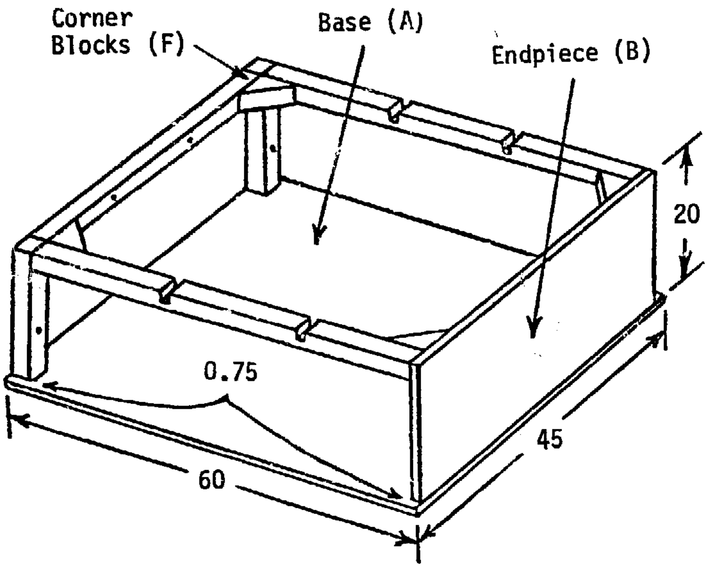
(3) Heat Source	1	Plywood (K)	44 cm x 16 cm x 1.0 cm
	1	Hardboard (L)	16.5 cm x 45 cm x 0.3 cm
	1	Plywood (M)	20 cm x 44 cm x 0.5 cm
	2	Plywood (N)	16.5 cm x 21 cm x 0.5 cm
	2	Wood (O)	20 cm x 4 cm x 1.0 cm
	1	Wood (P)	36 cm x 4 cm x 1.0 cm
	2	Sheet Metal (Q)	14 cm x 5 cm x 0.05 cm
	1	Plywood (R)	44 cm x 15 cm x 0.5 cm
	1	Light Bulb Socket (S)	Varies
	1	Light Bulb (T)	Varies
	1	Electric Cord (U)	150 cm long
	1	Plug (V)	Varies
(4) Screen	4	Bolts (W)	8 cm long, 0.5 cm diameter
	4	Wing Nuts (X)	0.5 cm inside diameter
	1	Wire Screen (Y)	20 cm x 45 cm
	2	Wood (Z)	21 cm x 3 cm x 0.5 cm
	2	Wood (AA)	39 cm x 3 cm x 0.5 cm
	2	Wood (BB)	45 cm x 3 cm x 0.5 cm
	2	Wood (CC)	15 cm x 3 cm x 0.5 cm
(5) Glass	1	Window Glass (DD)	59 cm x 44 cm x 0.25 cm
	2	Window Glass (EE)	19 cm x 59 cm x 0.25 cm
	2	Sheet Metal (FF)	12 cm x 4 cm x 0.05 cm

b. Construction

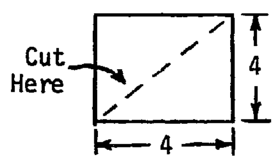
(1) Frame



Notches must be made in the two sidepieces (E) into which the dividers will be fit, Also, holes need to be drilled through the end (D) and the two uprights (C) through which the bolts hold the frame, screen, and heat source are put. However, these holes should be drilled when the three components (frame, screen, heat source) are held together in place with clamps in order to insure that the holes will be aligned.

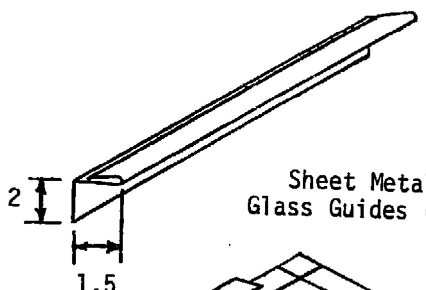


Nail, screw and/or glue the endpiece (B) to the base (A), flush to one edge and 0.75 cm from the other two edges. Nail two uprights (C) to the base, flush to the opposite end and each 0.75 cm from the outside edge. Nail the sidepieces (E) into position between the uprights and endpiece, and also nail the end (D) between the two uprights.

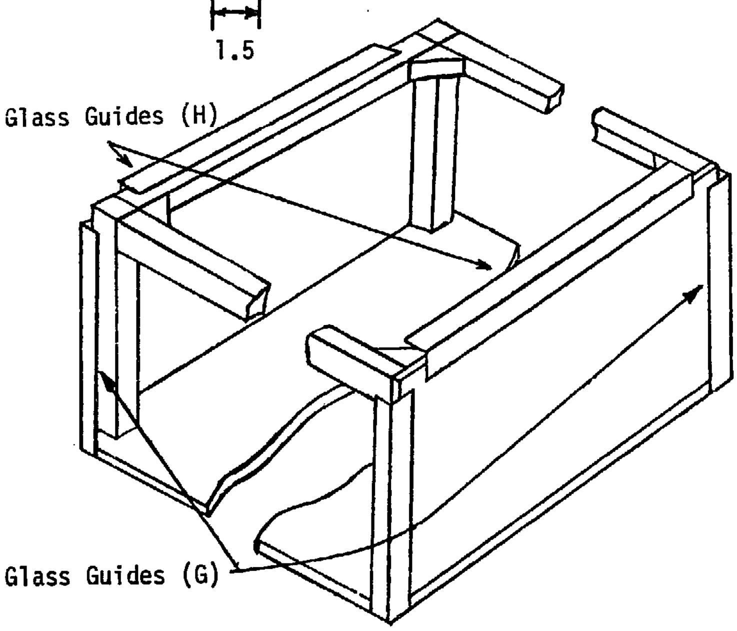


Corner Blocks (F)

Two square pieces of wood (F) cut into triangular shapes are used as corner blocks to provide additional support and strength.

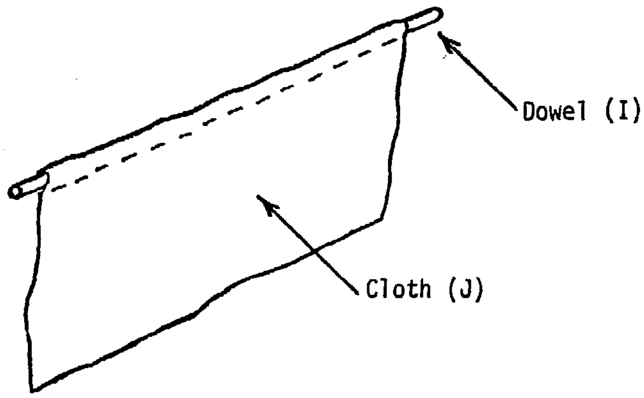


Sheet Metal
Glass Guides (G,H)



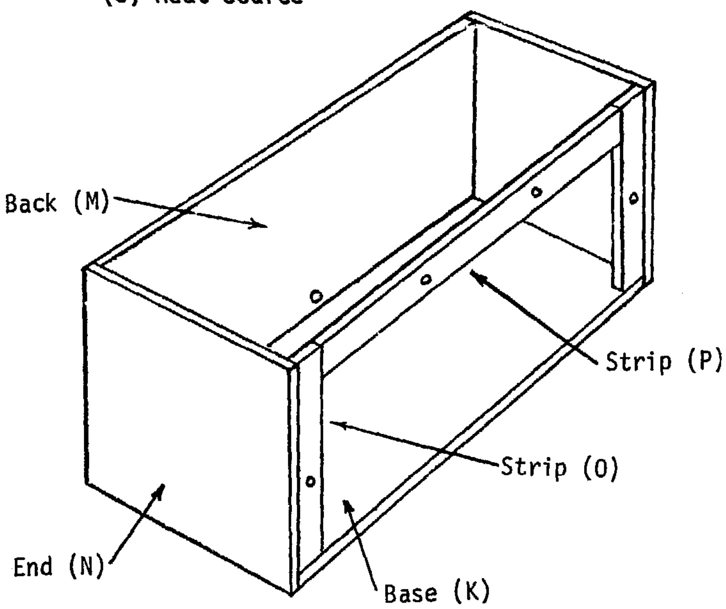
To provide guides for the glass, six rectangular pieces of aluminum sheeting (G, H) (0.05cm thick) are required. They are folded to the shape shown. Four (G) are nailed to the upright and endpiece. The remaining two (H) are nailed to the end and endpiece. These guides should be fastened in such a way as to provide approximately a 0.75 cm gap between wood and metal so that the glass can slide easily in and out.

(2) Dividers



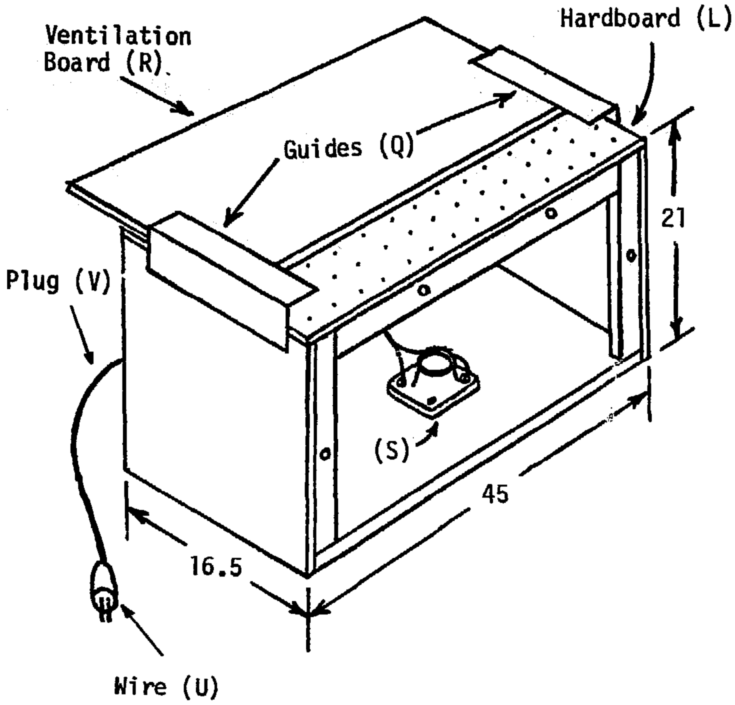
The dividers are simply made with wooden dowels (I). A piece of cotton cloth (J) is sewn around the dowel, and hangs down to within 1 or 2 cm of the base. The dividers (two are needed) are fit into the notches in the frame sides.

(3) Heat Source



Use the piece of plywood (K) as the base of the heat source. Fasten the two plywood pieces (N) to the ends of the base and the third plywood piece (M) to the back. Nail two of the wood strips (O) to the base and ends, and nail the remaining strip (P) between these two pieces (O).

Nail the piece of hardboard (L) to the top of the frame to enclose it. This hardboard should be the perforated type with 0.5 cm holes spaced every 2.5 - 3.0 cm. If such hardboard is not available, it can easily be made by making holes in regular board. Holes must also be made in the heat source, but again, these should be



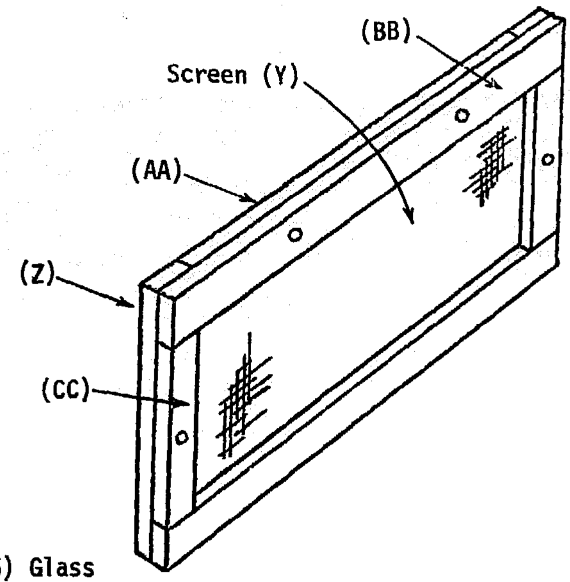
drilled when the frame, screen, and heat source can all be held together with clamps to insure alignment of the holes. Drill another hole in the back to allow the wire to the light bulb socket to run through.

Two guides (Q) are needed for the ventilation board, and are nailed to the sides of the heat source. Make these like the glass guides described in construction step (1). The ventilation board (R) is made of thin plywood slightly shorter in length and width than the top of the heat source. It should slide easily in and out between the guides (Q).

Finally, fasten a light bulb socket (S) in the middle of the heat source. Wire a plug (V) to the socket with the wire (U) and lead it out of the box through a small hole drilled in the back. Screw a bulb (T) in place.

(4) Screen

The screen is made with eight pieces of wood. Form two rectangular frames. Make one by nailing two pieces of wood (CC) between the two pieces (BB), and the second frame by nailing two pieces (AA) between the shorter pieces (Z). The aluminum screening (Y) (wire mesh) is fastened between the two frames with nails, and the frames are nailed and glued

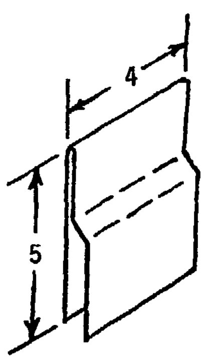


(5) Glass

together. The four holes for the connecting bolts (W) will be made when the three components (frame, screen, heat source) are clamped together, and the holes are drilled through all three parts at once.

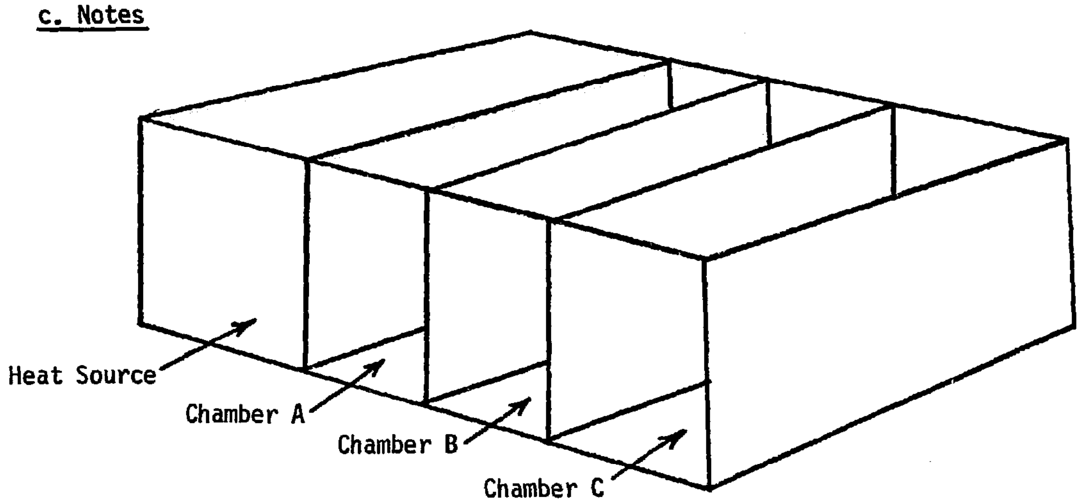
The heat source, screen, and frame are connected together with the bolts (W) and wing nuts (X).

Three glass plates are not shown in the main illustration in order to preserve clarity. However, the two side plates (EE) are made from standard window glass (0.2 cm in thickness). They fit between the glass guides on the frame sides. The top plate is also window glass (DD). The top plate of glass fits between the two glass guides on the top of the frame. Any of the three pieces of glass should slide easily in and out of place when the other two are in position. Additionally, air gaps should be kept to a minimum.



Finally, two pieces of aluminum sheeting (FF) can be folded to the shape shown and slipped over the top edge of one of the side pieces of glass (EE). These pieces of aluminum then act as stops to keep the top glass plate (DD) from sliding out.

c. Notes



(i) The vivarium is a cage in which the cloth dividers are used to loosely partition the interior into three chambers. The heat source employs light bulbs as the heating elements. A desirable result would be to maintain an even temperature gradient (i.e., 35°, 30°, 25° C) in the three chambers so that animals placed in the vivarium could seek their own optimal temperature level. For instance, the temperatures given above would imply that it was thought that the optimal environmental temperature for a given animal was 30°C (the temperature maintained in Chamber B). In this case, even if the vivarium were placed out-of-doors and subjected to temperature fluctuations of ± 5°C, one of the chambers would still maintain the 30°C level (e.g., temperatures in the vivarium might be depressed to 30°, 25°, 20° or elevated to 40°, 35°, 30° C). In order to insure that the desired temperature is maintained in at least one chamber, it may be necessary to increase the number of chambers from the three used in this experimentation. In fact, all the conclusions given here must be qualified by the limited nature of the experimentation.

(ii) Following construction of a vivarium, experimentation was carried out to determine which variables affect the establishment of the temperature gradient, and how these variables affect this gradient, both separately and in combination. Variables found to influence the temperature gradient included bulb size (wattage), divider material, height of the dividers above the floor of the cage, use of a reflector in the heat source and ambient (room) temperature.

(iii) Generally, increasing the bulb size (wattage) caused a marked increase in temperature in Chamber A, less so in Chamber B, and little or no change in temperature in Chamber C. The result was that the temperature gradient, rather than increasing in equal increments (i.e., 34°, 30°, 26° C), tended to increase in unequal increments (e.g., 36°, 26°, 23° C).

(iv) The material from which the dividers are made was found to have little effect on the temperature gradient maintained in the cage, but the amount of space left between the bottom of the dividers and the vivarium floor did have a compacting effect on the temperatures, i.e., bringing those in Chambers A and C closer to that in B.

(v) As might be expected, using a reflector in the heat source caused an overall rise in temperature in the vivarium. The last variable to be investigated, ambient (surrounding) temperature, was seen to have a profound influence on the internal temperatures in the vivarium, and is probably the most important variable to be considered. No doubt, the vivarium walls will have to be altered using better insulating materials (e.g., wood rather than glass) in order to reduce the influence of the ambient temperature.

(vi) Some other variables which were not investigated also may have an effect on temperature control. Among these is the material in the screen between the heat source and cage itself. It was aluminum screening for all the experimentation described here, but may well have different effects if it were made from steel rods or other materials. The type and amount of ventilation will also be an influence.

The dimensions of the vivarium are also important since a larger cage will obviously be harder to heat and maintain. The number and size of the chambers are variables to be reckoned with.

Finally, the most important factor will be the animals and their requirements. Testing must be done to see if a reasonable range of temperatures can be maintained for a variety of animals (e.g., baby chickens, mice, lizards, etc.). If experiments are to be run involving the determination of optimal temperature requirements for a particular animal, the range of temperatures provided must be narrow enough so that there will be some assurance that the animal has indeed chosen its favorite temperature, and not simply chosen the lesser of three evils. For example, if the optimal temperature for a certain lizard is thought to be 30°C, then the range should be 30°C plus or minus 2° or 3°C rather than plus or minus 6° or 8°.

(vii) Experimentation was also done with the cloth partitions removed, making the vivarium a single chamber. Three conditions were checked using three different bulb wattages (60, 100, 175). In the first condition, the vivarium was used as described above, only without the cloth partitions. In the second condition, one half of the glass top was removed and replaced by wood, and in the third case, the entire top was wood, leaving only the front piece of glass. In all three instances, the aluminum foil reflector was used, and the ventilated top of the heat source was fully closed. The results of this experimentation are tabulated below.

Table I

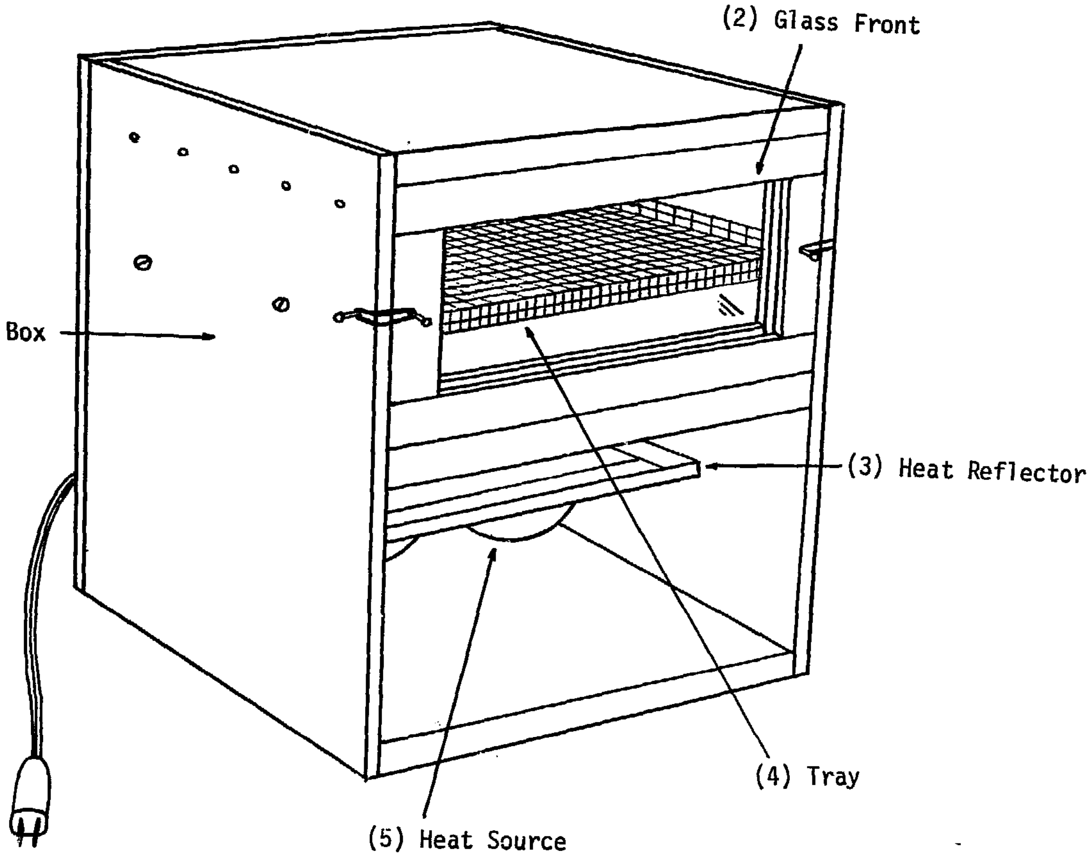
Condition	Wattage	Vivarium Temperature (°C)	Room Temperature (°C)
Top Completely Glass	60	26	22
	100	28	22
	175	33	22.5
Top One Half Glass, One Half Wood	60	26	22
	100	29	22.5
	175	38	24
Top Completely Wood	60	26	22
	100	30	22
	175	37	23

As the data show, there appears to be little significant difference in the various temperatures, although the additional wood does help hold the heat slightly better than the all glass top.

The vivarium will serve adequately as a controlled temperature environment as long as the ambient (room) temperature is kept relatively constant.

(viii) If the vivarium is to be used in a room where the outside temperature varies greatly, it is desirable to control its internal temperature more accurately. Therefore, use the thermostat, item VI/C3. Wire the heat source to the thermostat which should be mounted in the back panel of the vivarium if no wood is used in the top. Keep the thermostat as far from the heat source as possible. In addition, a screen or other protective device must be placed over the thermostat to prevent the animals (and students) from touching the exposed portions of the thermostat which carry current of 110 volts.

C2. Egg Incubator



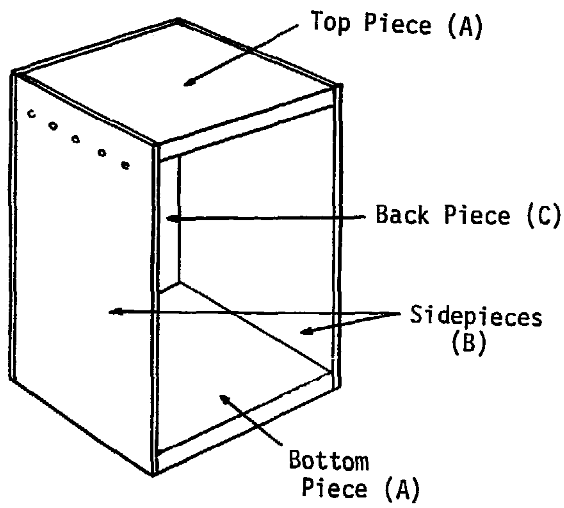
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Box	2	Wood (A)	23 cm x 20 cm x 1.5 cm
	2	Plywood (B)	20 cm x 36 cm x 1.0 cm
	1	Plywood (C)	25 cm x 36 cm x 1.0 cm
	1	Wood (D)	23 cm x 2 cm x 2 cm
	2	Wood (E)	14 cm x 1.0 cm x 1.0 cm
	1	Wood (F)	23 cm x 1.0 cm x 1.0 cm
	1	Plywood (G)	19 cm x 25 cm x 1.0 cm
(2) Glass Front	2	Glass (H)	18 cm x 10 cm x 0.3 cm
	2	Wood Strips (I)	10 cm x 0.5 cm x 0.5 cm
	2	Wood Strips (J)	17 cm x 0.5 cm x 0.5 cm
	2	Wood (K)	23 cm x 2.5 cm x 2 cm
	2	Wood (L)	15 cm x 2.5 cm x 2 cm
	4	Screws (M)	Approximately 2 cm long
	2	Rubber Bands (N)	--

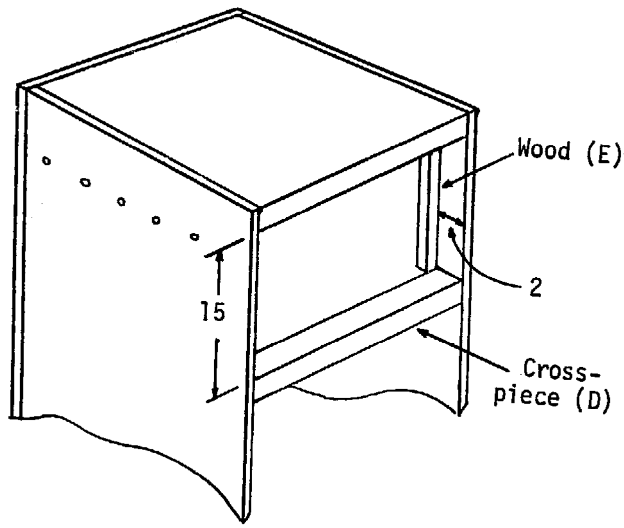
(3) Heat Reflector	1	Plywood (O)	23 cm x 15 cm x 1.0 cm
	1	Aluminum Foil (P)	28 cm x 20 cm
(4) Tray	1	Wire Mesh (Q)	26 cm x 20 cm
	4	Bolts (R)	Approximately 2 cm long
	4	Nuts (S)	To fit bolts
(5) Heat Source	2	Bulb Sockets (T)	10 cm diameter (base)
	4	Bolts (U)	Approximately 3 cm long
	4	Nuts (V)	To fit bolts
	1	Electrical Wire (W)	Approximately 100 cm
	1	Plug (X)	--
	2	Bulbs (Y)	--

b. Construction

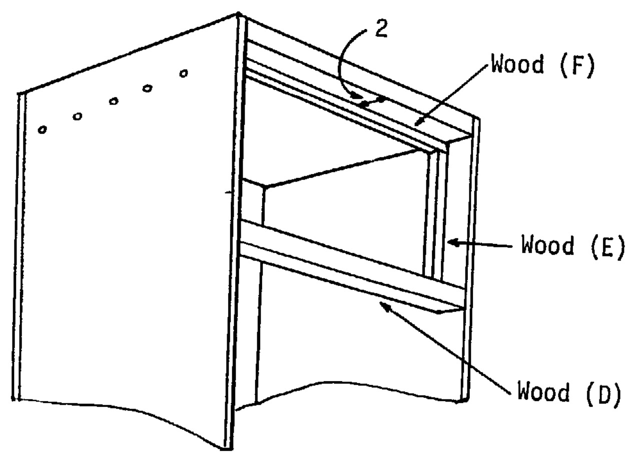
(1) Box

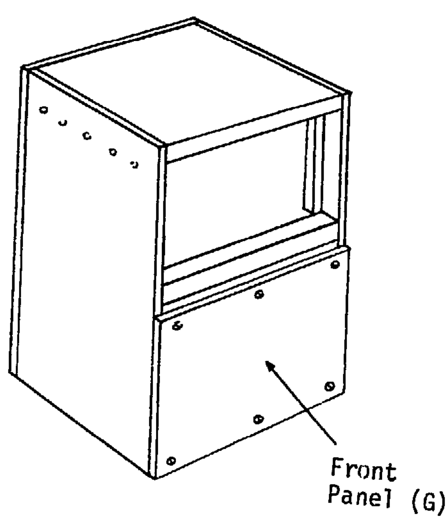


Nail or screw the two sidepieces of plywood (B) to the two pieces of wood (A) serving as the top and bottom of the box. Nail or screw the back (C) into position. Small ventilation holes (0.4 cm diameter) should be drilled along the tops of the sidepieces (B).



Make certain the crosspiece (D) fits very tightly, and nail or screw it into place. Nail or glue the wood strip (F) to the top (A), 2 cm from the front edge of the top. Likewise, nail or glue the other two wood strips (E) to the sidepieces (B), 2 cm from their front edges between the top (A) and cross-piece (D).

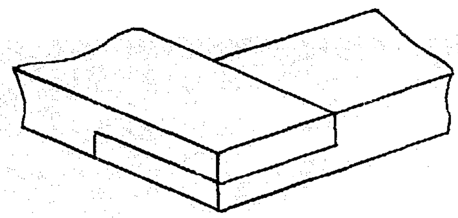




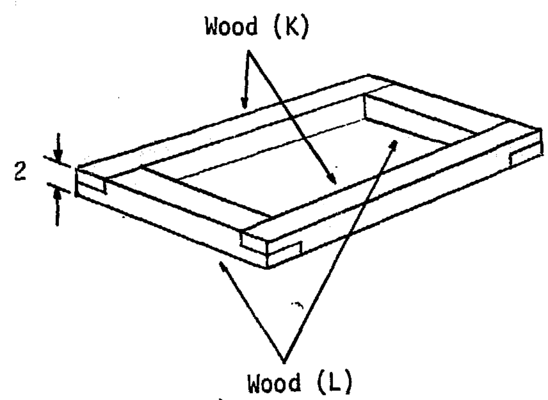
The front panel (G) is screwed into place so it may be easily removed to permit completing the construction of the incubator, and to permit changing the light bulb in the heat source.

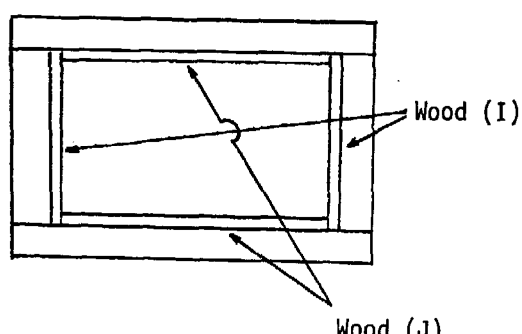
(2) Glass Front

Make the frame for the glass front with half-lap joints (see drawing). Use this type of joint to connect the two short pieces of wood (L) to the two longer ones (K). Glue the two wood strips (I) down the center of the inner surface of the short wood pieces (L), and similarly, glue the longer strips (J) down the center of the inner surface of the long pieces (K). These thin strips serve to separate the two pieces of glass (H) which can now be glued into place with epoxy resin cement.

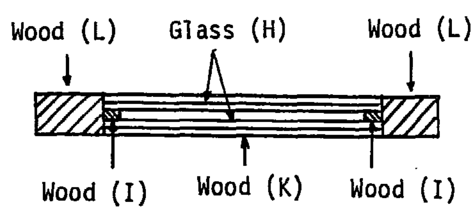


Half-lap Joint





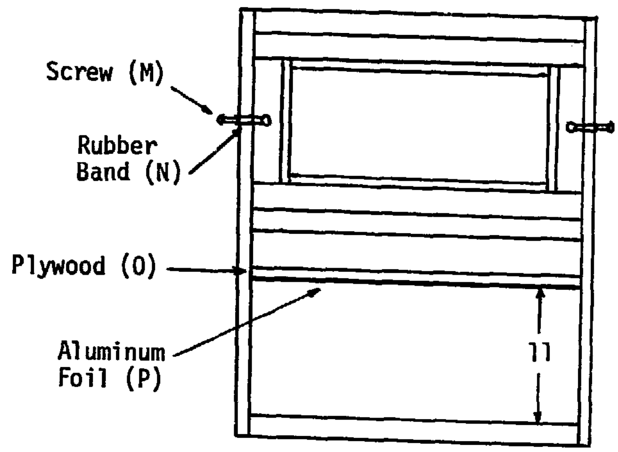
Front View



Cross Section

The glass front should fit tightly in the recess in the front of the box. To hold it in place, fasten one screw (M) on each side of the frame of the glass front and each side of the box adjacent to the glass front. Rubber bands (N) stretched tightly between adjacent screws should hold the glass front firmly in position.

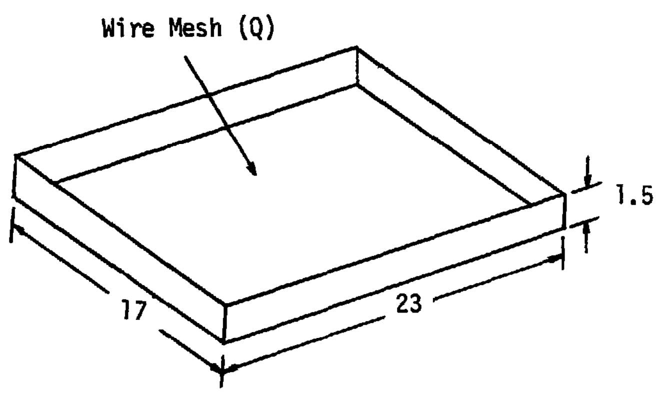
(3) Heat Reflector



Front View

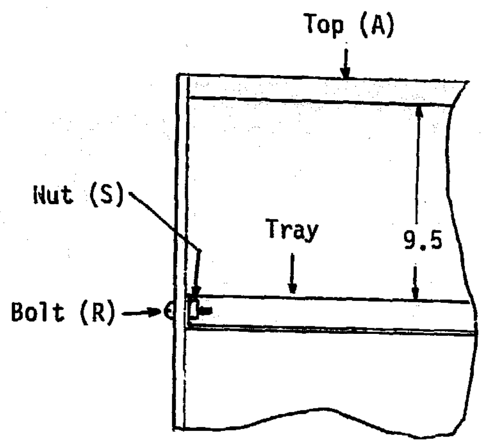
Cover the lower surface of the plywood (O) with the aluminum foil (P) and nail the heat reflector into position as shown. Be sure the rear edge is touching the back (C) of the box.

(4) Tray



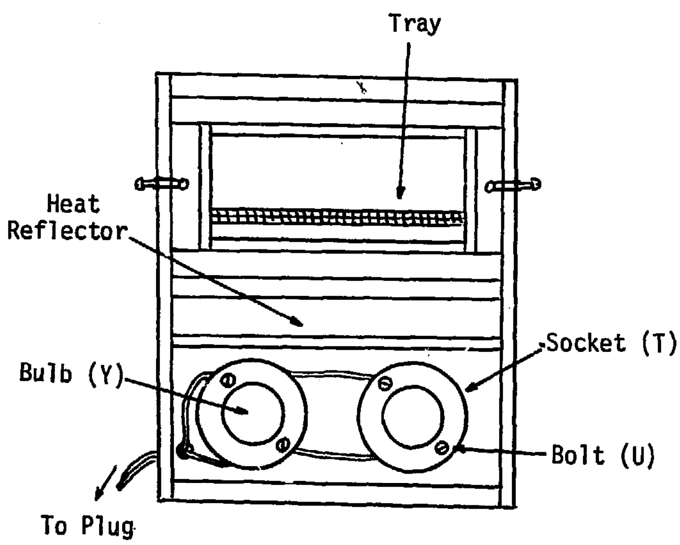
Tray (Diagram)

Use the wide (0.5 cm square) wire mesh (Q) for the tray and fold it so there is a 1.5 cm edge all around. Fasten it to the inside of the box by pinning the side edges of the mesh to the sides of the box with the nuts (S) and bolts (R). Obviously holes will have to be drilled through the sides of the box to permit passage of the bolts. The rear edge of the tray should touch the back (C) of the box.



Front View

(5) Heat Source



Front View

Drill four holes in the back of the box near the bottom through which the bolts (U) will be passed to hold the bulb sockets (T) in position. Wire the sockets together in parallel with short lengths of wire (W) and pass the remaining wire out of the box through a fifth hole drilled in the back. Wire the plug (X) in place, and tighten the nuts (V) onto the bolts (U) now that the bulb sockets are wired. Finally, place the desired number and power (wattage) of light bulbs (Y) in the sockets.

c. Notes

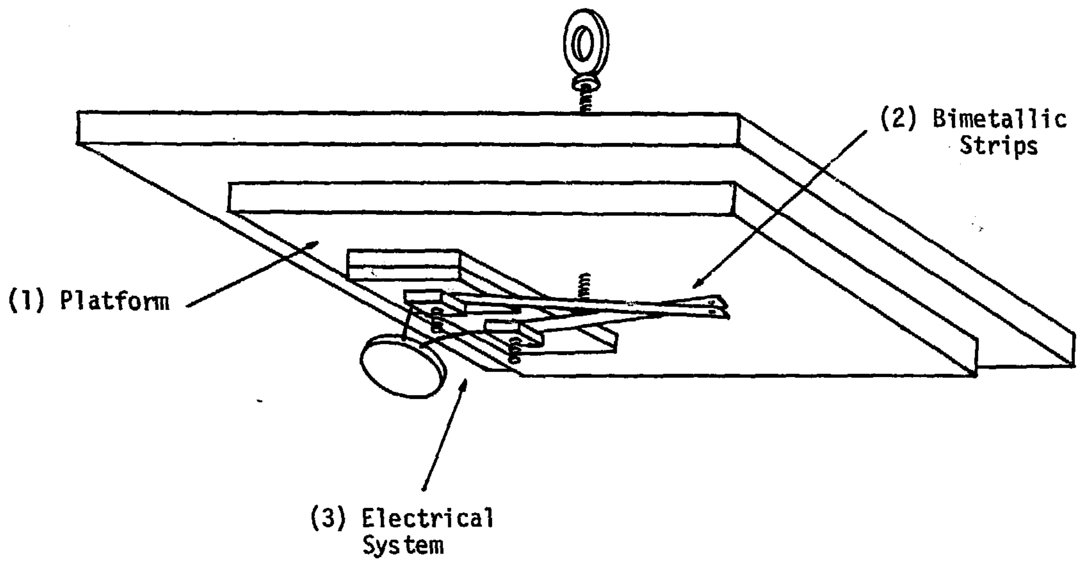
(i) Use the egg incubator in the study of the embryology of chicken or other eggs. The double glass front permits visual observation of the eggs on the tray without undue heat loss.

(ii) The temperature in the incubator will remain constant using varying wattages of light bulbs as long as the room temperature is relatively constant (see the table).

Watts	Incubator Temperature (°C)	Room Temperature (°C)
40	37.5	23.0
60	46.0	25.5
80	51.0	23.0
120	67.0	23.0

(iii) The thermostat (VI/C3) should be used with the incubator to insure that the internal temperature maintains itself at the correct level. Mount it in the top of the incubator, protected by a wire screen which will prevent hatchlings (and people) from touching the live wires. In fact, if the incubator is definitely to be used with the thermostat, increase the height of the top above the egg tray to insure that the hatchlings cannot touch the thermostat.

C3. Thermostat



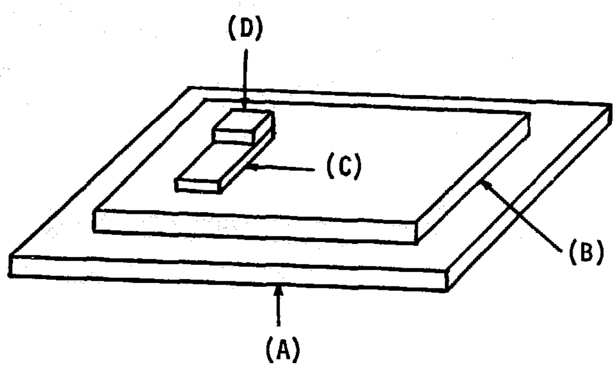
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Platform	1	Wood (A)	10 cm x 10 cm x 1.0 cm
	1	Wood (B)	6 cm x 6 cm x 1.0 cm
	1	Wood Strip (C)	3 cm x 2 cm x 0.5 cm
	1	Wood Strip (D)	2 cm x 1.5 cm x 0.5 cm
(2) Bimetallic Strips	2	Bimetallic (Brass/Steel) Strips (E)	Approximately 3.5 cm x 0.5 cm
	1	Platinum Wire (F)	#20, 3 cm long
	2	Bolts (G)	0.2 cm diameter, 4 cm long
	2	Nuts (H)	0.2 cm internal diameter
	4	Washers (I)	--
	1	Bolt (J)	0.3 cm diameter, 5 cm long
	1	Nut (K)	0.3 cm internal diameter
	1	Washer (L)	1 cm external diameter
	1	Plastic Tube (M)	0.3 cm internal diameter, 0.5 cm long
	--	Insulation Tape (N)	--
(3) Electrical System	1	Capacitor (O)	0.01 microfarads
	1	Roll of Copper Wire (P)	#20

1	Bolt (Q)	0.3 cm diameter, 2.5 cm long
2	Nuts (R)	0.3 cm internal diameter
1	Double Electrical Cord (S)	300 cm long
1	Plug (T)	110 volt

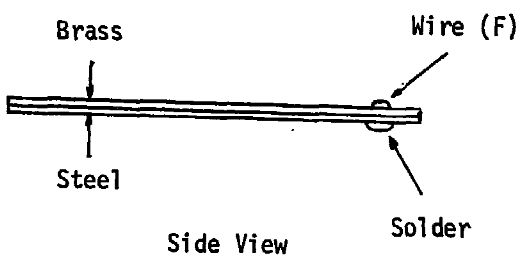
b. Construction

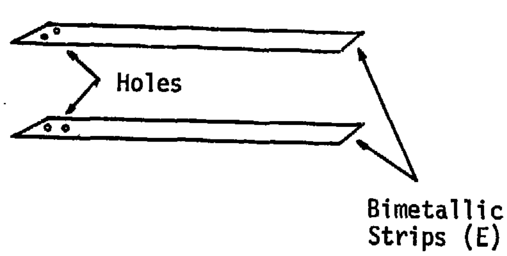
(1) Platform



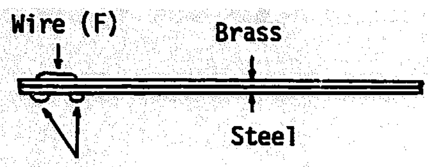
Glue the smaller wood piece (B) to the middle of the larger one (A). Next, glue wood strip (D) at one end of the other wood strip (E), and glue this resulting section near one edge of wood square (B).

(2) Bimetallic Strips

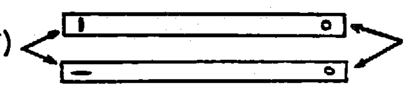




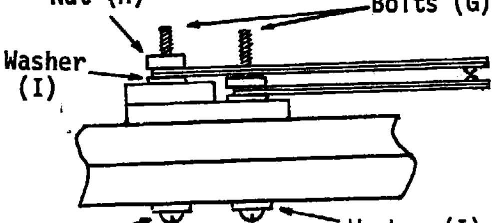
Drill a small hole (0.2 cm diameter or smaller) in one end of each bimetallic strip (E). Purchase these strips locally from a radio or electrical shop. Place a short piece of the platinum wire (F) through this hole and with a hammer, flatten each protruding piece of the wire flat as if the wire were a tiny rivet. Place a small drop of solder on the flattened portion of wire on the steel side of the bimetallic strip to insure good electrical contact. Alternatively, drill two very small holes in the end of each bimetallic strip, those in one strip in line with the short side of the strip and those in the other in line with the long side of the strip (see illustra-



Side View



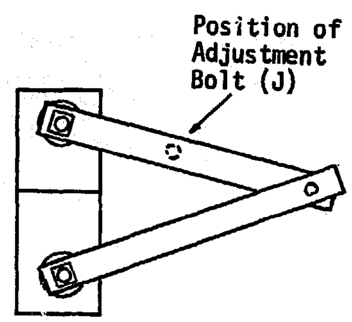
Top Views



Side View

tion). Place one end of a short piece of the platinum wire through each hole from the brass side of the strip and solder these ends to the steel side of the strip to provide good electrical contact. Flatten each wire slightly with a hammer to help make a greater surface area for electrical contact. Regardless of the manner in which the platinum is fixed to the end of the bimetallic strips, drill a small (0.2 cm diameter) hole in the opposite end of each strip. Also, make certain no solder is on the brass side of the bimetallic strips since this is likely to contaminate the surface of the platinum contacts.

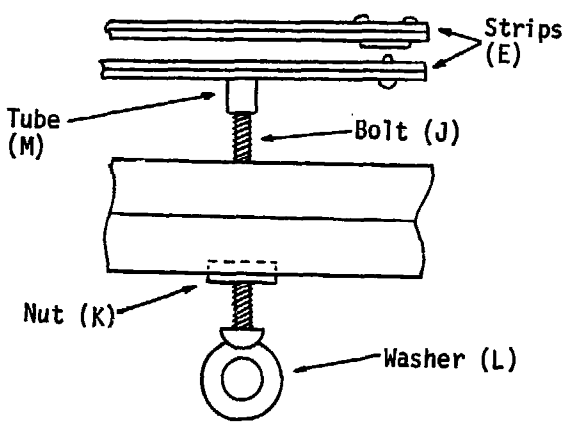
Next, drill two holes (0.2 cm diameter) through the platform, one through all four pieces of wood and the other through all but piece (D). Attach the bimetallic strips to the platform with the two bolts (G), two nuts (H), and four washers (I) as shown. The platinum contact point of the lower strip should face up while that of the upper strip should face down.



Top View

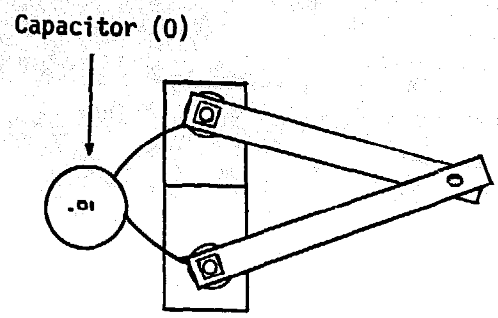
Pivot the free ends of the bimetallic strips toward one another so that the platinum contact points will touch one another when the strips are pressed together.

Side View



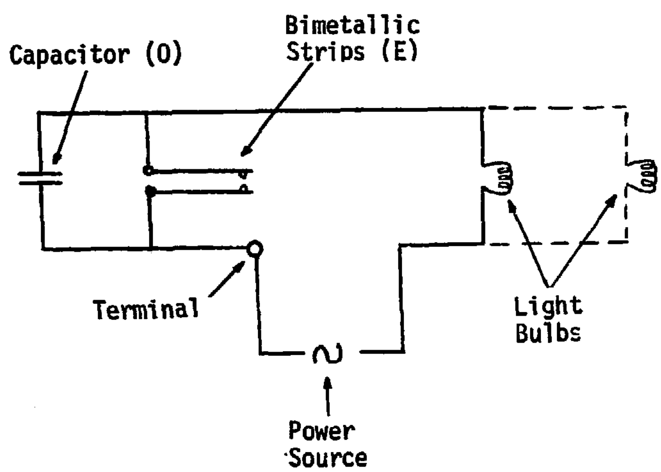
Drill a hole (0.3 cm diameter) through the platform directly below the middle of the lower bimetallic strip. Inset the nut (K) into the outside wood piece (A) directly over the hole. Thread the bolt (J) through the nut and hole. Place the piece of plastic tubing (M) on the end of the bolt (J) to prevent electrical contact between the bolt and metallic strip. Solder the washer (L) to the notch in the bolthead and cover both thoroughly with insulation tape (N). Make absolutely certain the bolt is completely insulated from the bimetallic strip as it will carry 110 volt current.

(3) Electrical System



Top View

Purchase the capacitor (O) locally, and connect it across the bimetallic strips. Cut a hole (6 cm x 6 cm) into the top of the container which is to be heated. The thermostat platform should fit firmly in the hole with the bimetallic strips beneath the platform.



Wiring Diagram

Use one piece of copper wire (P) to connect one of the bimetallic strips to one contact of the bulb socket of the heating source, and use another piece of the wire to connect the other bimetallic strip to a terminal [made from bolt (Q) and two nuts (R)] which must be put in the back of the cage or incubator which is to be heated. Then, connect the double electrical cord (S), with the plug (T) attached, to the terminal and the remaining contact on the bulb socket. The wiring circuit as shown in the diagram is now complete, and the thermostat is ready for use.

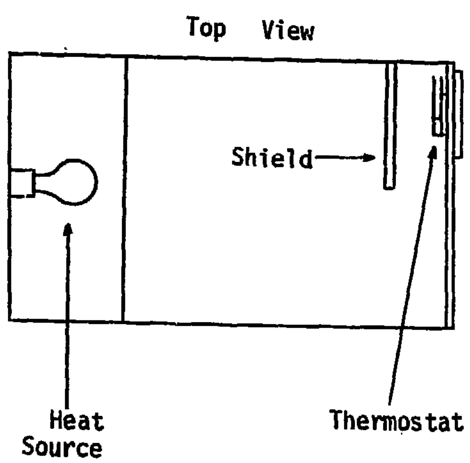
c. Notes

(i) It should be noted that due to lack of time the thermostat described here was tested out with the Microorganism Incubator (VII/A4) only. Care should therefore be taken to test the thermostat carefully when used in conjunction with either the Egg Incubator (VI/C2) or Vivarium (VI/C1).

(ii) It was noted that using the thermostat the temperature of the Micro-organism Incubator took about 25 minutes to stabilize.

Time Minutes	Cage Temperature °C
0	40.5
5	39.0
10	38.5
15	38.0
20	38.0
25	37.0
30	37.0 stabilized

(iii) Do not permit direct radiation from the heat source to fall on the thermostat, otherwise the thermostat will switch itself off before the air temperature has risen to the desired level. Where there is a possibility of direct radiation falling on the bimetallic strips of the thermostat make an appropriate shield to stop the radiation without restricting the circulation of air around the bimetallic strips.



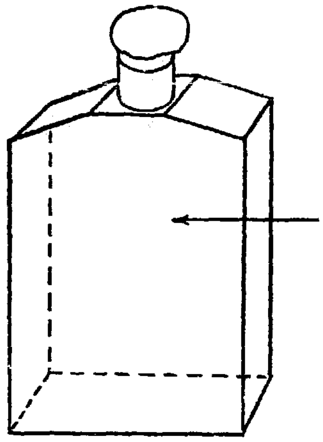
VII. MICROBIAL GROWTH APPARATUS

A. BASIC APPARATUS

Included here are improvised versions of the equipment necessary to perform elementary investigations in microbiology. Information on culturing microorganisms should be obtained from standard texts on the subject.

A. BASIC APPARATUS

A1. Culture Flask

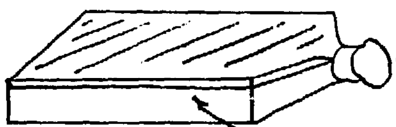


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Medicine Bottle (A)	About 100 ml or larger
	1	Cotton Plug (B)	--

b. Construction

(1) Bottle



Sterilize the bottle (A) and fill it 1/6 full of either liquid or gelatin culture medium. Stopper it with the cotton plug (B). If gelatin medium is used, lay the bottle on its side and allow the medium to set. Store the flask with the medium on the upper side of the flask so that no moisture film will form on the medium.

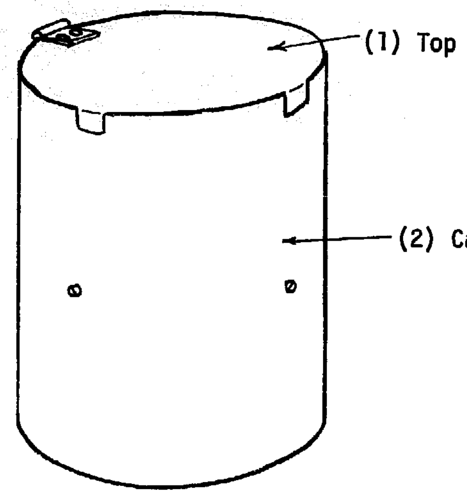
c. Notes

(i) Consult a standard microbiological text or source book for detail in working with bacteria and other microorganisms.

(ii) Use glass medicine bottles with flat sides if these are available.

(iii) Petri dishes are invaluable in working with microbes. See CHEM/V/A6 for instructions in making petri dishes.

A2. Sterilizer



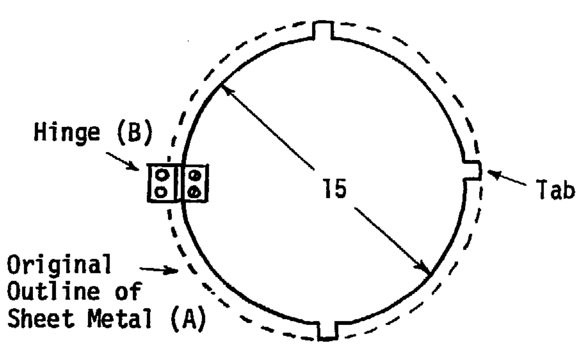
(3) Rack (Not visible)

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Top	1	Sheet Metal (A)	17 cm diameter, 0.075 cm thick
	1	Hinge (B)	3 cm x 2 cm
(2) Can	1	Tin Can (C)	15 cm diameter, 18 cm high
	4	Screws (D)	1.5 cm long
(3) Rack	1	Sheet Metal (E)	14.5 cm diameter, 0.075 cm thick

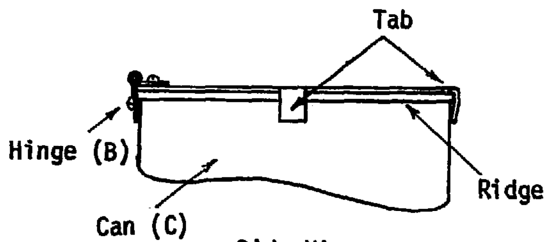
b. Construction

(1) Top



Cut the top from a circular piece of sheet metal (A). Leave three tabs to be bent down at right (90°) angles. The tabs are 1.0 cm long. Screw the small hinge (B) to the top directly opposite the middle tab.

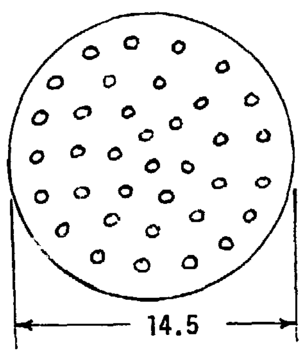
(2) Can



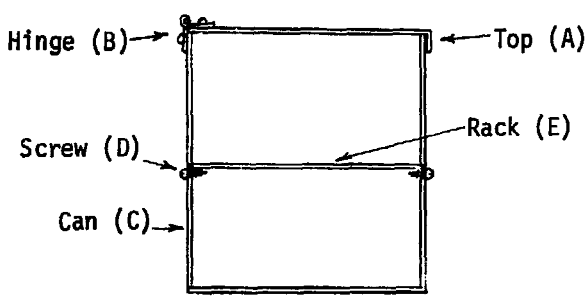
Side View

Remove one end from the tin can (C). Attach the top to the can by means of the hinge. Most tin cans have a ridge around the edge so that when the top is closed, the three tabs should catch on this ridge and hold the top down rather firmly. Finally, screw the four screws (D) through the outside into the inside of the can, 9 cm from the bottom and spaced about 12 cm apart.

(3) Rack



Punch a number of holes into the sheet metal disc (E). Set this disc inside the can so that it is supported by the four screws extending into the can.



Side View
(Cross-section)

c. Notes

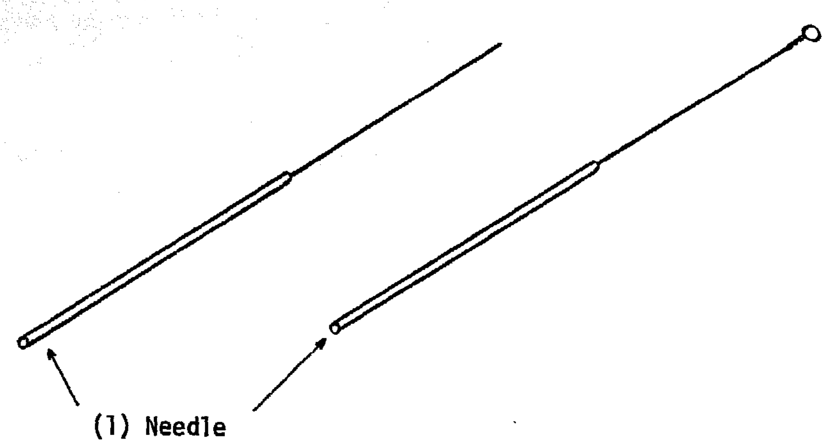
(i) To use the sterilizer, simply put 3 - 4 cm of water in the can and place the items to be sterilized on the rack. After the water has begun to boil, leave the items in the steam for about 90 minutes.

(ii) If the can used is large enough, two or more racks can be made for it to allow a larger number of articles to be sterilized at the same time.

(iii) This sterilizer will kill most, but not all, common bacterial contaminants. If pure sterility is desired, an autoclave or ordinary pressure cooker is needed. Place the articles on a rack and autoclave or pressure cook them for about 20 minutes.

(iv) An alternate rack can be made by fastening a circular piece of wire mesh to a frame of stiff wire.

A3. Inoculating Needles

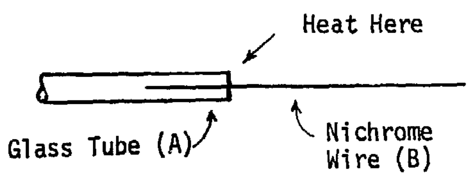


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Needle	1	Glass Tube (A)	0.3 cm diameter, 12 cm long
	1	Nichrome Wire (B)	10 cm long, #24 gauge

b. Construction

(1) Needle



Side View

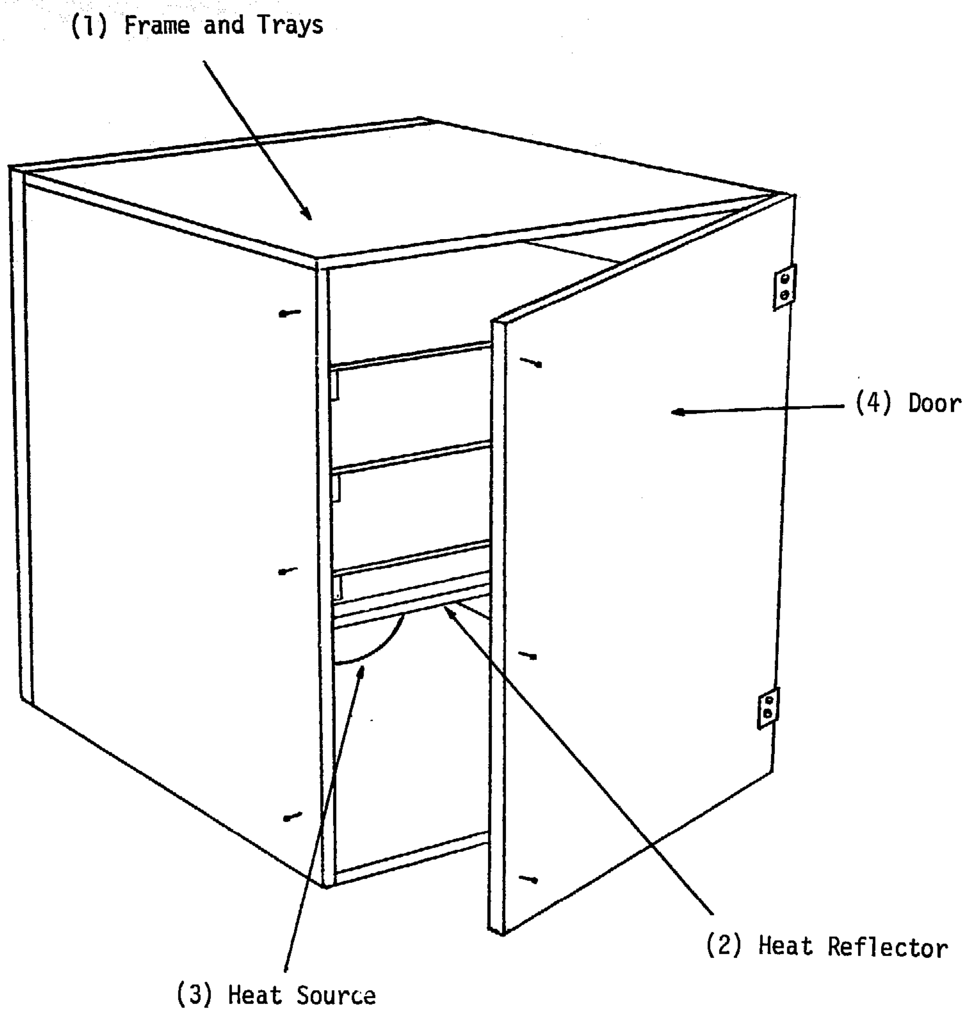
Use soft glass tubing (A) with a small diameter bore. Insert about 2 cm of the wire (B) in one end of the tube and heat this end in a hot flame until the end of the glass constricts and holds the wire fast.

c. Notes

(i) The nichrome wire may be left straight or a 0.3 cm loop may be made in the end by twisting the wire around a 0.3 cm round object with pliers.

(ii) Use inoculating needles for transferring small amounts of bacterial cultures from one medium to another.

A4. Microorganism Incubator



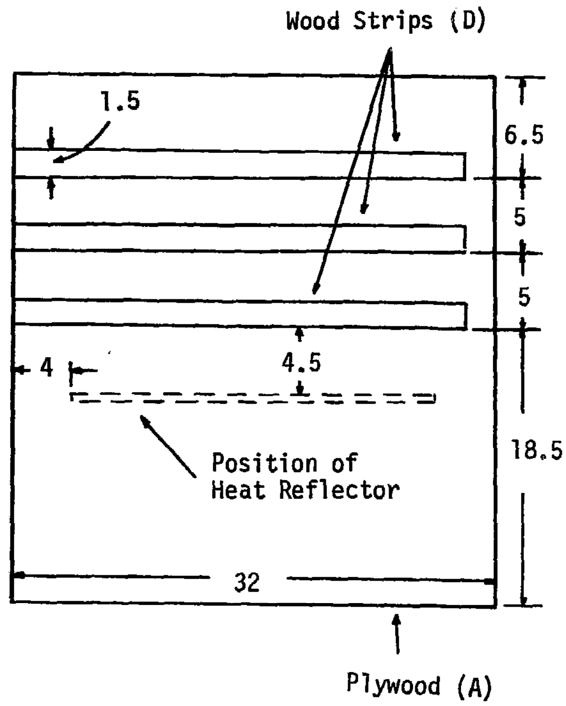
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame and Trays	3	Plywood (A)	35 cm x 32 cm x 1.0 cm
	1	Plywood (B)	33 cm x 32 cm x 1.0 cm
	1	Plywood (C)	35 cm x 36 cm x 1.0 cm
	6	Wood Strips (D)	30 cm x 1.5 cm x 1.0 cm
	3	Perforated Hardboard (E)	32.5 cm x 31 cm x 0.3 cm
(2) Heat Reflector	1	Plywood (F)	33 cm x 24 cm x 0.5 cm
	1	Aluminum Foil (G)	37 cm x 28 cm

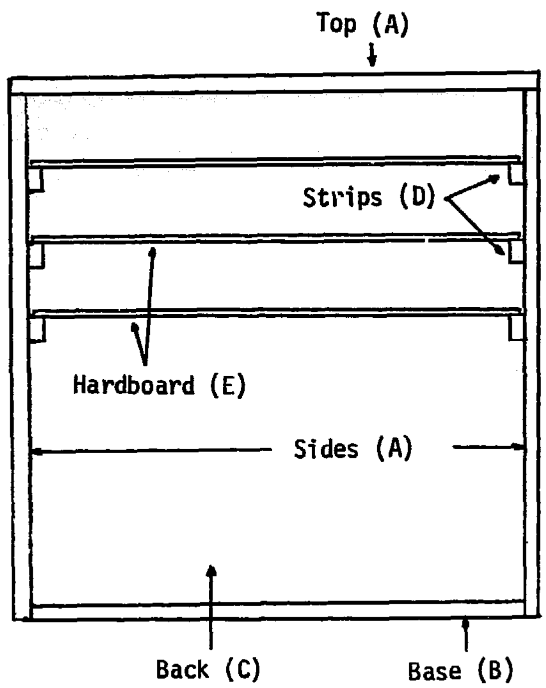
(3) Heat Source	1	Egg Incubator, Heat Source (H)	VI/C2, Component (5)
(4) Door	1	Plywood (I)	35 cm x 36 cm x 1.0 cm
	2	Hinges (J)	Approximately 4 cm long
	8	Screws (K)	0.7 cm long
	6	Nails (L)	1 cm long
	3	Rubber Bands (M)	--

b. Construction

(1) Frame and Trays



Nail three of the wood strips (D) to each of two of the pieces of plywood (A) as illustrated to make the two side pieces of the frame. Nail the bottom edges of the completed side pieces to the wood (B) used as the base. Nail the back piece (C) into position as well as the top piece (A). When the frame is finished, the pieces of perforated card-board (E) which serve as the trays should slide easily into the frame on the wood strips (D).



Frame and Trays

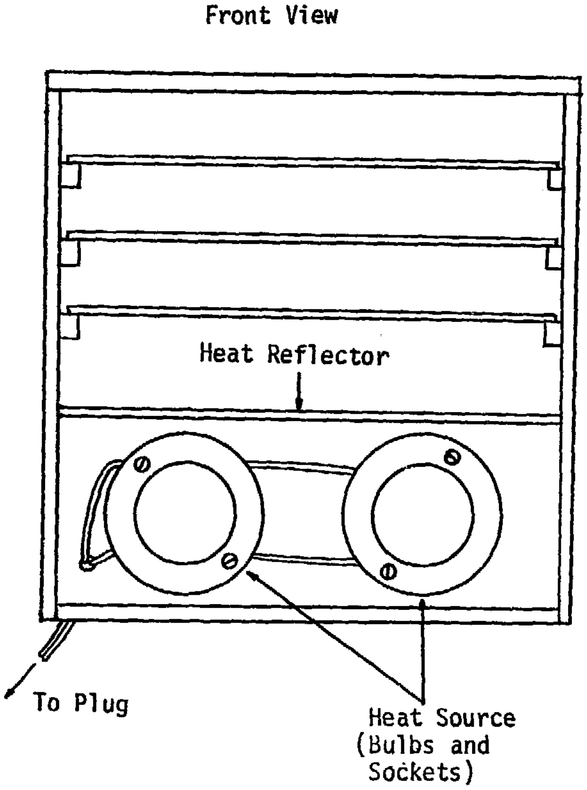
(Front view)

(2) Heat Reflector

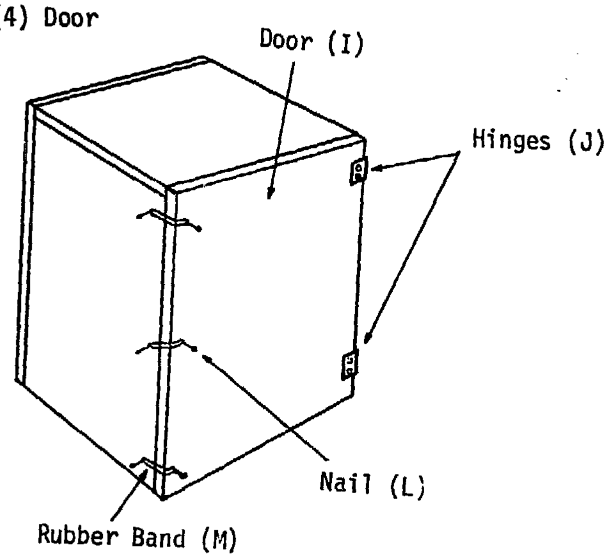
Cover one side of the plywood (F) with aluminum foil (G) to make the heat reflector. Nail the reflector into place 13 cm above the base (B) of the frame with a 4 cm gap between the rear edge of the reflector and the back (C) of the frame.

(3) Heat Source

Use two light bulbs as the heat source (H) exactly as described for item VI/C2, Component (5).



(4) Door



Fasten one edge of the plywood (I) to the side of the frame with the hinges (J) and screws (K) making certain the door shuts as closely to the frame as possible. Felt strips may be used as insulation between the door and frame if necessary, both to conserve heat loss and prevent the introduction of airborne contaminants. The door may be held closed by using rubber bands (M) which are stretched between adjacent pairs of nails (M) in the frame and door.

c. Notes

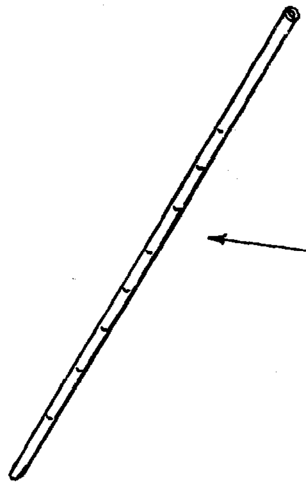
(i) Use the microorganism incubator to provide a proper environment for growing bacteria, mold, and other cultures. The dimensions of the incubator as given are to enable each tray to hold nine (three rows of three) standard petri dishes (9 cm diameter).

(ii) If the incubator is used in a constant temperature room, the temperature in the incubator can be held relatively constant. Using the correct combination of bulbs will yeild an internal temperature close to that desired. Rather than drilling ventilation holes to cool the incubator if it is too hot, it might be better to paint part of the light bulbs with black paint to cut down their heat. Ventilation holes would allow contaminants into the incubator. The following gives a few examples of temperatures which can be maintained in the incubator.

Wattage	Incubator Temperature (°C)	Room Temperature (°C)
40	35.0	23.5
60	40.5	22.0
80	48.0	23.5

(iii) The thermostat(VI/C3) should be used with the incubator to insure that the internal temperature maintains itself at the correct level. Mount it in the top of the incubator, protected by a wire screen which will prevent persons from touching the live wires. In fact, if the incubator is definitely to be used with the thermostat, increase the height of the top above the uppermost tray in order to insure that people placing cultures in the incubator have less chance of touching the thermostat.

A5. Transfer Pipette



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Pipette	1	Glass Tube (A)	35 cm long, 0.4 cm inside diameter

b. Construction

(1) Pipette

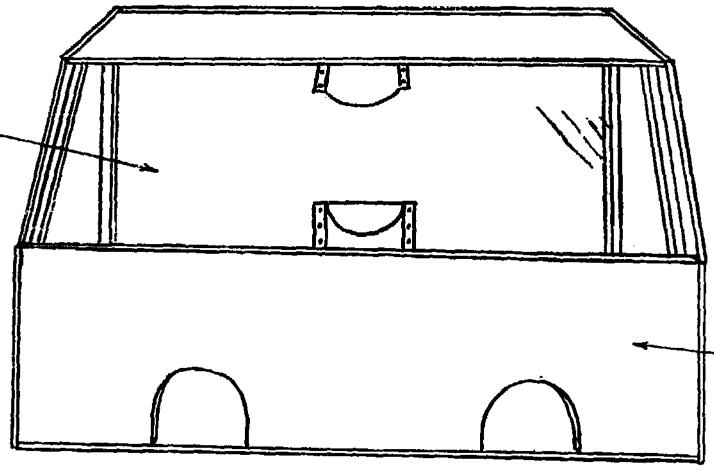
Hold one end of the glass tube (A) in a flame until the opening begins to constrict slightly. Remove it from the flame and let it cool when the opening is about 0.1 cm wide. To calibrate the pipette, a 10 cc (ml) syringe and short piece of rubber or plastic tubing is needed. Connect the ends of the pipette and syringe with the short (4 - 5 cm) piece of tubing. Fill the syringe and pipette with 7 or 8 cc of water and eliminate air bubbles by gently tapping the pipette. Hold the pipette vertically (syringe at the bottom) and withdraw the syringe plunger until the water empties from the pipette. Note the position of the syringe plunger on the scale and reinject water into the pipette 0.5 ml at a time until a total of 5 ml is reached. At each injection, mark the position of the water meniscus with a triangular file to form a permanent scale.

c. Notes

(i) This pipette is used in transferring exact amounts of culture broth from one container to another. Draw broth into the pipette with mouth suction and force the liquid out by gently blowing through the tube.

(ii) If desired, numbers may be written by the filed marks to indicate the capacity at that point. These numbers will last longest if they are drawn with waxed crayons or other types of pencils designed for writing on glass.

A6. Transfer Chamber *



a. Materials Required

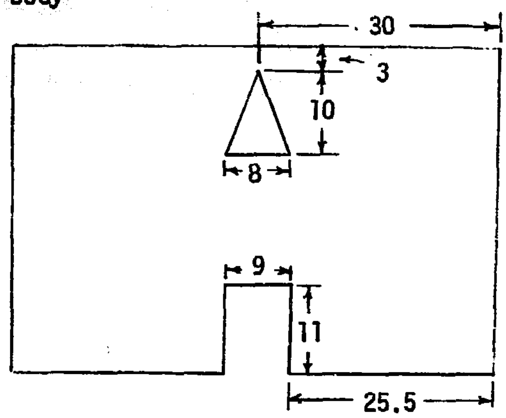
Components	Qu	Items Required	Dimensions
(1) Body	2	Plywood (A)	60 cm x 40 cm x 0.75 cm
	1	Plywood (B)	60 cm x 20 cm x 0.75 cm
	2	Plywood (C)	40.75 cm x 40 cm x 0.75 cm
	1	Plywood (D)	61.5 cm x 18 cm x 0.75 cm
	2	Wood (E)	60 cm x 2 cm x 2 cm
	2	Wood (F)	24 cm x 2 cm x 2 cm
	2	Wood (G)	36 cm x 2 cm x 2 cm
	2	Wood (H)	16 cm x 2 cm x 2 cm
	2	Wood (I)	37.25 cm x 2 cm x 2 cm
	2	Wood (J)	28 cm x 2 cm x 2 cm
	2	Wood (K)	15 cm x 2 cm x 2 cm
	2	Wood (L)	6 cm x 2 cm x 2 cm
	1	Wood (M)	20 cm x 2 cm x 2 cm
	1	Aluminum Sheet (N)	25 cm x 11 cm x 0.05 cm
	1	Aluminum Sheet (O)	20 cm x 14 cm x 0.05 cm

*Adapted from Richard E. Barthelemy, et. al., Innovations in Equipment and Techniques for the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964), pp 12-14.

(2) Glass	1	Window Glass (P)	28.5 cm x 58.5 cm x 0.3 cm

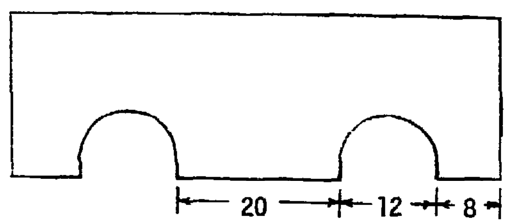
b. Construction

(1) Body



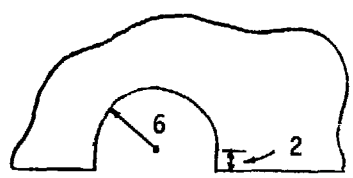
Plywood (A)

Begin the transfer chamber by cutting two holes into one of the large pieces of plywood (A). These will serve as ventilating holes when the chamber is enclosed.

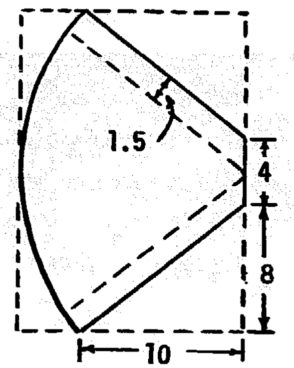


Plywood (B)

Cut two holes in the piece of plywood (B) to serve as arm-holes. The size and distance apart of these holes may be varied to suit personal prefer-ences.

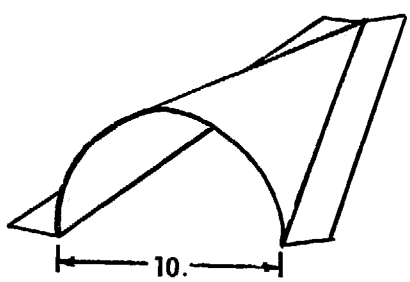


Detail of Hole



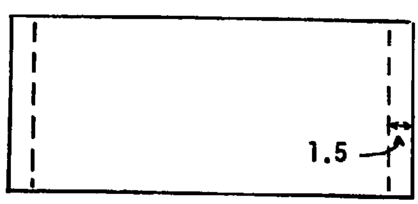
Pattern

Cut the piece of aluminum sheeting (O) (other metal sheeting may be substituted) to the given pattern. Bend up the straight sides along the dotted lines to form two flanges, each 1.5 cm wide.



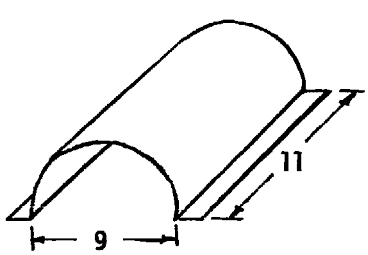
Half Cone

Roll the sheet metal (O) around a round object (e.g., a broom handle) until it takes the shape of a half cone.

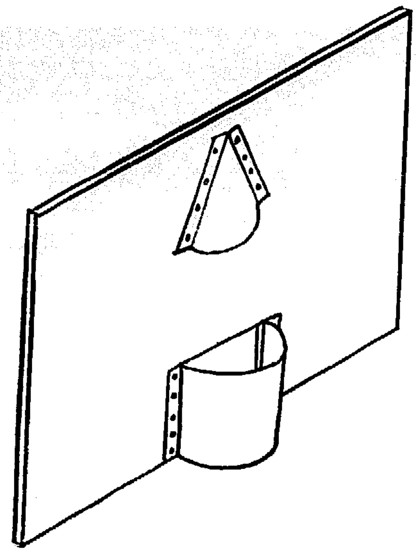


Pattern

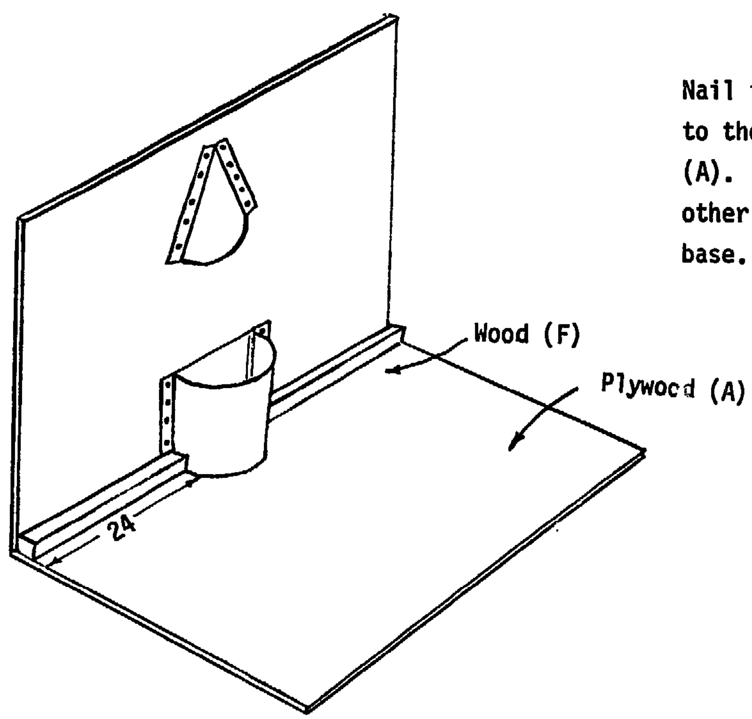
Similarly, bend up the two 11 cm sides of the other piece of aluminum (N), and roll it into a half-cylinder shape.



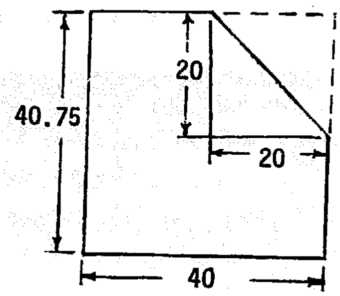
Half Cylinder



Nail the two aluminum pieces into position on the piece of plywood (A) in which the holes have been cut. Position the half cone directly over the triangular hole. Position the half cylinder so that its edges are even with the edges of the rectangular hole.

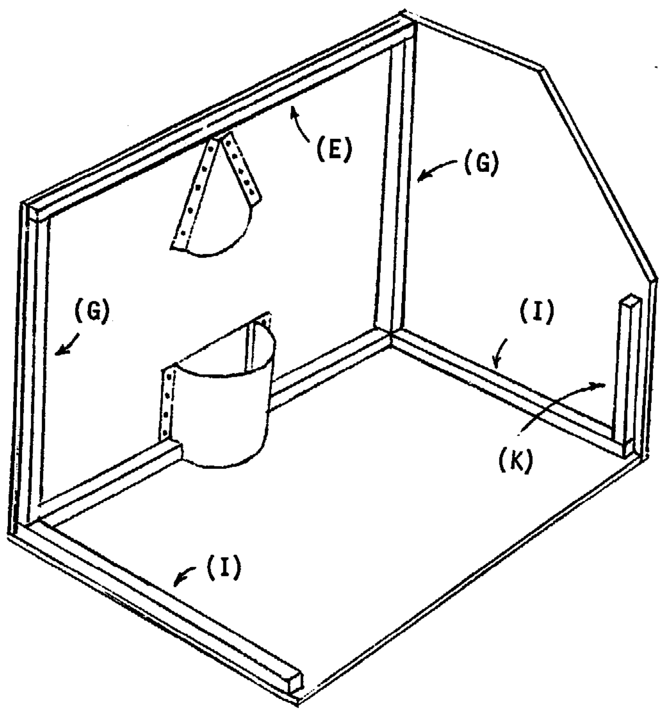


Nail the two wood strips (F) to the bottom edge of the back (A). Nail this in turn to the other plywood (A) used as the base.



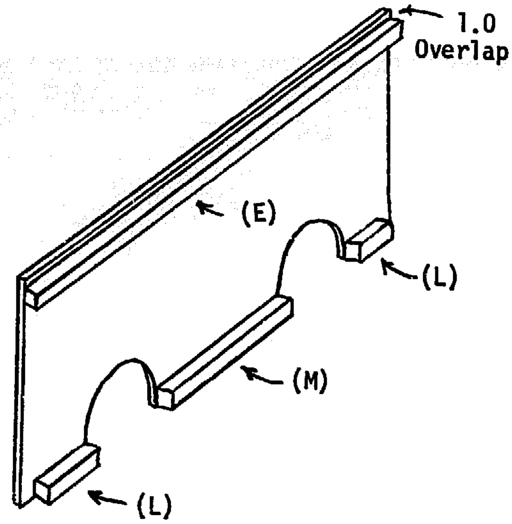
Endpiece (C)

Cut the two pieces (C) as shown. Use these pieces as endpieces for the chamber.

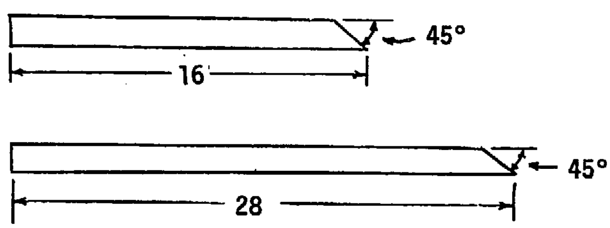


Frame

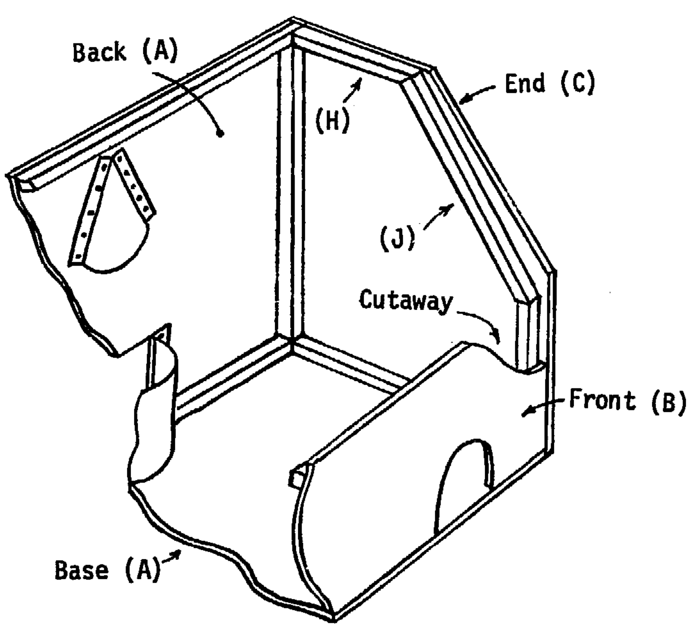
Nail two strips (G), two strips (I), and one strip (E) to the back and base. Then nail the two endpieces (C) into position. Nail the two strips (K) to the front edge of the end, being careful to leave a 0.75 cm overlap for the frontpiece to fit into.



Next, nail the two strips (L), and the other strip (E) and strips (M) to the back of the frontpiece (B) as shown. Properly done, this piece can now be nailed into the front of the chamber. Be sure there is about a 1.0 cm overlap of the plywood over the 60 cm strip.

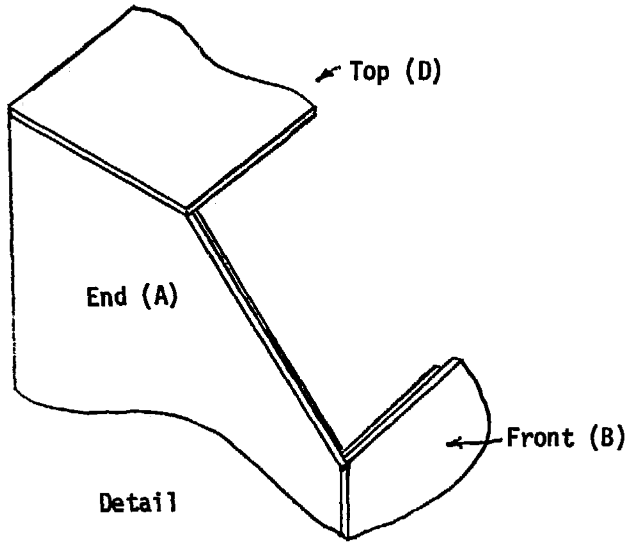


Cut one end of the wood strips (H) and wood strips (J) off at 45° angles



Cutaway View of One End

Nail one each of strips (J) and (H) to the endpieces (C) insuring they fit as shown in the drawing.



To complete the body, nail the last piece of plywood (D) to be the top, even with the edges of the back and sides.

(2) Glass

Simply rest the glass (P) on the frame made of the three wood strips, one on the front (E) and one each (J) on each endpiece. There should be no gaps between the glass and frame.

c. Notes

(i) Use the transfer chamber when transferring microbiological cultures from one container to another. With it, such techniques can be performed in a draft-free environment, thus reducing the possibility of airborne contamination. The students' or instructors' arms fit through the armholes in front while the glass permits all operations to be viewed easily.

(ii) The holes in the back serve for ventilation when the chamber is used with a bunsen burner.

VIII. PHYSIOLOGY MATERIALS

A. KYMOGRAPH

A wide range of physiological experiments using larger organisms may be performed using the kymograph.

B. VOLUMETER

In addition to identifying pressure changes, one may calculate the volume of gas exchanged with this equipment.

C. FERMENTATION TUBES

Fermentation rate is measured indirectly by the measurement of carbon dioxide.

D. MANOMETER

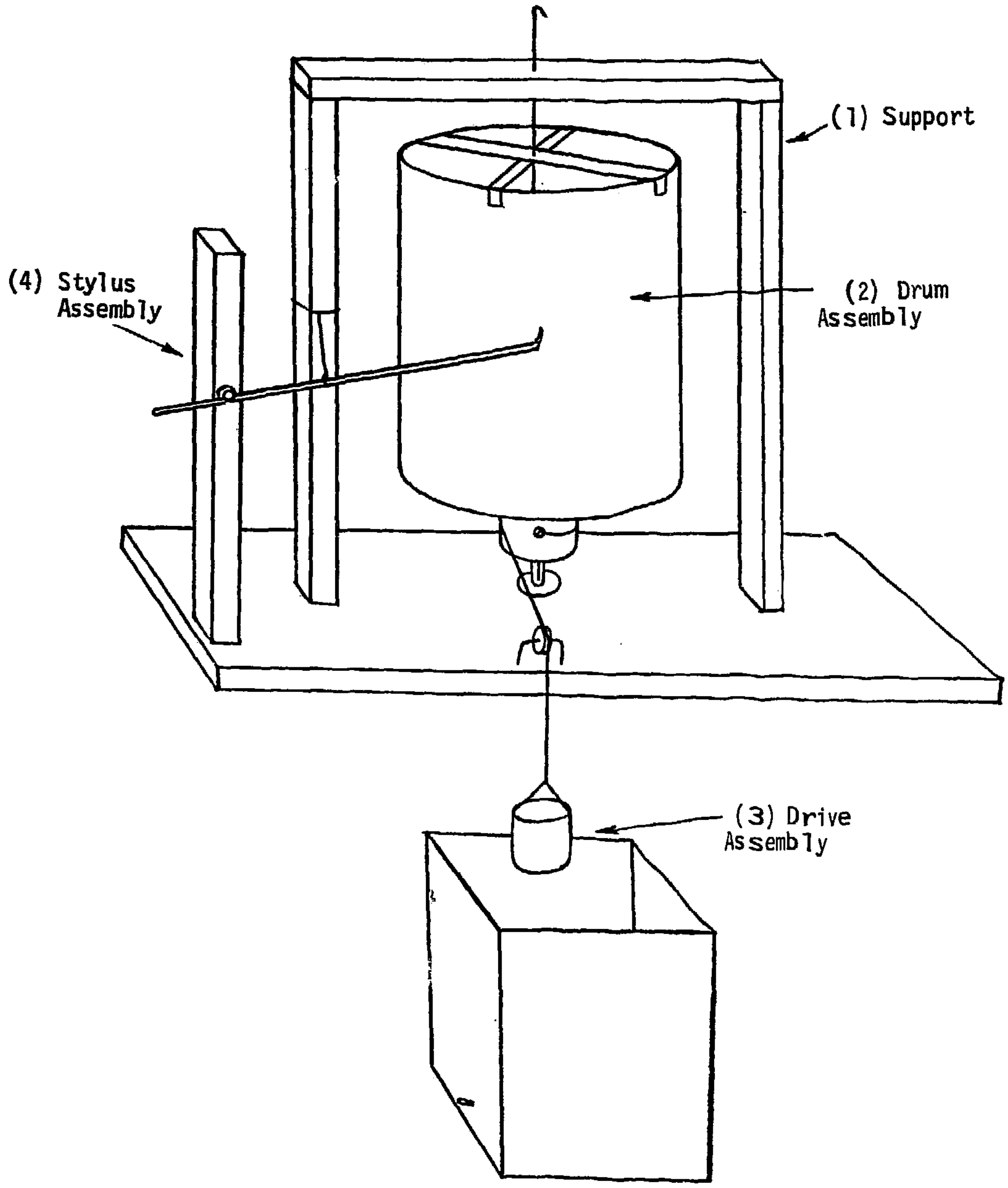
This apparatus enables one to identify changes in pressure within a biological system.

E. CHROMATOGRAPHY APPARATUS

Chromatography gives students useful insight into the techniques scientists use in investigating the biochemical composition of organisms.

A. KYMOGRAPH

A1. Kymograph



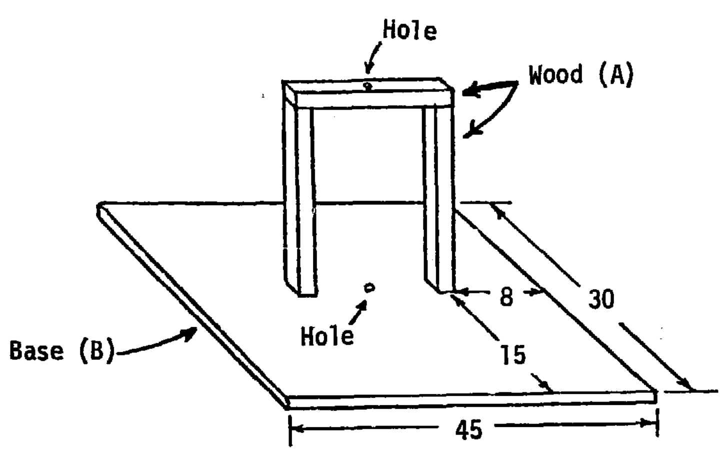
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support	3	Wood (A)	25 cm x 2 cm x 2 cm
	1	Wood (B)	45 cm x 30 cm x 1.0 cm

	1	Sheet Metal (C)	2 cm diameter
(2) Drum Assembly	1	Tin Can (D)	4 liter (i.e., 15 cm diameter, 17 cm high)
	2	Sheet Metal (E)	17 cm x 2 cm x 0.05 cm
	1	Stiff Wire (F)	30 cm long, 0.2 cm diameter
	1	Tin Can (G)	5 cm diameter, 6 cm high
	3	Sheet Metal Screws (H)	1 cm long
	1	Glass Tubing (I)	0.4 cm diameter, 1.0 cm long
(3) Drive Assembly	1	Wood (J)	3 cm diameter, 0.5 cm thick
	1	Stiff Wire (K)	16 cm long, 0.2 cm thick
	1	Tin Can (L)	1 liter capacity
	1	Sand (M)	600 g
	1	Stiff Wire (N)	20 cm long, #20 gauge (0.1 cm diameter)
	1	String (O)	100 cm
	1	Tin Can (P)	4 liter capacity
	1	Pencil Stub (Q)	--
(4) Stylus Assembly	1	Wood (R)	25 cm x 2 cm x 2 cm
	1	Stiff Wire (S)	30 cm long, 0.2 cm thick
	1	Nail (T)	1 cm long, 0.2 cm thick
	1	Rubber Band (U)	6 cm long

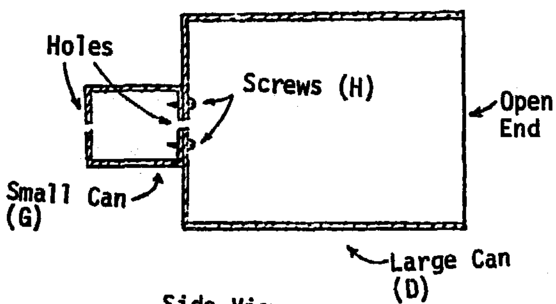
b. Construction

(1) Support

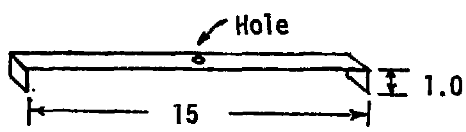


Drill a hole through one of the pieces of wood (A) directly in its center. Drill another hole in the base board (B) directly below the hole in the upper strip of wood. Each hole should have a diameter of about 0.3 cm. The hole in the base should be drilled only halfway through. Nail two of the strips (A) to the base and nail the crosspiece (A) so that the two holes are

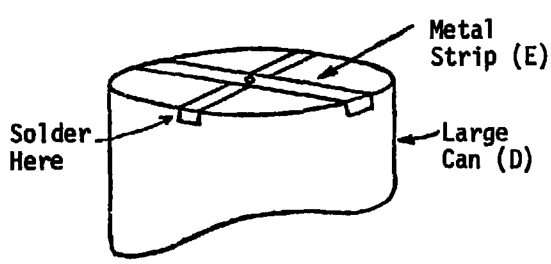
(2) Drum Assembly



Side View
(Cross-Section)



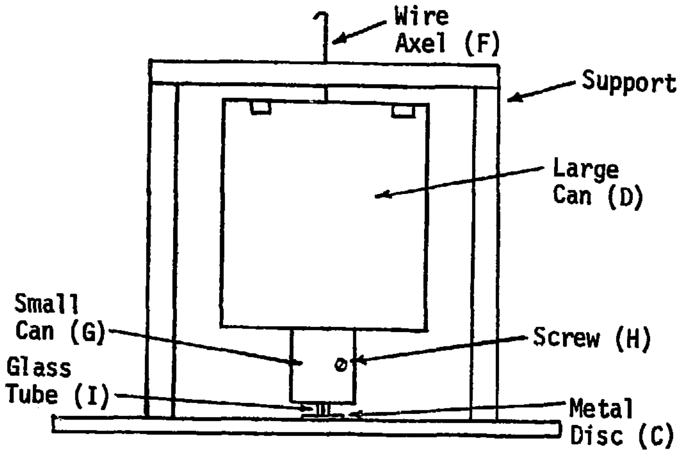
Metal Strip (E)



aligned. Finally, drill a 0.3 cm hole through the center of the disc of sheet metal (C) and nail the sheet metal to the base so that the hole in the base and the hole in the sheet metal are aligned.

Try to select two tin cans (D,G) for the drum assembly which have both ends more or less intact. Otherwise, adjustments must be made to compensate for the open ends. At any rate, drill holes 0.3 cm in diameter in the center of both ends of each of the tin cans. Solder the two cans together making certain the holes in each align. If one of the ends of one or both cans has been removed, then the two cans can be screwed together with two sheet metal screws (H). Here, the illustrations show the situation when the small can (G) is intact and the large can (D) has one end removed.

To solve the problem of the open end of the large can (D), take the two sheet metal strips (E) and bend a flap down 1.0 cm from each end. Drill a 0.3 cm hole through each strip in its center. Put the two metal strips across the top of the can so that they are at right angles (90°) and their holes are aligned. The flaps can be adjusted so that the strips are

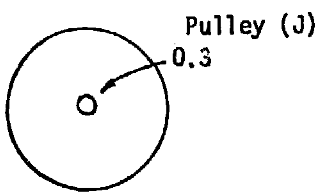


Front View

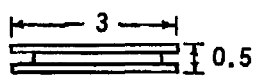
held tightly in place, or they may be soldered to the sides of the can.

Screw a short sheet metal screw (H) partway into the small can (G) to serve as an attachment point for the drive assembly string (O). Then, take the stiff wire (F) and insert it through the hole in the support, through the drum and through the glass tubing (I). Fire polish the ends of the glass to make them smooth. Finally, make sure the end of the wire rests in the hole in the base. The exposed end of the wire axle (F) may be bent for safety. The whole drum assembly should turn freely now.

(3) Drive Assembly

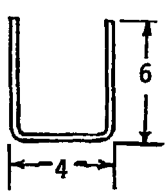


Top View



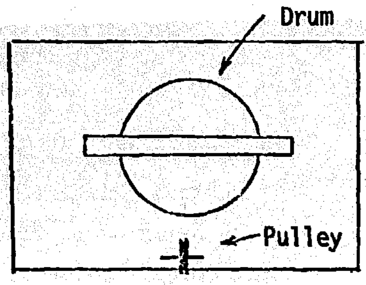
Side View

Saw a groove all around the circumference of the wood disc (J) to make it act as a pulley. Drill a hole 0.3 cm in diameter through its center. Make the pulley mount from the stiff wire (K) by bending it to a "U" shape.

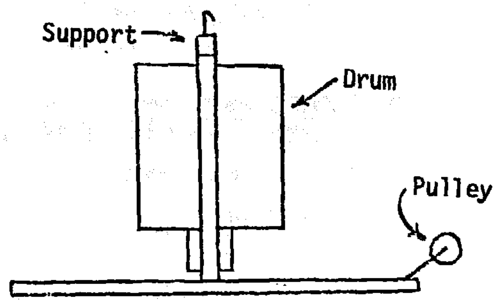


Pulley Mount (K)

Hammer the pulley mount into position on the base of the support after the pulley (J) has been slipped into place on the mount. It may be necessary

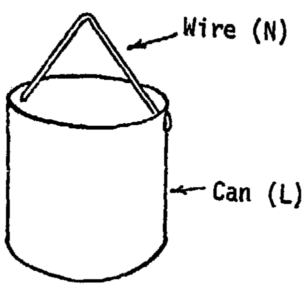


Top View

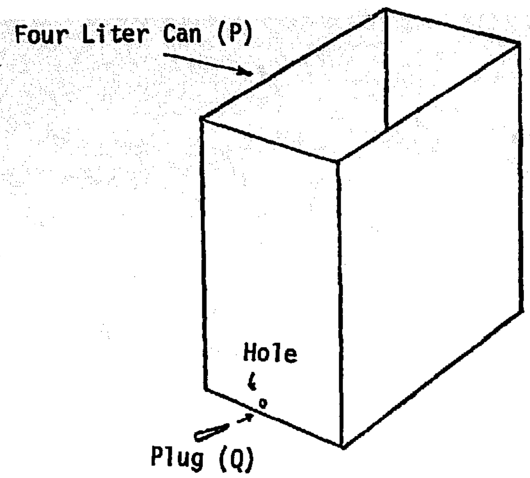


Side View

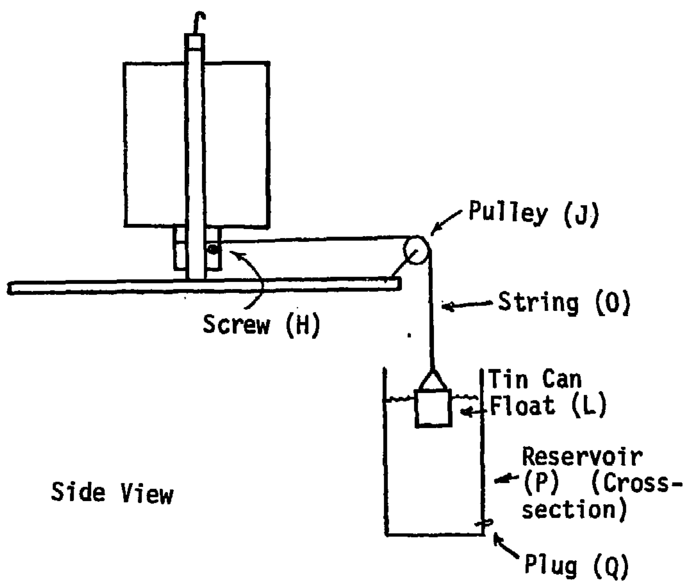
to drill small holes in the base for the pulley mount to fit into. The pulley and mount must be positioned at the front of the base directly in line with the drum assembly, and the pulley must extend beyond the edge of the base. The pulley mount can be bent over to insure that the pulley will extend out beyond the edge of the base, or alternatively, the holes into which the mount is inserted can be drilled at an angle.



Use the wire (N) to make a handle for the 1 liter can (L). Simply drill or punch two holes (0.2 cm diameter) near the top edge of the can, insert an end of the wire through each hole, and bend the ends up. Add the sand (M) to the can to act as ballast. This much weight should cause the can to float with only about 1 cm sticking above water level.

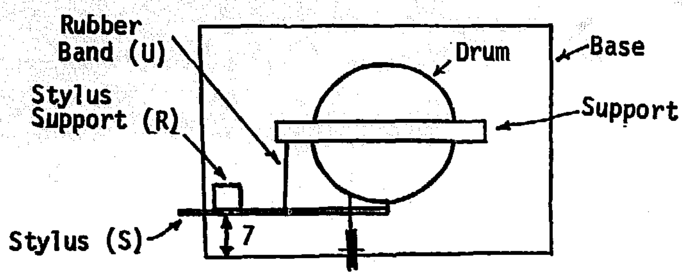


Make the 4 liter tin can (P) into a reservoir by removing its top. Tape the cut edges to prevent students from being cut. Drill or punch a small (0.15 cm diameter) hole at the bottom of the reservoir. Plug this hole with a pencil stub (Q) or piece of wood.

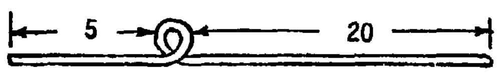


To set up the drive assembly, plug the hole in the reservoir (P) and fill it with water. Attach one end of the string (O) to the handle of the can (L) and make a small loop in the other end of the string. Put this loop around the screw (H) in the small tin can (G) under the drum, and wrap one turn of string around the small can. Run the string across the pulley (J), and float the tin can in the reservoir. Properly done, the float should lower gradually when the reservoir plug (Q) is pulled and water leaks out. As the float lowers, the string pulls on the drum causing it to slowly turn.

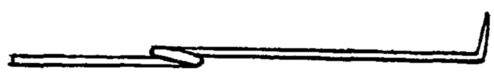
(4) Stylus Assembly



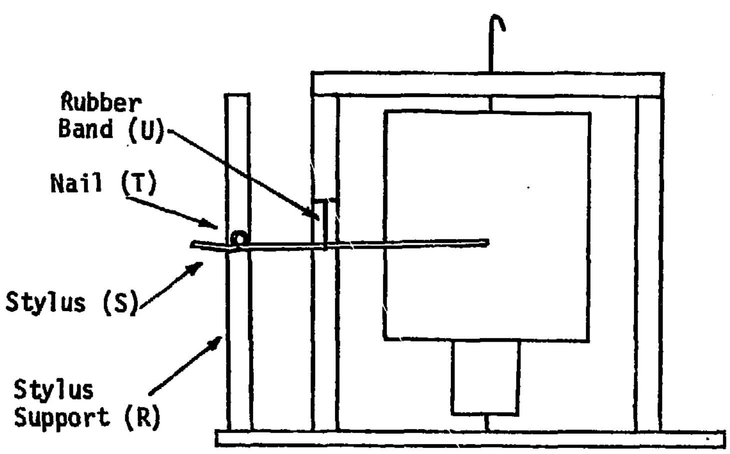
Top View



Side View of Stylus (S)



Top View



Front View

Nail or screw the stylus support (R) into position about 1.0 cm from one edge of the base, and 7 cm from the other edge. Make the stylus itself from the stiff wire (S) by making a loop in it about 5 cm from one end. Bend about 1 cm of the other end to a 90° angle to form the point. This point may be filed sharp to make a finer line. Position the stylus on the support by driving a nail (T) with a large head through the loop in the stylus. Drive the nail in only enough to allow the stylus to pivot freely without twisting a great deal. The position of the stylus point on the drum depends upon where on the stylus support the stylus is nailed, i.e., the higher the pivot point on the support, the higher on the drum the point of the stylus will strike. Finally, tie the rubber band (U) (break it at one point) to the upright support and to the middle of the stylus. Adjust this rubber band so that the stylus point strikes the drum firmly, yet lightly enough not to interfere with the rotation of the drum.

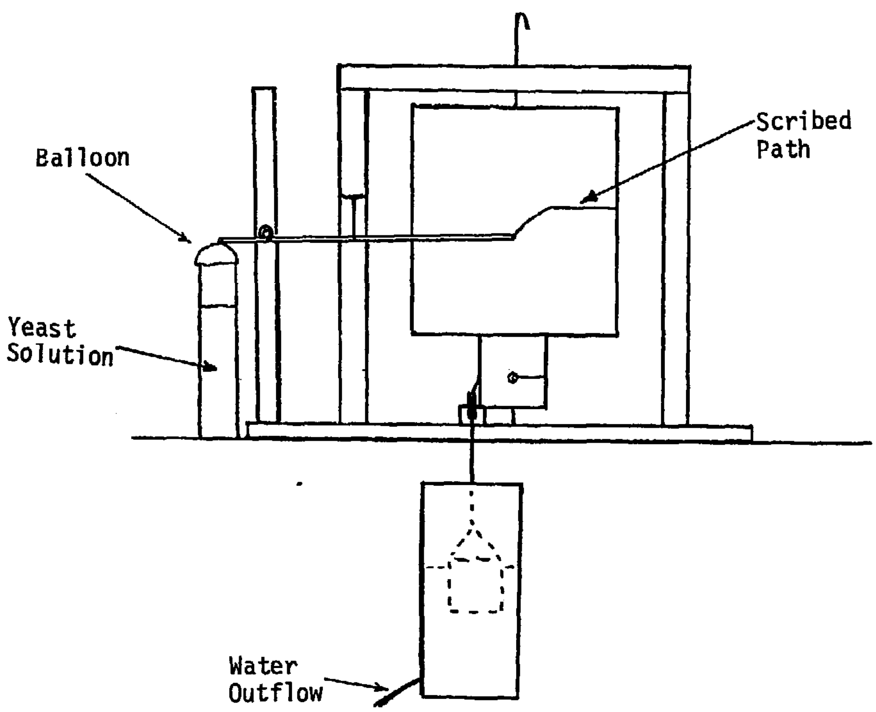
c. Notes

(i) To operate the kymograph, the drum must first be covered with a sheet of 17 cm x 50 cm glossy paper. Remove the drum from the support and attach the paper, glossy side out, to the drum with tape at the top and bottom. See that the seam where the two edges of the paper overlap is positioned in such a way that the stylus point will not catch on it (the seam) as the drum rotates.

Rotate the drum over a burning kerosene lamp. Hold the drum high enough so that the paper will not be scorched. Continue rotating it in the smoke until the drum is completely covered with carbon black. It takes about five minutes to cover the paper with carbon, requiring about 10 ml of kerosene. Handle the drum carefully since the carbon is easily scratched and rubbed off.

Replace the drum in the support, holding the stylus out of the way until the drum is in position. When the string to the float in the reservior is taut, the apparatus is ready to use.

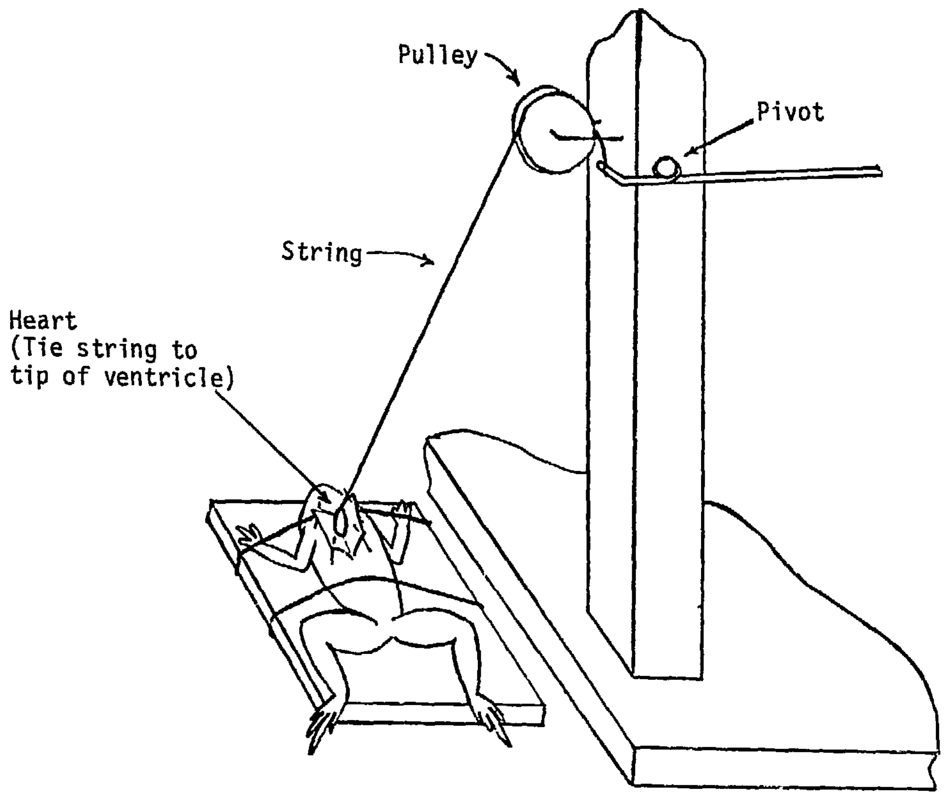
(ii) One example of the use of the kymograph will be given here. Refer to the drawing below:



Put some warm water, yeast, and sugar in a bottle or test tube and seal the end with an expandable membrane (a piece of balloon rubber works well). Place the solution under the end of the stylus so that the tip of the stylus rests on the balloon. Start the drum rotating by pulling the plug from the bottom of the reservoir. As the yeast respire, carbon dioxide gas is given off, gradually causing the balloon to expand, pushing the tip of the stylus up and its point on the drum down, leaving a scratch on the smoked paper. The slope of the scratched line indicates the rate of respiration of the yeast.

(iii) Use a clock, watch or other timing device to record time intervals (e.g., 30 seconds) and record these intervals by making a small mark on the drum each interval. These marks must be made as the drum revolves since the drum doesn't turn at a constant speed. This is because the velocity of the drum depends on the rate of flow of water from the reservoir which is not constant since the water pressure lowers as the depth lowers, thus causing the drum to slow down.

(iv) The stylus assembly may be altered to conform to requirements of other experiments. For example, the following illustration suggests how the stylus might be connected for studies of the heartbeat of an anesthetized frog:



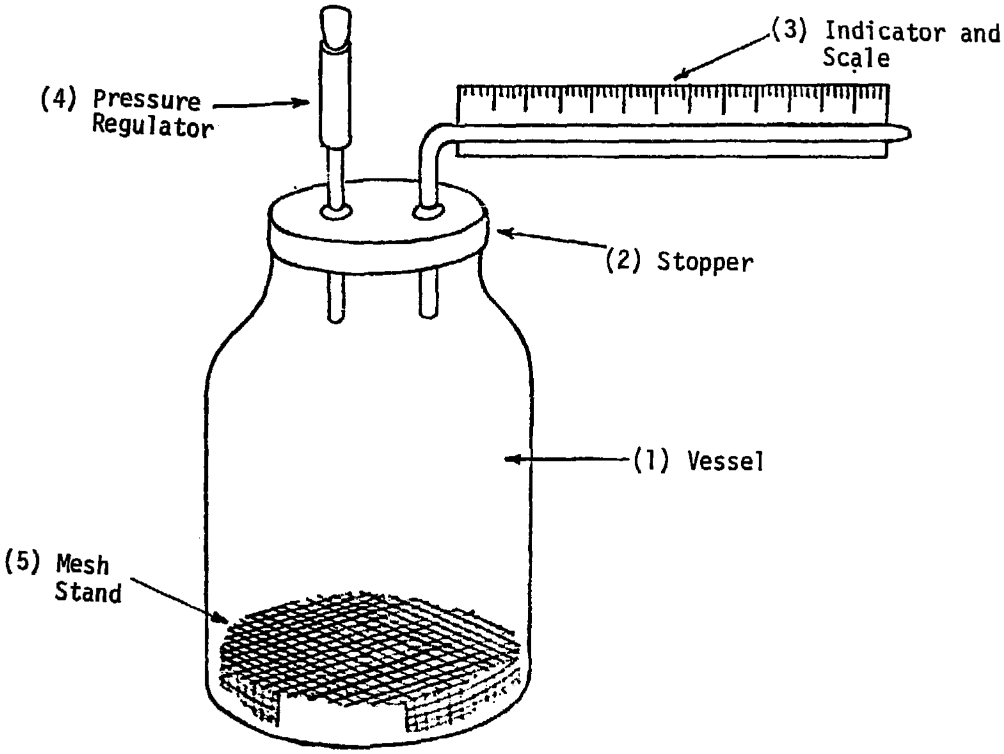
Here, as the frog's heart contracts and expands, its motion is translated into up and down movements of the stylus. Remember, the stylus acts as a lever, and the amount of movement of the pointer depends upon the relative lengths of the portions of the stylus to either side of the pivot point.

(v) The rate at which the drum revolves depends directly upon how fast the float lowers in the reservoir. Therefore, in order to make the float, and thus the drum, go faster, it is necessary either to enlarge the reservoir outflow hole or make several such holes. Conversely, to make the float and drum slower, a reservoir with a large cross-sectional area is needed. In this case, even though the float still drops the same distance per one revolution of the drum, more water must flow out of the larger can to cause it to drop the same distance as in a smaller can.

(vi) If, for any reason, it is necessary that the drum turn two or more consecutive revolutions, remember that the reservoir must be deep enough to allow the float to drop the additional distance required. To be precise, for each revolution of the drum, the float must lower a distance equal to the circumference of the small can which the drive string is wrapped around.

B. VOLUMETER

B1. Volumeter



a. Materials Required

Components	Qu	Items Required	Dimension
(1) Vessel	1	Wide Mouth Glass Jar (A)	Size depends on organism to be studied
(2) Stopper	1	2-Hole Rubber or Plastic Stopper or Screw Cap (B)	To fit vessel
(3) Indicator and Scale	1	Glass Tubing (C)	30 cm long, 0.75 cm outside diameter, 0.5 cm inside diameter
	1	Stiff Paper Strip (D)	20 cm x 2 cm
(4) Pressure Regulator	1	Glass Tubing (E)	4 cm long, 0.75 cm outside diameter, 0.5 cm inside diameter
	1	Rubber Tubing (F)	4 cm long, 0.75 cm inside diameter
	1	Tapered Wood or Glass Rod Plug (G)	To fit rubber tubing

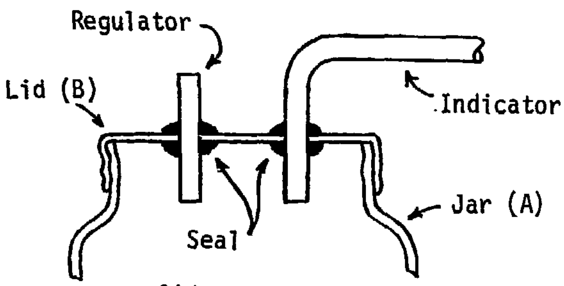
(5) Mesh Stand	1	Wire Mesh (H)	To fit vessel

b. Construction

(1) Vessel

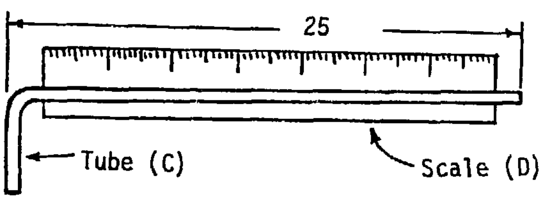
Almost any container (A) from a vial, to a test tube, to a jar will suffice. It must be a convenient size for the organism to be studied - a liter jar would not be used for small insects - and should have a tight-fitting lid or stopper.

(2) Stopper



Depending on what vessel is used, the stopper (B) could be a two-hole rubber stopper or a tight-fitting screw cap with two holes drilled in for glass tubing. If a jar lid is used, the openings must be sealed with clay or paraffin after the indicator and pressure regulator have been inserted to prevent gas leak. Seal the underside, also.

(3) Indicator and Scale

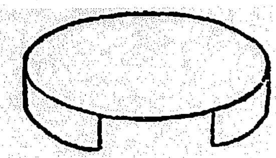


Bend a piece of glass tubing (C) at a 90° angle as indicated. Cement a paper scale (D) to the long arm, and add a drop of colored detergent solution to serve as an indicator.

(4) Pressure Regulator

This is a piece of glass tubing (E), topped with a section of rubber tubing (F) and a plug (G). To regulate the position of the indicator, one simply releases the plug for a short period of time.

(5) Wire Mesh

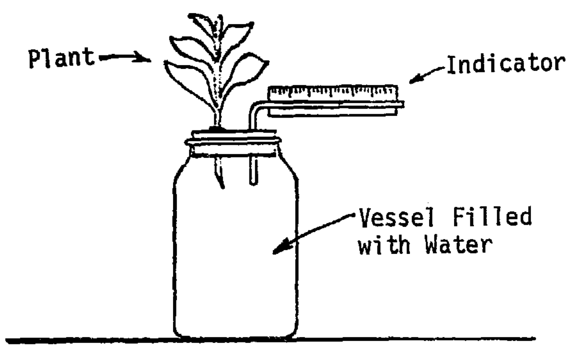


Cut the wire mesh (H) slightly larger than the diameter of the vessel. Bend the ends down to form a support on which the organism will be placed.

c. Notes

(i) If one wishes to study the oxygen uptake per unit time of an animal, a CO_2 absorber such as KOH should be placed in the vessel under the wire mesh support. As the animal respires, O_2 is taken up and pressure in the tube falls, causing the bubble to move toward the vessel. If one knows the size bore in the tubing, then one can compute the volume of gas being exchanged by noting the distance that the indicator moves per unit time.

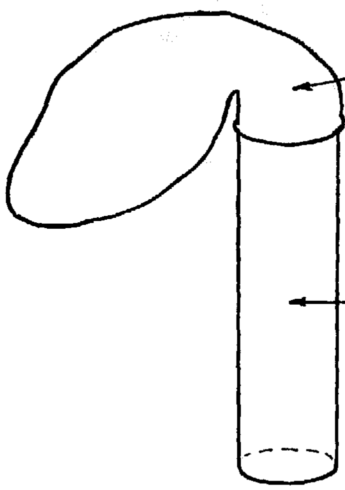
(ii) Transpiration may be measured by removing the pressure regulator from the top and inserting a broad-leaved plant cutting into the opening and sealing the joint with clay. Fill the container with water. Have the indicator bubble start at the open end of the sidearm tube. Allow the water to reach room temperature before setting the indicator bubble.



Volumeter Used as a
Transpirometer

C. FERMENTATION TUBES

Cl. Balloon Fermentation Tube



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Vial	1	Medicine Vial, Test Tube, or Small Bottle (A)	50 ml capacity
(2) Balloon	1	Balloon (B)	To fit vial opening

b. Construction

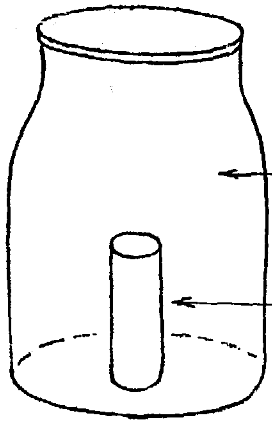
(1) Vial — Any small container (A) with a mouth narrow enough to stretch the open end of the balloon over will suffice.

(2) Balloon — Fit the open end of the balloon (B) over the bottle.

c. Notes

(i) Fill the vial with a yeast-sugar solution before attaching the balloon. As CO_2 is given off, it collects in the balloon from which it can be taken for analysis.

C2. Durham Fermentation Tube



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Jar	1	Wide-mouthed Glass Jar or Beaker (A)	500 ml capacity
(2) Vial	1	Medicine Vial or Test Tube (B)	50 ml capacity

b. Construction

(1) Jar

Any large wide-mouthed jar (A) or beaker will do. It must be large enough so that the small vial (B) can be covered completely with fermenting solution.

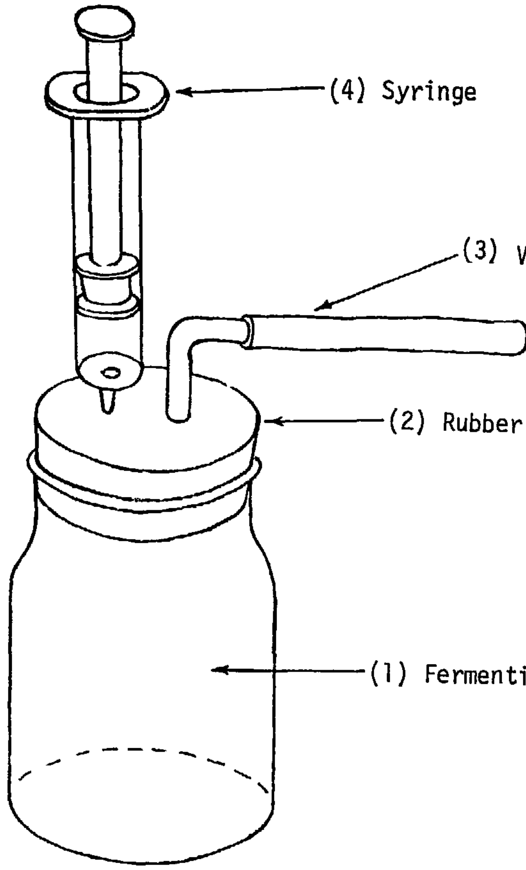
(2) Vial

The vial (B) should easily fit inside the jar where it can be completely submerged in solution.

c. Notes

(i) Fill both the jar and vial with a sugar-yeast solution. Place a finger over the open end of the vial, and invert it into the solution in the jar. As carbon dioxide is given off, some will be collected in the vial. This is useful for measuring relative amounts and rates of CO_2 production.

C3. Syringe Fermentation Tube



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Fermenting Bottle	1	Wide-mouth Jar (A)	300-500 ml capacity
(2) Rubber Stopper	1	2-Hole Rubber Stopper (B)	To fit fermenting bottle opening
(3) Vent Tube	1	Glass Tube (C)	6 cm long, 0.5 cm outside diameter
	1	Rubber Tube (D)	100 cm long, 0.5 cm inside diameter, 25-50 ml
	1	Plastic Syringe (E)	25-50 ml capacity

b. Construction

(1) Fermenting Bottle — Select a large glass or plastic container (A) with a wide mouth.

(2) Rubber Stopper — A two-hole rubber stopper (B) is needed to seal the bottle opening.

(3) Vent Tube

Bend the glass tube (C) to a right (90°) angle and insert it into one of the holes in the rubber stopper (B). Attach the rubber tubing (D) to the other end of the glass tube.

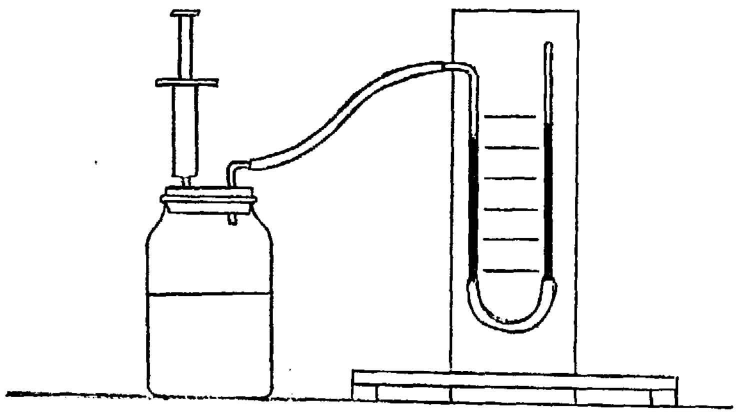
(4) Syringe

Insert the syringe nozzle (E) into the remaining hole of the stopper.

c. Notes

(i) One method of use for the syringe fermentation tube is as follows: Seal off the vent tube with a clamp or wood plug. Put about 250 ml of yeast solution in the fermenting bottle and put a known amount and concentration (e.g., 25 ml of 0.1 M) of glucose solution in the syringe. Inject the sugar water into the yeast solution and collect the carbon dioxide given off in the syringe.

(ii) Since it is difficult to accurately measure the amount of gas given off by the method described in (i) above, a further refinement is as follows:

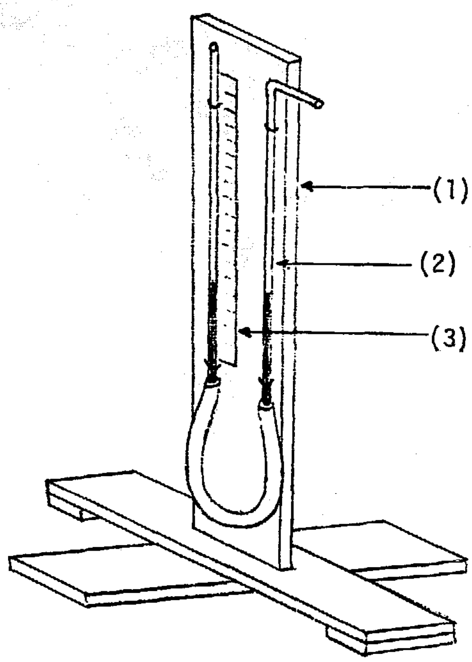


Fermentation Tube and
Manometer Combination

Connect the free end of the vent tube to a U-tube manometer (see VIII/D1). Fill the fermenting bottle with yeast solution, and add a measured amount of sugar water. As carbon dioxide is given off, continually raise the syringe plunger so as to keep the two columns of the manometer equal height. Continue this until gas is no longer evolved. When the gas has stopped evolving, the amount of gas trapped in the syringe will be a very accurate measure of the total amount of gas given off since use of the manometer insures that pressure in the rest of the system is maintained at the original level.

D. MANOMETER

D1. Manometer

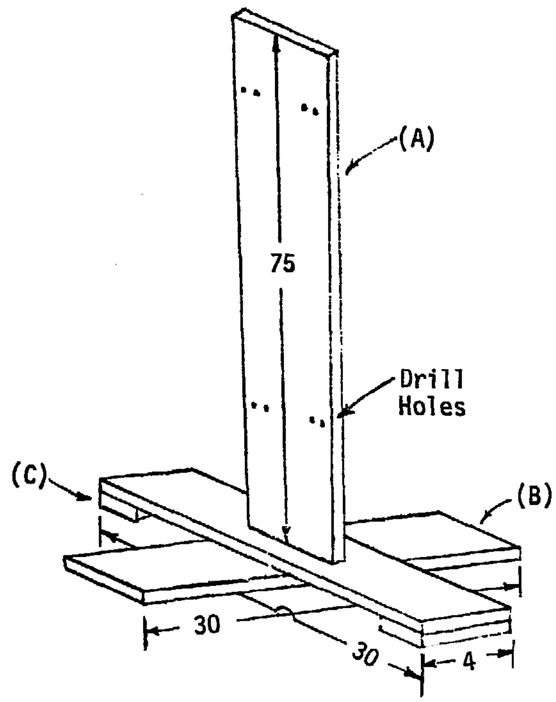


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Stand	1	Wood (A)	75 cm x 8 cm x 2 cm
	2	Wood (B)	30 cm x 4 cm x 2 cm
	2	Wood (C)	4 cm x 4 cm x 2 cm
(2) "U" Tube	2	Glass Tubing (D)	60 cm long, 0.75 cm outside diameter, 0.5 cm inside diameter
	1	Rubber Tubing (E)	50 cm long, 0.7 cm inside diameter
	4	Fine Wire (F)	8 cm long
(3) Scale	1	Graph Paper (G)	40 cm long, 2 cm wide

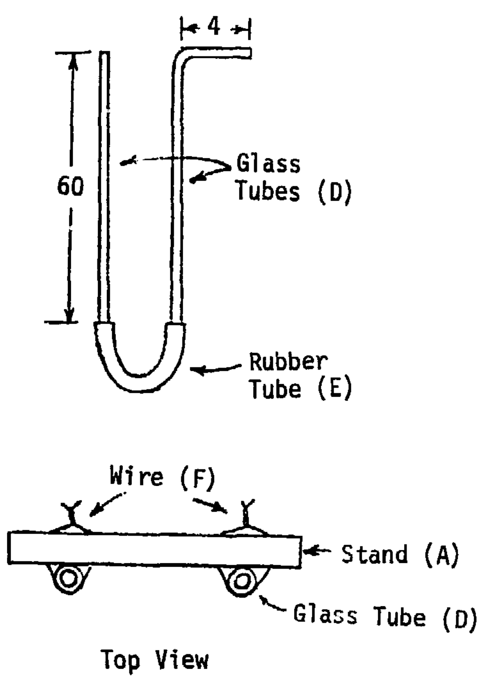
b. Construction

(1) Stand



Nail two pieces of wood (B) together at right angles to form the base of the stand. Nail the square blocks (C) under the upper board to provide stability. Finally, nail the other board (A) into an upright position on the base. Drill four pairs of small holes (0.2 cm in diameter) into the upright in such a position that each pair of holes will be in line with the position of the "U" tube when it is in place.

(2) "U" Tube



Heat one of the pieces of glass tubing (D) about 4 cm from one end and bend it to a right (90°) angle. Attach the rubber tubing (E) to the end of each piece of glass tubing (D). Fasten this "U" tube to the stand upright (A) by passing the fine wires (F) around the tubing, through the holes in the upright, and twisting the wires tight to hold the tubes in place. Do not fasten the straight tube too tight in order to allow it to slide up and down to adjust the height of the indicator liquid.

(3) Scale

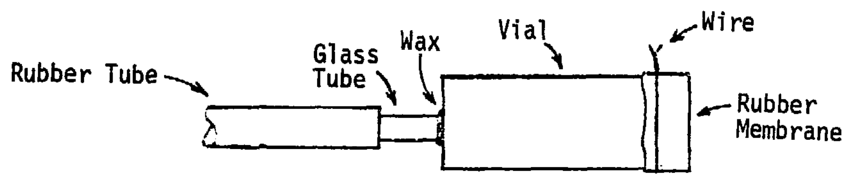
Glue or tape a piece of graph paper (G) between the two tubes to serve as a scale. Suitable scales can also be made by hand with plain paper and a rule.

c. Notes

(i) Use the manometer to detect and measure changes in pressure. To do so, it must be half filled with an indicator solution like colored water (use food coloring or ink) which serves as well as anything as an indicator. In normal usage, a rubber tube is used to connect the manometer to a closed system in which the pressure is changing (e.g., a jar containing a yeast-sugar solution or a jar containing a respiring animal with KOH to absorb the CO_2 given off. With the yeast solution, pressure in the jar will increase as the yeast oxidize the sugar. See VIII/C3 for further detail. In the case of the respiring animal, pressure will decrease as it takes up O_2 and gives up CO_2 which is taken up by the KOH.). As pressure changes, the indicator solution will move up or down depending on the direction of the pressure change.

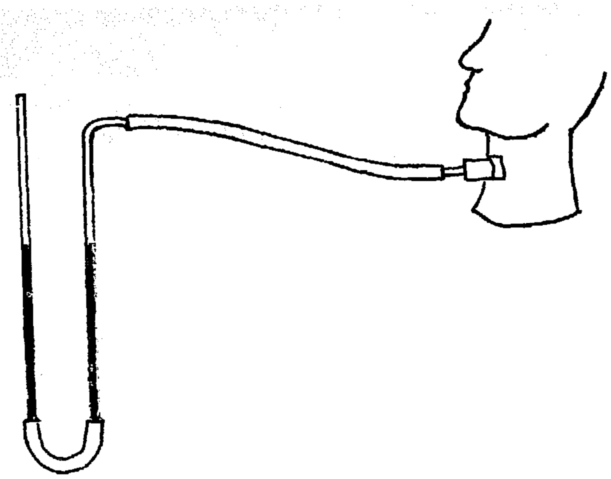
(ii) A detailed, specific example of the use of the manometer is as follows:

Drill a hole in the bottom of a plastic medicine vial. This hole needs to be large enough to insert a short piece of glass tubing (5 cm long). Attach a piece of rubber tubing (100 cm) to the glass tube, and insert the glass tube into the hole in the bottom of the vial. Seal the joint with melted wax from a candle. Stretch a rubber membrane or piece of toy balloon over the open end of the vial and fasten it securely with a string or rubber band to hold the membrane on the vial.



Side View

Attach the end of the rubber tubing to the bent piece of glass tubing on the manometer "U" tube. Slide the straight tube up or down to make the height of the indicator solution the same in both tubes. Place the rubber membrane against the carotid artery of the throat. A pulse can be seen by the rythmic rise and fall of the indicator solution. (See illustration on next page.)

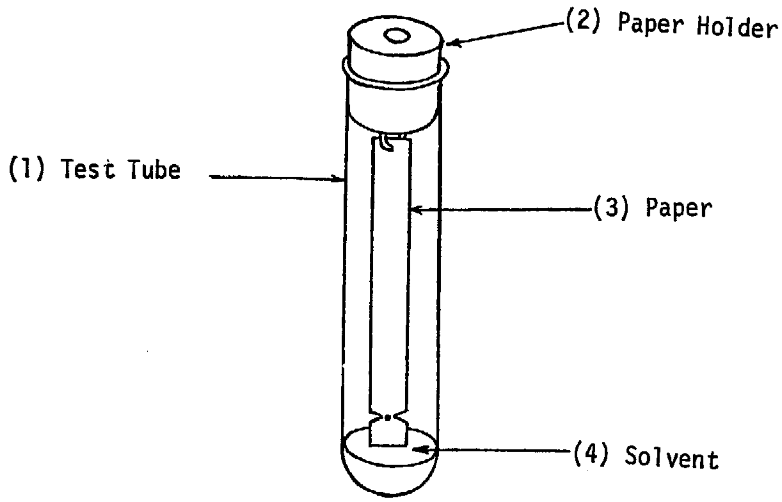


(iii) The manometer may be made from a single piece of glass tubing by bending it in a flame to a 180° angle. While this eliminates the need for a rubber tube, it also eliminates the possibility of adjusting the heights of the indicator solution.

(iv) Further instruction in the use of the manometer may be found in the Nuffield O-Level Biology, Teacher's Guide III, p 34, and the BSCS Blue Version text, p L8, L95, among other sources.

E. CHROMATOGRAPHY APPARATUS

E1. Chromatographic Device



a. Materials Required

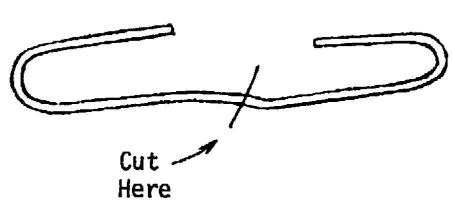
Components	Qu	Items Required	Dimensions
(1) Test Tube	1	Test Tube (A)	15 cm long, 2 cm diameter
(2) Paper Holder	1	1-Hole Stopper (B)	To fit test tube
	1	Paper Clip (C)	--
(3) Paper	1	Filter Paper (D)	1 or 2 cm shorter than the length of the test tube
(4) Solvent	--	Acetone (E)	2 ml
	--	Petroleum Ether (F)	23 ml

b. Construction

(1) Test Tube

Use a rack or holder to support the test tube (A).

(2) Paper Holder



Open up the paper clip (C) and cut it as shown. A short piece of wire can be bent to the same shape, too. Punch the U-shaped piece of clip or wire through one end of the paper (D) and force the ends of the wire up into the one-hole stopper (B) until it is held fast.

(3) Paper — Use standard filter paper (D) or chromatography paper if it is available. Cut it about 1.0 cm wide.

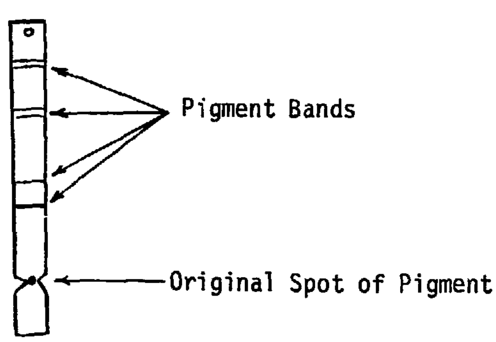
(4) Solvent — Mix the acetone (E) and petroleum ether (F) and add the mixture to the test tube.

c. Notes

(i) This chromatographic device is used to separate plant pigments. To prepare the sample of pigments, grind several heavily pigmented plant leaves together with some fine sand and about 5 ml of acetone. When thoroughly ground, filter this mixture through filter paper. Alternatively, heat several finely chopped leaves in about 5 - 10 ml of alcohol in a water bath. Do not heat the alcohol directly. Heat this mixture until the liquid is dark green.

Avoid both touching the surface of the paper with the fingers (oil affects the results) and having the paper touch the table where the pigment's to be placed. Thus, support the paper strip between two pencils or other small objects. About 1 cm from one end of the paper, place a small drop of pigment. This is most easily done with a fine-pointed pipette or a hypodermic syringe. When the first drop is dry, add another. Try to make the spot as small and as densely colored as possible. At least four drops should be placed one atop the other.

Make a notch in the paper on each side of the spot to mark its position. Attach the paper to the wire and put the wire into the stopper. Insert the paper holder in the test tube so that the end of the paper is in the solvent with the spot about 0.5 cm above the level of the liquid. It may be necessary to adjust the paper holder to keep the paper at the proper level. When the upper level of the solvent has soaked into the paper almost to the paper holder wire, remove the chromatogram and allow it to dry. The bands of color can be studied when the chromatogram is thoroughly dry. A number of excellent references exist describing additional exercizes and information for chromatography.



Finished Chromatogram

IX. MULTIPURPOSE SYRINGES

Disposable plastic syringes afford a variety of uses in biological studies. A few of these will be given in this section. Additionally, syringes can be used as pipettes, burettes, etc., and for many of the functions normally taken by test tubes. They are potentially one of the most useful items in the laboratory. All syringes in this chapter are to be used without their needles. The categories given below have been arrived at according to the function of the syringe within the system.

Readers with special interest in disposable syringes are referred to Paul D. Merrick, Experiments with Plastic Syringes, and two articles by Andrew Farmer in the School Science Review.

A. INJECTION AND EXTRACTION SYSTEMS

In these devices, disposable syringes are used for accurately injecting or extracting precise amounts of materials into or out of closed systems.

B. COLLECTION APPARATUS

Here, syringes are used to collect gases in measurable quantities.

C. REACTION CHAMBER

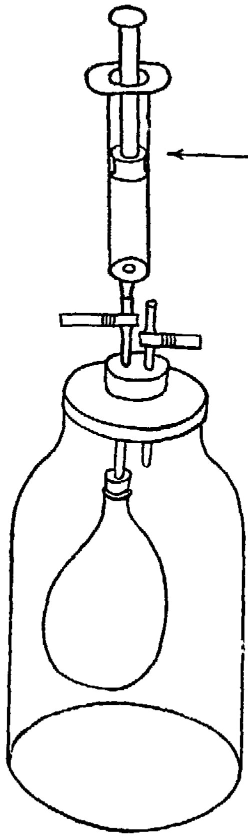
In this device, the syringe itself is used as the container for the reactions.

D. RESPIROMETERS

Two versions of respirometers fashioned from plastic syringes are given.

A. INJECTION AND EXTRACTION APPARATUS

A1. Diffusion Chamber ©



a. Materials Required

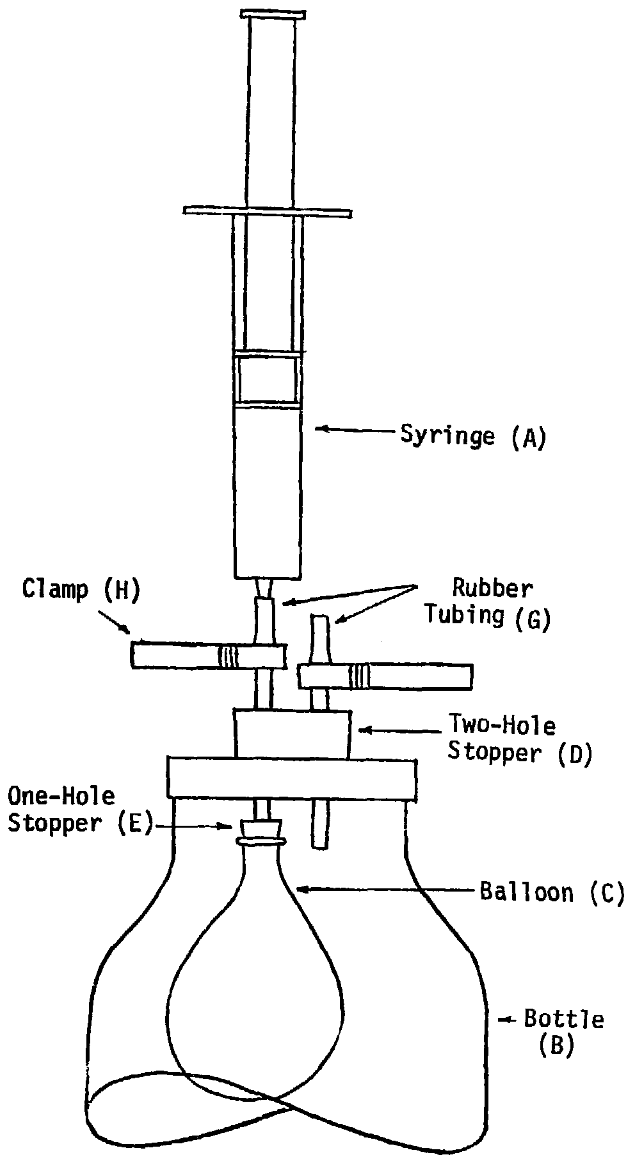
Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Syringe (A)	20-35 cc
(2) Chamber	1	Glass Bottle (B)	1 liter
	1	Balloon (C)	--
	1	2-Hole Stopper (D)	--
	1	1-Hole Stopper (E)	--
	2	Glass Tubing (F)	9 cm long, 0.5 cm diameter
	2	Rubber Tubing (G)	7 cm long, 0.4 cm diameter
	2	Clamps (H)	CHEM/IV/A4 or A5

©From Andrew Farmer, "The Disposable Syringe: Additional Experiments," School Science Review, CLXXVIII (1970), 61-62.

(1) Syringe

Use the syringe (A) to inject air into the chamber.

(2) Chamber



Side View

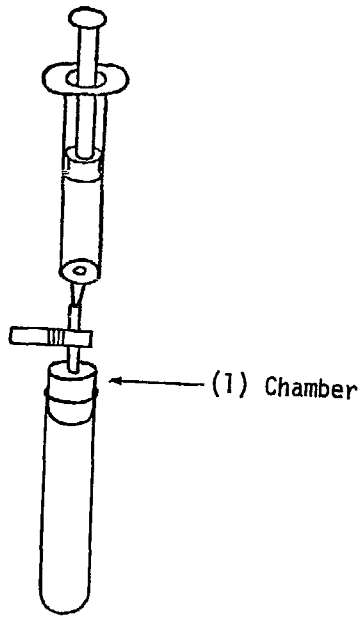
Take the top from the glass bottle (B) and drill or punch a hole in the center of it which allows for a tight fit of the two-hole stopper (D), and then glue the stopper in place. Insert one of the glass tubes (F) into the one-hole stopper (E) so that one end of the glass tube is even with the end of the stopper. Next, insert the two glass (F) tubes into the two-hole stopper, making sure that the one with the one-hole stopper attached to it will be inside the bottle when the lid is placed on the bottle. Place the balloon (C) over the one-hole stopper and glue it into place, thus preventing a gas leakage at this end. To the two ends of the glass tubes which are to be outside of the bottle, attach the sections of rubber tubing (G). To the glass tube having the one-hole stopper on it, connect the rubber tubing to the syringe (A). Finally, place the clamps (H) over both pieces of rubber tubing.

c. Notes

(i) This apparatus is used to demonstrate the diffusion of a gas through a permeable membrane. One such experiment will be described here. It is concerned with the diffusion of carbon dioxide through a membrane. Remove the clamp from the piece of rubber tubing going to the syringe. Next, place 2 - 3 g of baking soda ($NaHCO_3$) into the syringe to which is added 8 - 10 ml of vinegar. Immediately force the mixture into the balloon using the plunges in the syringe, and then replace the clamp on the rubber tubing. Allow the apparatus to rest for 24 hours. Place the syringe on the other piece of rubber tubing, remove the clamp, and draw out some of the gas in the bottle (not in the balloon) into the syringe. This gas should contain a largc proportion of carbon dioxide. To show this, inject the gas into a solution of limewater in which a white precipitate will be formed.

(ii) Plastic tubing can be used in lieu of rubber tubing.

A2. Anesthetizing Chamber ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Chamber	1	Syringe (A)	25-50 cc
	1	Test Tube (B)	10 ml
	1	1-Hole Stopper (C)	--
	1	Clamp (D)	CHEM/IV/A4 or A5
	1	Glass Tubing (E)	5 cm long, 0.5 cm diameter
	1	Rubber Tubing (F)	3 cm long, 0.4 cm diameter

b. Construction

(1) Chamber

Insert the piece of glass tubing (E) into the one-hole stopper (C) so that a small portion of it extends out of the end to be placed in the test tube (B). Next, slide the rubber tubing (F) over the other end of the glass tube and

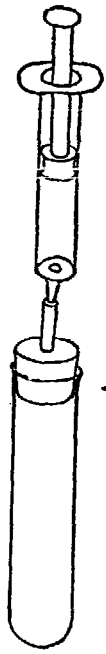
©From Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 8.

connect this to the syringe (A). Finally, insert the one-hole stopper into the test tube (B) and pinch the rubber tubing shut by using the clamp (D).

c. Notes

(i) This anesthetizing system can be employed in one of two ways. First, small insects can be put into the barrel of the syringe. The clamp is removed, the stopper is taken out of the test tube, and the plunger is depressed as far as possible without crushing the insects. The clamp is then replaced and a gas suitable for anesthetizing the insects (for example, carbon dioxide) is put into the test tube and the stopper is replaced into the test tube. The clamp is then removed and gas is drawn into the barrel of the syringe, anesthetizing the insects. Alternatively, the barrel of the syringe and the test tube can reverse roles.

A3. Enzymatic Reaction Chamber ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Chamber	1	Syringe (A)	25-50 cc
	1	Test Tube (B)	10 ml
	1	1-Hole Stopper (C)	--
	1	Glass Tubing (D)	5 cm long, 0.5 cm diameter
	1	Rubber Tubing (E)	3 cm long, 0.4 cm diameter

b. Construction

(1) Chamber

Insert the piece of glass tubing (D) into the one-hole stopper (C) so that a small portion of it extends out of the end to be placed in the test tube (B). Next, slide the

©From Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 19.

rubber tubing (E) over the other end of the glass tube and connect this to the syringe (A). Finally, insert the one-hole stopper into the test tube.

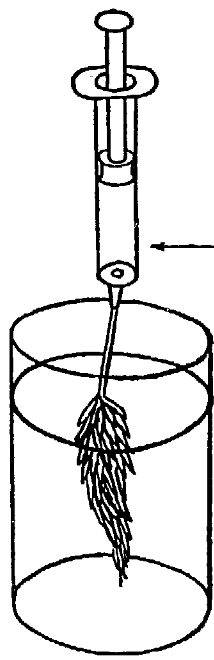
c. Notes

(i) To operate this piece of apparatus, remove the stopper from the test tube and place a suspension of dried yeast and water into it. Place a 3% solution of hydrogen peroxide (H_2O_2) in the syringe. Replace the stopper in the test tube and inject the hydrogen peroxide solution into the test tube. Oxygen gas is given off as a result of the reaction.

(ii) The reaction can be made quantitative by carefully noting the amount of hydrogen peroxide used.

B. COLLECTION APPARATUS

B1. Plant Gas Collection Device ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Syringe (A)	20-25 cc
	1	Beaker (B)	100-500 ml
	1	Aquatic Plant (C)	--

b. Construction

(1) Syringe

Fill the syringe (A) with water and then keep the plunger in a fixed position. Fill the beaker (B) with water. Cut a sprig from a fully leaved plant (C), for example, pondweed (elodea), and put the cut stem into the nozzle of the syringe. Finally, place the rest of the

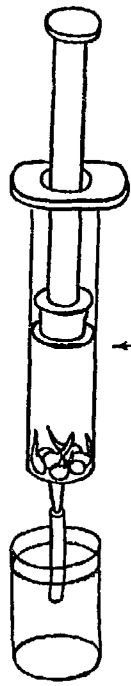
©From Andrew Farmer, "The Disposable Syringe: Additional Experiments," School Science Review, CLXXVIII (1970), 63-64.

sprig into the beaker of water.

c. Notes

(i) The bubbles of gas given off from the stem of the plant as it carries on respiration and/or photosynthesis will be trapped in the syringe where the gas may be kept for analysis. At the end of the experiment, the water in the syringe should be boiled and allowed to cool to remove dissolved gases. Several plants may have to be used to obtain a sufficiently large amount of gas for analysis. Since photosynthesis consists of two reactions, a light reaction and a dark reaction, it would be desirable to do two experiments--one with the plants in the presence of light and one with the plants in the dark. The gases can then be analyzed to determine the differences in constitution.

B2. Seedling Gas Collection Device



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Syringe (A)	35-50 cc
	1	Beaker (B)	50-100 ml
	1	Rubber Tubing (C)	5 cm long, 0.4 cm diameter
	10	Day-old Bean Seedlings (D)	--

b. Construction

(1) Syringe

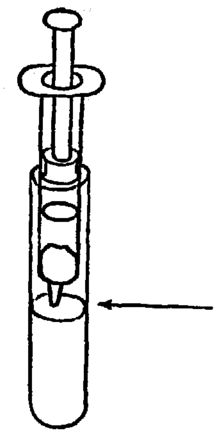
Fasten the rubber tubing (C) to the nozzle of the syringe (A) and place the bean seedlings (D) in the barrel of the syringe. Next, fill the beaker (B) with water and put the end of the tubing in the water to prevent gas from escaping from the syringe.

c. Notes

(i) Day-old bean seedlings carry on only respiration. Thus, the gas collected in the syringe after a period of six hours will be primarily carbon dioxide (CO_2). This can be shown by injecting the collected gas into a solution of limewater in which a white precipitate will be found. No reaction will occur if normal air is injected into the limewater. This same experiment can be done using insects.

C. REACTION CHAMBER

C1. Carbon Dioxide Production Chamber©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Chamber	1	Syringe (A)	1-10 cc
	1	Test Tube (B)	10-20 ml
	1	Small Piece of Wool (C)	--
	1	Dry Yeast (D)	0.5 g

b. Construction

(1) Chamber

Place the wool (C) loosely in the bottom of the barrel of the syringe (A) and sprinkle the dry yeast (D) over it. Replace the syringe plunger and fill the test tube (B) with a sugar and water solution.

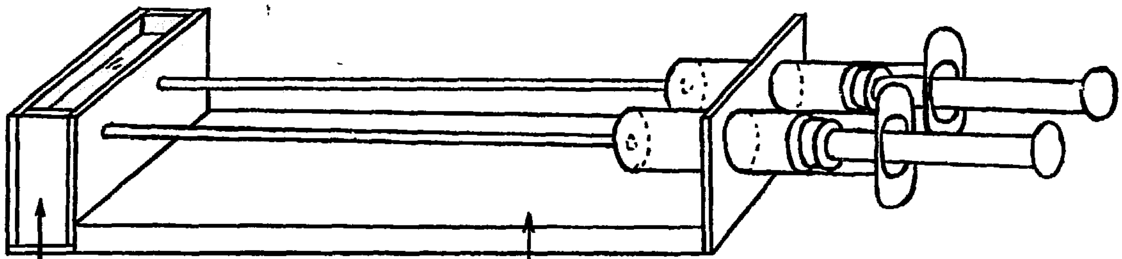
c. Notes

(i) To operate, depress the plunger until it almost touches the yeast, insert the nozzle of the syringe into the test tube, and withdraw the plunger, thus filling the syringe with sugar water. Set the apparatus aside and check it after 24 hours. The syringe will be full of gas which can be shown to be carbon dioxide (CO_2).

©From Andrew Farmer, "The Disposable Syringe: Additional Experiments," School Science Review, CLXXVIII (1970), 64-65.

D. RESPIROMETERS

D1(1). Respirometer ©



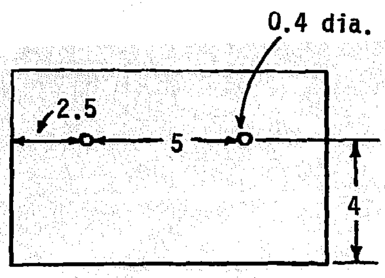
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Reservoir	2	Wood (A)	10 cm x 6 cm x 0.5 cm
	2	Wood (B)	6 cm x 1.5 cm x 0.5 cm
	1	Wood (C)	10 cm x 2.5 cm x 0.5 cm
	2	Stiff Plastic Tubing (D)	3 cm long, 0.4 cm diameter
(2) Body	1	Wood (E)	30 cm x 10 cm x 2 cm
	1	Wood (F)	10 cm x 6 cm x 0.5 cm
	2	Syringes (G)	25-35 cc
	2	Flexible, Clear Plastic Tubing (H)	30 cm long, 0.5 cm diameter

©From Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 11.

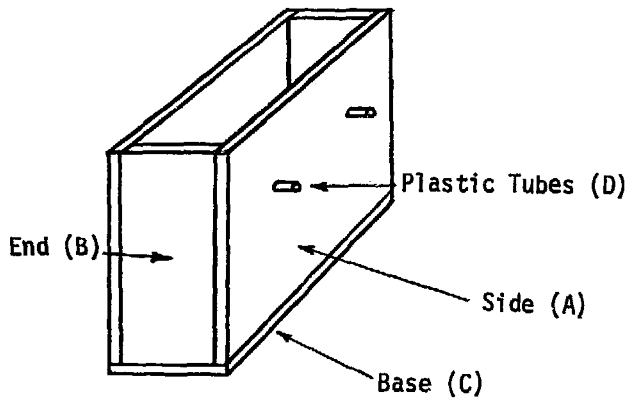
b. Construction

(1) Reservoir



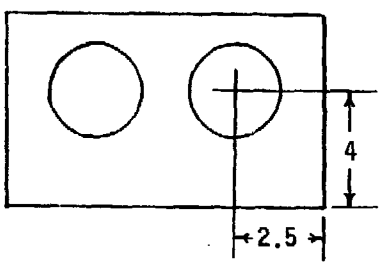
Front View of
Wood (A)

In one of the pieces of wood (A), drill two holes 0.4 cm in diameter into which the two pieces of stiff plastic tubing (D) are to be glued so that they stick out equally on each side of the wood.



Glue the two longer pieces of wood (A) to the base (C), and then glue the narrow pieces (B) between the base and sides. Be sure to use a waterproof glue. Coat the inside of the reservoir with either waterproof glue or paint.

(2) Body



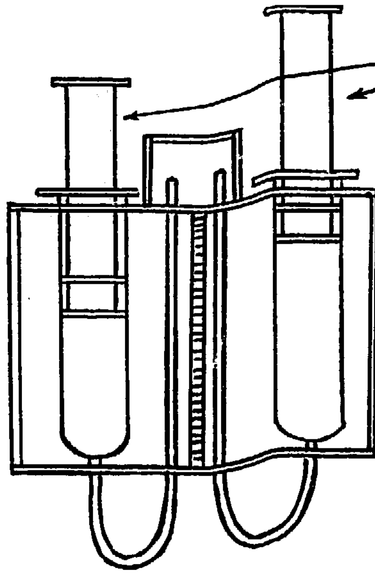
Front View of
Wood (F)

Into one piece of wood (F), drill two holes slightly larger in diameter than the syringes (G) used. Nail this piece to the base (E). Glue the reservoir to the other end of the base with the plastic tubes (D) facing the wood piece (F). Put both syringes (G) through their holes and attach the syringe nozzles to the plastic outlets of the reservoir with the clear tubing (H). The syringes may be glued in position if desired.

c. Notes

(i) This apparatus can be used to study the respiration rates of small animals and plants. One syringe serves as a control and the other as a chamber for the animals or plants (e.g., flies, seedlings). Into each syringe, put a small container of powdered or liquid lye (NaOH or KOH) to absorb carbon dioxide. At the beginning of the experiment, draw some of the water in the reservoir into the tubes so that the two water columns are the same length. If the syringe plungers are put at the same position, then the volumes of each system will be the same to begin the experiment. As the organisms in one syringe respire, carbon dioxide will be given off and taken up by the lye. This will cause a change in the pressure of the air in the syringe and thus, cause a change in the relative lengths of the water columns. Varying the diameter of the plastic tubes will cause the changes to be faster or slower depending on whether the diameter is decreased or increased, respectively.

D1(2). Respirometer ©



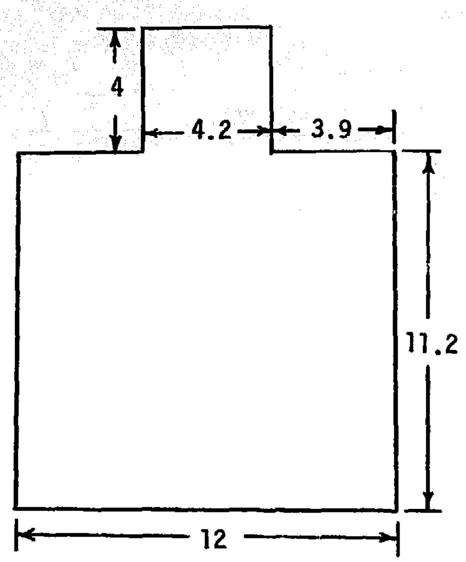
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Reservoir	1	Wood (A)	15.2 cm x 12 cm x 0.6 cm
	2	Wood (B)	12 cm x 6 cm x 0.6 cm
	2	Wood (C)	10 cm x 6 cm x 0.6 cm
	2	Wood (D)	6 cm x 4 cm x 0.6 cm
	1	Wood (E)	6 cm x 3 cm x 0.6 cm
	2	Stiff Plastic Tubing (F)	3 cm long, 0.4 cm diameter
(2) Syringes	2	Syringes (G)	25-35 cc
	2	Flexible, Clear plastic Tubing (H)	15 cm long, 0.5 cm diameter
	1	Waterproof Paper (I)	11 cm x 0.5 cm

©From Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 31.

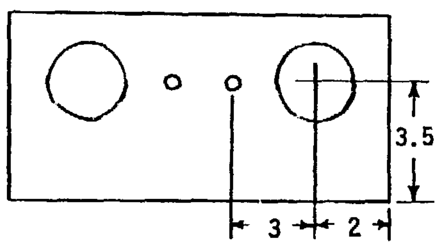
b. Construction

(1) Reservoir

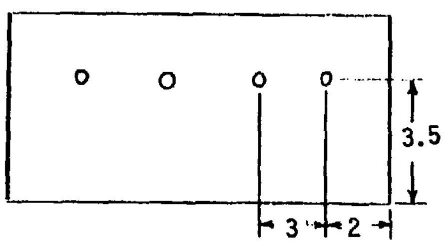


Base (A)

Cut the base (A) as shown in the drawing. Take one of the pieces of wood (B) and drill two holes equal in diameter to the diameter of the barrels of the syringes (G) being used. In addition, drill two holes 0.4 cm in diameter for the two pieces of stiff plastic tubing (F). Take this piece of wood and, using waterproof glue, attach it to the end of the base having the wood projection. Next, glue the two sides (C) in place.

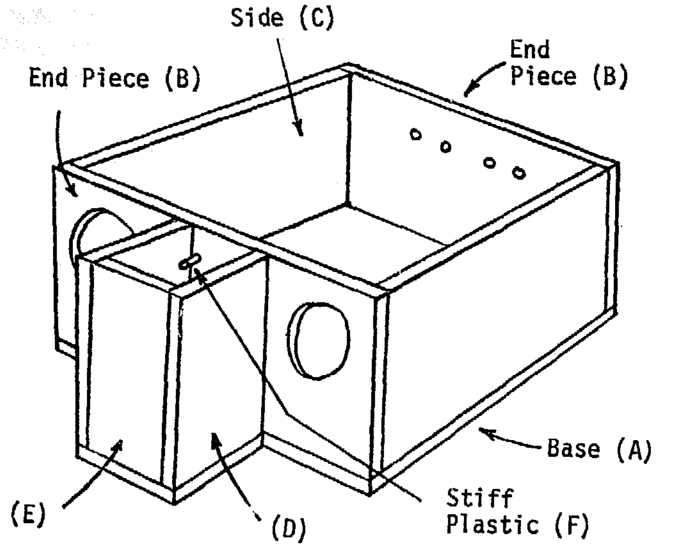


End Piece (B)



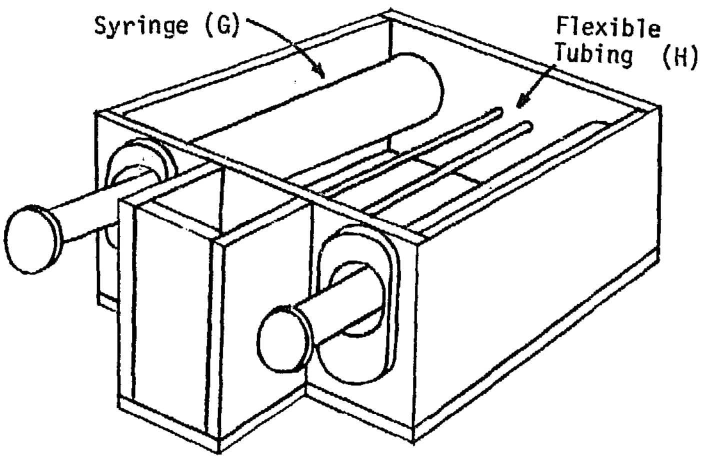
End Piece (C)

Drill two holes in the other piece of wood (B) equal in diameter to the nozzle of the syringes (G), and two holes equal in diameter to that of the flexible plastic tubing (H).



Secure this piece of wood in place using waterproof glue. Using the three pieces of wood (D,E) and waterproof glue, form a reservoir against the end of the box using the wood projection as a base. Paint the inside of the entire apparatus using an oil base paint in order to prevent the wood from warping.

(2) Syringes



Glue the syringes (G) in the holes made for them and attach the flexible, clear plastic tubing (H) as shown. Finally, seal either all inside or outside seams with waterproof glue. If so desired, a scale (I) may be placed between the two pieces of flexible tubing to measure the relative movement of water in the two tubes.

c. Notes

(i) Place the respiring organism in one syringe along with a small container of sodium hydroxide (NaOH, to absorb carbon dioxide), and place a similar container of sodium hydroxide in the other syringe along with some inert material to compensate for the volume of the organism. When the apparatus has been correctly set up, fill the small reservoir with colored water (use a non-fast dye), and fill the main reservoir with room-temperature water to serve as insulation. Setting both syringes at the same volume should cause water to be drawn from the small reservoir into the plastic tubing to the same mark on the scale. As the organism respires, more water will be drawn from the reservoir (the dye allows it to be easily seen), and the change will be measurable.

If desirable, the piston of the syringe containing the organism may be depressed to reset the water level in the tubing.

(ii) The advantage of this respirometer over the previous one described is that with this apparatus, the water both keeps the syringes and the water in the plastic tubing at the same temperature thus eliminating the possibility of temperature variation between one syringe and the other which in turn might cause a difference in respiration rates.

BIBLIOGRAPHY

A number of texts have proved to be extremely valuable references to the Inexpensive Science Teaching Equipment Project, and these are listed below.

American Peace Corps, Science Teachers Handbook, (Hyderabad, India: American Peace Corps, 1968).

This handbook contains many ideas for improvising science teaching equipment.

Association for Science Education, The School Science Review, (London: John Murray).

A quarterly journal containing articles on science experiments and equipment in all the sciences at all school levels.

Association for Science Education, The Science Master's Book, (London: John Murray).

Part 2 of Series 1 and 2, and Part 3 of Series 3 and 4 of The Science Master's Book contain articles from The School Science Review dealing with experiments and equipment in biology.

Knudsen, Jens W., Biological Techniques, (New York: Harper and Row, 1966).

An excellent reference for those persons interested in collecting, preserving, and illustrating animals and plants.

Merrick, Paul D., Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968).

This book and accompanying materials form a good basis for developing curriculum materials based on disposable plastic syringes.

Morholt, Evelyn, Paul F. Brandwein, and Alexander Joseph, A Sourcebook for the Biological Sciences, (New York: Harcourt Brace, and World, 1966).

This book gives many ideas and methods concerned with the day-to-day teaching of biology.

The UNESCO Sourcebook in Science Teaching, (Paris, France: UNESCO, 1972).

This book, recently revised, contains many simple ideas for teaching science at a relatively elementary level.

In addition to the above texts, the materials from a large number of projects in the files of the International Clearinghouse on Science and Mathematics Curricular Developments at the University of Maryland have also been particularly valuable. Further details of these projects, and the three listed below, may be found in:

The Seventh Report of the International Clearinghouse on Science and Mathematics Curricular Developments 1970, (College Park, Maryland: University of Maryland, 1970).

This is a source of information on curriculum projects throughout the world including project director, materials available, publishers, etc. The Eighth Report will be available in late 1972.

Biological Sciences Curriculum Study (BSCS).

This is the major United States project concerned with the biological sciences at the secondary level. One publication, Innovations in Equipment and Techniques in the Biology Teaching Laboratory, (Boston: D. C. Heath, 1964) is especially useful to those interested in equipment development.

FUNBEC, Science Education Projects for Primary, High School and College Level.

A Brazilian project, FUNBEC has developed an excellent series of inexpensive science kits including some dealing with biology.

Nuffield Foundation, Nuffield Biology.

The Nuffield projects are the major British curriculum projects in science. Expecially interesting to the secondary biology teacher and administrator are the "O-level" and "A-level" material.

GUIDEBOOK TO CONSTRUCTING INEXPENSIVE SCIENCE TEACHING EQUIPMENT

Volume II: Chemistry

Inexpensive Science Teaching Equipment Project

Science Teaching Center

University of Maryland, College Park

U.S.A.

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FOREWORD

History

The Inexpensive Science Teaching Equipment Project was initiated by Dr. J. David Lockard, and got underway under his direction in the summer of 1968. Originally entitled the Study of Inexpensive Science Teaching Equipment Worldwide (IS-TEW or IS-2 Study), the Project was to (1) identify laboratory equipment considered essential for student investigations in introductory biology, chemistry and physics courses in developing countries; (2) improvise, wherever possible, equivalent inexpensive science teaching equipment; and (3) produce designs of this equipment in a Guidebook for use in developing countries. Financial support was provided by the U.S. Agency for International Development through the National Science Foundation.

The initial work of the Project was undertaken by Maria Penny and Mary Harbeck under the guidance of Dr. Lockard. Their major concern was the identification of equipment considered basic to the teaching of the sciences at an introductory level. An international survey was conducted, and a list of equipment to be made was compiled. A start was also made on the writing of guidelines (theoretical designs) for the construction of equipment.

Work on the development of the Guidebook itself got underway in 1970, with the arrival of Reginald F. Melton to coordinate the work. Over 200 guidelines were completed during the year by Donald Urbancic (Biology), Chada Samba Siva Rao and John Delaini (Chemistry), and Reginald Melton (Physics). Full use was made of project materials from around the world which were available in the files of the International Clearinghouse on Science and Mathematics Curricular Developments, which is located in the Science Teaching Center of the University of Maryland. The guidelines were compiled into a draft edition of the Guidebook which was circulated in September, 1971, to some 80 science educators around the world for their comments and advice.

The work of constructing and developing equipment from the guidelines, with the subsequent production of detailed designs, began in a limited way in 1970, the major input at that time being in the field of chemistry by Chada Samba Siva Rao, who was with the project for an intensive two-month period. However, the main work of developing detailed designs from the guidelines was undertaken between 1971 and 1972 by John Delaini (Biology), Ruth Ann Butler (Chemistry) and Reginald Melton (Physics). Technical assistance was given by student helpers, with a special contribution from David Clark, who was with the project for a period of 18 months.

Thanks are due to those graduates, particularly Samuel Genova, Melvin Soboleski and Irven Spear, who undertook the development of specific items of equipment while studying at the Center on an Academic Year Institute program; to student helpers, especially Don Kallgren, Frank Cathell and Theodore Mannekin, who constructed the equipment; and to Dolores Aluise and Gail Kuehnle who typed the manuscripts.

Last, but not least, special acknowledgement is due to those individuals, and organizations, around the world who responded so willingly to the questionnaires in 1968 and to the draft edition of the Guidebook in 1971.

The Guidebook

The designs presented in the Guidebook are based on the premise that many students and teachers in developing countries will wish to make equipment for themselves. This does not mean that students and teachers are expected to produce all their own apparatus requirements. It is recognized that teachers have specific curricula to follow, and that "class hours" available for such work are very limited. It is also recognized that teachers, particularly those in developing countries, are not well paid, and often augment their salaries with supporting jobs, thus placing severe limits on the "out-of-class hours" that are available for apparatus production.

However, in designing equipment for production by students and teachers, two factors have been kept in mind. One, project work in apparatus development can be extremely rewarding for students, bringing both students and teachers into close contact with the realities of science, and relating science and technology in the simplest of ways. Two, it is not difficult for cottage (or small scale) industries to adapt these designs to their own requirements. The Guidebook should therefore not only be of value to students and teachers, but also to cottage industries which may well be the major producers of equipment for schools.

Although all the designs in the Guidebook have been tested under laboratory conditions in the University of Maryland, they have not been tested in school situations nor produced and tested under local conditions in developing countries. It is therefore recommended that the designs should be treated primarily as limited resource materials to be subjected to trial and feedback. It is suggested that the first time that an item is constructed it should be made precisely as described in the Guidebook, since variations in the materials, or the dimensions of the materials, could alter the characteristics of the apparatus. However, once this item has been tested the producer is encouraged to make any number of modifications in the design, evaluating the new products against the original.

Before producing new equipment in quantity, it is recommended that educators with experience in the field of science education should be involved in determining how best to make use of the Guidebook. They will wish to relate the apparatus to their own curriculum requirements, and, where necessary, prepare relevant descriptions of experiments which they recommend should be undertaken using the selected apparatus. They will want to subject the experiments and related equipment to trials in school situations. Only then will they consider large-scale production of apparatus from the designs in the Guidebook. At this stage educators will wish to control the quality of apparatus production, to train teachers to make the best use of the new apparatus, and to insure that adequate laboratory conditions are developed to permit full utilization of the apparatus. Too often in the past apparatus has sat unused on many a classroom shelf, simply because the teacher has been untrained in its usage, or the laboratory facilities have been inadequate, or because the apparatus available did not appear to fit the requirements of the existing curriculum. Such factors are best controlled by educators in the field of science education in each country. Clearly the science educator has a crucial role to play.

Apparatus development, like any aspect of curriculum development, should be considered as a never ending process. This Guidebook is not presented as a finished product, but as a part of this continuing process. There is no doubt that the designs in this book could usefully be extended, descriptions of experiments utilizing the apparatus could be added, and the designs themselves could be improved. No extravagant claims are made concerning the Guidebook. It is simply hoped that it will contribute to the continuing process of development.

TOOLS AND RAW MATERIALS

The raw materials required to make specific items of equipment are indicated at the beginning of each item description. However, there are certain tools and materials which are useful in any equipment construction workshop, and these are listed below.

Tools

Chisels, Wood

3, 6, 12, 24 mm
(i.e., 1/8", 1/4", 1/2", 1")

Cutters

Bench Shears: 3 mm (1/8") capacity
Glass Cutter
Knife
Razor Blades
Scissors: 200 mm (8")
Snips (Tinmans), Straight: 200 mm (8")
Snips (Tinmans), Curved: 200 mm (8")
Taps and Dies: 3 to 12 mm (1/8" to 1/2") set

Drills and Borers

Cork Borer Set
Countersink, 90°
Metal Drill Holder (Electrically Driven), Capacity 6 mm (1/4")
Metal Drills: 0.5, 1, 2, 3, 4, 5, 6, 7 mm
(i.e., 1/32", 1/16", 3/32", 1/8", 5/32", 3/16", 7/32", 1/4") set
Wood Brace with Ratchet: 250 mm (10")
Wood Augur, Bits: 6, 12, 18, 24 mm
(i.e., 1/4", 1/2", 3/4", 1")

Files, Double Cut

Flat: 100 mm, 200 mm (4", 8")
Round: 100 mm, 200 mm (4", 8")
Triangular: 10C mm (4")

Hammers

Ball Pein: 125, 250, (1/4, 1/2 lb)
Claw 250 g (1/2 lb)

Measuring Aids

Caliper, Inside
Caliper, Outside
Caliper, Vernier (may replace above two items)
Dividers: 150 mm (6"), Toolmakers
Meter, Electrical (Multipurpose - volts, ohms, amps, etc.)
Meter Stick
Protractor
Scriber

Measuring Aids (Continued)

Set Square
Square, Carpenter's: 300 mm (12") blade
Spoke Shave: 18 mm (3/4")
Wood Smoothing Plane

Pliers

Combination: 150 mm (6")
Needle Nose: 150 mm (6")
Side Cutting: 150 mm (6")
Vise Grips

Saws, Metal

300 mm (12") blades

Saws, Wood

Back Saw: 200, 300 mm (8", 12")
Coping Saw: 200 mm (8")
Cross Cut: 600 mm (24")
Hand Rip: 600 mm (24")
Key Hole Saw: 200 mm (8")

Screw Drivers

100 mm (4"), with 2 and 3 mm tips
150 mm (6"), with 5 mm tip
200 mm (8"), with 7 mm tip

Vises

Metal Bench Vise: 75 mm (3")
Wood Bench Vise: 150 mm (6")

Miscellaneous

Asbestos Pads
Goggles, Glass
Oil Can: 1/2 liter (1 pint)
Oil Stone, Double Faced
Punch, Center
Sandpaper and Carborundum Paper, Assorted grades
Soldering Iron: 60 watts, 100 watts

Raw Materials

Adhesives

All Purpose Cement (Elmers, Duco)
Epoxy Resin & Hardener (Araldite)
Rubber Cement (Rugy)
Wood Glue (Weldwood)
Cellophane Tape
Plastic Tape
Masking Tape

Electrical Materials

Bulbs with Holders: 1.2, 2.5, 6.2 volts
Dry Cells: 1.5, 6 volts
Electrical Wire: Cotton or Plastic covered
Fuse Wire: Assorted
Lamps: 50, 75, 100 watts
*Magnet Wire: #20, 22, 24, 26, 28, 30, 32, 34
Nichrome Wire: Assorted
Parallel Electrical Cording
Plugs
Switches

Glass and Plastic

Acrylic (Plastic) Sheets: 2 cm and 2.5 cm thick
Plates, Glass
Tubes, Glass: 3, 6 mm (1/8", 1/4") internal diameter

Hardware

Bolts and Nuts, Brass or Steel; 3 mm (1/8") diameter: 12, 24, 48 mm (1/2", 1", 2") lengths
Nails: 12, 24 mm (1/2", 1") lengths
Screws, Eye
Screws, Wood: 12, 18, 24, 26 mm (1/2", 3/4", 1", 1 1/2") lengths
Thumbtacks
Washers (Brass and Steel): 6, 9 mm (1/4", 5/16") diameter
Wingnuts (Steel): 5 mm (3/16")

Lumber

Boxwood (Packing Case Material)
Hardboard: 6 mm (1/4") thick
Kiln Dried Wood: 2.5 x 15 cm (1" x 6") cross section
1.2 x 15 cm (1/2" x 6") cross section
Plywood: 6, 12 mm (1/4", 1/2") thickness
Wood Dowels: 6, 12 mm (1/4", 1/2") thickness

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* U. S. Standard Plate numbers are used in this book to indicate the gauge of different wires. Where wires are referenced against other numbering systems appropriate corrections should be made in determining the gauges of materials required. The following comparison of gauges may be of interest:

Standard	Diameter of #20 Wire
Brown & Sharp	0.08118
Birmingham or Stubs	0.089
Washburn & Moen	0.0884
Imperial or British Standard	0.0914
Stubs' Steel	0.409
U. S. Standard Plate	0.09525

Metal Sheets

Aluminum: 0.2, 0.4 mm (1/100", 1/64") thickness.
Brass: 0.4, 0.8 mm (1/64", 1/32") thickness.
Galvanized Iron: 0.4 mm (1/64") thickness.
Lead: 0.1 mm (1/250") thickness.
Spring Steel, Packing Case Bands

Metal Tubes:

Aluminum, Brass, Copper: 6, 12 mm (1/4", 1/2") internal diameter.

Metal Wires

Aluminum: 3 mm (1/8") diameter
Coathanger: 2 mm (1/16") diameter
*Copper: #20, 24
Galvanized Iron: 2 mm (1/16") diameter
*Steel: #20, 26, 30.

Paint Materials

Paint Brushes
Paint Thinner
Varnish
Wood Filler

Miscellaneous

Aluminum Foil
Cardboard Sheeting
Containers (Plastic or Glass)
Corks (Rubber or Cork)
Grease
Hinges: Assorted
Machine Oil
Marbles
Mesh (Cotton, Nylon, Wire)
Modelling Clay (Plasticene)
Paper Clips
Pens: Felt (Marking Pens)
Pins and Needles
Rubber Bands
Soldering Lead
Soldering Paste
Spools
Steel Wool
Straws
String (Cord, Cotton, Nylon)
Styrofoam
Syringes: Assorted
Wax (Paraffin)

*See footnote on previous page.

I. GLASSWARE TECHNIQUES AND ACCESSORIES

Equipment made of glass or using glass components has applications in all branches of science. This chapter includes some basic glass-working techniques that will be necessary for constructing much of the equipment in this book.

These are presented in sections which describe the type of equipment needed, the type of glass to use, and techniques for working with several forms of glass.

A. BURNERS, TOOLS, AND EQUIPMENT

This section discusses burners that can be used in working glass, as well as listing the tools and other items necessary for working with glass.

B. GLASS

This section describes the type of glass that works best with the burners listed in section A.

C. SAFETY

Notes for safe handling and working of glass are given here.

D. PROCEDURES FOR GLASS TUBING AND RODS

Directions for working with glass tubing and solid rods are given in this section.

E. GLASS SHEET OPERATIONS

This section tells how to cut and drill glass sheets.

F. BOTTLE AND JAR TECHNIQUES

Much useful laboratory glassware can be made by using discarded bottles and jars. This section includes directions for cutting and drilling these items.

G. STOPPERS

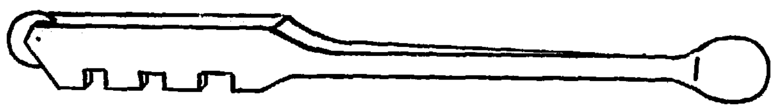
This section discusses types of stoppers and describes techniques for drilling holes in them.

A. BURNERS, TOOLS, AND EQUIPMENT

Glass-working techniques described here are designated for use with Modified Alcohol Burner (II/B2), and the Gas Burner (II/C2). Of these, the gas burner, if available, is most highly recommended.

The general items required for general glass-working techniques are as follows:

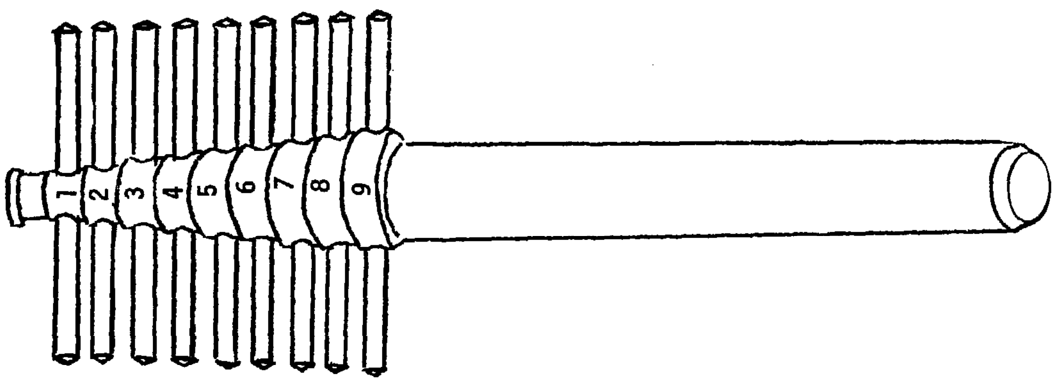
Glass Cutter



Triangular File

Round File

Set of Cork-borers



Pliers

Brick or Asbestos Pads

Rags or Pieces of Cloth

Clean rags, or pieces of cloth no smaller than about 10 cm x 10 cm.

String

Kerosene

Camphor

Ruler

Blotting Paper or Paper Towels

Emery Paper

Container of Sand

B. GLASS

There are many different types of glass, with different properties, depending upon the chemical composition of the glass. Two very common types of glass that are discussed here are "soft glass" and "hard glass."

Soft Glass

This term includes a number of the oldest known and most common types of glass in general use. Most bottles, jars, window glass, and much glass tubing and rods are made of some type of soft glass. Such glass is used for items of simple design and moderate thickness, that will not be subjected to very high temperatures.

One of the most important properties of soft glass, from the point of view of this book, is that it can be softened in the heat of an air-gas flame. This is the type of flame produced by the burners specified in section A. Also, soft glass has a wide range of working temperatures, which makes it easy to work even after it has been removed from flame.

Although it is easy to work, soft glass has some limitations and must be used with care. An empty container of soft glass cannot be greatly heated, or it will crack. If, however, such a container holds a liquid or powder, it can safely be heated, slowly. Also, a soft glass container, with or without anything inside, must not be suddenly cooled when hot or suddenly heated when it is cold. Otherwise, it will break.

Hard Glass

Hard glass has been developed during the twentieth century. Of a number of types produced, "Pyrex" is one of the most common brand names. Most manufactured laboratory glassware is now made of hard glass, which is harder, stronger, more chemically inert, and safer to use over a wider temperature range than soft glass.

Laboratory glassware made of hard glass is safer than soft glass. It can be rapidly heated or cooled to greater temperature extremes without danger of breaking. It does not scratch easily, and it does not break as easily as soft glass if struck or dropped.

Although it is often manufactured into laboratory glassware, hard glass is not generally made into the bottles and jars that are used for much of the apparatus described in this book. Therefore, it is not as generally available as soft glass. As tubing, rods, and sheets, it is usually more expensive than the same items made of soft glass.

Hard glass's most important disadvantage here is that it must be worked in an oxygen-enriched flame. The burners described in section A cannot heat hard glass hot enough for working.

Therefore, only soft glass is suitable for use with the alcohol or gas burners described. The techniques here listed have been tested using soft glass and the air-gas flames produced by such burners.

Testing for Soft Glass

To determine whether a piece of glass is "hard glass" or "soft glass", heat it in the flame of an alcohol or gas burner. If the glass begins to glow and soften enough to be easily worked, it is soft glass. If it does not soften, it is hard glass and cannot be worked without specialized equipment.

C. SAFETY

Glass working, like most other laboratory procedures, carries a set of risks. By arranging a safe work area and taking a few precautions, however, most such risks can be avoided.

Sharp Edges and Points

There is always a danger of being cut by sharp points and edges of broken or cut glass. Be careful of such edges and points, and try to handle the glass away from the edges. Fire polish or smooth with emery paper any cut edges or points that are part of a finished project. Keep such edges away from the mouth and eyes at all times, and keep the work area clear of waste glass.

Burns

Hot glass looks just like cool glass! To avoid burns, allow heated glass to cool before handling it. Rest it on bricks or asbestos pads, or in a container of sand. Before picking up a piece of previously heated glass, touch it lightly with the fingertips to check that it is cool enough to handle. In cases where hot or warm glass must be handled, protect the hands with a holder of several layers of cloth, or use holders such as those described in the section on holders (IV). Protect the body from burns with clothing, an apron, overall, or laboratory coat.

Fire

Both the burner flame and hot glass can start a fire. Prevent this by keeping all flammable material, such as paper or cloth away from the flame and any hot glass. Set hot glass down on things that will not burn, such as bricks, asbestos pads, or sand. To keep hair or clothing from being singed or igniting, tie back long hair, roll up sleeves, and secure loose clothing close to the body. Inspect the burner, fittings, tubing, and fuel supply each time the equipment is used to prevent leaks of fuel that might lead to a fire. If any alcohol should spill, immediately put out the flame and mop up the spill.

The container of sand mentioned for holding hot glass is also useful for fire control. If paper, cloth, or spilled alcohol should ignite, smother the fire by dumping sand on it. If, on the other hand, the gas burner system (II/C1) is used and a fire develops, get away fast!

Eye Damage

To prevent eye damage, keep all sharp edges and points, all hot glass, and all flames away from the eyes. Wear safety goggles or eye glasses to provide additional protection for the eyes.

Gas Danger

If natural gas or bottled gas is used as fuel for the burner, a leak in the system can release gas that is poisonous to breathe. To avoid this danger, inspect all pipes, tubing, and fittings often.

D. PROCEDURES FOR GLASS TUBING AND RODS

D1. Cutting

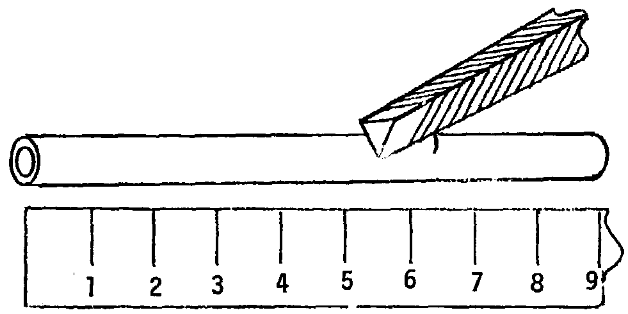
a. Materials Required

Length of soft glass tubing or solid rod

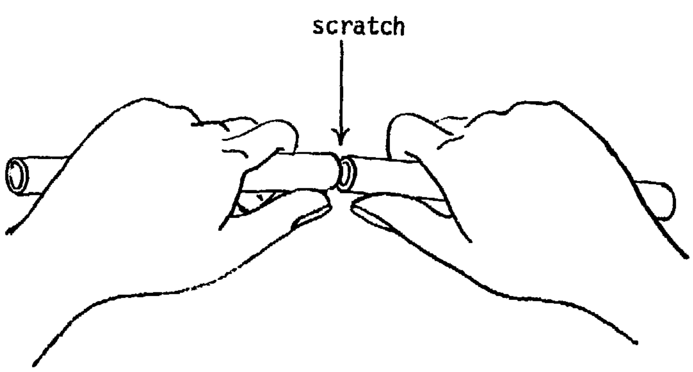
Triangular file

Ruler

b. Procedure



Lay the tubing or rod flat on the work surface and measure the desired length. Make a scratch on the glass at this point by drawing one edge of the file across the tube. Press hard enough with the file to make a deep scratch.



Moisten the scratch, then grasp the glass firmly in both hands with the thumbs on the side of the tube opposite the scratch. Apply pressure with the thumbs while pulling out and down with the hands until the tube or rod snaps cleanly.

D2. Bending

a. Materials Required

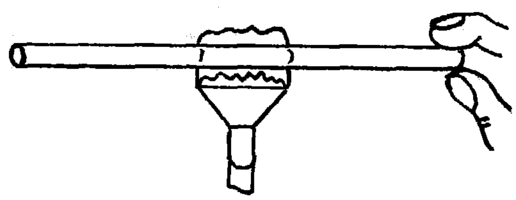
Burner: wide-flame alcohol burner
or
wing tip with gas burner

Length of soft glass tubing or solid rod

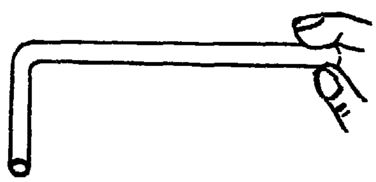
Cooling surface: brick
or
asbestos pad

b. Procedure

Gravity Bending

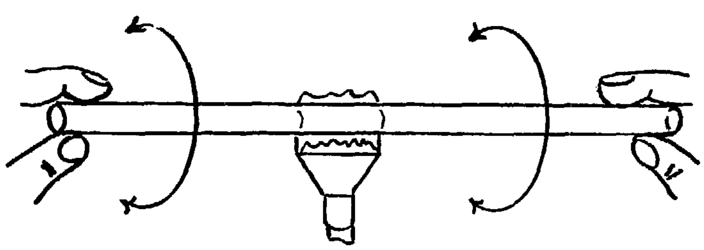


With one hand, hold the tubing or rod, just above the inner cone of the flame. Rotate the tubing to heat it evenly until the free end droops under its own weight.

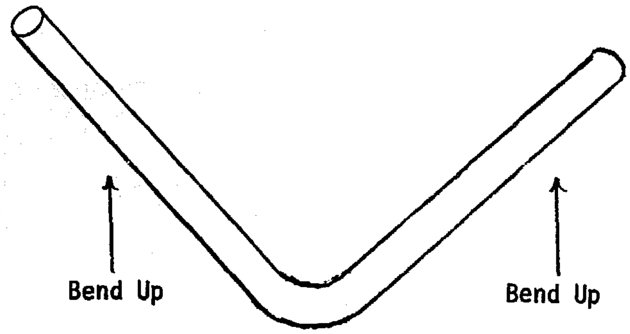


Remove the glass from the flame. It should bend to a right angle. Allow it to cool.

Manual Bending



Install the wing tip on the gas burner, and light the burner. Hold each end of the tubing or rod. Support the glass so that it is level, with its middle in the hottest part of the flame. Turn the tubing or rod back and forth by rotating the thumb and first finger. Continue to heat it evenly until it softens.

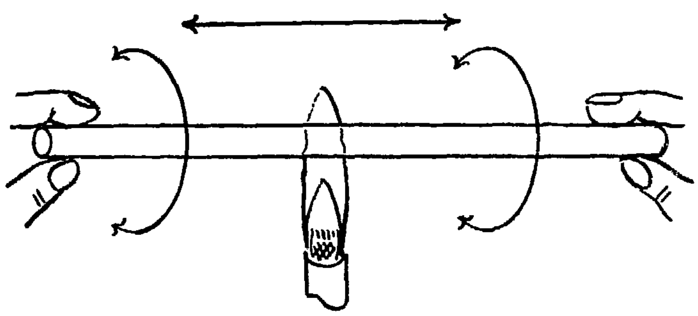


When the tubing or rod is soft, remove it from the flame. Immediately, bend the ends <u>up</u> until the tubing or rod is bent at a right angle (90°).

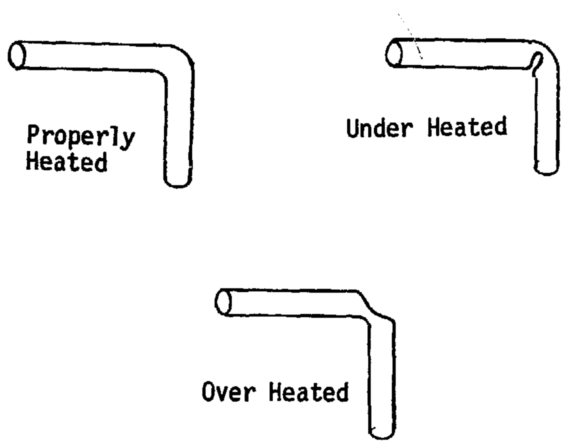
Rest the hot tubing or rod on a brick or other cooling surface.

c. Notes

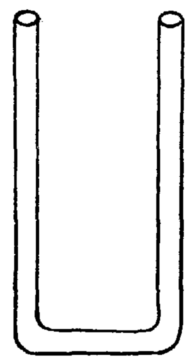
(i) If a wing tip is not available, or if a standard alcohol burner is used, the tubing or rod must be heated differently. Hold each end of the glass and support it so that it is level, with the middle just above the inner core of flame. Rotate the tubing back and forth. At the same time, move it to the left and right so that about 0.3 cm of its length of evenly heated. Continue to both rotate and move the tubing or rod until the heated section softens. Remove from the flame and bend it as described above.



(ii) With a little practice with glass tubing, you should be able to achieve a bend in which the opening stays the same throughout the bend. Overheating or underheating the tubing, however, will produce poor bends. Underheating causes the tube to fold in at the bend. Overheating causes the tube to collapse at the bend.



(iii) If a U-shaped bend is desired, first make one 90° bend as described above. After allowing the glass to cool, make another 90° bend near the first one.



D3. Stretching

a. Materials Required

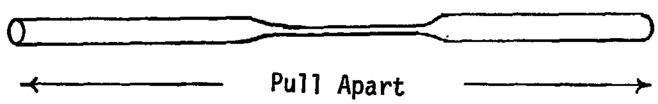
Burner: wide-flame alcohol burner

or

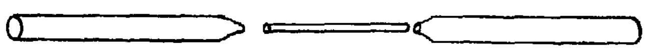
wing tip with gas burner

Length of soft glass tubing or rod

b. Procedure



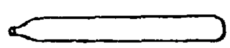
Hold the glass tubing or rod in the flame. Turn it as it heats, just as for making a bend. Heat the glass evenly until it softens. When the tubing or rod is soft, remove it from the flame. Pull the ends apart until the center has become narrow and stretched about 25 - 30 cm.



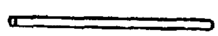
After the stretched part has cooled, it can be cut as required (I/D1). Carefully fire polish the edges (I/D4).

c. Notes

(i) Stretched glass tubing has many applications in laboratory glassware. For example, the ends of the stretched tubing pictured above, with a narrow opening at one end, may be used as nozzles or jets.



The very narrow section of the tubing, the stretched part, may be used as a capillary tube.



(ii) If a wing tip or wide-flame burner is not available, follow the procedure given for heating a wide area of glass without the wing tip [I/D2, Note (i)].

D4. Fire Polishing Tubing

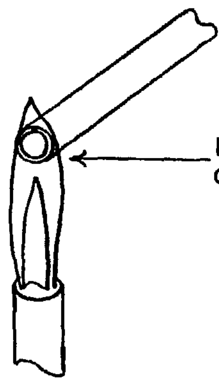
a. Materials Required

Glass tubing with cut edge

Burner

Cooling surface

b. Procedure



Hold the rough, cut end of the glass tubing in the hottest part of the flame, just above the inner cone. Turn the tubing constantly until the edge glows red.

Remove the tubing from the flame. Examine the heated end. If it is now rounded smoothly, rest the hot tubing on a brick, asbestos pad, or sand to cool. If the other end of the tubing is also rough, repeat the fire polishing procedure.

c. Notes

(i) Do not overheat the end of the tubing, or it will tend to close entirely.

(ii) Fire polish the ends of all glass tubing in use, as a safety measure.

(iii) Tubing with thick walls--for example, 0.5 cm (inside diameter) and larger--must be annealed to prevent cracking. To do this, hold the end in the flame for about one second, then remove from the flame for about one second. Repeat this procedure eight or ten times, then hold the end in the flame, turning it constantly until it is red hot. To cool thick-walled tubing slowly, remove it from the flame, but hold the tubing near the flame for a few seconds. Gradually move the hot end of the tubing further from the flame until it can be rested on the brick or other cooling surface.

D5. Closing Tubing

a. Materials Required

Burner

Glass tubing

Cooling surface

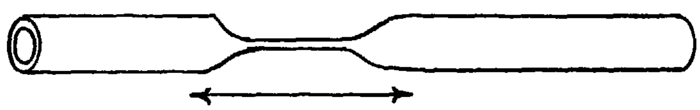
b. Procedure

Narrow Tubing

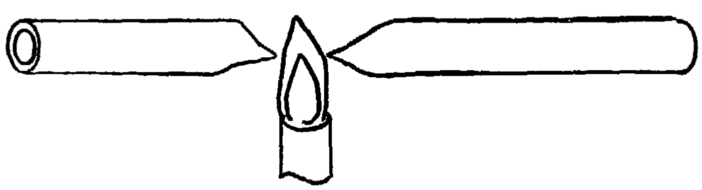
When using tubing with a diameter of less than 1.0 cm, hold the end of the tubing in the hottest part of the flame, just as for fire polishing. Turn the tubing constantly. Continue heating until the end closes.

Wide Tubing

When using tubing with a diameter greater than 1.0 cm, heat the tubing near one end, rotating the tubing as it heats. When the tubing is soft, pull it apart.



Continue to heat and pull the ends apart until the ends separate and the pointed end has closed.



D6. Glass Blowing

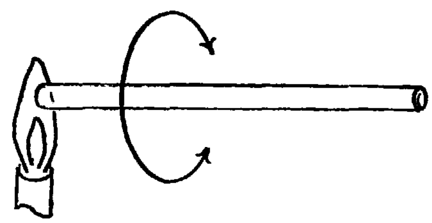
a. Materials Required

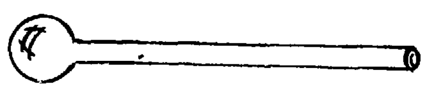
Gas burner

Length of soft glass tubing

Cooling surface

b. Procedure





Fire polish one end of the tubing. Allow it to cool. Close the other end by heating in the flame. Heat the closed end, rotating it constantly. While continuing to heat and rotate the tube, blow very gently, in short, light puffs, into the open end of the tube. Just as the closed end of the tube begins to swell and glow pale red, remove it from the flame. Blow strongly into the tube, while rotating it, to form a small round bulb.

c. Notes

(i) This procedure takes practice and patience to learn. It is helpful to begin with the narrowest tubing available; 0.3 cm tubing, for example. A common problem is blowing out the side of the bulb while the tubing is still in the flame.

(ii) A limiting factor in the size of tubing that can be used and the size of the bulb that can be blown is the burner used. The gas generating system (II/C1) and burner (II/C2) are adequate to allow 0.3 cm and 0.5 cm tubing to be blown into bulbs about 0.8 cm in diameter.

D7. Making Rim in Tubing

a. Materials Required

Burner

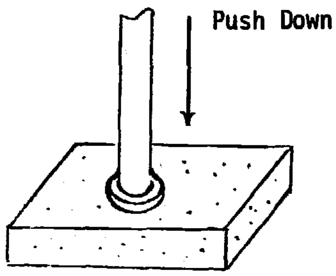
Glass tubing

Triangular file

Brick, or asbestos pad

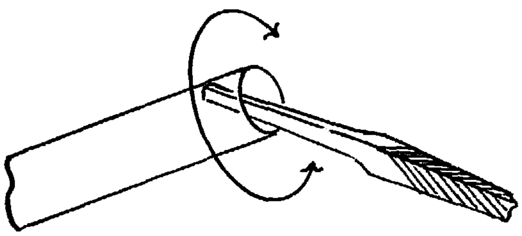
b. Procedure

Flattening



Hold one end of the tubing in the hottest part of the flame. Turn it constantly until the edge glows red. Remove the tubing from the flame. Quickly push the hot end evenly down against the brick or asbestos pad. A lip should form. Allow the glass to cool.

Flaring



Heat one end of the tubing until it is red hot. Remove the tubing from the flame. Hold the thin handle end of the file inside the end. Press gently outward on the file, while turning the tube to form a flared edge. Allow the glass to cool.

D8. Finishing Ends of Rods

a. Materials Required

Soft glass rods

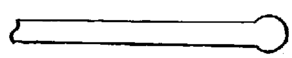
Burner

Brick, or asbestos pad

Pliers

b. Procedure

Fire Polishing

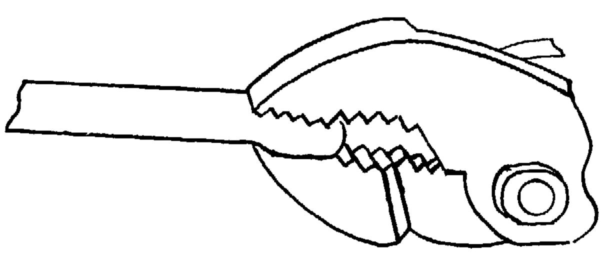


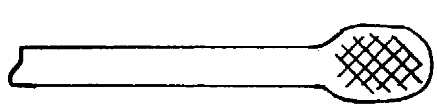
Follow the procedure for fire polishing glass tubing (I/D4). It will be necessary to heat the end of the rod for a longer period of time. The fire polished end will have a small, solid bulb. Holding the rod in the flame for a longer time will produce a larger bulb at the end.
Allow the rod to cool.

Flattening

Follow the procedure for flattening glass tubing (I/D7) to form a flat disc at the end. Allow the rod to cool.

Squeezing

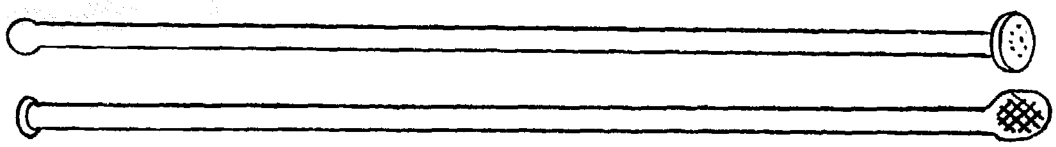




Heat one end of a rod as before. When it is hot, remove it from the flame. Compress about 1 cm of the end of the rod between the jaws of the pliers. A flattened paddle-shaped end will form.
Allow the rod to cool.

c. Notes

(i) A useful stirring rod can be made with a rod of about 0.3 - 0.5 cm diameter, 15 - 20 cm long. Flatten one end and squeeze or fire polish the other.



E. GLASS SHEET OPERATIONS

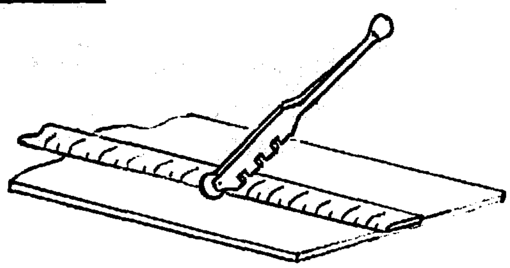
E1. Cutting

a. Materials Required

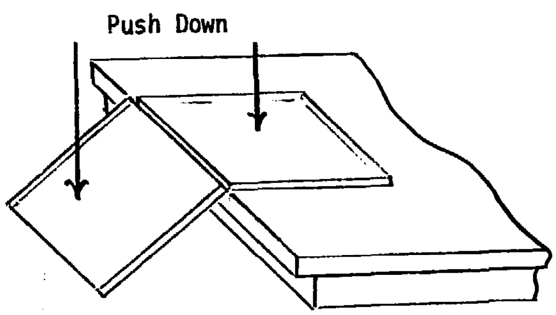
Glass cutter

Sheet of glass
(for example, a pane of window glass)

b. Procedure



Lay the glass flat on bench of table. Hold the ruler along the line to be cut, with one hand; and with the other hand, draw the wheel of the glass cutter on the glass along the ruler. Press hard enough to scratch the glass.



Place the underside of the scratch exactly over the edge of the table or bench. Press down on both sides to break the glass cleanly along the scratch.

E2. Drilling a Hole

a. Materials Required

Sheet of glass

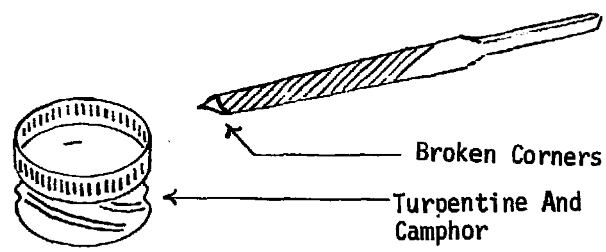
Triangular file

Hammer

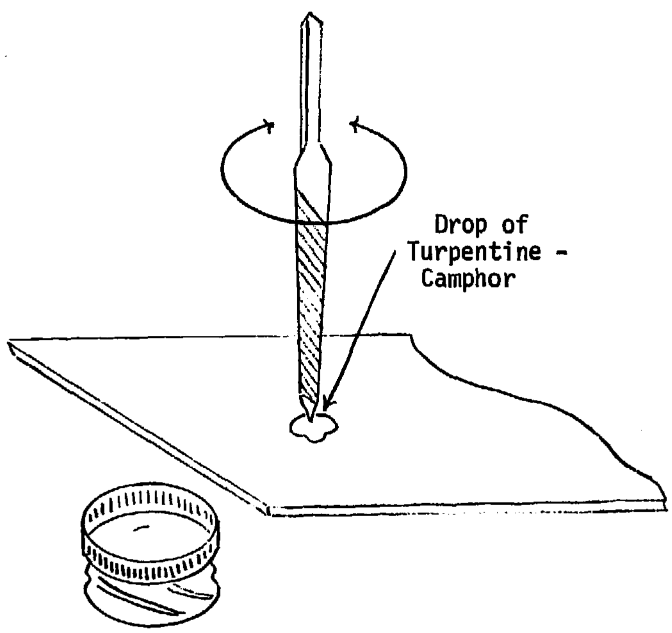
Turpentine

Camphor

ߺ. Procedure



Take a little turpentine in a bottle cap. Put a small amount of camphor in it. Chip off the end of the triangular file with a hammer. This chipped end has sharp corners.



Place the glass flat on a table. Dip one of the sharp corners of the broken file into the turpentine-camphor mixture.

Press this corner of the file down on the spot to be drilled. Twist the file back and forth to drill into the glass. Use more turpentine-camphor as needed and continue drilling until the hole is complete.

c. Notes

(i) Drilling by hand is slow and may take ten or fifteen minutes.

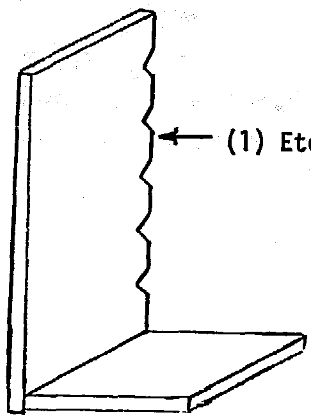
(ii) A completed hole can be enlarged with the edge of the triangular file or a round file, and the turpentine-camphor mixture.

(iii) After making the beginning hole on the surface of the glass, it is in fact easier to use a hand drill with the triangular file as the bit. However, extreme care must be taken. Do not push down on the drill at all, or the glass might break. Let only the weight of the drill be the force on the glass.

(iv) Follow this same procedure to drill a hole in a glass bottle or jar.

F. BOTTLE AND JAR TECHNIQUES

F1. Etching



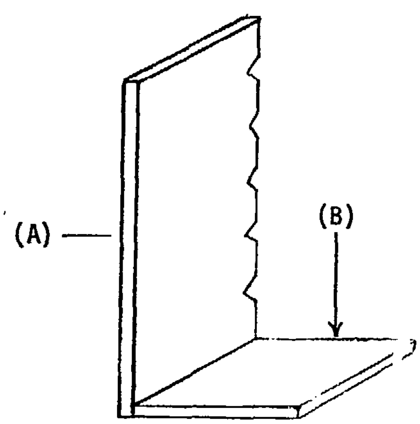
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Etching Guide	1	Wood (A)	Approximately 10 cm x 20 cm x 1 cm
	1	Wood (B)	Approximately 10 cm x 10 cm x 1 cm

b. Construction

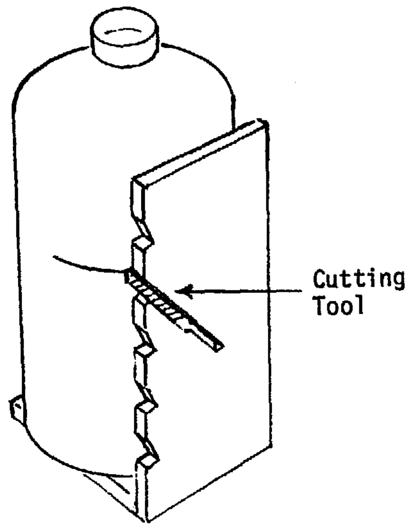
(1) Etching Guide

Cut V-shaped notches into one edge of a wooden board (A). Make the notches about 1 cm deep and about 2 cm (or other desired interval) apart. Then secure the base (B) at right angles to (A) with nails or glue and screws.



c. Notes

(i) The etching guide is used in combination with a triangular file or glass cutter to scratch a continuous line on a bottle or jar, prior to cutting. The

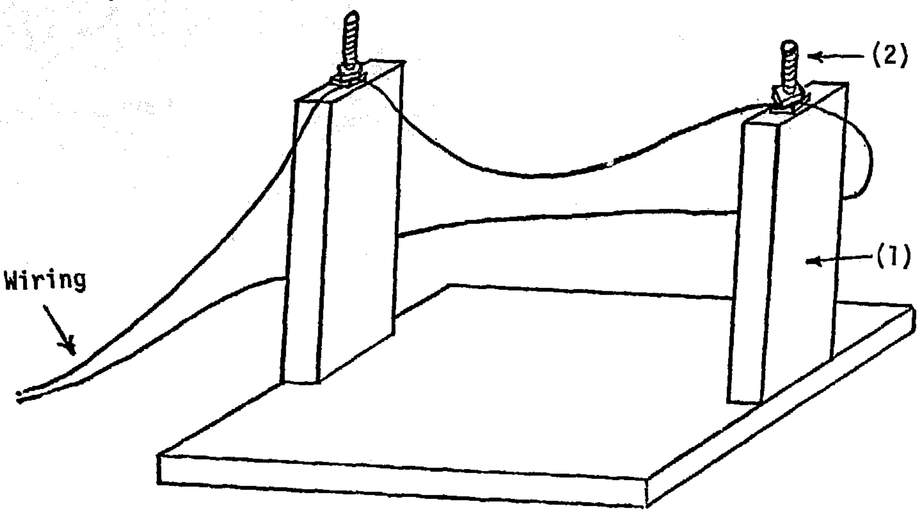


bottle or jar is placed on the stand and a glass cutter or triangular file is placed in a notch at the desired height. The bottle is rotated, and pressure is maintained against it with the tool so that a continuous scratch is scored around it.

(ii) A second method for etching a bottle, jar, light bulb, etc. to be cut is to wrap a strip of adhesive tape or paper around the glass as a guide. After the line has been scratched completely around the glass, the tape is removed.

(iii) After the glass has been etched in either of these two fashions, it may be cut using one of the techniques described in the following section.

F2. Cutting
Electrical Heating

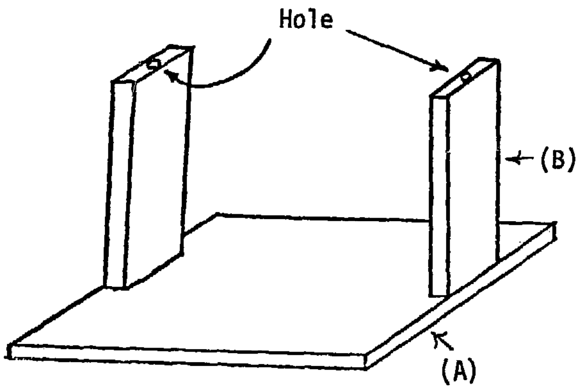


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Stand	1	Wood (A)	30 cm x 10 cm x 2 cm
	2	Wood (B)	25 cm x 4 cm x 2 cm
(2) Terminal	2	Bolts (C)	3 cm long, 0.5 cm diameter
	4	Nuts (D)	0.5 cm
(3) Wiring	1	Nichrome Wire (E)	Size #24 (0.06 cm diameter), 34 cm long
	2	Insulated Copper Wire (F)	Size #20 (0.08 cm diameter), 125 cm long

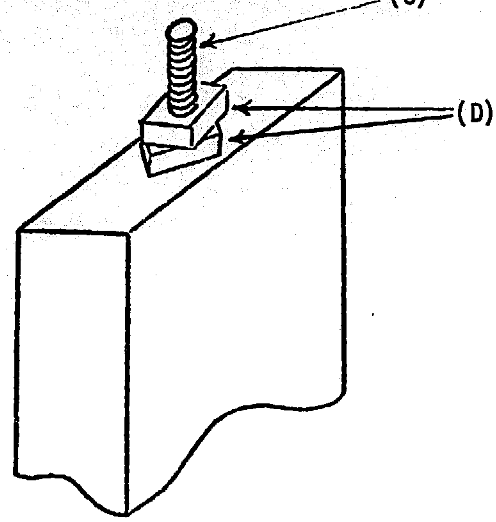
b. Construction

(1) Stand



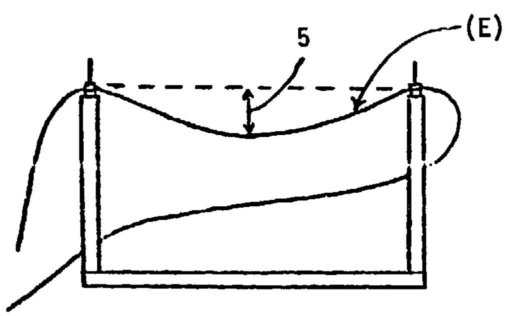
Drill a hole in one end of each of the two uprights (B). This hole should be slightly smaller in diameter than the bolts (C) used for the terminals. Next, nail or screw the uprights to the base (A).

(2) Terminal



Cut the heads off the two bolts (C), and put glue into the holes in the uprights (B). Screw the bolts down into the hole, leaving about 1.5 - 2 cm protruding. Next, secure the bolts by screwing on one nut (D) until it is tight. Screw on the second nut (D) loosely.

(3) Wiring



Wrap one end of the #24 nichrome wire (E) around one bolt (C) for one or two turns and do the same with the other end. Tighten the second nut (D) on the terminals until the nichrome wire is firmly held. There should be about a 5 cm sag in the middle. Fasten the copper wires (F) to each terminal in the same manner. Connect clips to these wires. For power use a transformer (PHYS/VII/A2) wired to a wall outlet [Note (iii)], or a heavy-duty battery.

c. Notes

(i) Prepare the jar, bottle, light bulb, etc., to be cut by etching a continuous line around the glass (I/F1). Connect the cutter to a power supply until the wire is hot, then place the etched line on the hot wire. Hold the glass in this position until it cracks along the healed portion. Then rotate the glass to heat another portion of the etched line. Continue this procedure until the crack has circled the glass and the two sections separate.

(ii) The broken edges of the glass can be smoothed by rubbing them with wire gauze or wet sandpaper (emery paper).

(iii) If the wire cutter is used with a wall outlet (120 volt) then a transformer must be employed to bring the voltage down to 12 volts, 3 amps. The cutter can also be used with a standard 12 volt automobile battery. However, using a battery requires more time for heating the ètched line, since the wire does not get as hot.

String Heating

a. Materials Required

Bottle, jar, or light bulb

String

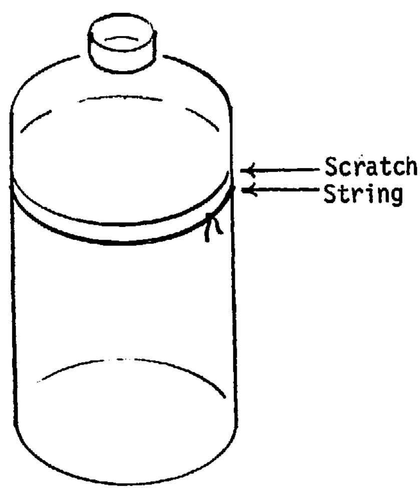
Container of cold water

Alcohol, kerosene, or turpentine

Tape or paper

Glass cutter or triangular file

b. Procedure



Prepare the bottle or jar as described in I/F1 above. After the paper or tape guide has been removed, tie a piece of string or cord which has been soaked in a flammable liquid around the bottle about 0.5 cm below the scratch. Light the string with a match, and as soon as the flame dies down, pour cold water on the bottle. The sudden change from hot to cold will break the bottle along the scratch. This process may have to be repeated to break thick glass. Smooth the cut edge of the glass as described in Note (ii) above.

Wet Paper Cooling

a. Materials Required

Bottle, jar or light bulb

Alcohol or gas burner, or candle

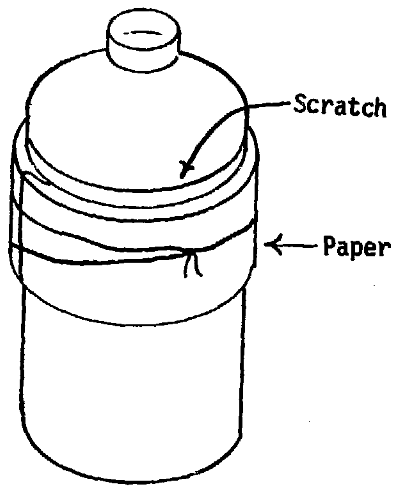
Triangular file or glass cutter

Blotting paper or wrapping paper

String

Container of cold water

b. Procedure



Wind a strip of blotting paper, paper towel, or wrapping paper about 5 cm wide around the bottle at one side of the line to be cut. Wrap the paper at least 0.5 cm thick and then tie the paper with string or rubber bands. With the file or glass cutter, scratch a line completely around the bottle at the top edge of the paper. Put the bottle into cold water until the paper is soaked (about five minutes). Remove the bottle from the water, and rotate it in a horizontal position, with the scratch on the glass just above a small, fine flame. Continue this for four or five minutes. If the bottle has not dropped apart, put the bottle vertically into the water. The bottle should break into two parts along the scratch. If it does not, repeat the heating and cooling until it does. It is crucial that the flame be very small so as to heat a minimum of glass on either side of the scratch.

c. Notes

(i) To drill a hole in a glass bottle or jar, follow the procedure outlined for drilling in a glass sheet (I/E2).

G. STOPPERS

Stoppers for use in scientific apparatus are commonly manufactured of either cork or hard rubber.

Rubber Stoppers

Rubber stoppers are more durable for general use than cork stoppers. They are available in standardized sizes, and are manufactured with no holes as well as with one, two or three holes. Although they tend to react with organic solvents like gasoline, they provide an excellent seal in most cases and can even be sterilized. (BIO/VII/A2). If a stopper with holes is specified in the directions for a piece of apparatus, use rubber stoppers with pre-drilled holes if at all possible. If it becomes necessary to drill a hole or holes in a rubber stopper, consult the notes following the discussions of boring and drilling holes in cork stoppers (I/G1 and G2).

Cork Stoppers

Cork stoppers, while generally less expensive than those made of rubber, are not as suitable for general use. They tend to lose their shape after long use, are not available with holes pre-drilled, tend to absorb reagents, and cannot be adequately sterilized. Should it be necessary to bore a hole or holes in a cork stopper for the insertion of glass tubing, one of the following methods may be employed.

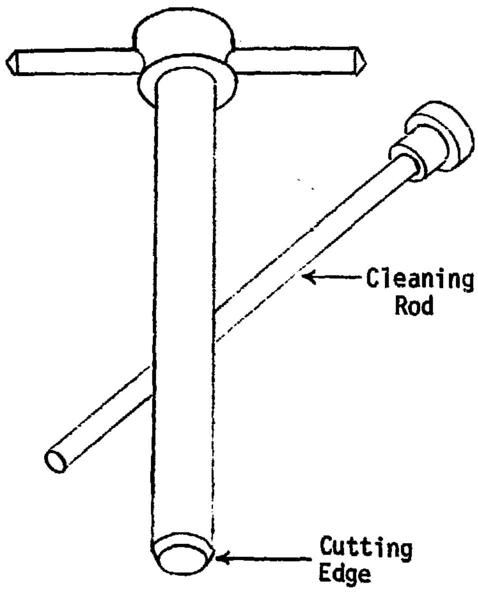
G1. Cork Boring

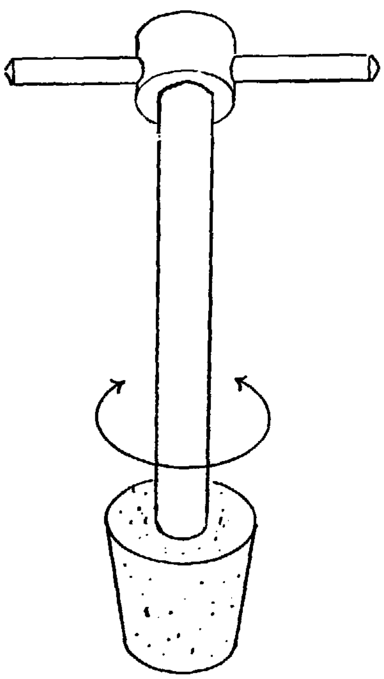
a. Materials Required

Cork stopper

Set of hand cork borers

b. Procedure





If a set of hand cork borers in graduated sizes is available from a scientific supply house, choose a cork borer of the same or slightly smaller diameter as the glass tubing that is to go through the cork.

The cork borer set generally is supplied with a rod to clean pieces of cork out of the borer. Soften the cork by wrapping it in a piece of paper and rolling it gently on the floor under your foot.

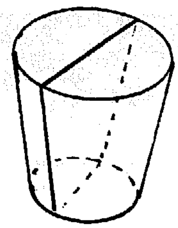
With one hand, hold the cork firmly on the table or bench, wide end up. With the other hand, place the cutting edge of the cork borer in the center of the cork. Then with a gentle twisting motion on the cork borer, bore into the cork until the tool is about halfway through the cork.

It is not necessary to push hard; but twist gently with light pressure. Remove the cork borer from the cork and push out small pieces of cork inside it with the cleaning rod.

Turn the cork over and repeat this process until there is a hole through the cork.

c. Notes

(i) If two holes are desired, the first must be bored near one edge of the cork in the manner described above. The second hole is then bored in the same way. A guide line, drawn around the middle of the cork, is helpful in determining the positions of the two holes.



(ii) This method is suitable for boring holes in rubber stoppers. However, the stopper as well as the end of the boring tool should be lubricated with glycerine.

G2. Cork Drilling

a. Materials Required

Cork stopper

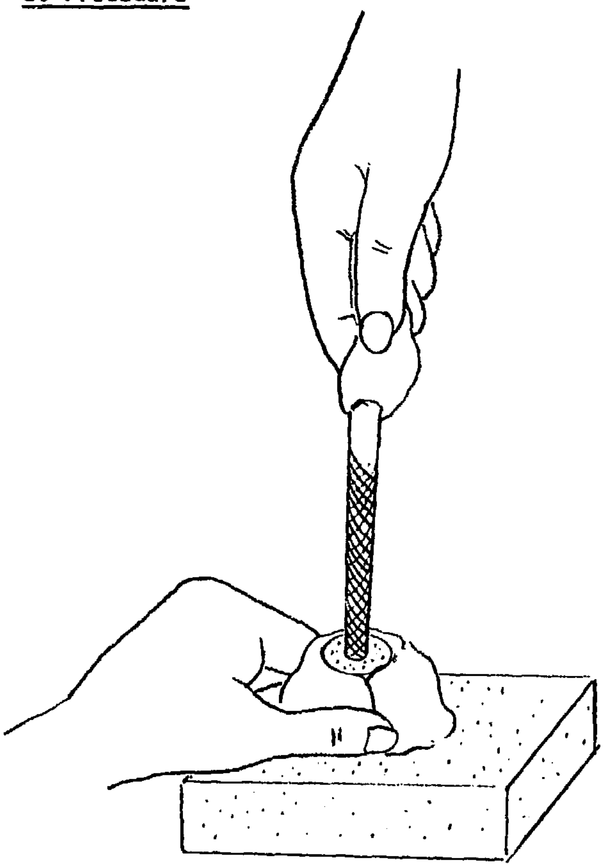
Round file

Cloth, or wooden handle

Burner

Brick or asbestos pad

b. Procedure



Soften the cork as described in I/G1 above. Hold the cork, wrapped in cloth or clamped in pliers, securely against the brick or asbestos pad with one hand. Hold the file, wrapped in cloth or in a wooden handle, by its four-sided end in the other hand. Heat the round end of the file in the burner flame. Remove the file from the flame when it glows red hot, and push it gently into the center of the cork. Push it only about half-way through the cork, then remove it.

Turn the cork over, reheat the file, and make another hole to meet the first one.

Allow the file to cool, then enlarge the hole to the desired size by gentle filing.

c. Notes

(i) Care must be taken not to overheat the file, or it may set the cork on fire. Should this happen, blow the flame out quickly.

(ii) Two holes can also be made through the cork with this method.

(iii) Very small holes can be made in corks in the same manner by using heated wire.

(iv) If a hand drill or electric drill is available, holes can easily be bored by using either a regular drill bit or the round file as the drill bit. The cork must be rigidly held in a vise. For an accurate hole, just as with the other methods of drilling, a hole should be drilled halfway through the cork from each side, to meet in the center of the cork.

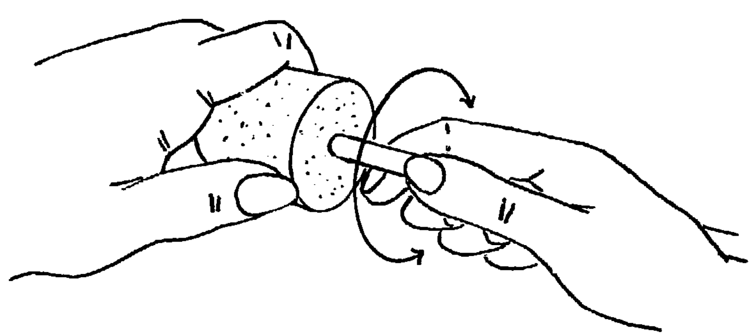
(v) It is possible to drill holes in rubber stoppers with a hand drill or electric drill, but the hot file method will not work in rubber stoppers.

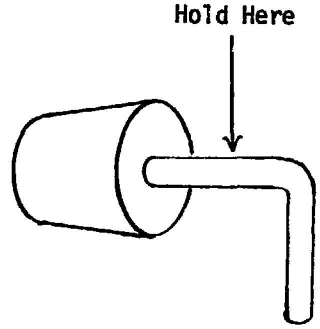
G3. Inserting Glass Tubing Through a Stopper

a. Materials Required

Glass tubing
Burner
One-hole cork or rubber stopper
Cloth
Glycerine

b. Procedure





Fire polish the end of the tube that is to go into the stopper. Allow it to cool. Hold the tubing about 2 - 3 cm from the fire-polished end in one hand. Lubricate this end of the tube with glycerine. Hold the stopper in the other hand. Gently and carefully push the tube into the stopper with a twisting motion. Do not use too much force or the tube will snap.

When pushing a piece of bent tubing into a stopper, always hold the tube between the bend and the stopper. Do not push on the bend; it is weak and will break easily.

c. Notes

(i) This is a technique that, if improperly done, can be quite dangerous. When done correctly, however, it is quite safe.

II. BURNERS

These have been grouped according to the type of fuel used.

A. SOLID FUEL BURNERS

These are the simplest burners to make, and include candles as well as charcoal burners.

B. LIQUID FUEL BURNERS

These include several types of alcohol burners.

C. GAS BURNERS AND SYSTEMS

These are functional items, providing the cleanest, most intense heat. However, they are somewhat more sophisticated for production purposes.

A. SOLID FUEL BURNERS

A1. Candle Burner

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Shallow Tin Can (A)	5 cm diameter or larger
(2) Heat Source	3	Household Candles (B)	Varies

b. Construction

(1) Container	Select a tin can (A) with low sides.
(2) Heat Source	Melt the wax at the base of the candles (B) and place tnem at equal intervals within the container.

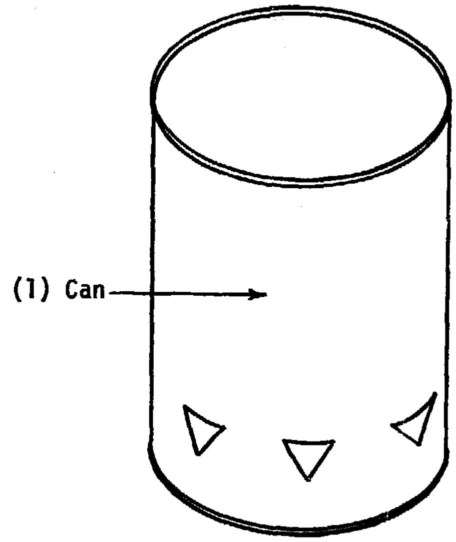
c. Notes

(i) The intensity of the heat produced may be increased by increasing the number of candles, but the total intensity is low.

(ii) The efficiency of a candle burner may be improved by collecting all the wax that melts into the container and using it again with new wicks made from soft string.

(iii) The candle flames tend to deposit soot on the surface of whatever is being heated.

A2. Charcoal Burner *

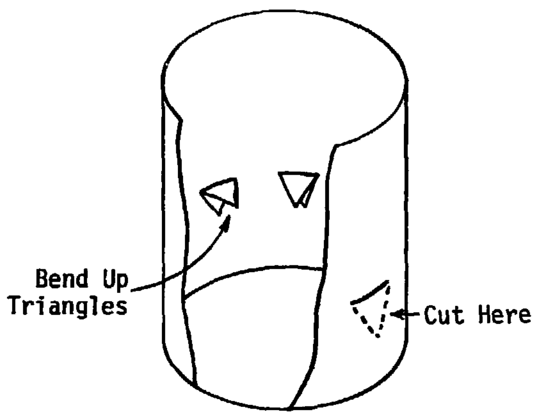


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Empty Metal Can (A)	10 cm diameter or larger

b. Construction

(1) Can



Remove top from can (A). Approximately 4 cm from the bottom of the can, mark off triangular windows all around.

With shears, cut along the sloping sides of each triangle to make the windows. Do not cut along the base line (horizontal edge) of the triangle.

Bend the triangles up to form a tray.

*Adapted from UNESCO, Source Book for Science Teaching, (Paris: UNESCO, 1967), pp 34-35.

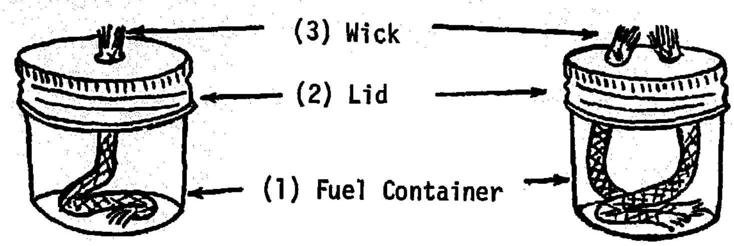
c. Notes

(i) The holes permit air to circulate freely to the burning charcoal.

(ii) Comments from users of the charcoal burners indicate that they are hard to start. Also, once started, they present a considerable fire and carbon monoxide risk.

B. LIQUID FUEL BURNERS

B1. Simple Alcohol Burner



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Fuel Container	1	Glass or Metal Container (A)	150-200 ml, approximate capacity
(2) Lid	1	Screw Top (B)	To fit fuel container
(3) Wick	1	Soft Cotton Fiber Cord (C)	Long enough to extend to bottom of container and to cover it.

b. Construction

(1) Fuel Container — Make the fuel container from a glass or metal container (A) with a screw-on metal lid (B). Select a container with a wide base to insure stability.

(2) Lid — Punch a hole in the lid (B) with a nail, making it as round and smooth as possible, with a diameter smaller than that of the wick to be used.

(3) Wick — Select a piece of cord (C) with soft cotton fibers. The wick should protrude 0.5 cm above the surface of the lid.

c. Notes

(i) If a hotter, broader flame is required, punch two holes in the lid and use two wicks to produce a single, broad flame.

(ii) The wick should be soaked in alcohol before lighting the burner.

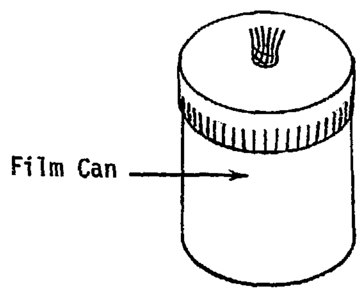
(iii) Methyl alcohol or denatured ethyl alcohol is the usual fuel used in the burner. Kerosene may also be used, but it tends to produce a smoky flame which blackens heated objects.

(iv) Important: Use a stable container. Otherwise, there is danger that the burner will tip over easily.

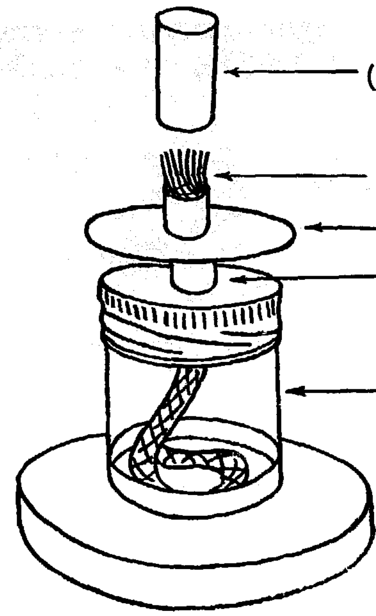
(v) If the burner is used for prolonged periods, overheating of the container, with build-up of internal pressure, is possible.

(vi) Make certain that the wick fits tightly into the hole in the lid. Otherwise, it is possible for the flame to climb down the wick into the container.

(vii) A user of alcohol burners notes that those made from 35 mm film cans have several advantages over larger ones made from glass containers. First, they are unbreakable. Second, if the inside is filled with cotton wadding (cotton wool) they are unspillable if knocked over. Also, these small film cans hold only enough for immediate use, so that evaporation losses are not serious.



B2. Modified Alcohol Burner

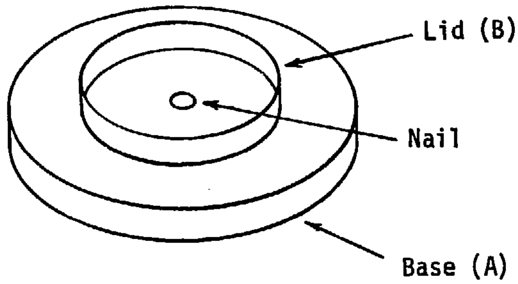


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wooden Platform (A)	Approximately 10 cm diameter (round), or approximately 10 cm x 10 cm (square)
	1	Metal Lid (B)	To fit fuel container bottom
(2) Fuel Container	1	Glass or Metal Container (C)	100-200 ml capacity
	1	Metal Lid (D)	To fit fuel container top (C)
(3) Wick Holder	1	Metal Tube (E)	Approximately 4 cm long, 0.7 cm or 0.8 cm diameter
(4) Heat Barrier	1	Metal Disc (F)	5 cm diameter or larger
(5) Wick	1	Cord (G)	Approximately 10 cm long, 0.5 cm or more in diameter
(6) Cap	1	Ball Point Pen Top or Metal Tube (H)	To fit wick holder

b. Construction

(1) Base

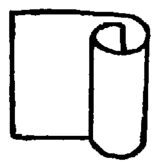


Nail the metal lid (B) (with a diameter equal to that of the fuel container) to the round or square wooden base (B).

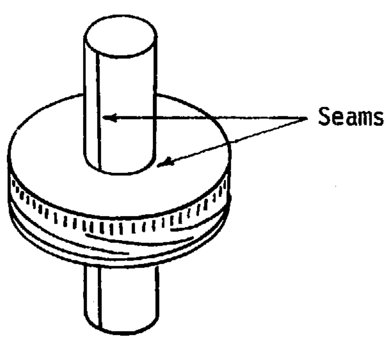
(2) Fuel Container

Select a glass or metal container (C) with a screw-on lid (D).

(3) Wick Holder

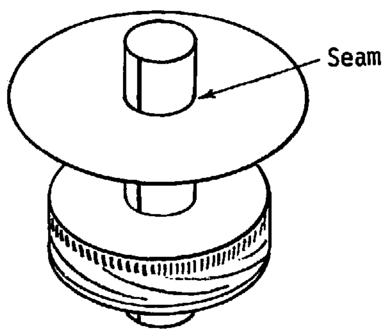


Make the wick holder from a metal tube (E) about 4 cm long x 0.7 or 0.8 cm internal diameter, or roll a piece of sheet metal (4 cm x 2.5 cm) into a tube.



Drill a hole in the fuel container lid (D) large enough to allow insertion of the wick holder. Insert the wick holder so that it penetrates about 1 cm into the container. Solder the seam along the tube and between the tube and the lid.

(4) Heat Barrier



Cut the metal disc (F) from metal sheeting, or use a tin can top. The disc should be slightly larger than the fuel container lid (D).

Drill a hole in the center of the disc large enough to allow insertion of the wick holder (E). Insert the wick holder so that about 1.0 - 1.5 cm protrudes above the disc. Solder the seam between the heat barrier and wick holder.

(5) Wick

Make the wick from a piece of cord (G) or rope with soft cotton fibers. Insert the wick into the wick holder. Trim the wick with scissors so that about 0.4 - 0.5 cm protrudes above the top of the wick holder.

(6) Cap

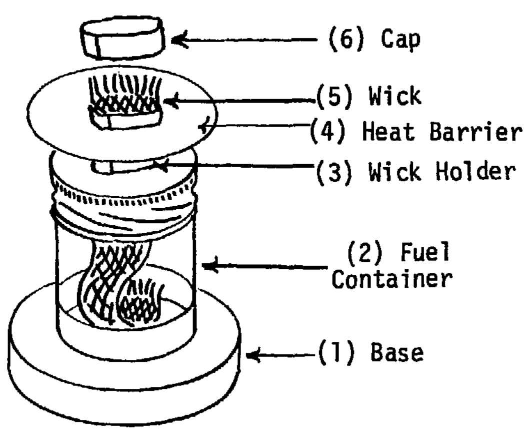
Use a ball point pen top (H) as a cap or make a metal cap large enough to fit snugly over the wick holder when the burner is not in use. The cap prevents evaporation of the alcohol.

c. Notes

(i) The design of this burner overcomes the major hazards of the simple alcohol burner (II/B1).

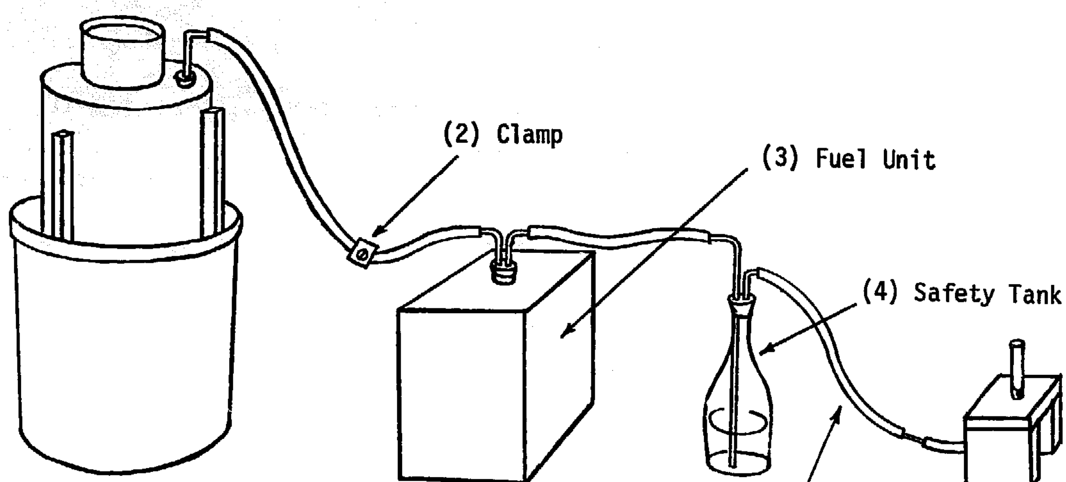
(ii) This design can be modified to produce a wide flame that is particularly useful for working with glass. All parts of the design are the same, except for the shape of the wick, wick holder, and cap.

For the wick holder, cut a piece of metal sheeting about 5 cm x 4 cm. Bend it into a flat tube about 2 cm wide and 0.5 cm deep. Solder the seam. Install this wick holder in the fuel container lid and heat barrier just as in the previous design. For the wick, use flat cotton webbing about 2 cm wide and 10 cm long, or braid (plait) a flat wick from six to ten strands of cotton cord or string. Make a cap from metal sheeting to fit snugly over the wick holder when the burner is not in use.



C. GAS BURNERS AND SYSTEMS

C1. Fuel System for Gas Burner *



a. Materials Required

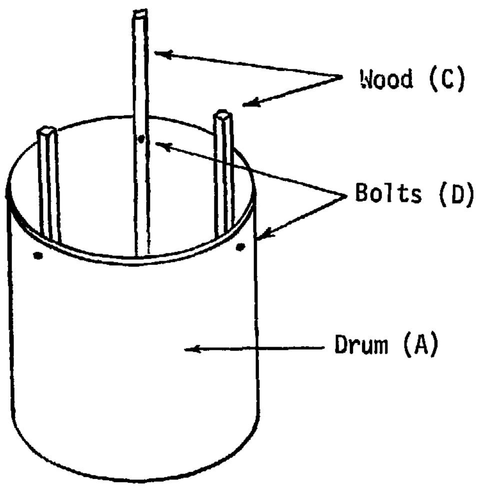
Components	Qu	Items Required	Dimensions
(1) Pressure Unit	1	Metal Drum (A)	Approximately 26 liter capacity
	1	Metal Drum (B)	Approximately 16 liter capacity
	3	Wood (C)	3 cm x 2 cm x 65 cm
	3	Bolts (D)	0.5 cm diameter, 4 cm long
	1	1-Hole Stopper (E)	Approximately 2.5 cm diameter (large end)
	1	Glass Tubing (F)	0.5-0.7 cm diameter, 10 cm long
	1	Container and Sand (G)	Approximately 6 kg
(2) Clamp	1	Screw Clamp (H)	IV/A5
(3) Fuel Unit	1	Metal Can (I)	4 liter capacity, approximately
	1	2-Hole Rubber Stopper (J)	To fit opening in can

*Adapted from C. S. Rao (Editor), Science Teachers' Handbook,(Hyderabad, India: American Peace Corps, 1968), pp 140-141.

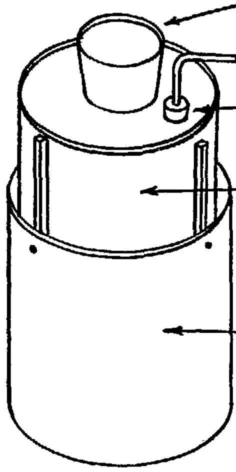
	1	Glass Tubing (K)	0.5 cm diameter, 10 cm longer than height of can
	1	Glass Tubing (L)	0.5 cm diameter, 10 cm long
(4) Safety Tank	1	Narrow-neck Bottle (M)	500 ml capacity, approximately
	1	2-Hole Rubber Stopper (N)	To fit bottle
	1	Glass Tubing (O)	0.5 cm diameter, 10 cm longer than height of bottle
	1	Glass Tubing (P)	0.5 cm diameter, 10 cm long
(5) Burner	1	Gas Burner (Q)	II/C2
(6) Connecting Tube	3	Plastic or Rubber Tubing (R)	Approximately 1 cm diameter, and approximately 1 meter long

b. Construction

(1) Pressure Unit



Select two metal drums (A,B) of approximately the same depths, but different diameters, so that one drum (B) will fit inside the other (A). Each drum should have one end open. Bolt the three pieces of wood (C) to the larger drum (A) with the bolts (D) so that the space between them is just sufficient to allow the smaller drum (B) to slide down easily between them.



Use an alcohol lamp to make a 90° bend in the middle of the glass tubing (F), or cut a shorter piece of straight tubing. Fit the glass tube into the stopper (E). Bore a hole near one side in the bottom of the smaller drum (B). Insert the stopper into this hole.

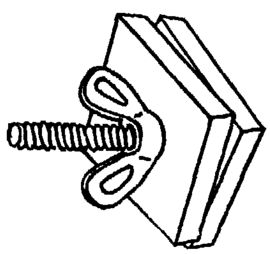
Fill the larger drum (A) with water equal to the volume of the smaller drum.

Fit the smaller drum, open side down, between the wooden uprights of the larger drum.

Push down on the upper (air) drum (B). It should slide down into the lower drum (A). Air should be felt escaping from the glass tubing (F).

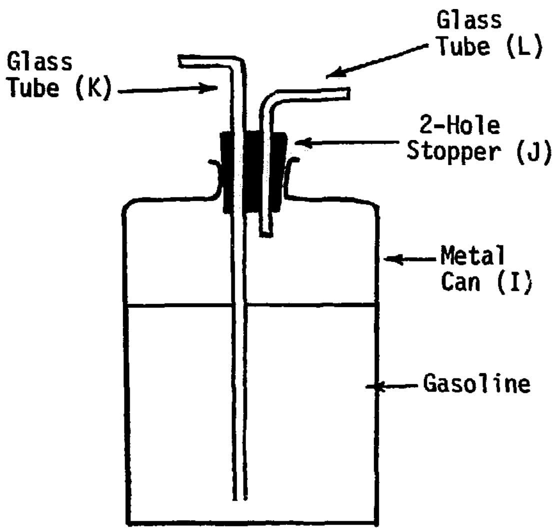
Place a can or bucket filled with sand (G) on the air drum, as a weight.

(2) Clamp



Use the screw-type clamp (H) or any standard screw-type clamp to control the air pressure from the fuel tank.

(3) Fuel Unit



Fuel Unit
(Cross-section)

Make the fuel container from a metal drum (I) or can with a single outlet, rather than a lid. Fit the drum with a two-hole rubber stopper (J).

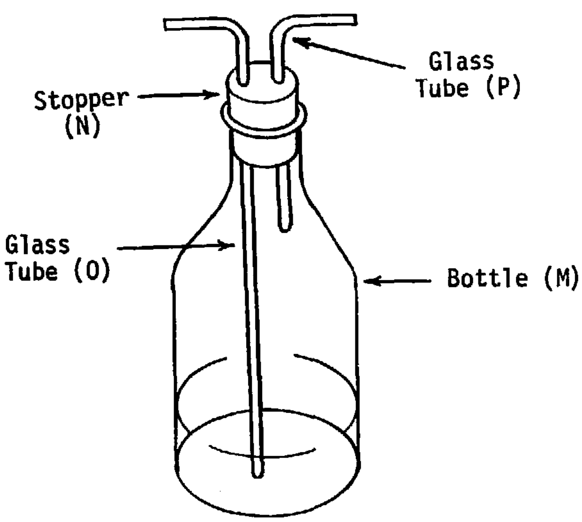
Make a 90° bend about 5 cm from one end of the longer piece of glass tubing (K), or use a slightly shorter piece of straight tubing.

Make a 90° bend in the middle of the short piece of glass tubing (L).

Insert both pieces of tubing into the stopper as illustrated.

Fill the can about 3/4 full of gasoline (petrol).

(4) Safety Tank



Select a glass or metal container (M) with a narrow neck. Fit the container with the two-hole rubber stopper (N).

Bend both pieces of glass tubing (O,P) as described above, and insert each into the stopper as illustrated.

Fill this container about 1/3 full of water.

(5) Burner

Construct a Bunsen burner (Q) as described in the next section (II/C2).

(6) Connecting Tubing

Use flexible tubing (R) (rubber or plastic) to connect the apparatus as illustrated.

Connect the tubing from the Pressure Unit (1) with the long glass tube of the Fuel Unit (3).

Connect the tubing from the short glass tube of the Fuel Unit (3) with the long glass tube of the Safety Tank (4).

Attach the connecting tubing from the short glass tube of the Safety Tank (4) to the Bunsen burner (5). Take care to see that the tubing is not kinked anywhere.

When all components are assembled and correctly connected, remove the weight and stopper from the upper (air) drum. Lift the drum until its lower edge is just below the water level in the lower drum. Replace the stopper and check to see that it is tight, and replace the weight on top of the drum.

c. Notes

(i) As the air drum sinks into the water of the lower drum under its own weight and the pressure of the weight on top, the air thus displaced is driven into the fuel drum and bubbles up through the petrol. The petrol evaporates as the air passes through it, and the air-gas mixture is driven through the water in the safety tank to the burner.

(ii) This system is potentially dangerous because the petrol-air mixture present from the fuel tank is an explosive mixture, but several safety precautions have been incorporated into the design.

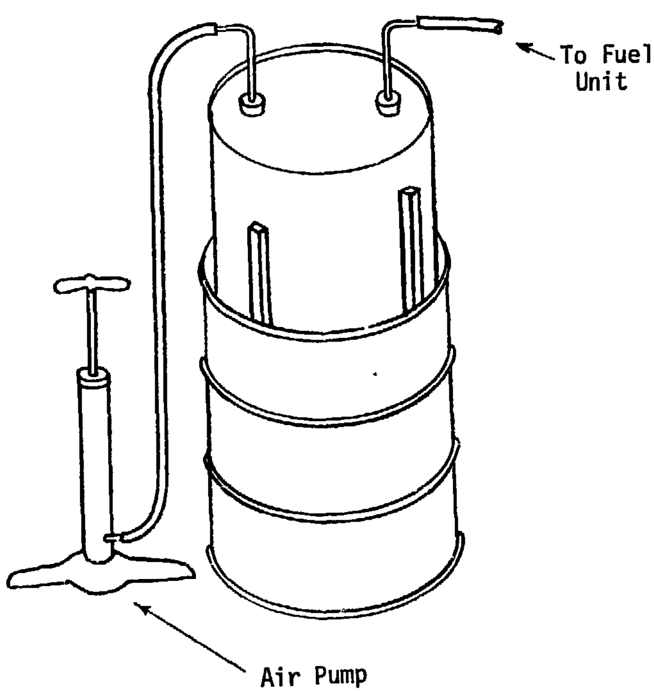
The greatest safety factor is the needle valve in the burner; even when the burner occasionally "backfires" (the flame jumps down from the end of the burner tube to the needle opening) the flame is very unlikely to move back through the needle's narrow opening. In the unlikely event that a flame should move back down the tubing, the safety tank prevents it from reaching the fuel drum. As a further safety measure in the safety tank, the stopper should be snug, but not jammed tightly into the neck of the container. Thus, should the flame move back into the safety tank, it will be more likely to blow the stopper out of the tank than to blow the tank apart.

Despite the built-in safety precautions, however, feedback comments suggest extreme care in the use of this system.

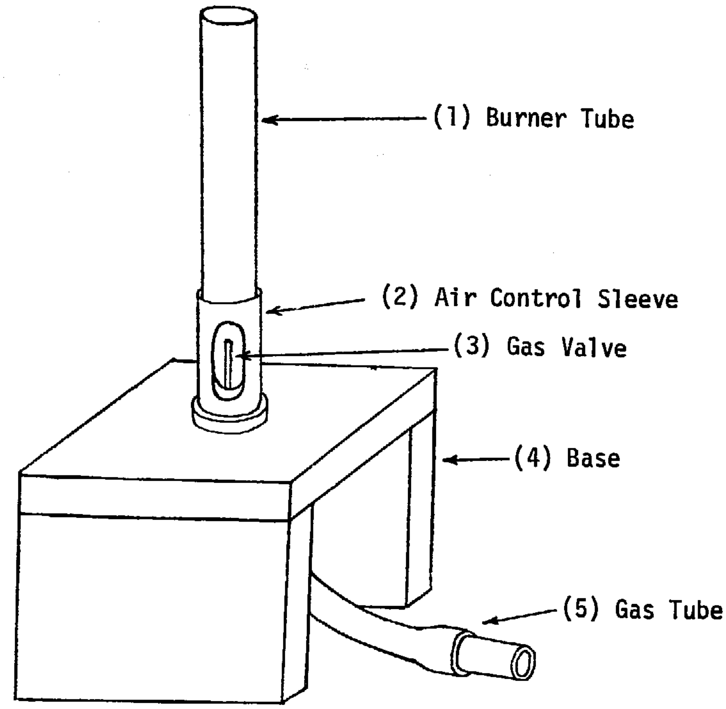
(iii) In the system described here, a glass bottle, encased in a cage of wire mesh for additional safety, was used as a water tank. This made it possible to observe the rate of bubbles in the water, an indicator of the pressure in the system. A fairly rapid rate of bubbles, about 100 or more per minute, was necessary to produce a burner flame 3 - 4 cm high. It is recommended, however, that once the bubbling rate is established, a metal safety tank of similar size be substituted for the glass bottle.

(iv) A weight of approximately 5.5 kg on an air drum with an area of 490 cm^2 (diameter 25 cm) provided 11 g/cm^2 pressure to run the Bunsen burner described in the following section (II/C2) for about a half-hour.

(v) The system and dimensions described here constitute a small, laboratory version suitable for running one Bunsen burner. For a larger system, the same components and principles apply, but experimentation on the details of construction will be necessary. For example, a larger pressure system, with a large, heavy oil drum for the upper drum would provide pressure for a longer period of time and might not require a weight on top. An air pump could be added to fill the drum with air without lifting it.



C2. Gas Burner *



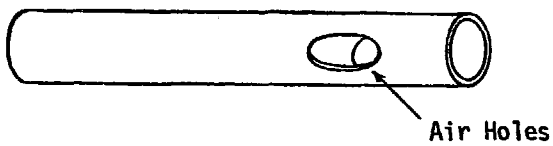
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Burner Tube	1	Copper Tubing (A)	10.5 cm long, 1 cm dia[illegible]r
(2) Air Control Sleeve	1	Metal Sheet (B)	3 cm x 3.[illegible] cm
(3) Gas Valve	1	Hypodermic Needle (C)	18 gauge (0.125 cm outside diameter)
	1	Adhesive Tape or Electrical Tape (D)	Approximately 1 cm wide, 15-30 cm long
(4) Base	1	Wooden Block (E)	10 cm x 10 cm x 2 cm
	2	Wooden Block (F)	10 cm x 5 cm x 2 cm
(5) Gas Tubing	1	Rubber or Plastic Tubing (G)	Approximately 15-20 cm long, approximately 0.6 cm internal diameter
	1	Metal Tube (H)	3 cm long, 1 cm diameter

*Adapted from C. S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968), pp 138, 141.

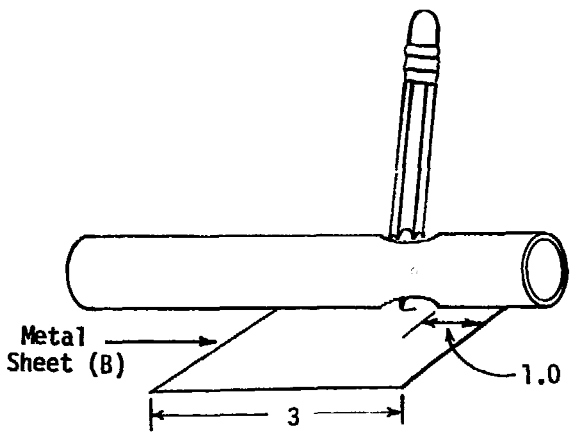
b. Construction

(1) Burner Tube



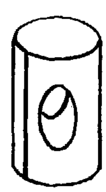
Drill two holes on opposite sides of the copper tube (A) about 2 - 2.5 cm from one end. Enlarge the holes to an oval shape, about 1 cm long x 0.6 cm wide.

(2) Air Control Sleeve



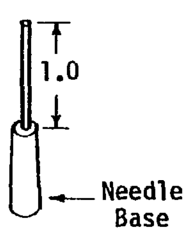
Lay the metal sheet (B) flat on a table. Lay the burner tube on it with the end of the tube with the holes in it about 1.0 cm from the 3.5 cm edge. Actually, the holes themselves should be 1.0 cm from the 3.5 cm edge.

Use a pencil to trace the outline of one of the holes in the tube onto the metal sheet. Cut this hole out. Wrap the metal sheet around the burner tube until it forms a cylinder. Align the hole in the metal sheet with one of those in the tube. Trace the outline of the other hole in the tube onto the metal sheet. Remove the metal sheet, and cut out the second hole.

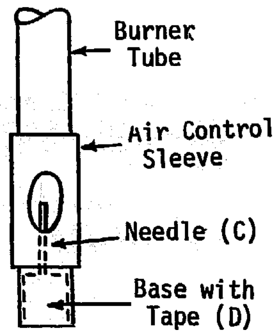


Reroll the air control sleeve and place it in position on the burner tube.

(3) Gas Valve



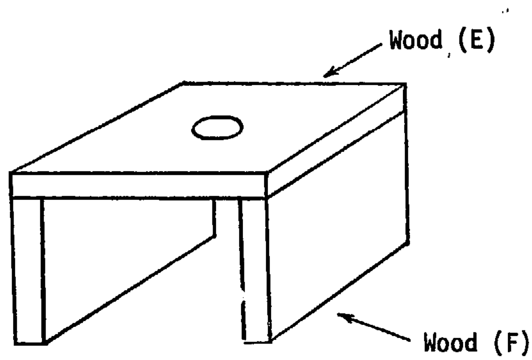
Cut the top off the hypodermic needle (C) so that about 1 cm of the needle remains. File the cut end of the needle open.



Side View

Wrap the adhesive tape (D) or electrical tape around the needle holder until the base of the needle will fit tightly into the bottom of the burner tube. The open end of the needle should be near the middle of the air holes.

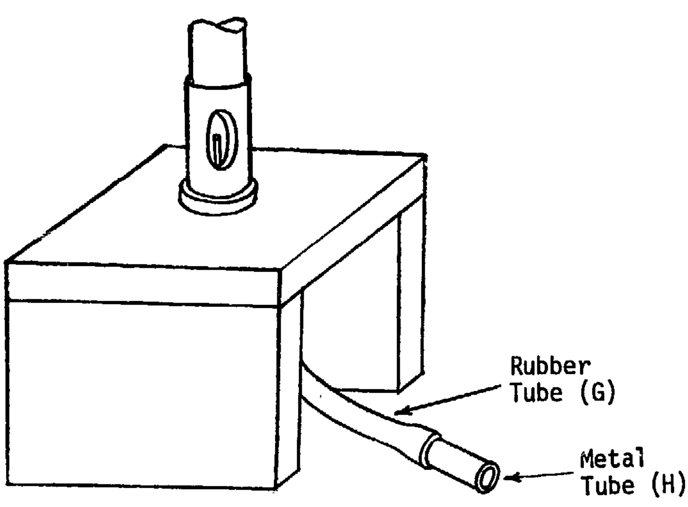
(4) Base



Drill a hole approximately 1.2 cm in diameter in the center of the square piece of wood (E). Enlarge the hole with a file to tightly hold the burner tube and gas tubing in place.

Nail the two rectangular pieces of wood (F) to the square to form the sides of the base.

(5) Gas Tubing



Connect one end of the plastic or rubber tubing (G) to the bottom of the burner tube. Then push the burner tube through the hole in the top of the base. It should fit snugly in place and should not wobble.

Pass the other end of the gas tubing through one open side of the base. Insert the small metal tube (H) into the open end of the gas tubing.

Connect tubing from the gas supply to this metal tube.

c. Notes

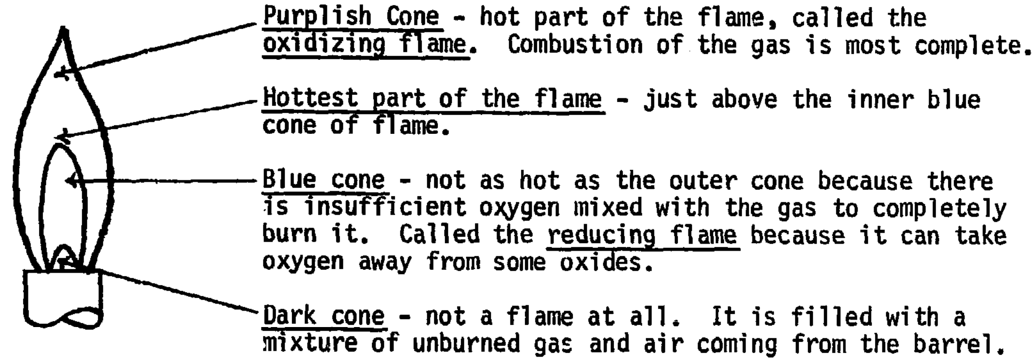
(i) This burner has been tested with both commercially supplied natural gas and with the gas generating system described in the previous section II/C1.

(ii) When the burner is lit, the air control sleeve can be used to control the nature and intensity of the flame. The sleeve is closed when its holes and the holes in the burner tube are not lined up with each other. No air enters the burner tube. The flame is smoky, yellow, and glowing. It gives little heat. The absence of air prevents the gas from being completely burned.

When the sleeve is turned so that its holes and those of the burner tube are partly lined up, some air enters the burner tube. The flame is almost colorless, and does not glow. It is quite hot. The gas is more completely burned in this flame because of the presence of some air.

When the holes of the air control sleeve completely match those in the burner tube, the maximum amount of air enters the burner tube.

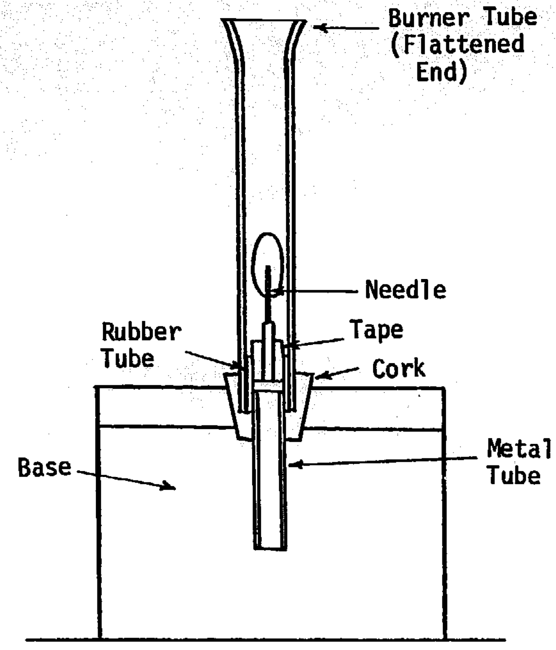
This produces a very hot, roaring flame with a bright blue center cone. The gas is completely burned, producing the hottest flame, because there is plenty of air entering the burner tube.



Use a blue flame, about 4 cm high, for glass-working operations and most other heating operations. Adjust the gas supply and air control sleeve of the burner to produce a quiet blue flame with distinct cones.

(iii) In use this burner produced an excellent flame suitable for working soft glass and for blowing small bulbs in 0.3 cm and 0.5 cm soft glass tubing. However, the burner tube tended to heat up after a few minutes use. The larger diameter burner, of slightly more complex design, avoids this difficulty to some extent.

(iv) If a larger diameter tube (e.g., 1.5 cm diameter) is used for the burner tube, several alterations must be made to the design of the burner. First, a larger diameter syringe needle is needed (16 gauge, 0.15 cm outside diameter), and it must be cut off shorter, i.e., 0.5 cm rather than 1.0. Secondly, the end of the burner tube must be flattened slightly to restrict the flow of air/gas mixture through it. Thirdly, the connection between burner tube, gas valve, and gas tube must be altered. One way in which this can be done is to drill a hole 1.0 cm in diameter through a cork. Enlarge the hole at one end to 1.5 cm diameter, and 1.5 cm deep. Insert a 1.0 cm diameter piece of metal tubing through the hole and place a short (1.0 cm) piece of rubber tubing on the end of it. Insert the needle into the rubber tube (the base may have to be built up with tape). Insert the burner tube into the enlarged hole in the cork. Make certain the fit is tight. Finally, insert the cork into the hole in the base, put the air control sleeve in place, and attach the gas tubing.

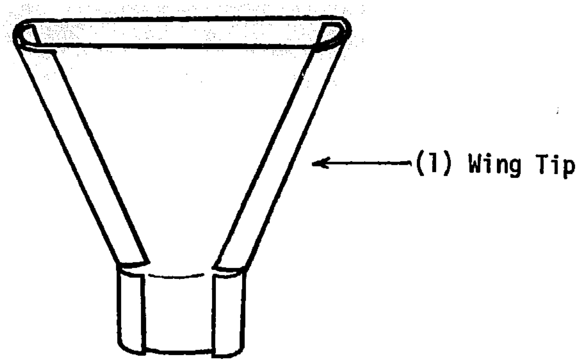


Cross Section

If, when this burner is in use, the flame should tend to blow itself out because the tube opening is too wide, decrease it further by pinching with pliers.

(v) It must be noted that various components of the burner design are dependent on the diameter of the burner tube. These include burner tube length, size of the air holes, gauge and length of the needle, width at the top of the tube, and various connecting devices such as metal and rubber or plastic tubing. For example, if the diameter of the burner tube is increased, the diameter of the needle used and the length of the tube must also be increased, but the size of the opening at the top of the tube must be decreased. Therefore, if tubing of a size different from those described here is used, experimentation with the other components will be necessary in order to construct a working Bunsen burner.

C3. Wing Tip

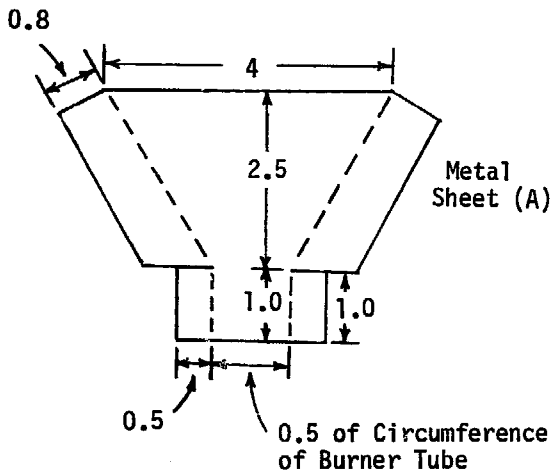


a. Materials Required

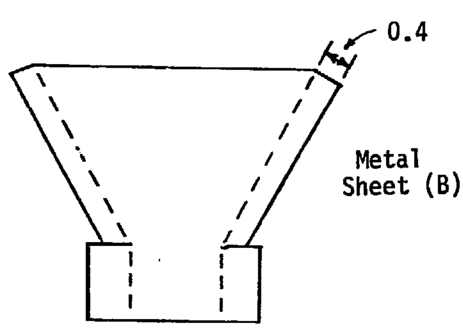
Components	Qu	Items Required	Dimensions
(1) Wing Tip	1	Metal Sheet (A)	6 cm x 4 cm
	1	Metal Sheet (B)	6 cm x 4 cm

b. Procedure

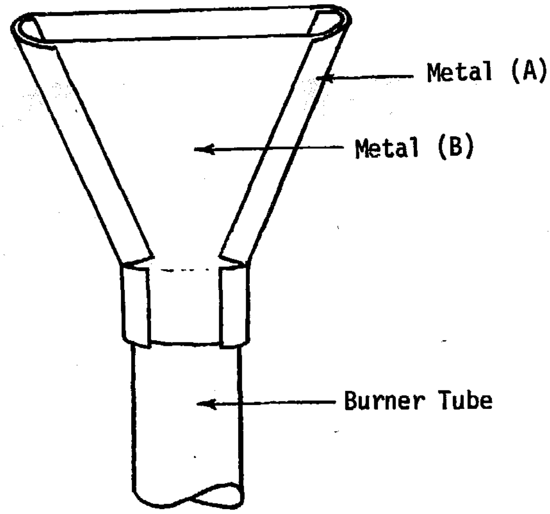
(1) Wing Tip



Measure the circumference of the burner tube. Draw and cut out a paper pattern as illustrated. Cut one piece of this pattern from the metal sheeting (A). Cut on the solid lines. Bend on the dotted lines.



Cut another piece from the metal sheeting (B), but trim the flaps on the wing to 0.4 cm. Cut on the solid lines. Bend on the dotted lines.



Bend the wing flaps on piece (B) at 90°. Bend the wing flaps of piece (A) around the outside of the flaps on (B). Pinch the flaps on (A) to hold (B) in place.

Place the wing tip on the burner tube, such that the wing extends above the burner tube.

Bend the support strip flaps of (B) and (A) to fit snugly around the burner tube. Small holes left at the corners of the flaps will not affect the wing tip's performance.

c. Notes

(i) The wing tip is an accessory used with the gas burner when a wide flame is desired. It is especially useful for working with glass.

III. MEASURING APPARATUS

A. DEMONSTRATION DEVICES

These devices demonstrate thermal expansion of liquids and solids.

B. VOLUMETRIC MEASURES

These are all measures of liquid volume and range from single volume measures like volumetric flasks to multiple measures such as measuring cylinder. Also included under this heading is the specific gravity bottle.

A. DEMONSTRATION DEVICES

A1. Demonstration Thermometer

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Thermometer	1	Pill Bottle (A)	7 cm high, 3 cm diameter
	1	Pill Bottle Cap (B)	To fit pill bottle (A)
	1	Glass Tubing (C)	25 cm long, 0.5 cm outside diameter, 0.3 cm inside diameter

b. Construction

(1) Thermometer

Make a hole in the pill bottle cap (B) (or a suitably sized cork) through which the glass tubing (C) is inserted.

Be certain the seal is airtight (it may be necessary to use glue to insure an airtight seal).

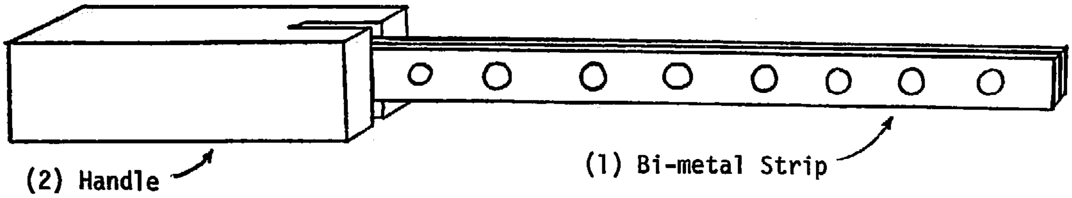
Fill the bottle (A) completely with water or other liquid. Force the cap or cork down onto the mouth of the bottle so that some liquid is forced up into the tube and the rest of the excess liquid spills over the side of the bottle where it is wiped away. Some liquid must rise up far enough into the tube so that it can be seen.

c. Notes

(i) This thermometer is used simply to demonstrate the expansion of a liquid as it is used in standard thermometers. Putting the demonstration thermometer into a 60°C water bath will cause the level of the water in the tube to rise about 2 cm.

(ii) Be certain to eliminate all air bubbles from the bottle unless it is desirable to show the effect of having air trapped in the bottle.

A2. Bi-Metal Strip

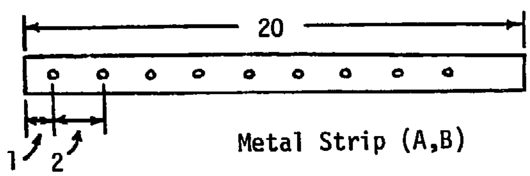


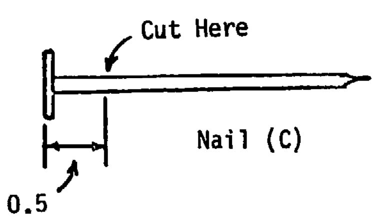
a. Materials Required

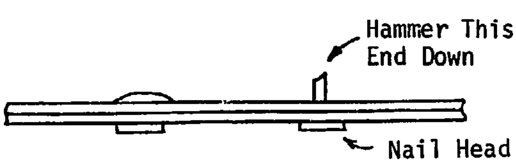
Components	Qu	Items Required	Dimensions
(1) Bi-metal Strip	1	Steel Strapping (A)	20 cm x 1.2 cm x 0.8 cm
	1	Aluminum Sheet (B)	20 cm x 1.2 cm x 0.6 cm
	9	Nails (C)	#4 d (0.2 cm diameter with large heads)
(2) Handle	1	Wood (D)	1.5 cm x 2.0 cm x 10 cm

b. Construction

(1) Bi-metal Strip





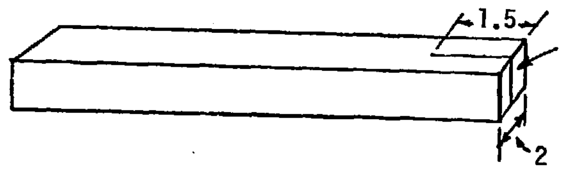


Side View

Hold the two pieces of metal (A,B) tightly together, and drill nine holes through both at 2 cm intervals beginning 1.0 cm from one end. These holes must be very slightly larger in diameter than the nails (C) used.

Cut the head off each nail (C) with a hacksaw, chisel, or tin snips so that the portion with the head is about 0.5 cm long. Push the nails through the holes in the two strips (A,B) and hammer down the cut ends to rivet the two strips together. It is best to begin by riveting the strip at its center and moving out toward each end at the same time. The strips should be firmly held together all along their length.

(2) Handle



Make a narrow notch in one end of the wood (D) the width of a saw blade. This notch ought to be about 1.5 cm deep. Insert the end of the bi-metal strip into this notch to complete the device.

c. Notes

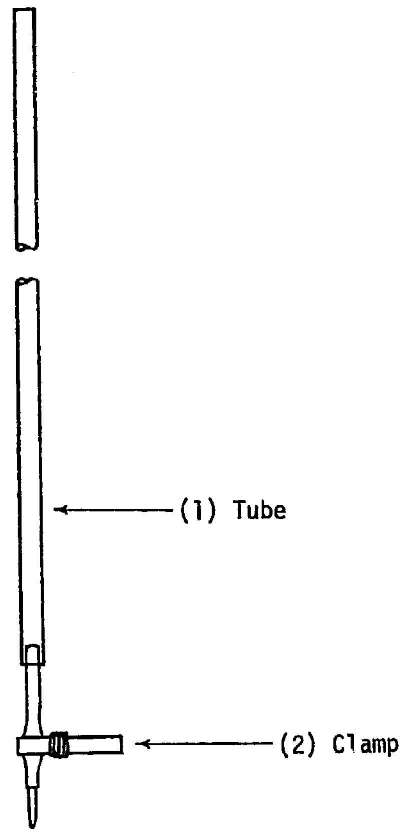
(i) This device is used to demonstrate the fact that metals expand when they are heated. When the bi-metal strip is held in a flame, it will bend in the direction of the steel since the aluminum expands more than does the steel.

(ii) Different combinations of metals (e.g., copper and steel, brass and aluminum, etc.) can be used with the same results.

(iii) The metal strips may be soldered together as opposed to riveted. Melt a thin layer of solder onto the surface of one of the two strips. Lay the other strip on top of it and hold the soldering iron down on both strips until the solder melts between the two strips. Keep the two strips pressed together with a screwdriver or other object to prevent them from coming apart before the solder cools. Repeat this process until the two strips are soldered all along their lengths. (Note: This procedure will not work if aluminum is used as one of the metals unless special solder is used.)

B. VOLUMETRIC MEASURES

B1. Burette

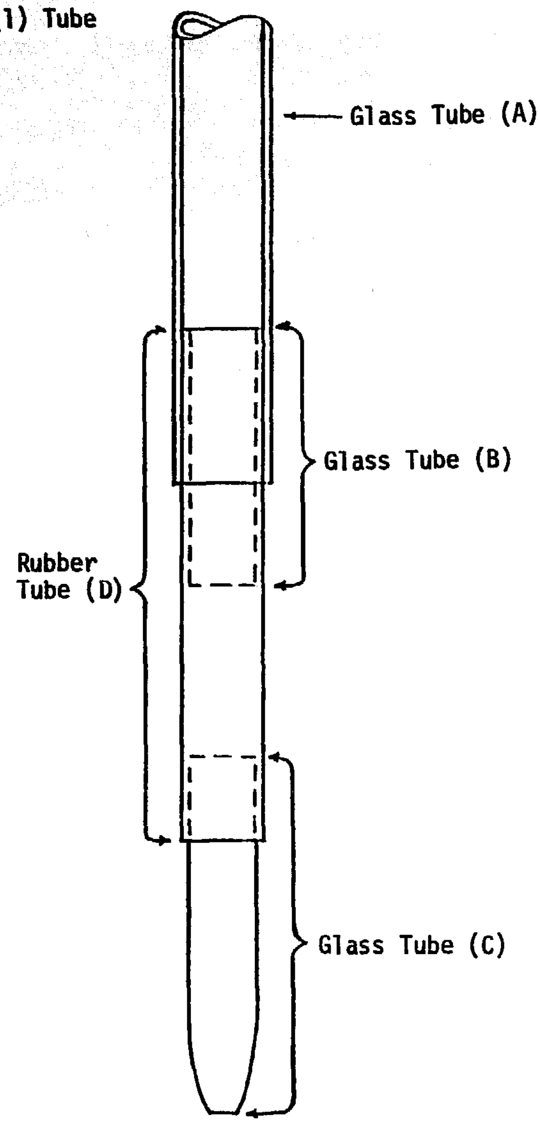


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Tube	1	Glass Tube (A)	45 cm long, 1.3 cm outside diameter, 1.1 cm inside diameter
	1	Glass Tube (B)	4 cm long, 0.7 cm outside diameter, 0.5 cm inside diameter
	1	Glass Tube (C)	9 cm long, 0.7 cm outside diameter, 0.5 cm inside diameter
	1	Rubber Tubing (D)	10 cm long, 1.0 cm outside diameter
(2) Clamp	1	Pinch Clamp (E)	IV/A4

b. Construction

(1) Tube



Detail

Insert the glass tubing (B) into the end of the rubber tubing (D) so that the ends of both pieces of tubing are even. Insert this end into one end of the large glass tubing (A) for a distance of about 1 - 1.5 cm. If the seal between the rubber and large glass tubing is not watertight, use thin rubber sheeting (e.g., balloon material) to fill in the gas. Seal this joint with glue to insure a watertight fit. Draw out one end of the remaining piece of glass tubing (C) in a flame to form a narrow neck. Break off the neck, and fire polish the end of the tube. Insert the wide end of this tube into the end of the rubber tubing (D) for a distance of about 2 cm. Check the tube now for watertightness.

(2) Clamp

Use the clamp (E) to regulate flow in the burette. Be sure the clamp is large and strong enough to completely shut off flow from the burette.

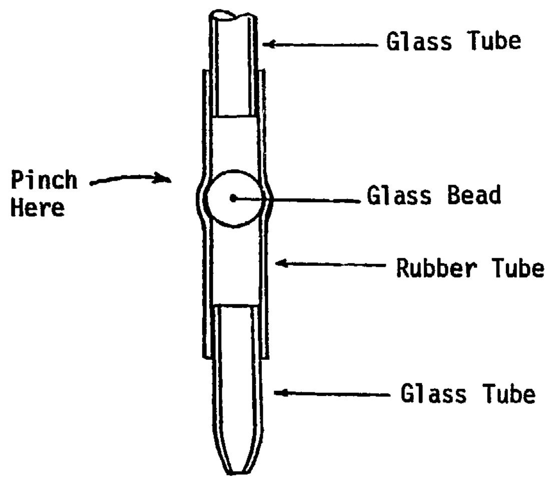
c. Notes

(i) The most common use of the burette in chemistry is in doing titrations.

Quite often they are used in pairs, and must always be supported by a stand.

(ii) Each burette needs to be fitted with a scale. Attach a long, thin strip of paper to the burette tube with transparent tape. Fill the burette from a known source (e.g., a plastic syringe) one milliliter at a time and mark the level of the meniscus on the paper. Place the "0" mark in such a way that several milliliters of liquid will still remain in the burette when "0" is reached as this will insure greater accuracy.

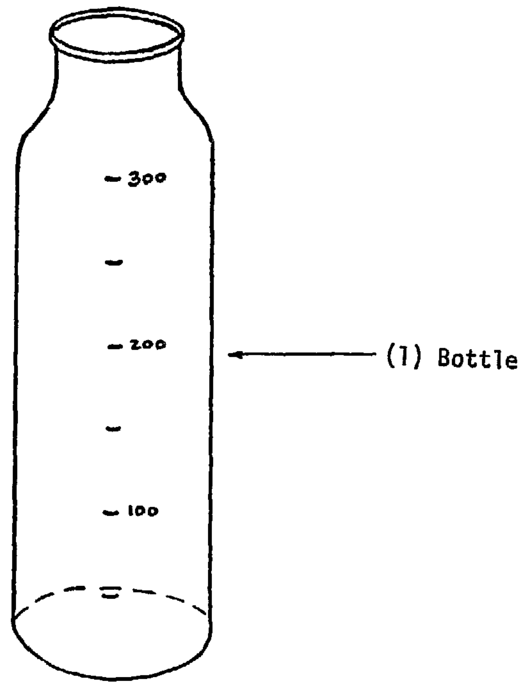
(iii) A glass bead just slightly larger than the internal diameter of the rubber tubing may be used in place of the pinch clamp. Push the bead into the rubber tubing before inserting the glass nozzle. The bead will seal the rubber tube. To dispense liquid from the burette, squeeze the tube between thumb and forefinger at the location of the head.



Cross Section

(iv) Because of the use of rubber tubing in this burette, it is not suitable for use with strong corrosives that attack rubber.

B2. Measuring Glass



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Glass Bottle (A)	Variable

b. Construction

(1) Bottle

Use a glass bottle (A) with straight sides and a flat bottom. Make graduations by calibrating the bottle using a known source. The graduations may be tape, paint, or scratches on the glass itself.

c. Notes

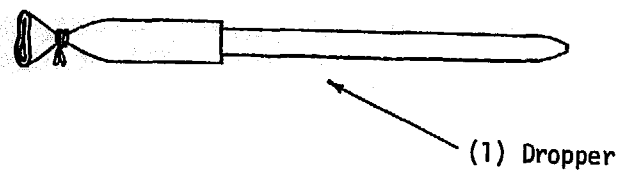
(i) Inaccuracies may occur due to transfer of liquid from the known source, failure to wait for liquid to "settle" before making calibration marks, and human error in marking exact height of liquid. However, for most purposes these measuring glasses are adequate.

(ii) Graduations may be made every 10, 25, 50, or 100 ml, depending on the size of the bottle and the uses to which it is to be put.

c. Notes

(iii) If the bottle is narrow enough in diameter, the graduations may be made closer together (i.e., every milliliter), but the accuracy will not approach that of a commercially made graduated cylinder.

B3. Dropper



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Dropper	1	Dropper	BIOL/II/A6

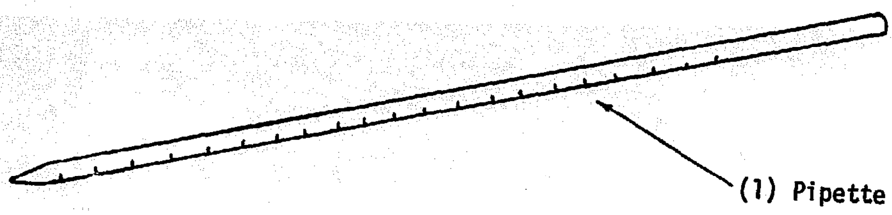
b. Construction

(1) Dropper — Construct the dropper as described in BIOL/II/A6.

c. Notes

(i) Since commercial droppers are usually readily available and inexpensive, this item is as easily purchased as it is improvised.

B4. Pipette



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Pipette	1	Transfer Pipette	BIOL/VII/A5

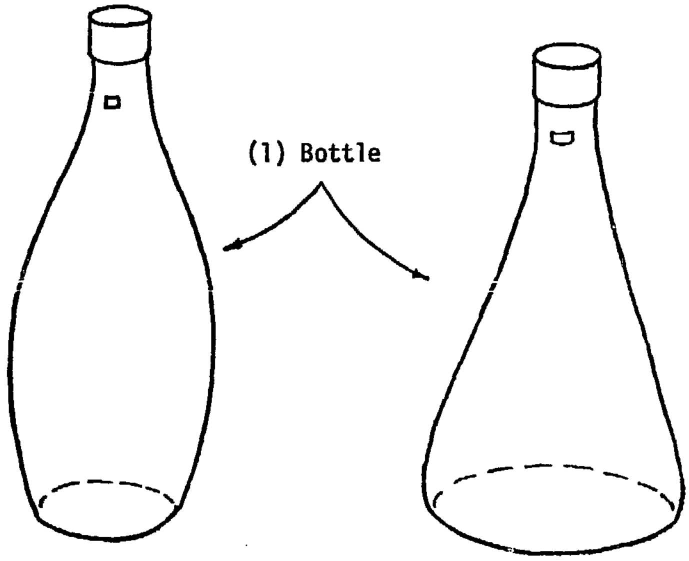
b. Construction

(1) Pipette — Construct the pipette as described in BIOL/VII/A5.

c. Notes

(i) The pipette is used to transfer and precisely measure quantities of liquids.

B5. Volumetric Flasks



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Transparent Glass Bottle (A)	Variable
	1	Bottle Cap (B)	To fit bottle (A)

b. Construction

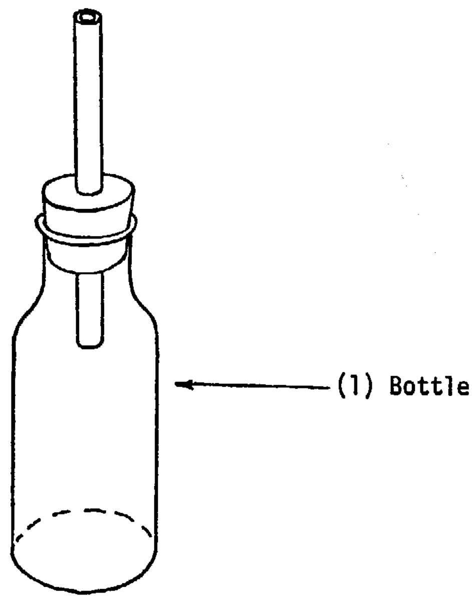
(1) Bottle — Select any common glass bottle (A) with a narrow neck.

(2) Cap — Use a cap seal (B) which will be airtight to prevent leakage and evaporation.

c. Notes

(i) The flasks must be calibrated from a known source. Put a single calibration mark on the neck of the bottle to indicate its capacity. This may be done with paint, tape, a scratch mark, etc.

B6. Specific Gravity Bottle



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bottle	1	Pill Bottle (A)	5 cm high, 3 cm diameter
	1	Rubber or Cork Stopper (B)	To fit bottle (A)
	1	Glass Tube (C)	8 cm long, 0.5 cm outside diameter, 0.3 cm inside diameter

b. Construction

(1) Bottle

Simply insure that there are airtight seals between the stopper (B) and bottle (A), and between the glass tube (C) and cork (B).

c. Notes

(i) To use the specific gravity bottle, first remove the stopper and tubing and fill the bottle to the brim with the liquid to be measured. Reinsert the stopper, making sure liquid flows completely out of the end of the tubing and that there is no air trapped in the bottle. Wipe away the excess liquid on the outside of the bottle. Accurately weigh this amount of liquid and subtract the mass of the empty specific gravity bottle. Compare the mass of the liquid to that of an equal volume of water (found in the same way) to find the specific gravity of the liquid.

(ii) A screw-top bottle may be used instead of the stopper arrangement. Punch a hole in the top and seal the joint between the tubing and top with waterproof cement.

IV. SUPPORTS, STANDS, AND HOLDERS

A. HOLDERS

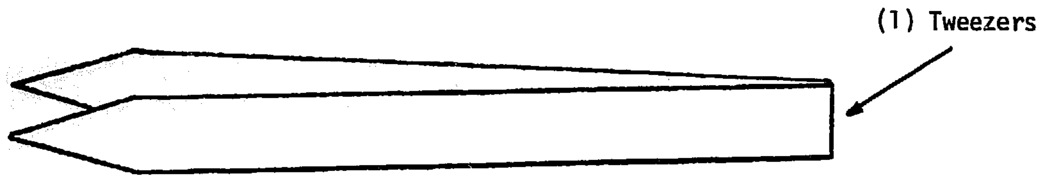
Holders are classified as small, portable, hand-held devices used to support other pieces of apparatus.

B. SUPPORTS AND STANDS

These devices are used to hold items stationery for relatively long periods of time.

A. HOLDERS

A1. Tweezers (Forceps)



a. Materials Required

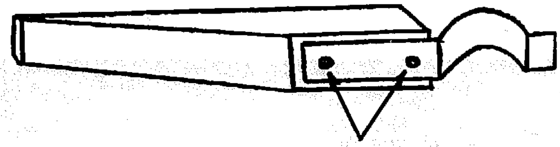
Components	Qu	Items Required	Dimensions
(1) Tweezers	1	Forceps	BIOL/II/A4

b. Construction

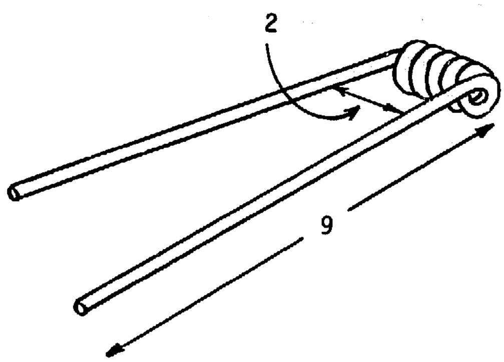
(1) Tweezers — See BIOL/II/A4 for construction details.

c. Notes

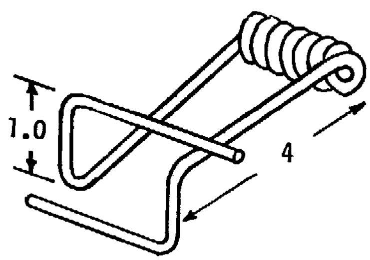
(i) Uses of forceps in chemistry operations include the handling of small items or radioactive materials.



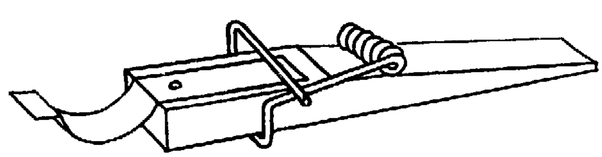
Fasten one strapping clamp to the short end of each of the handles with the nails (C).



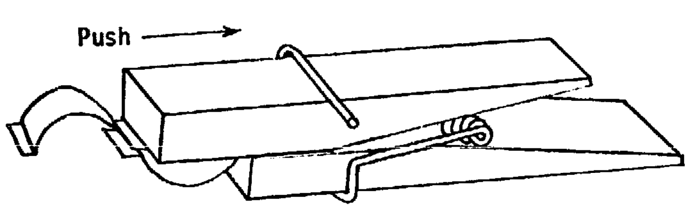
Clamp a pencil or stick of about 0.8 cm diameter in a vise. Starting at the center of the wire (D), coil the wire around the pencil. Make at least six turns, or a coil that extends beyond the width of the wood block (2 cm) by one wire-thickness on each side. Leave at least 9 cm of straight wire at each end of the spring.



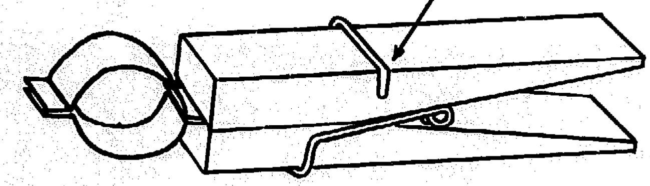
Approximately 4 cm from the spring, make a 90° bend in each straight section of wire, as shown. One cm from each of the first bends, make a second 90° bend.



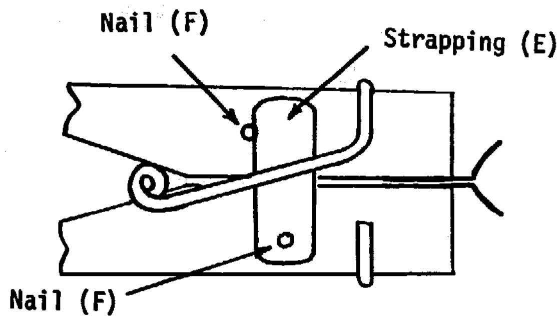
Slide the spring on to one of the handles as shown.



Slide the second handle into place.



Trim excess wire to within 1.5 cm of the edge of the handle. Bend this remaining wire around handles to hold the spring in place.



Top View

Lay the holder on its side. Slide one small piece of strapping under the spring as shown. Secure the strapping in place on one handle with one nail. Nail a second guiding nail into the other handle just at the edge of the strapping. Turn the holder over and repeat with another small piece of strapping. These guides keep the handles from twisting out of alignment.

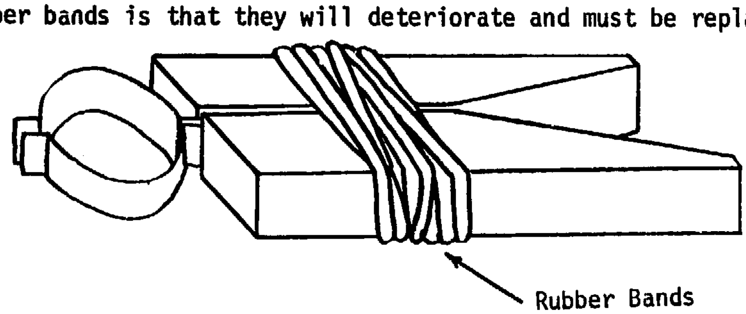
c. Notes

(i) This design is based on the spring-type clothespin. If one is available, it will be a helpful construction guide.

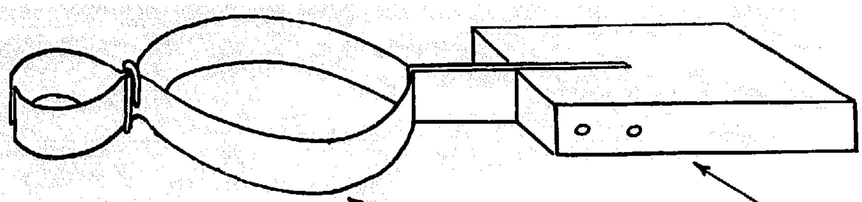
(ii) Squeezing the handles together will cause the clamp to open and close.

(iii) The sizes of the components used in this item will vary with the use to be made of the holder. The clamp and handle can be reduced in size for use with test tubes, or enlarged for use with large flasks.

(iv) For a simpler version of this design, three or four strong rubber bands provide the spring action. Cut the handles and attach the clamps as described. Then place the two handles together as indicated in the diagram. Wrap the rubber bands around the top part of the handles to draw them together. The chief problem with using rubber bands is that they will deteriorate and must be replaced from time to time.



A3. Test Tube Holder

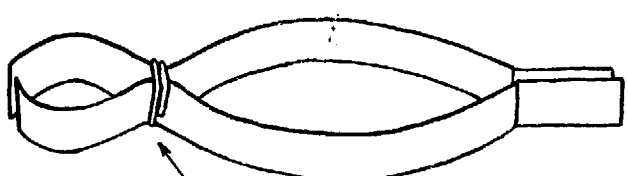


a. Material Required

Components	Qu	Items Required	Dimensions
(1) Clamp	2	Metal Strapping (A)	20 cm long
	1	Thin Wire (B)	Approximately 0.1 cm thick, 4-5 cm long
(2) Handle	1	Wood Block (C)	Approximately 10 cm x 3 cm x 2 cm

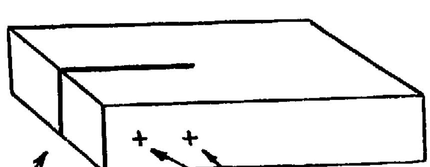
b. Construction

(1) Clamp



Bend two loops in each piece of strapping (A) as shown. Fit the smaller loops to the test tubes to be used. Wrap a small piece of wire (B) around the two pieces of strapping at the point where they curve inward, just behind the front loops, to hold the pieces together.

(2) Handle



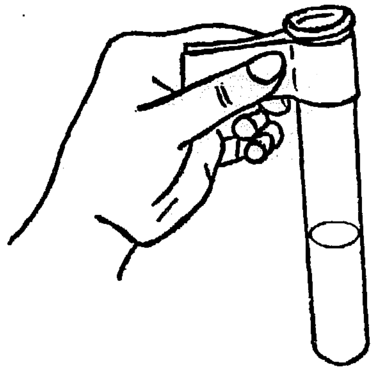
Cut a slit about halfway down the center of the block (C). Insert the flat portions of the strapping clamps into the slit. Secure the clamp to the handle with two nails.

c. Notes

(i) To open this clamp, squeeze together the large loop between the handle and the wire. Release the loop to close the clamp.

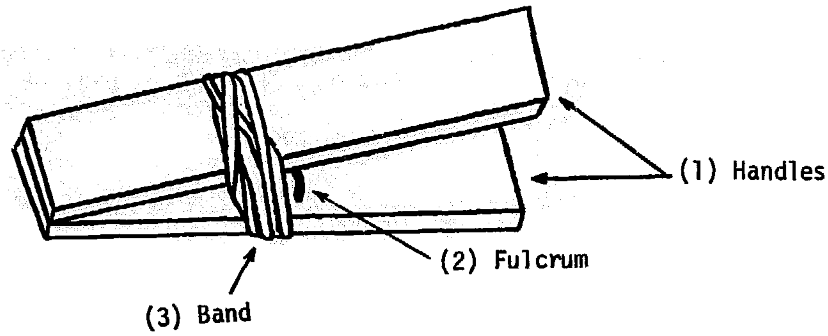
(ii) This design is best suited for small, light-weight test tubes.

(iii) A quick and convenient holder for handling hot test tubes can be made with a piece of paper measuring approximately 15 cm x 8 cm. The paper is folded into



thirds, lengthwise, to form a strip. This strip can be wrapped around a test tube near the top, then grasped tightly, next to the test tube.

A4. Wooden Pinch Clamp



a. Materials Required

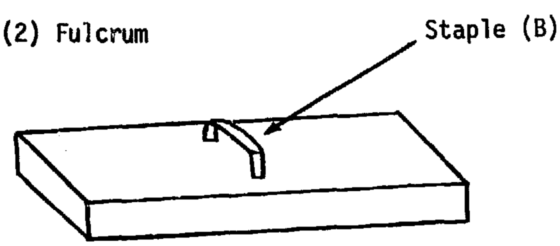
Components	Qu	Items Required	Dimensions
(1) Handles	2	Wooden Strips (A)	2 cm x 8 cm x 0.5 cm
(2) Fulcrum	1	Metal Staple or Tack (B)	1 cm wide
(3) Band	2	Rubber Bands (C)	0.5 cm x 9 cm

b. Construction

(1) Handles

Sand any splinters or rough edges from the wood strips (A).

(2) Fulcrum



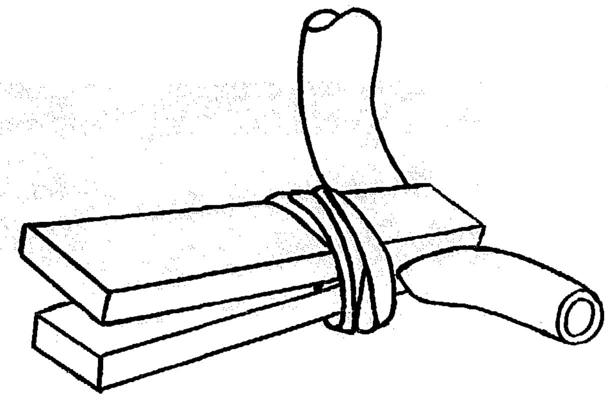
Drive the staple (B) or tack into the middle of one of the handles. Allow about 0.5 cm of the staple or tack to protrude from the wood.

(3) Band

Place the handles together with the fulcrum between them. Wrap the two rubber bands (C) tightly around the handles at a point just in front of the fulcrum.

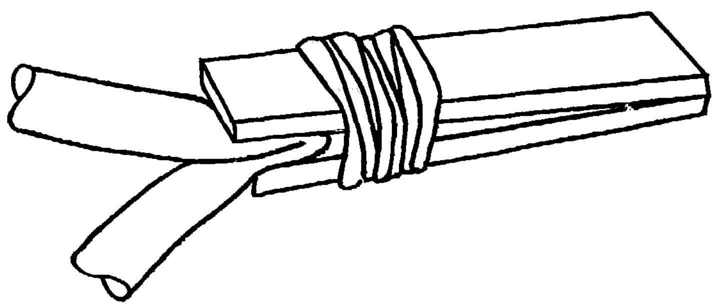
c. Notes

(i) If the rubber bands are sufficiently tight, it should be possible to



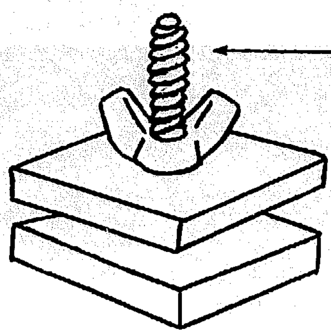
completely close off the flow of a liquid such as water through 1 cm wide rubber tubing,

(ii) To completely close off plastic tubing and heavier rubber tubing, it will be necessary to bend the tubing back upon itself and secure the clamp at the bend.



(iii) If pinch-type clothespins are available, they may be substituted for this clamp. However, it will be necessary to bend rubber tubing as well as plastic tubing back upon itself, as in the above illustration, in order to completely close the tubing with a clothespin clamp.

A5. Wooden Screw Clamp



a. Materials Required

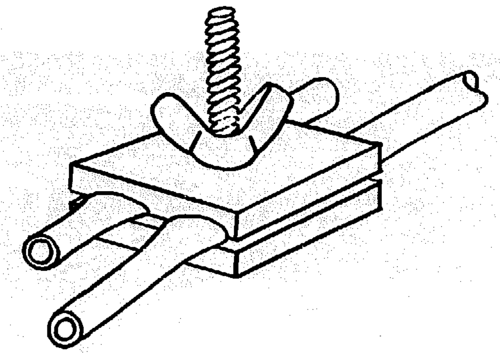
Components	Qu	Items Required	Dimensions
(1) Jaws	2	Wood (A)	3.5 cm x 3.5 cm x 0.7 cm
(2) Bolt Assembly	1	Bolt (B)	0.5 cm diameter, approximately 4-5 cm long
	1	Wing Nut (C)	To fit bolt (B)

b. Construction

(1) Jaws	Sand the wood squares (A) to remove rough edges and splinters. Drill a hole 0.6 cm in diameter in the center of each square.
(2) Bolt Assembly	Insert the bolt (B) through the hole in each square and check to see that the holes are just large enough to permit the bolt to slide through easily. Screw the wing nut (C) in place on the bolt.

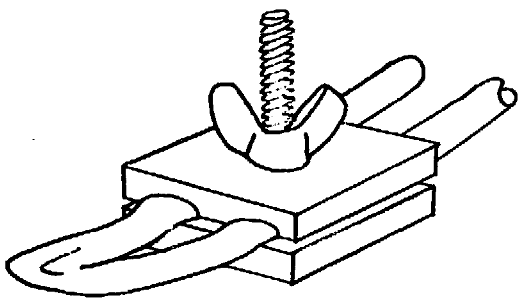
c. Notes

(i) To use this clamp with rubber tubing, a short (approximately 4 cm long) section of tubing of the same type as that in use is cut. The tubing in use is



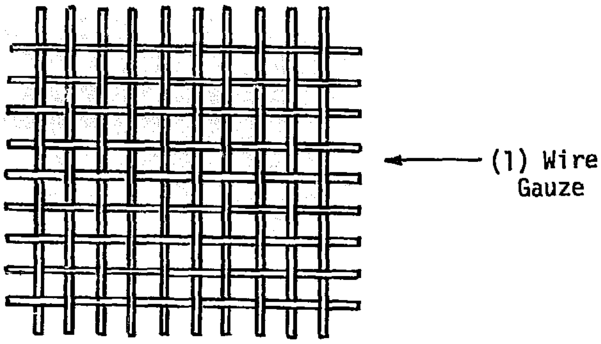
passed through the jaws on one side, as close to the bolt as possible. The short section of tubing is passed through the jaws on the opposite side to balance the force of the clamp. By turning the wing nut to tighten the clamp, the flow of a liquid or gas through rubber tubing can be controlled or shut off completely.

(ii) The flow rate of a liquid or gas through plastic tubing can be controlled in the same way, but the stiffness of plastic tubing makes it difficult to close the tubing completely. To close plastic tubing, it is necessary to bend the tubing back on itself, passing each section of the tubing through the clamp and tightening the wing nut as much as possible.



B. SUPPORTS AND STANDS

B1. Wire Gauze



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Wire Gauze	1	Wire Mesh (A)	Approximately 10 cm x 10 cm of heavy guage wire

b. Construction

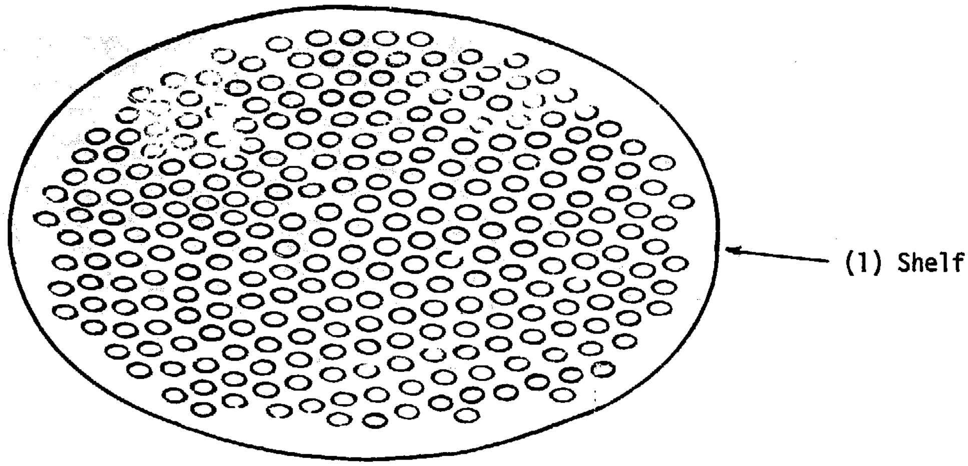
(1) Wire Gauze

Cut the wire mesh (A) to a size approximately 10 cm x 10 cm. Trim off sharp ends.

c. Notes

(i) This item is generally used in conjunction with the tripods and ring stand described in the sections that follow. The wire screen is placed on the tripod, heating stand, or ring to support a flask or beaker. A burner may be placed beneath the stand to heat the contents of the container.

B2. Heating Shelf



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Shelf	1	Tin Can Top or Bottom (A)	10 cm diameter or larger

b. Construction

(1) Shelf

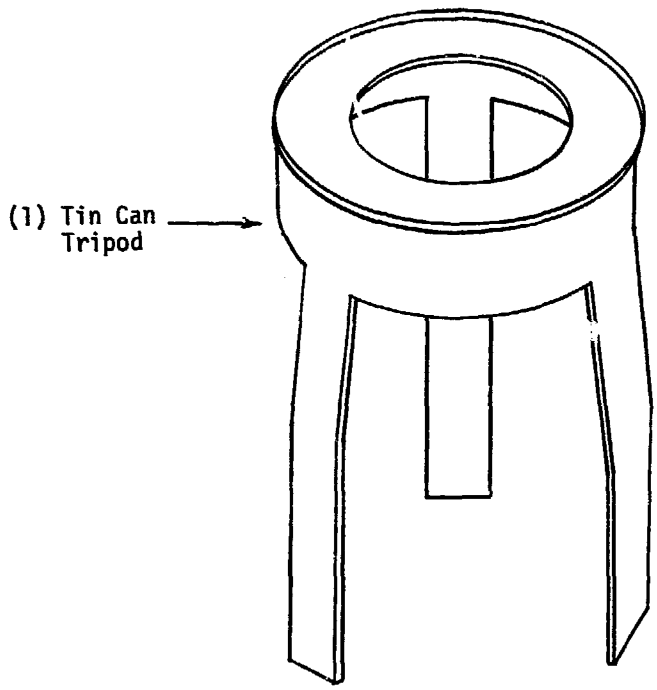
Remove the top (A) or bottom from a tin can. Punch many holes in it with a large nail.

c. Notes

(i) This item is used in the same way as the wire gauze (IV/B1); that is, to support a flask, beaker, or other container upon a tripod or similar support.

(ii) This is also a useful item to keep hot glass from contacting the tabletop.

B3 (1). Tripod (Tin Can)

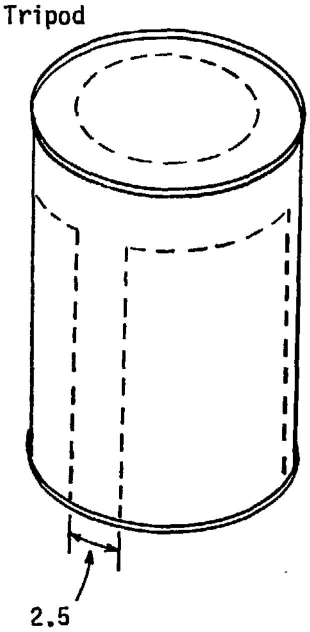


a. Material Required

Components	Qu	Items Required	Dimensions
(1) Tin Can Tripod	1	Tin Can (A)	Approximately 8 cm diameter, 12 cm high

b. Construction

(1) Tin Can Tripod

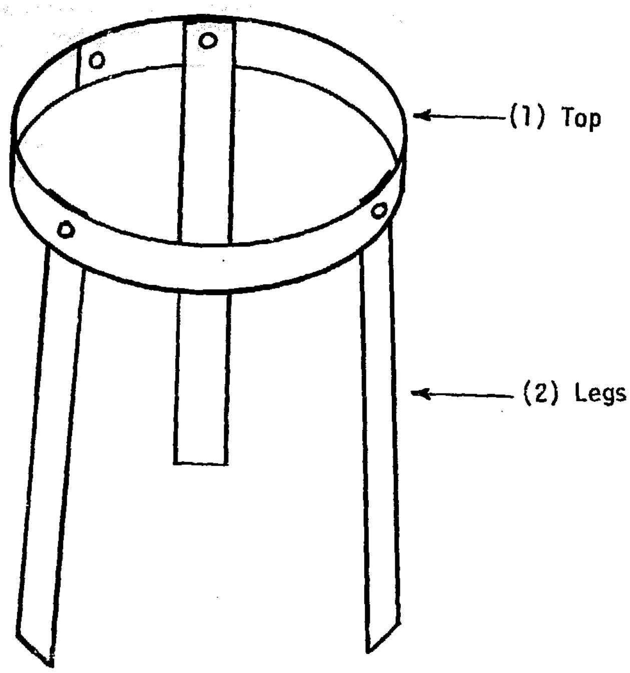


Cut a circle about 5 cm diameter from the bottom of the can (A). Mark the position for three legs, evenly spaced around the can. Allow a ring of about 1.5 cm at the top of the tripod before marking the legs. Allow approximately 2.5 cm for the width of each leg. Then cut along the marked lines to produce the three legs. With pliers, bend in the outside edge of each leg slightly to provide extra support.

c. Notes

(i) This tripod is simple to make, but it must be used with caution because of sharp edges and instability. It is suitable for supporting lightweight items, such as a funnel.

B3 (2). Tripod (Strappings)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Top	1	Metal Strapping (A)	1.5 cm x 42 cm
(2) Legs	3	Metal Strapping (B)	1.5 cm x 34 cm

b. Construction

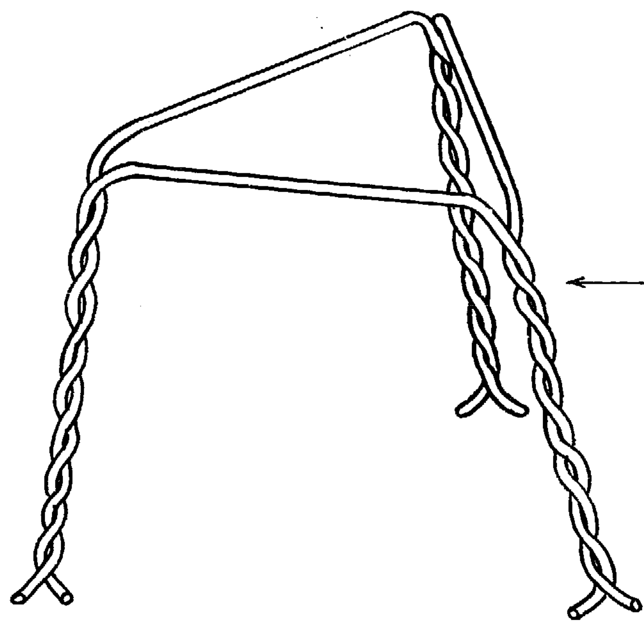
(1) Top — Bend the section of strapping (A) into a circle and secure the ends with a metal rivet.

(2) Legs — Fold each of the three sections of strapping (B) in half and pinch the fold closed. Secure the open ends of each leg to the top with metal rivets.

c. Notes

(i) The dimensions given produce a tripod that is useful for most applications, but this tripod can also be made larger or smaller by varying the length of the strapping used.

B3 (3). Tripod (Wire)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Wire Tripod	3	Heavy Wire	0.2 cm diameter, 40 cm long

b. Construction

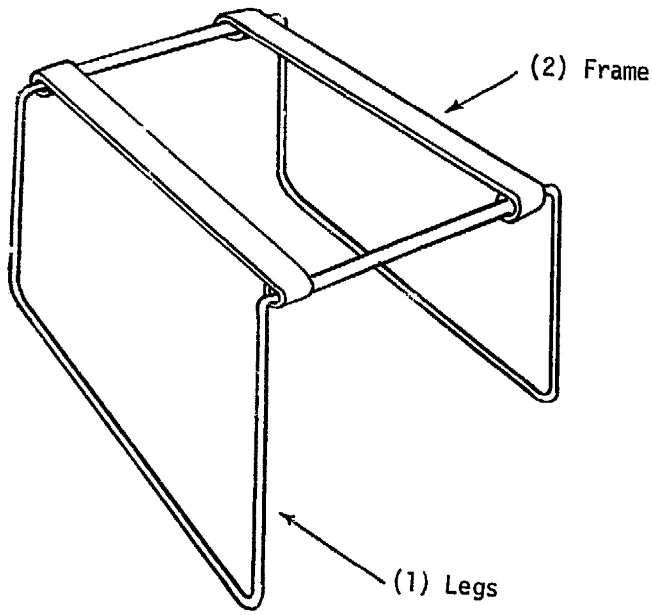
(1) Wire Tripod

Twist together the ends of two pieces of wire (A) for approximately 15 cm to form one leg. Twist the free ends of these two pieces together with each end of the third piece of wire. Make each twisted leg 15 cm long. Bend the legs down to form a tripod with a level top, as illustrated.

c. Notes

(1) This size tripod is useful for most applications, but it may also be made larger or smaller by varying the length of the wire used.

B4. Collapsible Heating Stand



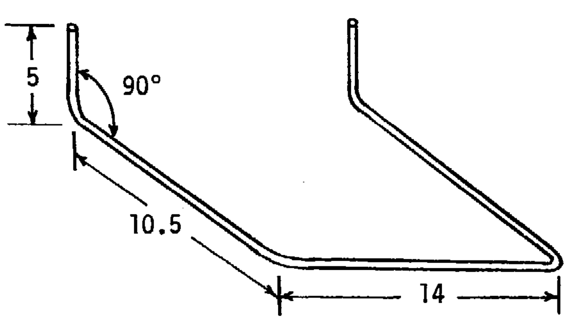
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Legs	2	Thick Wire (A)	0.4 cm diameter, 45 cm long
(2) Frame	2	Metal Sheeting (B)	10 cm x 3 cm
	2	Metal Strapping (C)	1.5 cm x 16 cm

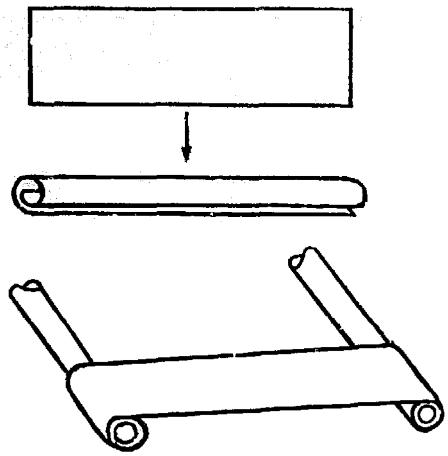
b. Construction

(1) Legs

Bend the two pieces of heavy wire (A) to the shape indicated.



(2) Frame



Strapping

Roll each of the rectangular pieces of metal sheeting (B) into long tubes that just fit around the legs.

Roll 3 cm at each end of the metal strapping pieces (C) around each end of the tubes.

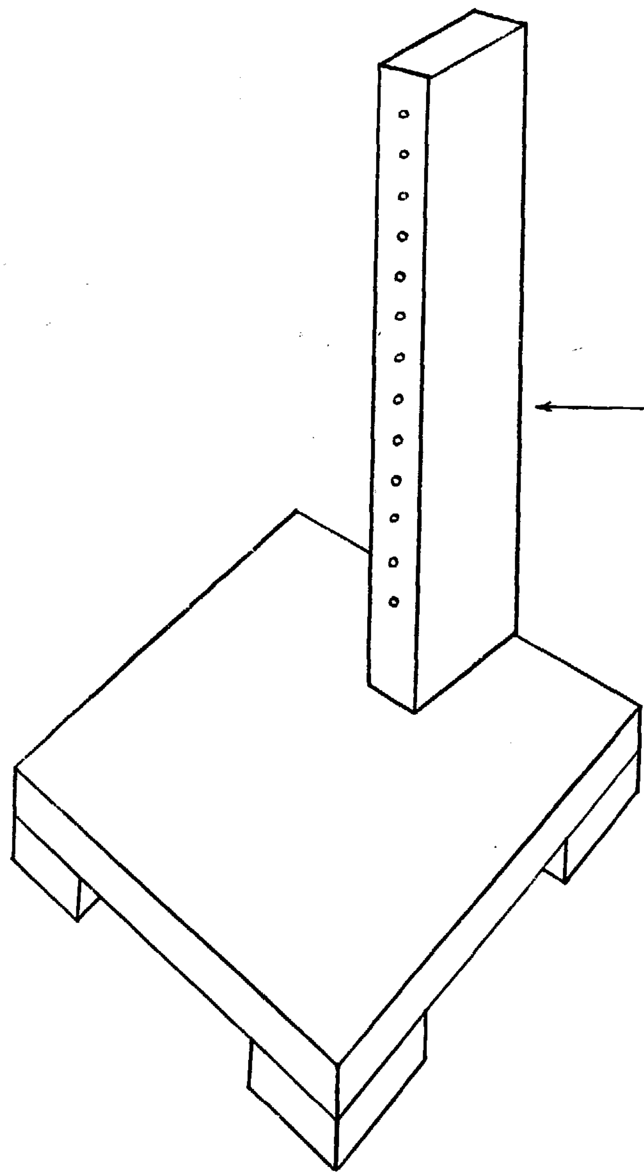
Insert the free ends of the legs (A) into the ends of the tubing (B) to complete this stand.

c. Notes

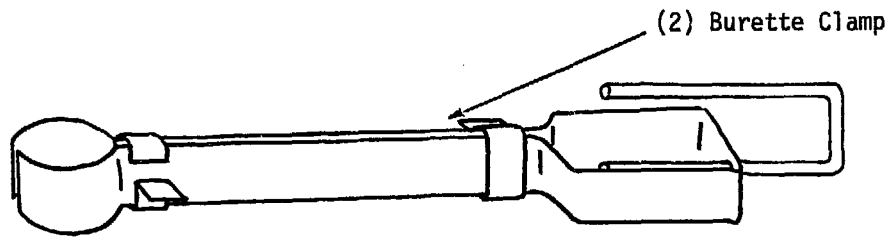
(i) Like the tripods, this stand is generally used with wire gauze (IV/B1) or heating shelf (IV/B2).

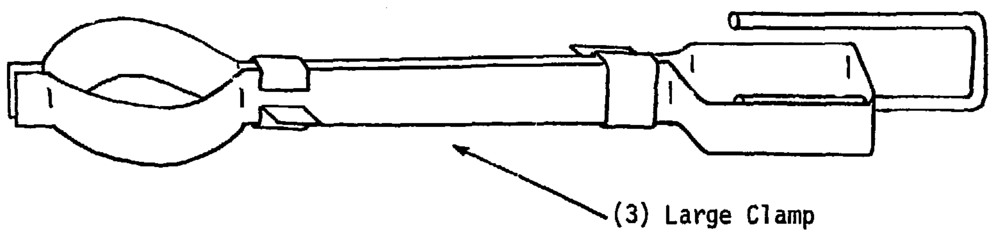
(ii) When this stand is not in use, the legs may be removed for ease in storing.

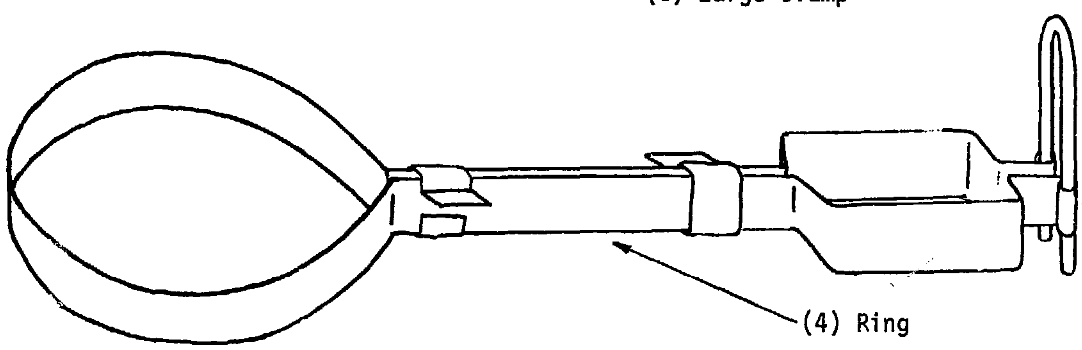
B5. Ring and Burette Stand with Attachments*

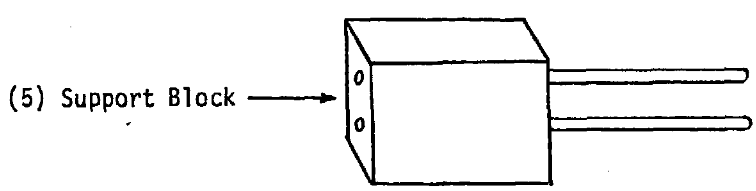


*Adapted from C. S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968), pp 144-146.









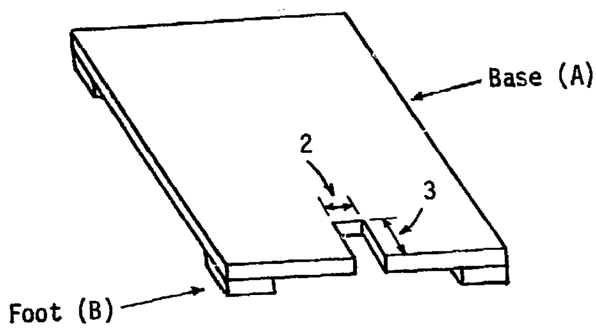
a. Materials Required

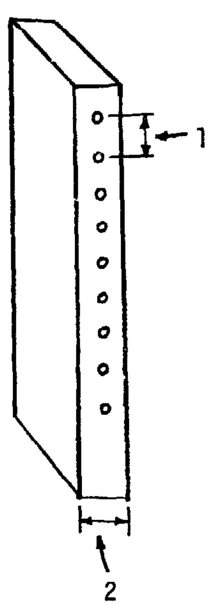
Components	Qu	Items Required	Dimensions
(1) Ring and Burette Stand	1	Wood Block (A)	14 cm x 18 cm x 2 cm
	4	Wood Block (B)	2 cm x 4 cm x 1.5 cm
	1	Wood Block (C)	3 cm x 2 cm x 40 cm

(2) Burette Clamp	1	Metal Strapping (D)	1.5 cm x 27 cm
	2	Metal Strapping (E)	1.5 cm x 5 cm
	1	Heavy Wire (F)	0.2 cm diameter, 10-12 cm long
(3) Large Clamp	1	Metal Strapping (G)	1.5 cm x 35 cm
	2	Metal Strapping (H)	1.5 cm x 5 cm
	1	Heavy Wire (I)	0.2 cm diameter, 10-12 cm long
(4) Ring	1	Metal Strapping (J)	1.5 cm x 50-60 cm
	2	Metal Strapping (K)	1.5 cm x 5 cm
	1	Heavy Wire (L)	0.2 cm diameter, 10 cm long
(5) Support Block	1	Wood Block (M)	5 cm x 2 cm x 4 cm
	2	Nails (N)	0.35 cm diameter, 8 cm long

<u>b. Construction</u>

(1) Ring and Burette Stand

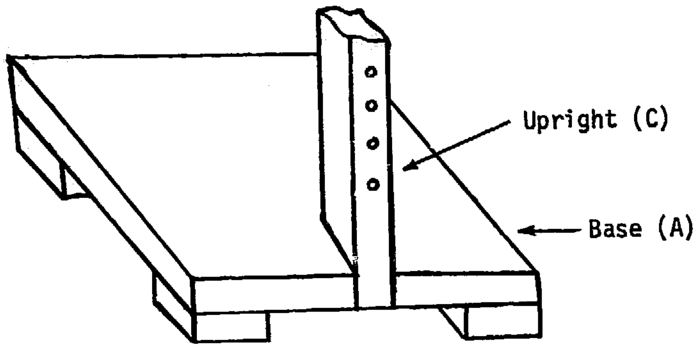




Sand all the wood blocks to remove splinters and rough edges. Nail a small wood block (B) to each corner of the flat block (A) to make feet.

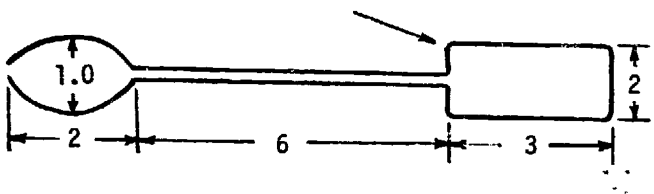
In the center of one of the short sides of the base (A) cut a rectangular notch 3 cm long x 2 cm wide.

Drill 0.6 - 0.7 cm holes at 1 cm intervals all the way through the long block (C) as shown.

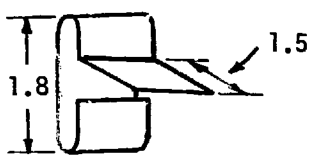


Fit this block into the rectangular notch in the base (A) and nail it in place to form the upright.

(2) Burette Clamp

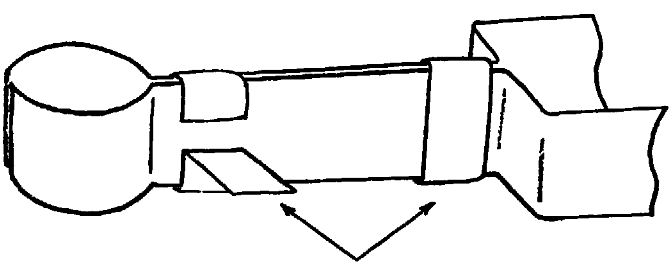


Bend the piece of metal strapping (D) as shown. Adjust the stand attachment section so that it will fit securely around the upright of the stand, yet be able to slide up or down along the upright.



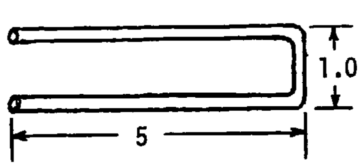
Tightening Clip (E)

Bend two small pieces of strapping (E) as indicated to form tightening clips. Fit them around the straight section of the burette clamp to hold the clamp tightly closed.

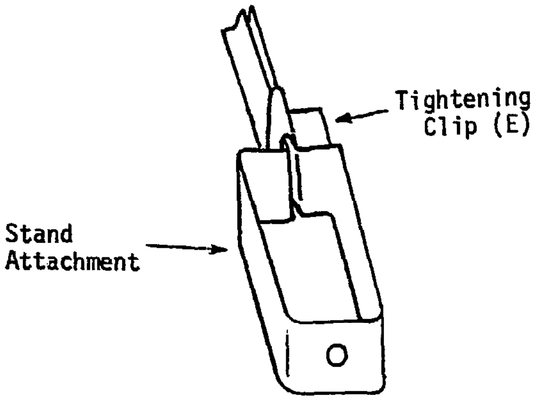


Tightening Clip (E)

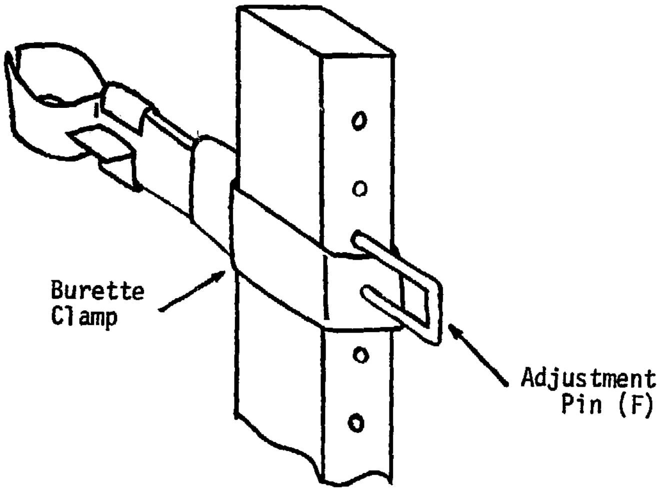
Adjustment Pin (F)



Bend a 10 - 12 cm piece of heavy wire (F) as indicated to make an adjustment pin. Adjust the width between the legs to match the holes drilled in the upright.

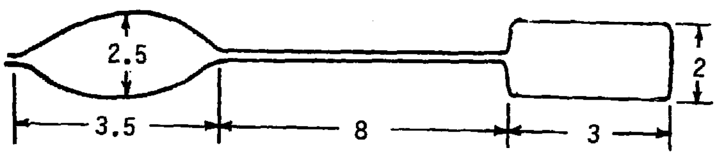


Drill a hole approximately 0.4 cm diameter in the burette clamp as shown.

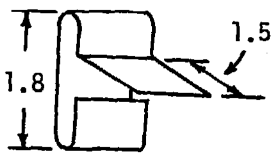


To position the burette clamp on the stand, slide the rectangular section of the clamp along the upright to the desired height, with the clamp facing the base of the stand. Align the hole in the burette clamp with a hole in the upright. Insert one of the legs of the adjustment pin through the burette clamp and into the upright. Insert the other leg of the pin into the next higher hole of the upright.

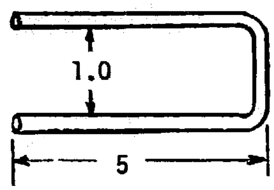
(3) Large Clamp



Bend the piece of strapping (G) in the same general shape as the burette clamp, but slightly larger.



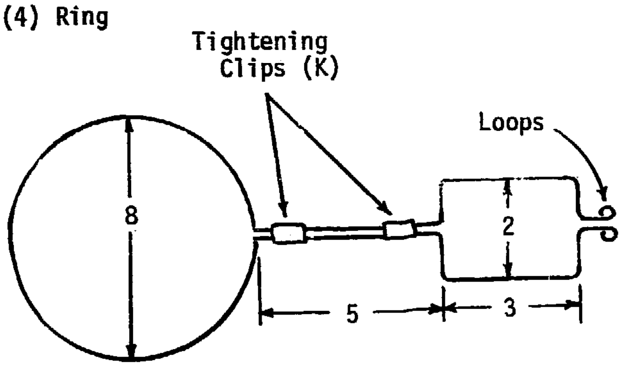
Construct two tightening clips (H) just as with the burette clamp. Position the clips on the clamp to hold it closed.



Construct an adjustment pin from a piece of heavy wire (I). Follow the procedure given for the burette clamp.

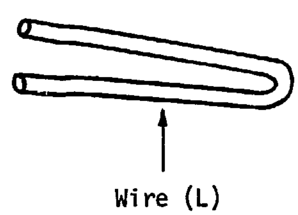
Drill a hole in the large clamp for the adjustment pin, as described for the burette clamp.

(4) Ring

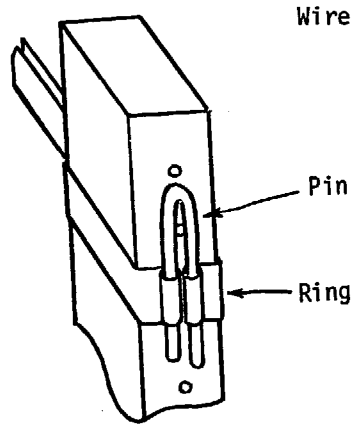


Bend the piece of metal strapping (J) into the shape shown. Bend the ends of the strapping into loops approximately 0.4 cm diameter.

Make two tightening clips according to the directions given with the burette clamp from the strapping (K). Secure them in the positions shown.

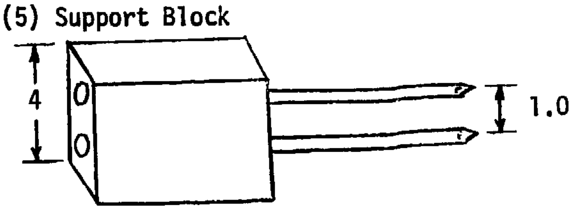


Construct a pin to hold the end loops together by bending the length of heavy wire (L) in half.

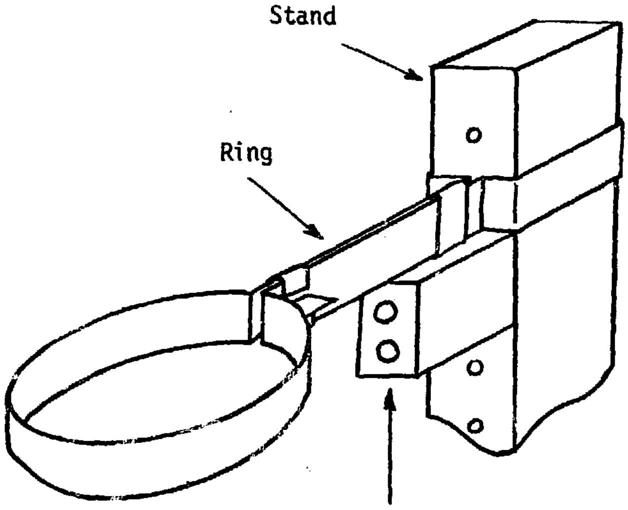


To position the ring on the stand, slide the rectangular section of the ring along with the upright to the desired height, with the clamp facing the base of the stand. Push the pin through the end loops.

(5) Support Block



Drive two nails (N) all the way into a small block of wood (M) 1 cm apart.



Position the support block to prevent the front of the ring from leaning forward under the weight of materials placed on it. Insert the two prongs of the support block into the two holes in the upright just below the ring.

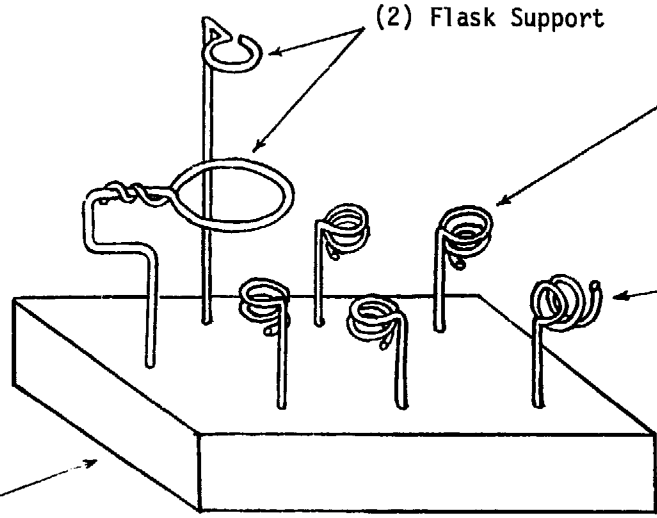
c. Notes

(i) To loosen the burette clamp or large clamp, slide the tightening clips toward each other. To tighten, slide the clips away from each other.

(ii) Although the burette clamp and large clamp have adjustment pins to hold them in place, they are much more stable when the support block is pushed into theupright immediately beneath the clamp. This prevents the burette clamp or large clamp from leaning forward.

(iii) The ring will safely support masses up to about 1 kilogram. It can support round-bottomed containers or flat-bottomed containers with a diameter slightly larger than that of the ring. To support smaller containers, a wire gauze (IV/B1) or heating shelf (IV/B2) may be placed on the ring. For large conatiners, a more stable support, such as one of the tripods (IV/B3) or the collapsible heating stand (IV/B4) is recommended.

B6. Multipurpose Stand

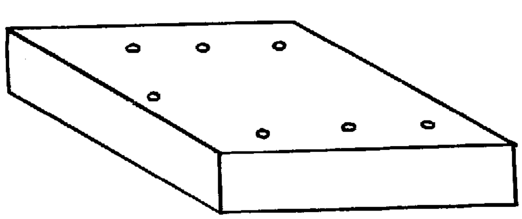


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	9 cm x 4 cm x 18 cm
(2) Flask Support	1	Heavy Wire (coat hanger) (B)	0.2 cm diameter, 35 cm long
	1	Heavy Wire (coat hanger) (C)	0.2 cm diameter, 40 cm long
(3) Test Tube Support	4	Heavy Wire (coat hanger) (D)	0.2 cm diameter, 15-20 cm long
(4) Heating Clamp	1	Heavy Wire (coat hanger) (E)	0.2 cm diameter, 20 cm long

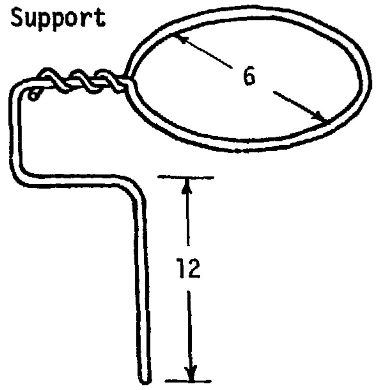
b. Construction

(1) Base

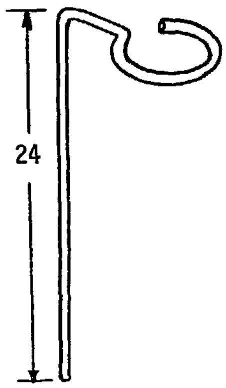


Drill seven holes approximately 0.2 cm in diameter into the wood block (A) as shown. If a larger block is used, or if more attachments are desired, drill more holes.

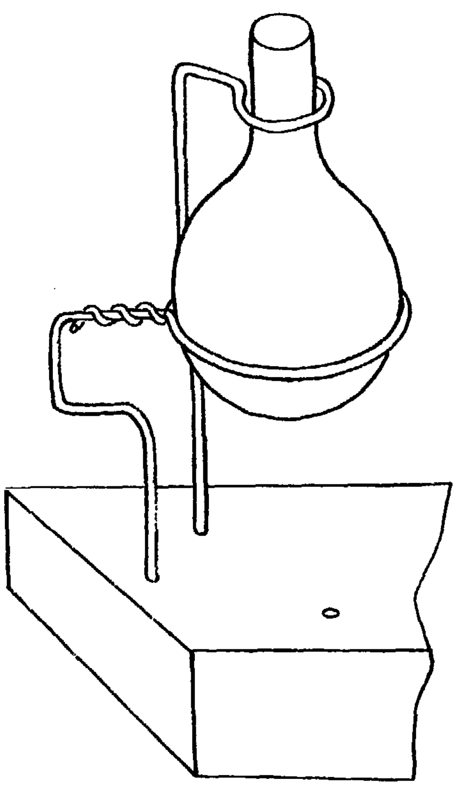
(2) Flask Support



Bend the piece of heavy wire (C) as shown to form the base of the flask support. Make the circular loop about 6 cm in diameter.

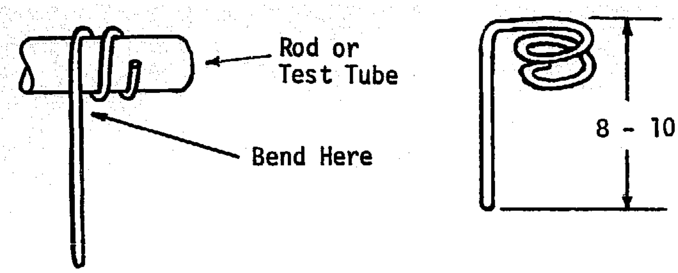


Bend the shorter piece of heavy wire (B) into a loop to form a support for the neck of a flask or light-bulb flask (IV/A1). Make the open loop about 4 cm in diameter.



Insert the two sections of the support into adjacent holes in the base. Adjust them so that they will support a flask or light-bulb flask as illustrated.

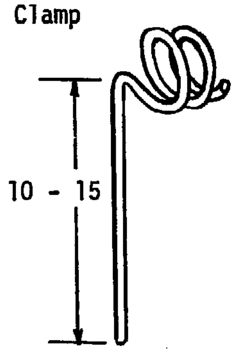
(3) Test Tube Support



Use pliers to bend each of the pieces of heavy wire (D) around a wooden rod or test tube of the desired diameter (2 cm for example). Follow the steps illustrated.

Insert the supports into holes in the base.

(4) Heating Clamp

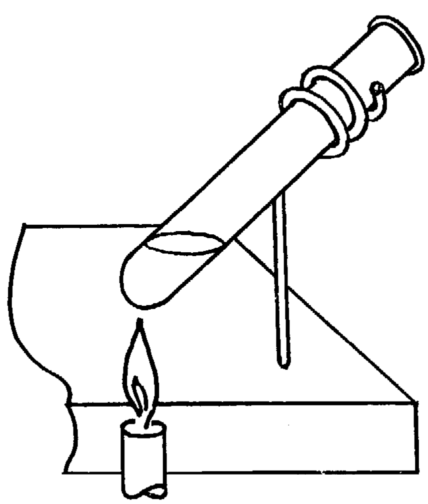


Bend the piece of heavy wire (E) into loop just as for the test tube support shown above. However, tilt the loop at an angle, rather than vertically as was done for the test tube supports. Insert the heating clamp into one of the holes in the base.

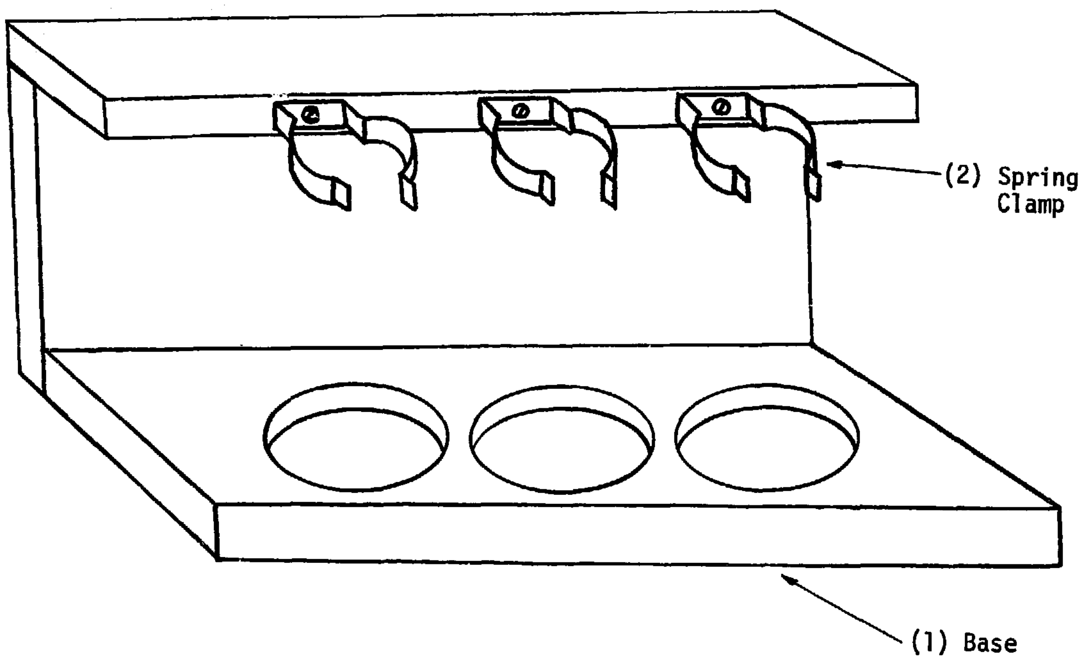
c. Notes

(i) Sizes and number of the supports constructed, as well as the size of the base, may be varied to suit individual needs.

(ii) The heating clamp is used to hold a test tube at an angle while its contents are heated. Supporting the test tube at an angle presents a greater area to be heated. As a safety measure, it allows the mouth of the test tube to be pointed away from everyone in the vicinity.



B7. Rack for Light-Bulb Glassware

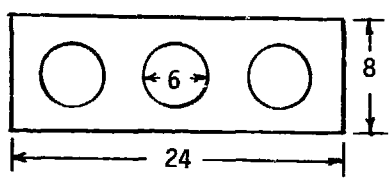


a. Materials Required

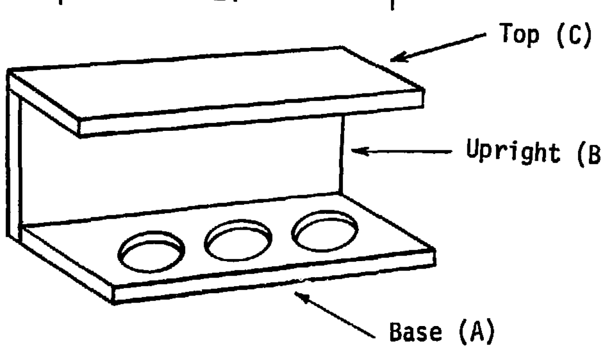
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	8 cm x 24 cm x 2 cm
	1	Wood (B)	9 cm x 24 cm x 2 cm
	1	Wood (C)	4 cm x 24 cm x 2 cm
(2) Spring Clamp	3	Metal Strapping (D)	1 cm x 14 cm

b. Construction

(1) Base

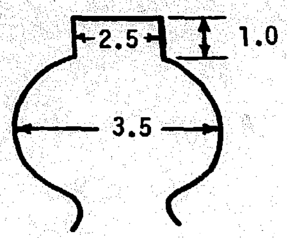


Drill or cut three circular holes, 6 cm in diameter in the large piece of wood (A). Allow about 1.5 cm between holes.



Attach top (C) and upright (B) with glue and screws as shown.

(2) Spring Clamp

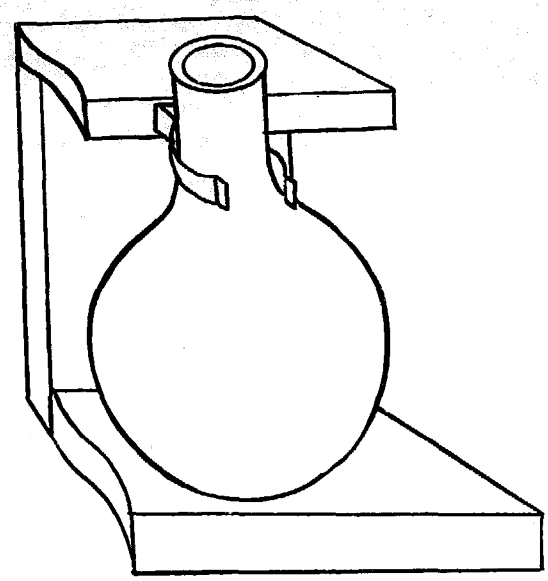


Drill a hole approximately 0.5 cm diameter in the center of each of the pieces of metal strapping (D). Bend each piece of metal strapping into the shape shown.

Center each clamp over each hole in the base. Secure each clamp to the top (horizontally) piece of the base with a screw.

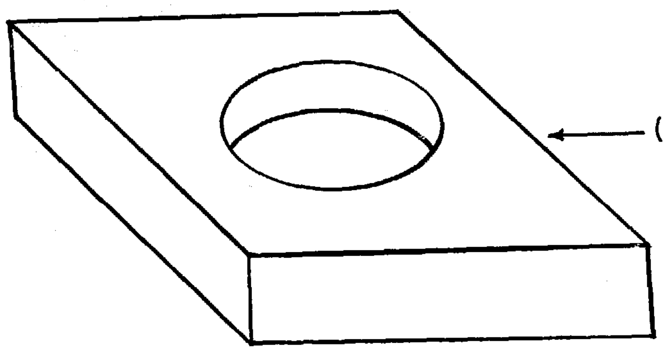
c. Notes

(i) The spring clamp holds the neck of a light-bulb flask securely, while the hole in the base supports the round bottom of the flask.



(ii) This design may be modified to accommodate more flasks, or flasks of different sizes.

B8. Stand for Light-Bulb Glassware



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Flask Stand	1	Wood Block (A)	9 cm x 9 cm x 4 cm

b. Construction

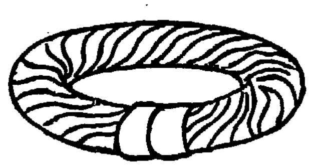
(1) Flask Stand

Drill or cut a circular hole through the center of the block (A). Adjust the diameter of the hole to the size of the light-bulb flask used:

6 cm diameter hole for bulbs from 60 to 200 watts. 7 cm diameter hole for larger bulbs.

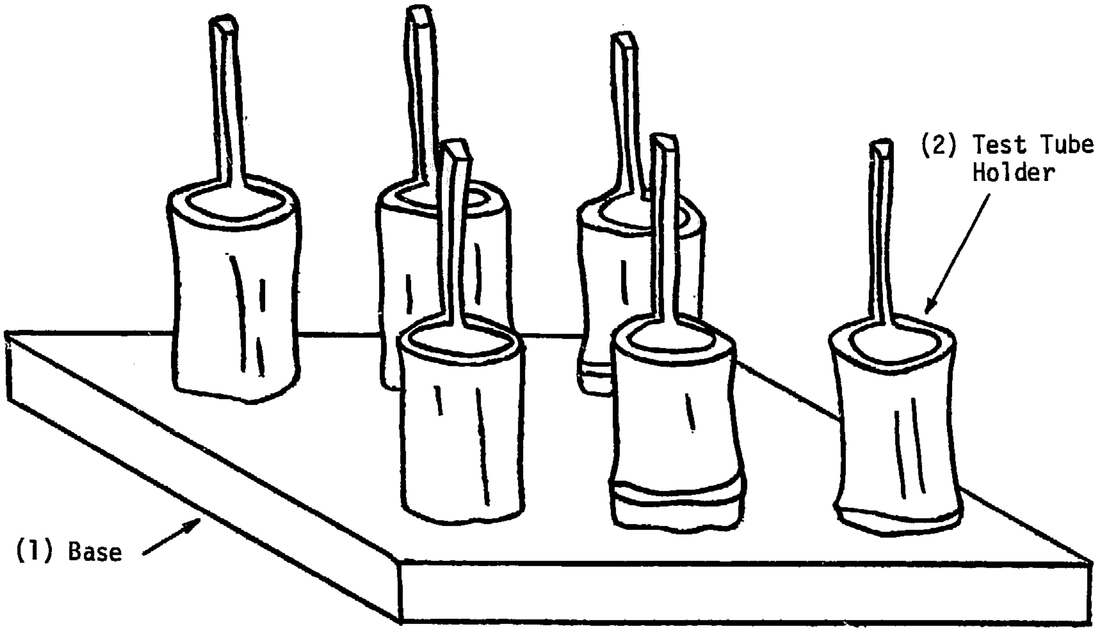
c. Notes

(i) Another stand for a single piece of light-bulb, or any round-bottomed glassware, can be made with a piece of heavy rope approximately 3 cm in diameter.



The rope is cut to a length slightly shorter than the maximum circumference of the flask, and the ends of the rope are taped or spliced together to form a ring.

B9. Bamboo Test Tube Rack



a. Materials Required

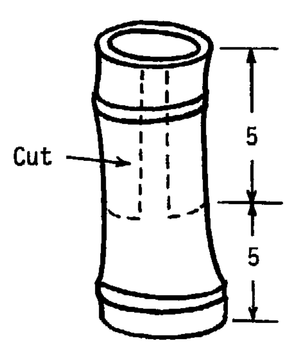
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood Block (A)	1 cm x 7 cm x 18 cm
(2) Test Tube Holder	6	Bamboo Sections (B)	Approximately 2.5 cm outside diameter, 10 cm long

b. Construction

(1) Base

Sand the wood block (A) to remove splinters and rough edges.

(2) Test Tube Holder



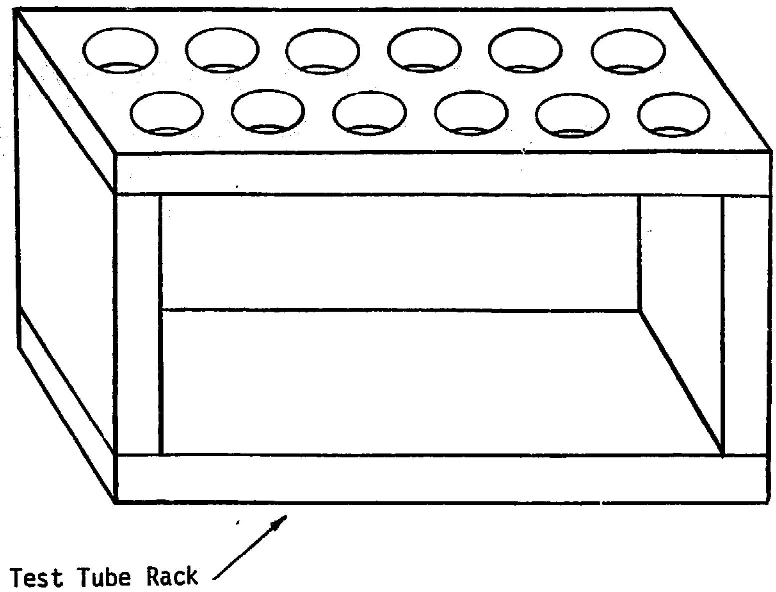
Select bamboo sections (B) with thick walls (at least 0.2 cm). Cut away approximately half the length of each bamboo section, but leave one upright piece as shown. Cement these cylinders to the base.

c. Notes

(i) The upright section remaining on each bamboo cylinder is used to support test tubes upside down for drying.

(ii) The size of the base may be varied to accommodate a convenient number of bamboo cylinders. The diameter of the bamboo cylinders may be varied to suit the size of the test tubes used.

B10. Wooden Test Tube Rack



(1) Test Tube Rack

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Test Tube Rack	2	Wood (A)	8 cm x 20 cm x 1 cm
	2	Wood (B)	8 cm x 12 cm x 2 cm

b. Construction

(1) Test Tube Rack

Drill 12 holes, 2.2 cm in diameter at evenly spaced intervals in one of the larger pieces of wood (A) to form the top of the rack.

Secure the sides (B) to the top (A) as shown, with nails or cement. Secure the bottom (A) in place with nails or cement.

c. Notes

(i) For larger or smaller test tubes, the dimensions may be varied.

V. GLASSWARE AND CROCKERY

A. GLASSWARE

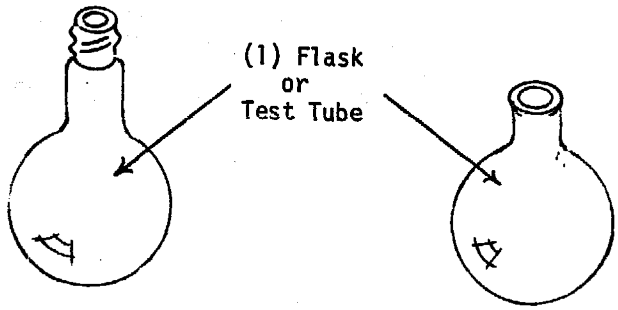
This section describes the construction of various items of laboratory glassware. The chief activity in making these is glass cutting, which is described in detail in a separate section. Refer to GLASSWARE TECHNIQUES AND ACCESSORIES (I) for specific direction for cutting and working glass.

B. CROCKERY

Included in this section is one item composed of concrete.

A. GLASSWARE

A1. Light Bulb Glassware *



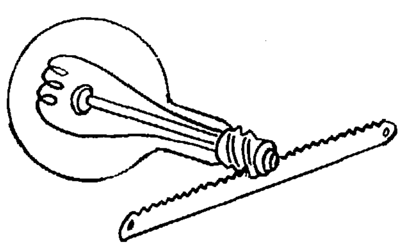
a. Materials Required

Components	Qu	Item Required	Dimensions
(1) Flask or Test Tube	1	Clear Incandescent Light Bulb (A)	Varies

b. Construction

(1) Flask or Test Tube

Sawing



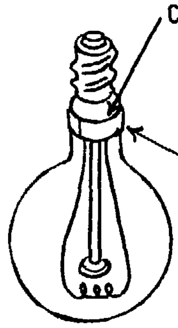
Secure a hacksaw blade in a vise. Hold the bulb (A) horizontally, and wrapped in cloth for safety. Cut around the edge of the base near the terminals. Remove the end thus cut.

*Adapted from C. S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: The American Peace Corps, 1968), pp 146-147.

With a triangular file, puncture the inner seal and remove all the parts from inside the bulb. Smooth cut edge with emery paper or the file.

Heat cutting

Wrap a piece of tape around the neck of a clear bulb (A), about 0.3 cm from the base, as a cutting guide. With a triangular file or glass cutter, make a continuous scratch all the way around the neck of the bulb.



Remove the tape, and use the electric bottle cutter (I/F2) to heat the scratch until the bulb cracks all the way around. Discard the base and internal components.

Wrap the lower portion of the bulb in cloth to protect the hands. Hold the cut edge in a gas or alcohol burner flame until the edge softens and curls back upon itself to form a smooth lip.

c. Notes

(i) The average 150 watt bulb forms a flask of about 150 ml capacity, the average 200 watt bulb a flask of about 200 ml capacity

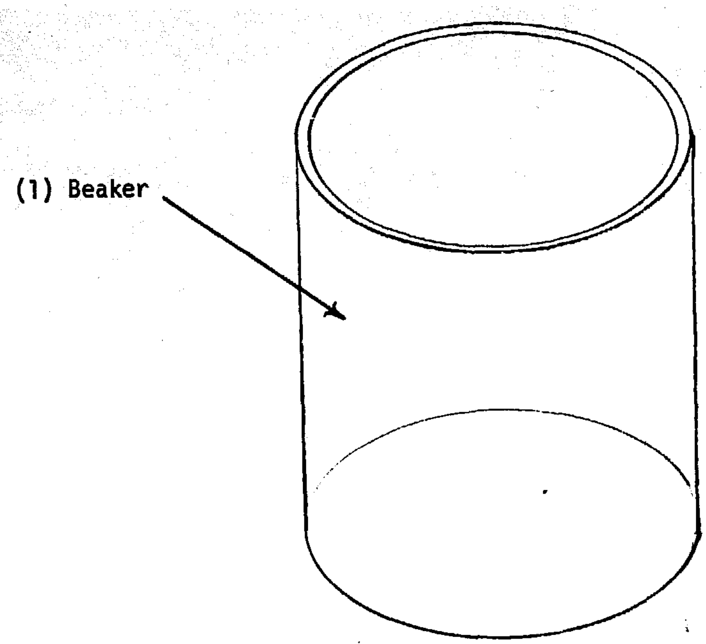
(ii) Bulbs of 100 watts or less may be used for test tubes.

(iii) Small test tubes may also be made from glass medicine vials or discarded antibiotic ampules.

(iv) The bulb is made of thin enough glass to be heated safely while containing a liquid.

(v) The glassware made from light bulbs requires special supports to hold it upright. Consult the section on Supports, Stands, and Holders (IV) for suggestions.

A2. Beaker



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Beaker	1	Wide-bottom Jars or Bottles (A)	Varies

b. Construction

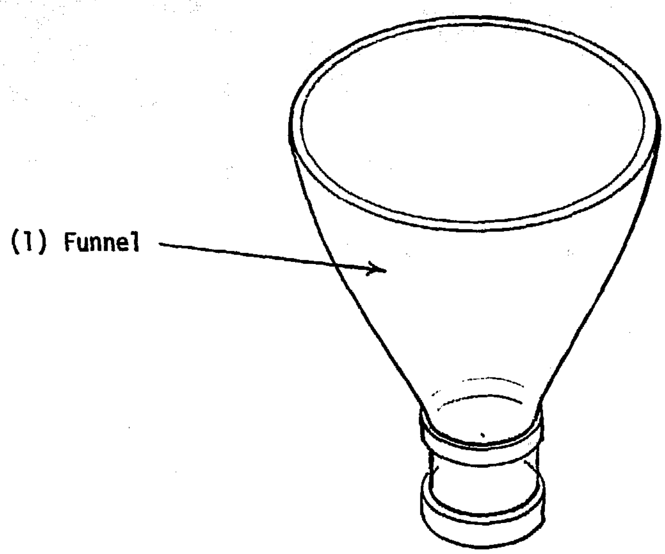
(1) Beaker

Cut off the bottom portion of jars or bottles (A) to make beakers of various sizes (I/F2). Smooth the rough edge by filing with emery paper or a file.

c. Notes

(i) Since bottles and jars are generally made of soft glass, rather than hard, heat resistant glass; beakers made from bottles or jars cannot be used for hot substances or for substances that are to be heated. When heated, they will break.

A3. Funnel



a. Materials Required

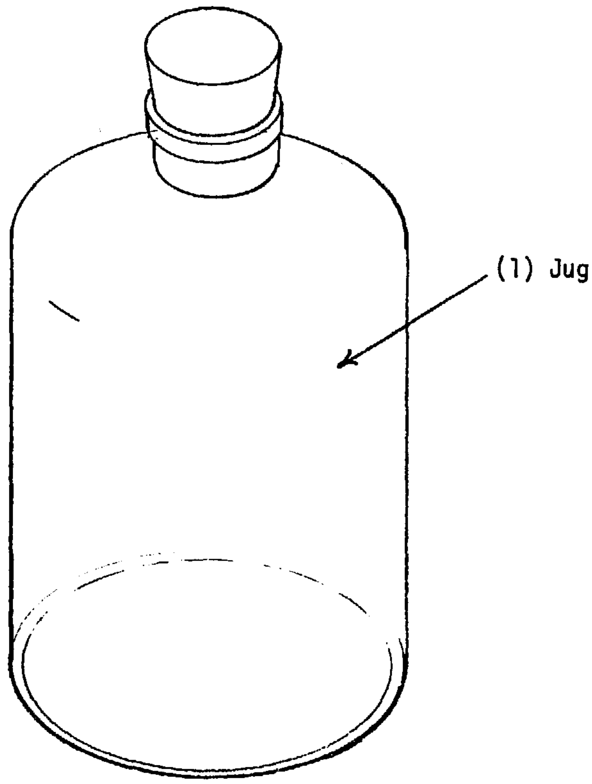
Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	Varies

b. Construction

(1) Funnel

Cut off the top portion of narrow-mouthed glass bottles (A) to make funnels of various sizes (I/F2).

A4. Bell Jar



a. Materials Required

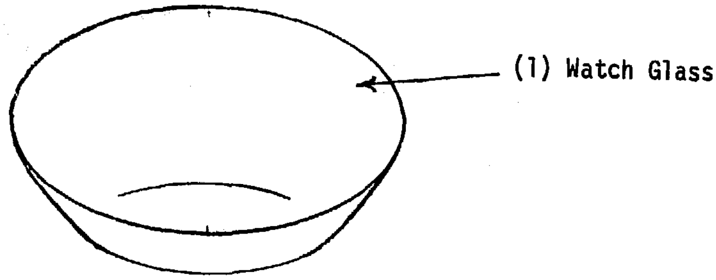
Components	Qu	Items Required	Dimensions
(1) Jug	1	Glass Jug or Carboy (A)	4-8 liters
	1	Rubber or Cork Stopper (B)	To fit Jug (A)

b. Construction

(1) Jug

Cut off the bottom of the glass jug or carboy (A). Sand the cut edge smooth with emery paper. Seal the neck of the jug with the stopper (B).

A5. Watch Glass

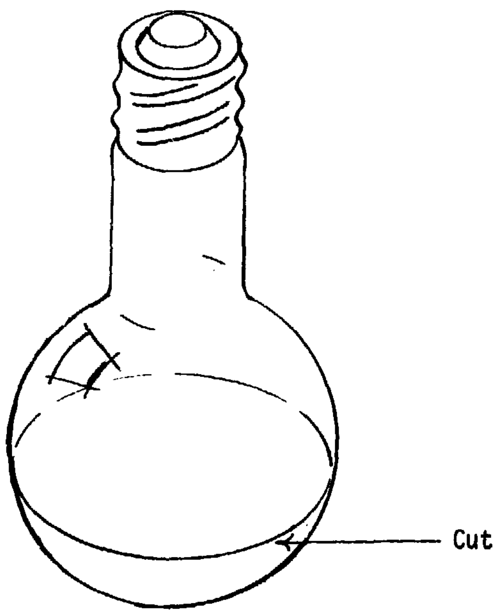


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Watch Glass	1	Light Bulb (A)	Varies

b. Construction

(1) Watch Glass

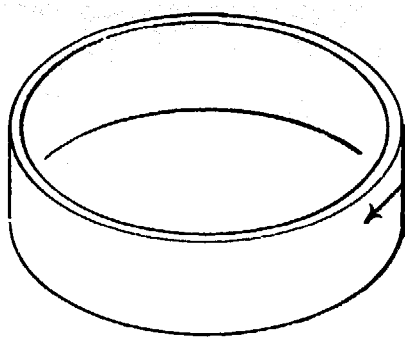


Carefully cut the tops off old light bulbs (A) to make watch glasses of various sizes. Smooth the cut edges by fire polishing.

c. Notes

(i) The watch glass is commonly used to hold small quantities of a solution fror which crystals are to be collected.

A6. Petri Dish



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Petri Dish	1	Wide-bottom Bottles or Jars (A)	Varies

b. Construction

(1) Petri Dish

Cut off the bottom of a wide-bottom glass bottle or jar (A). Make as many as needed. Smooth the rough edge with emery paper.

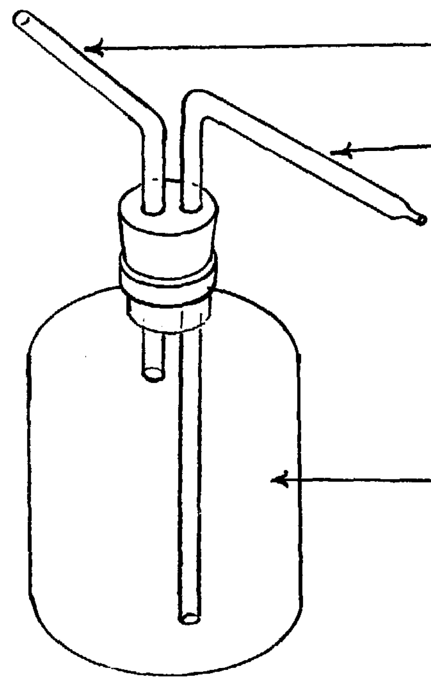
c. Notes

(i) Jar lids or aluminum foil make satisfactory tops for these dishes. Waxed paper or cardboard dipped in wax also make suitable covers.

(ii) Petri dishes are often used to hold small quantities of a liquid from which crystals are to be collected.

(iii) They may also be used to contain food or culture media for growing bacteria, fungi, or molds. When petri dishes are used for culturing purposes, they must be used with lids and must be sterilized (BIOL/VII/A2).

A7. Wash Bottle



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Glass or Plastic Bottle (A)	Approximately 250 ml capacity
	1	2-Hole Stopper (B)	To fit container (A)
(2) Delivery Tube	1	Glass Tubing	Approximately 0.5 cm diameter, and at least 20 cm longer than height of container.
(3) Mouthpiece	1	Glass Tubing (D)	About 0.5 cm diameter, and shorter than delivery tube.

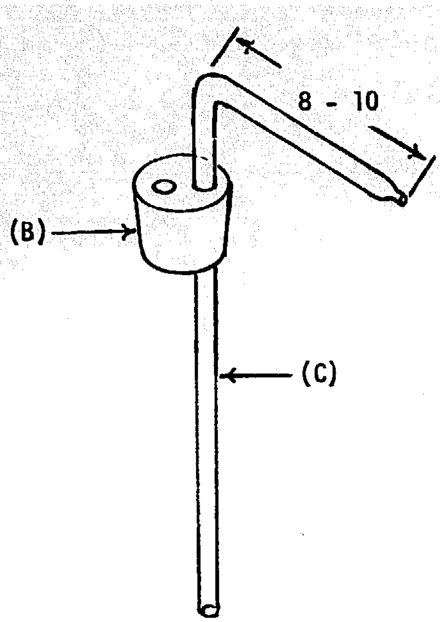
b. Construction

(1) Container

Select a glass or plastic bottle with a narrow neck and a capacity of about 250 ml or larger (A).

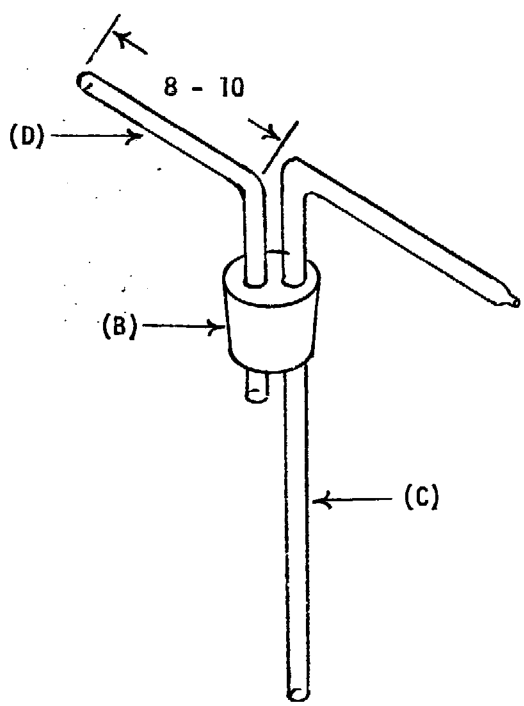
Fit the container (A) with a two-hole stopper (B).

(2) Delivery Tube



Make a nozzle (I/D3) at one end of the long glass tube (C). Fire polish both the nozzle and the other end and let the tube cool. Next, bend the tube, about 8 - 10 cm from the nozzle end at a sharp angle as shown. When it is cool, carefully push the tube into the stopper (B) so that it extends to within 0.5 cm of the bottom of the container. Trim to the correct length, if necessary, and fire polish the end.

(3) Mouthpiece

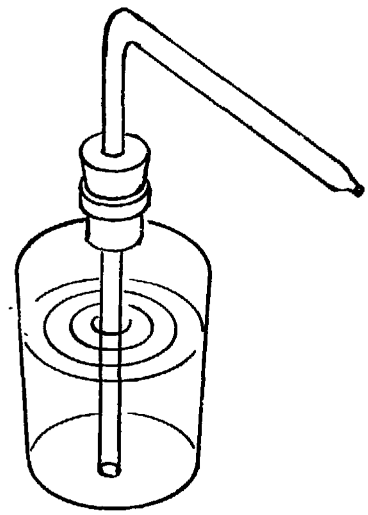


Fire polish both ends of the glass tube (D). About 8 - 10 cm from one end, make a wide-angled bend. When the tube has cooled, push it carefully into the stopper (B). Insert the stopper into the container (A).

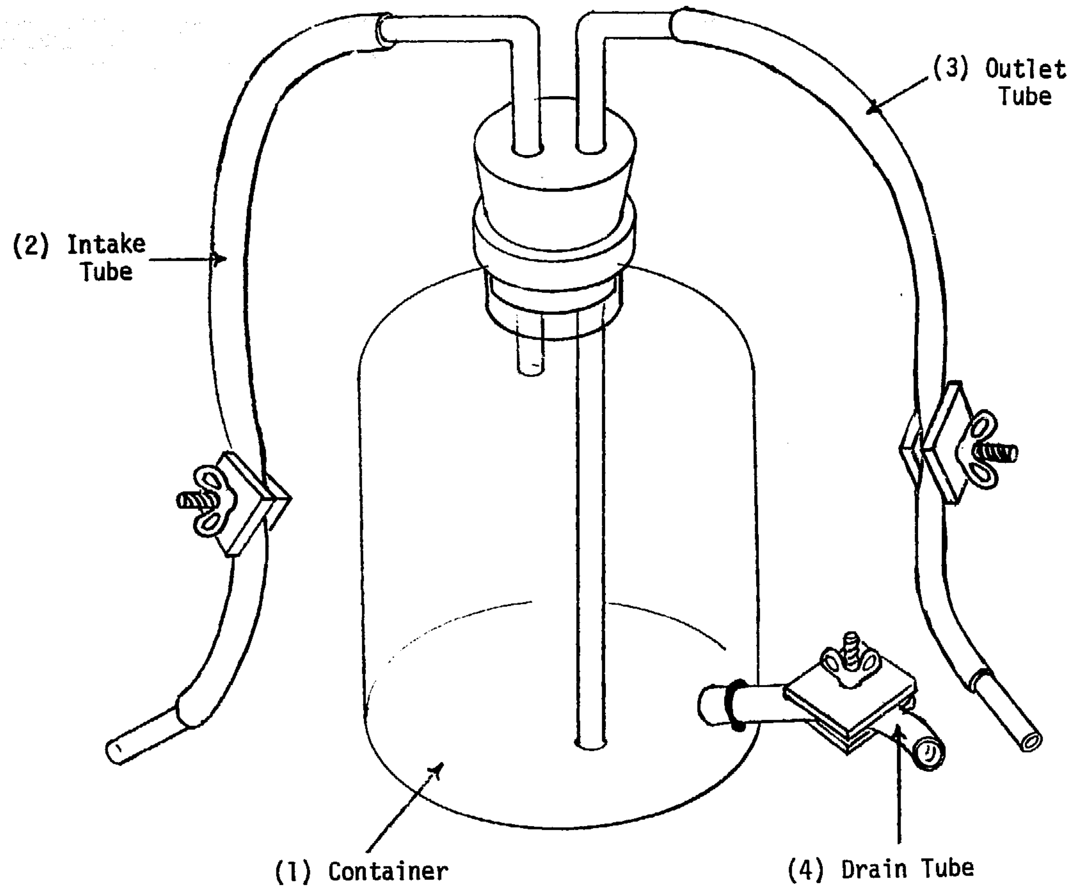
c. Notes

(i) To use the wash bottle, fill it with (distilled) water. Direct the delivery tube in the desired direction and blow through the mouthpiece to force water through the nozzle in a fine stream.

(ii) If a soft plastic squeeze bottle is used, only the delivery tube and a one-hole stopper are necessary. Squeeze the bottle to force water out the nozzle.



A8. Aspirator



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Bottle (A)	4-8 liter capacity
	1	2-Hole Rubber Stopper (B)	To fit Bottle (A)
(2) Intake Tube	1	Glass Tubing (C)	0.5 cm diameter, approximately 15 cm long
	1	Glass Tubing (D)	0.5 cm x 10 cm
	1	Plastic or Rubber Tube (E)	Approximately 1.0 cm diameter, 35 cm long
	1	Screw Clamp or Pinch Clamp (F)	(IV/A4 and A5)
(3) Outlet Tube	1	Glass Tube (G)	0.5 cm diameter, 10 cm longer than height of bottle
	1	Glass Tube (H)	0.5 cm x 10 cm
	1	Plastic or Rubber Tube (I)	Approximately 1.0 cm diameter, 35 cm long

	1	Screw Clamp or Pinch Clamp (J)	(IV/A4 or A5)
(4) Drain Tube	1	Plastic or Rubber Tube (K)	Approximately 1.0 cm diameter, 20 cm long
	1	Screw Clamp or Pinch Clamp (1)	(IV/A4 or A5)

b. Construction

(1) Container

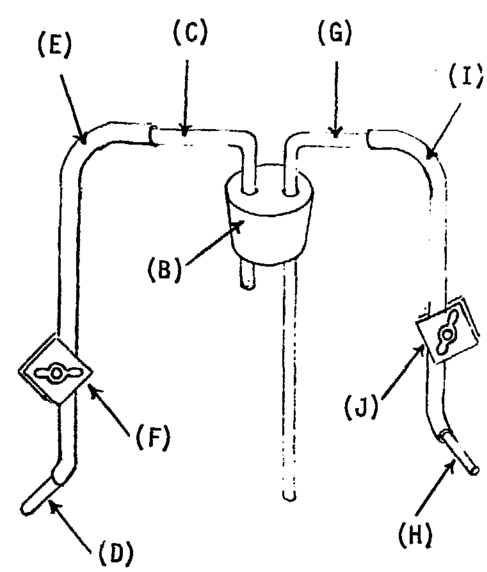
Fit the bottle (A) with a two-hole rubber stopper (B). Carefully bore a hole approximately 1.0 cm in diameter, 2 cm from the bottom of the bottle.

(2) Intake Tube

Make a 90° bend about 5 cm from one end of the longer glass tube (C). Insert this tube into one of the holes in the stopper of the bottle. Fit the other end of the tube into the plastic or rubber tubing (E). Insert the short glass tube (D) into the open end of the plastic or rubber tubing (E).

Construct a screw clamp or pinch clamp (F) (IV/A4 or A5) to close the tubing (E).

(3) Outlet Tube



Make a 90° bend about 5 cm from one end of the longer glass tube (G). Insert this tube into one of the holes of the rubber stopper (B) such that the straight section of the tube reaches within 2 cm of the bottom of the bottle as illustrated.

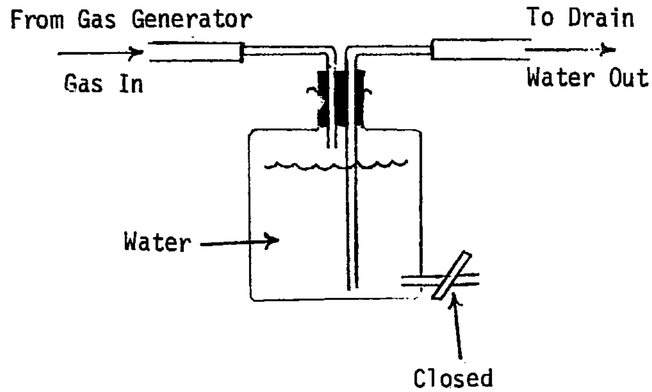
Attach the plastic or rubber tubing (I) to the other end of the glass tube (G). Fit the shorter glass tube (H) into the free end of the tubing (I) and close it with a clamp (J).

(4) Drain Tube

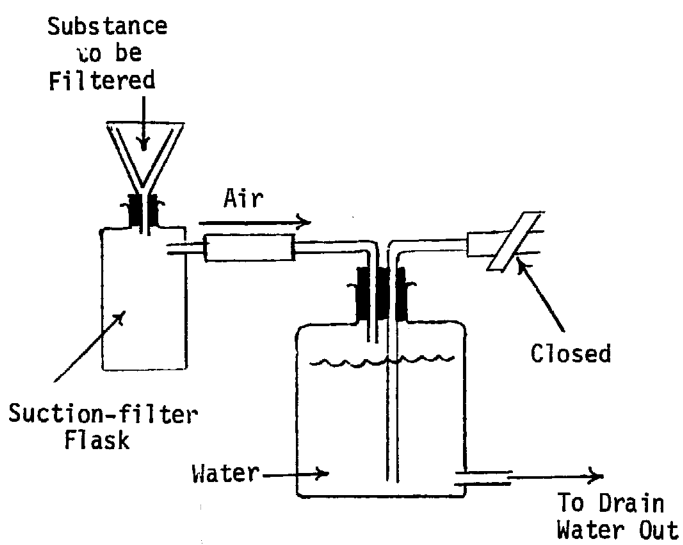
Insert the plastic or rubber tubing (K) into the hole in the side of the container extending it 1 - 2 cm inside the bottle. Seal the tubing (K) in the hole with epoxy resin. Close the tube with a clamp (L).

c. Notes

(i) This item may be used to collect gas by water displacement. First, the bottle is filled with water and all three tubes are closed with clamps. The intake tube is then attached to the gas generator and the outlet tube is directed into a drain or waste receptacle. When both the intake and outlet tubes are opened (drain tube remains closed) gas will enter the bottle, and displaced water will be forced out through the outlet tube.

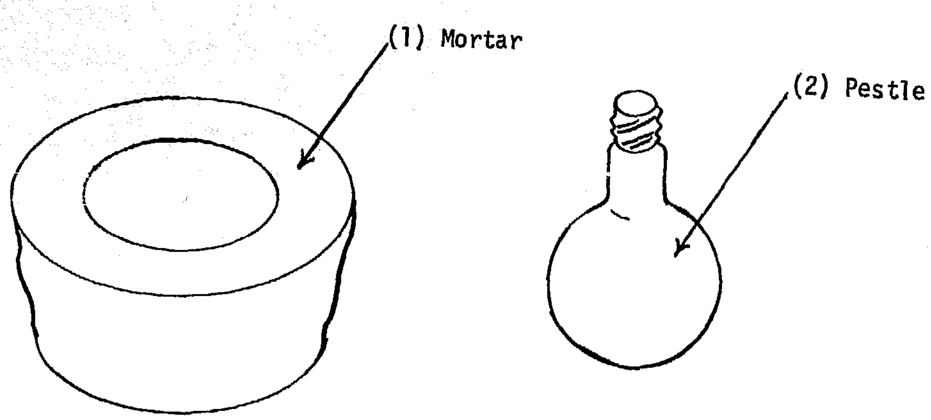


(ii) The aspirator may also be used to provide suction to aid in filtration. Again, the bottle is filled with water, and all three tubes are closed with clamps. The intake tube is connected to the suction tube of a suction-filter flask (VI/A4). The drain tube is directed into a drain or waste receptacle. The liquid to be filtered is poured into the filter funnel (fitted with filter paper), and the intake and drain tubes are opened. The outlet tube remains closed. The flow of water from the aspirator bottle creates a negative pressure that tends to increase the rate of filtration in the suction filtration apparatus.



B. CROCKERY

B1. Mortar and Pestle

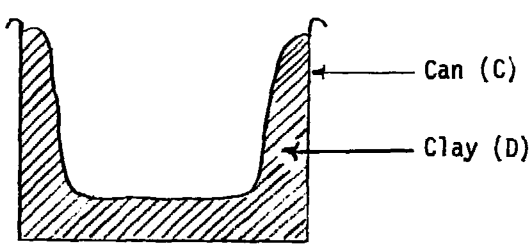


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Mortar	0.5 kg	Sand (A)	Fine grain
	1.5 kg	Cement (B)	--
	1	Tin Can (C)	Capacity approximately 0.5 kg
	0.5 kg	Modeling Clay (Plasticine) (D)	--
	1	Wire Mesh (E)	10 cm x 10 cm
	1	Epoxy Glue (F)	--
	1	Light Bulb (G)	100 watts
(2) Pestle	1	Light Bulb (H)	60 watts
	1	Epoxy Glue (I)	--
	1	Nail (J)	Approximately 10 cm long

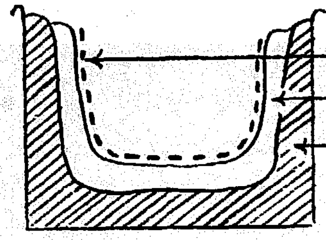
b. Construction

(1) Mortar



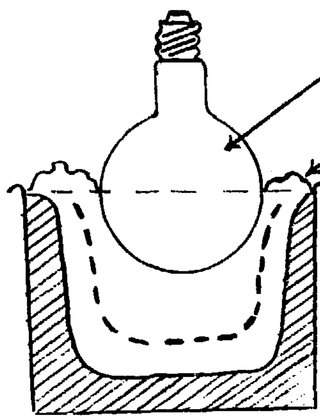
Cross Section

Cut the tin can (C) in half. Pack the modeling clay (plasticine) (D) into the bottom half of the can. Then mold the clay into the external shape of the mortar. Make the bottom of the clay mold smooth and flat, as this will be the bottom of the mortar.

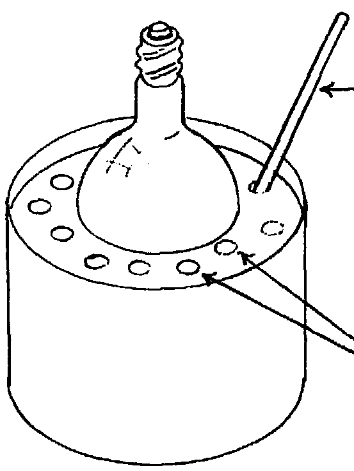


Cross Section

Make a mixture of 3:1 cement (B)/ sand (A). Add water to make a thick concrete paste. Next, cover the mold with a 2 - 3 cm layer of concrete (A and B). Cut the wire mesh (E) into 2 cm wide strips and press the strips on the coating of concrete. Cover the entire surface of concrete with the screening strips (E).



Fill the remaining space with concrete. Cover the 100 watt light bulb (G) with oil and press it halfway into the mold. Scrape away and discard any concrete that overflows the mold. Level off the top of the concrete.

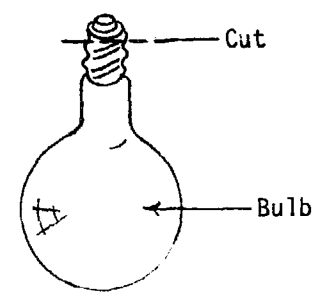


Take a thin wooden or metal rod and push it in and out of the concrete around the bulb (G), touching the bulb. Break up, in this way, any air bubbles between the bulb and the concrete.

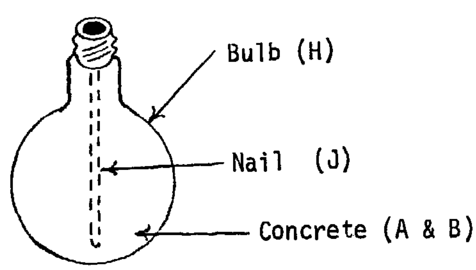
Allow at least 24 hours or more for the concrete to dry. Then cut away the can with a can opener and tin snips and peel away the clay mold. Break and remove the bulb, taking care to remove all pieces of broken glass. Place the mortar in a large can or crock and cover it with water. Allow it to soak for three weeks in order to cure. Add water to the container as it is absorbed by the mortar.

When the mortar has cured, remove it from the water and allow it to dry. Then cover the entire surface with epoxy glue (F) to seal the concrete, fill air bubbles, and provide a smooth grinding surface.

(2) Pestle



Cut the metal tip off the 60 watt light bulb (H) with a hacksaw. Remove the insides. File the cut edges smooth with a round file.



Support the bulb upright in a container of sand or appropriate stand and fill the entire bulb with the concrete paste (A and B). Insert a nail almost all the way to the bottom of the bulb, to provide support for the concrete.

Allow the concrete to dry (at least 24 hours). Break the glass glass, leaving the metal end intact. Cure the pestle immersed in water for three weeks. Remove, dry, and coat with epoxy glue (I), making sure all air bubbles are filled.

c. Notes

(i) The mortar and pestle are used to grind crystals or lumps of substances into powder. The substance to be ground is placed in the mortar, and ground with the pestle to the desired consistency.

(ii) If the epoxy-coated grinding surfaces of the mortar and pestle become worn away with use, clean them and reapply a layer of epoxy glue to provide a smooth surface.

VI. SEPARATORS AND PURIFIERS

This section on separators and purifiers has been divided into four subsections:

A. MECHANICAL SEPARATORS

These are devices for separating solid/solid, liquid/solid, or solid/liquid mixtures. Included are magnets, sieves, filtration apparatus, and separatory funnels.

B. DISTILLATION APPARATUS

These devices are used for separating liquid solutions and include several types of distillation apparatus.

C. ELECTRICAL SEPARATOR

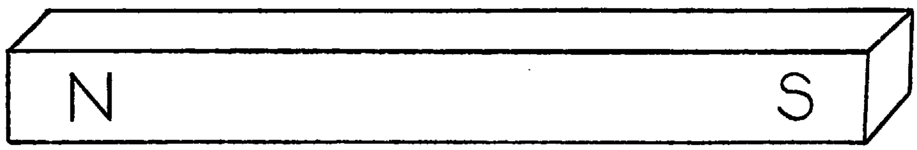
This device is used in the electrolytic separation of substances and to demonstrate Faraday's quantitative laws of electrolysis.

D. CENTRIFUGAL SEPARATORS

Centrifugal separators are used to cause the rapid precipitation of materials in suspension.

A. MECHANICAL SEPARATORS

A1. Magnets



(1) Bar Magnet

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Bar Magnet	1	Bar Magnet	PHYS/IX/A1, Notes

b. Construction

(1) Bar Magnet

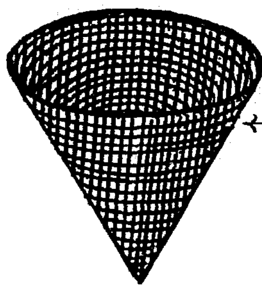
Purchase a magnet, or magnetize a steel bar according to the instructions described in PHYS/IX/A1, Notes.

c. Notes

(i) Magnets are used to separate ferromagnetic materials from other materials, such as dirt or sand.

(ii) Magnets in a variety of shapes, materials, and field strength may be purchased from commercial sources and may be used in place of the bar magnet above.

A2. Cone Sieve

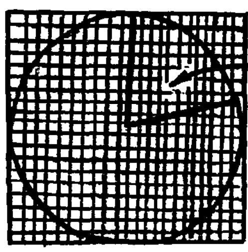


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cone Sieve	1	Wire Mesh (A)	Approximately 7 cm x 7 cm
	1	Thin Wire (B)	Approximately 10 cm

b. Construction

(1) Cone Sieve



Cut a circle from the wire mesh (A). Then cut out and remove a segment of the circle as shown.

Roll the wire mesh into the shape of a cone, overlapping the edges slightly. Thread the thin wire (B) in and out of the wire mesh, at the overlapped edges, to hold them together.

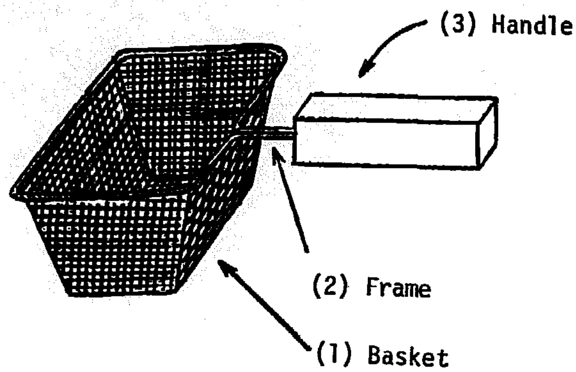
c. Notes

(i) This cone may be made larger or smaller by varying the dimensions of the wire mesh used.

(ii) Material suitable for replacing the wire mesh may be made by dipping a cloth having a very coarse weave into melted wax, varnish, or starch.

(iii) Sieves are suitable for grading small particles or washing small amounts of materials under a stream of water.

A3. Basket Sieve

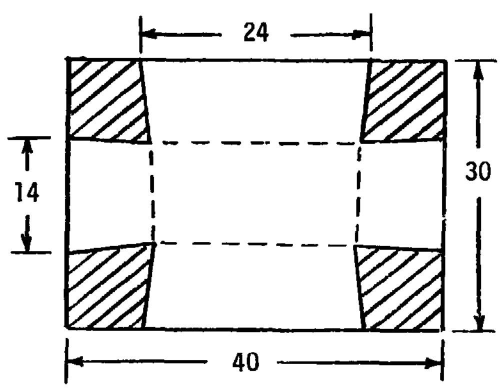


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Basket	1	Wire Mesh (A)	Approximately 30 cm x 40 cm
	4	Thin Wire (B)	Approximately 20 cm
(2) Frame	1	Stiff, Heavy Wire (C)	Approximately 4 cm diameter, 80 cm long
	1	Thin Wire (D)	Approximately 80 cm long
(3) Handle	1	Wood (E)	2 cm x 2 cm x 15 cm

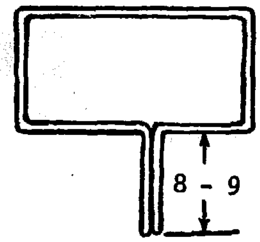
b. Construction

(1) Basket



Cut the wire mesh (A) according to the pattern shown, and discard the shaded portions. Then fold all the flaps up along the dashed lines. Overlap the cut edges slightly, and thread the thin wires (B) in and out of the wire mesh at the overlapped edges to hold them together.

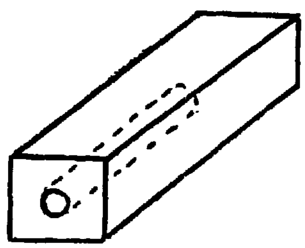
(2) Frame



Bend the heavy wire (C) as shown, to fit the dimensions of the top of the basket. Allow an extension of 8 - 9 cm to fit into the handle (E).

Fold the top 1 cm of the basket around the frame to the inside, and lace the thin wire (D) in and out of the basket mesh to secure the frame in place.

(3) Handle



Drill a hole approximately 0.8 cm in diameter and approximately halfway through the length of the wooden handle (E).

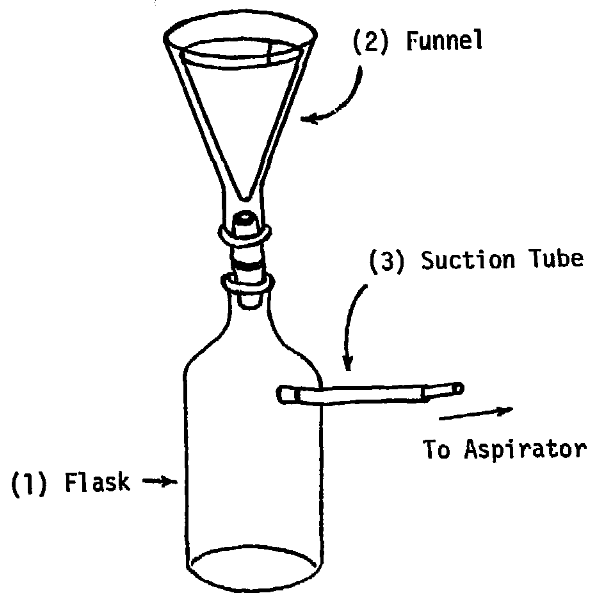
Insert the straight section of the frame into this hole in the handle, and cement it in place.

c. Notes

(i) This basket sieve may be made larger or smaller by varying the dimensions of the wire mesh, frame, and handle used.

(ii) This sieve is used just as the funnel sieve in the preceding section, but for larger amounts of material.

A4. Suction-Filter Flask

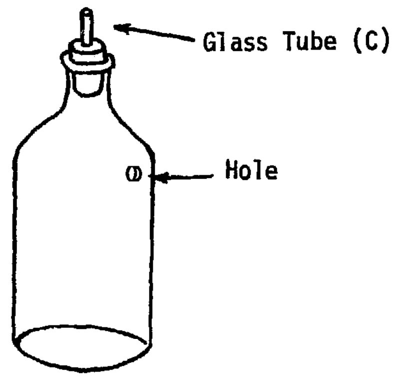


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Flask	1	Glass Bottle (A)	Capacity 250-500 ml
	1	1-Hole Rubber Stopper (B)	To fit bottle (A)
	1	Glass Tube (C)	0.5 cm diameter, 6 cm long
(2) Funnel	1	Funnel (D)	V/A3
	1	1-Hole Rubber Stopper (E)	To fit neck of funnel (D)
	1	Filter Paper (F)	Approximately 15 cm diameter
(3) Suction Tube	1	Rubber Tube (G)	1.0 cm diameter, 15 cm long
	1	Glass Tube (H)	0.7 cm diameter, 10 cm long

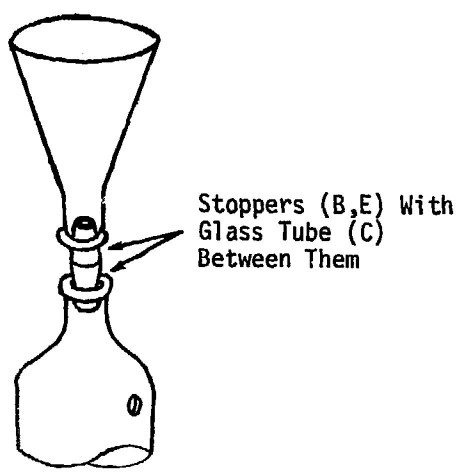
b. Construction

(1) Flask



Bore a hole (I/E2) just slightly smaller than 1.0 cm in diameter in the side of the bottle (A) near the top. Insert the glass tube (C) into the rubber stopper (B) so that approximately half the tube protrudes from the top of the stopper. Fit the stopper into the mouth of the bottle.

(2) Funnel



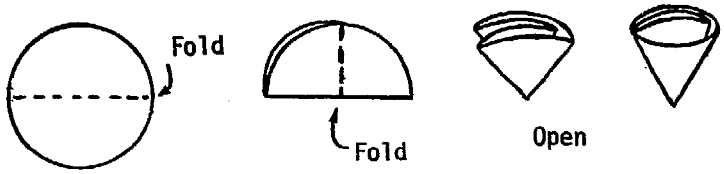
Insert the protruding end of the glass tube into the stopper (E) for the funnel (D). Push the two stoppers together, and fit the funnel stopper into the neck of the funnel (D).

(3) Suction Tube

Insert the rubber tubing (G) into the hole in the side of the bottle so that about 1 cm of tubing is inside the bottle. Seal the tubing in place with eqoxy resin. Insert a short piece of glass tubing (H) into the open end of the rubber tubing.

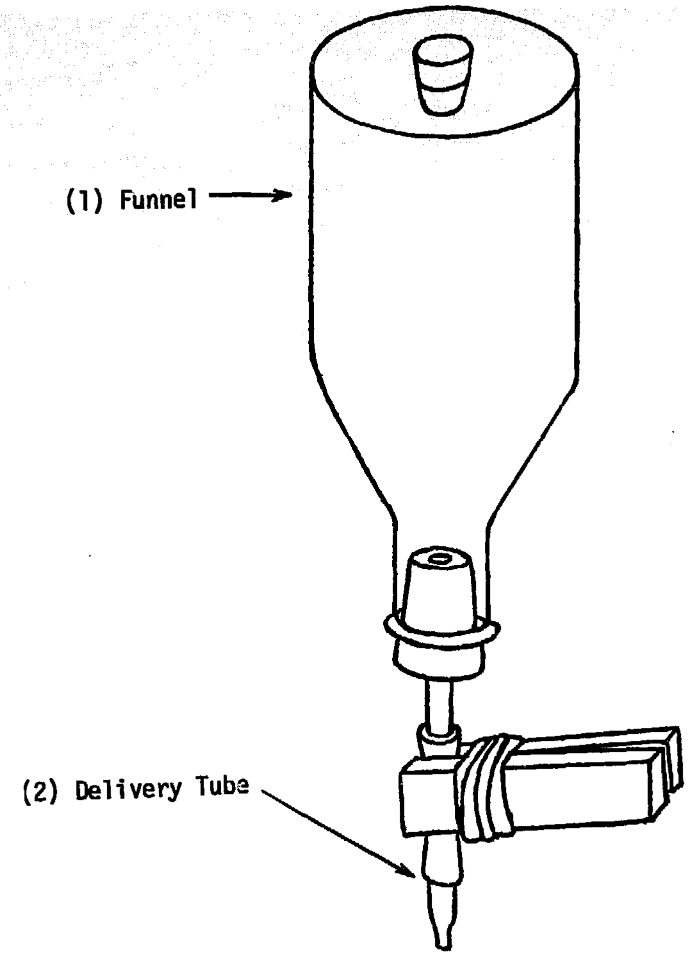
c. Notes

(i) A circle of filter paper is folded as illustrated and placed in the funnel. The suction tube is then connected to the water-filled aspirator (V/A8). The material to be filtered is placed in the filter paper in the funnel. Water is then allowed to drain from the aspirator. The partial vacuum thus formed will draw air from the flask, and air on the outside will be drawn through the funnel, causing more rapid filtration to occur.



(ii) Filter paper is available from commercial suppliers, but substitutes include paper towels, blotting paper, or cotton.

A5. Separatory Funnel

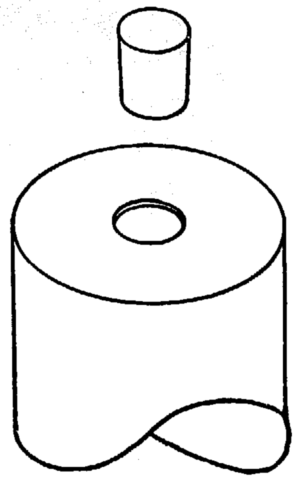


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Funnel	1	Glass Bottle (A)	Capacity 250-500 ml
	1	Rubber Stopper (B)	Approximately 2 cm diameter (large end)
(2) Delivery Tube	1	1-Hole Rubber Stopper (C)	To fit bottle (A)
	1	Glass Tubing (D)	0.7 cm diameter, 15 cm long
	1	Rubber Tubing (E)	1 cm diameter, 8 cm long
	1	Wooden Pinch Clamp (F)	IV/A4

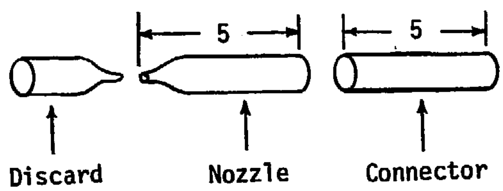
b. Construction

(1) Funnel

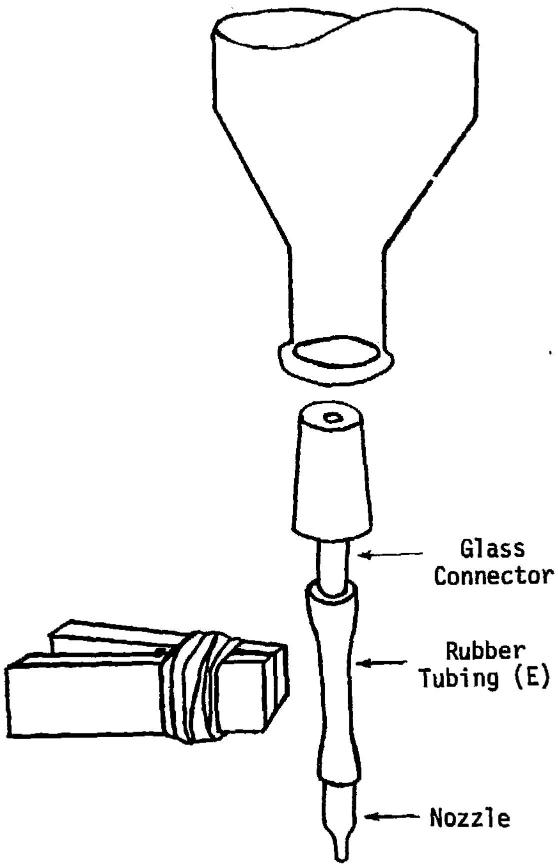


Select a clear glass bottle (A) with a tapered, narrow neck. Drill a hole in the bottom of the bottle and enlarge it sufficiently to receive the rubber stopper (B). Smooth the rough edge with emery paper before sealing.

(2) Delivery Tube



Heat the glass tubing (D) with a burner and draw it out near one end and cut as shown to leave a 5 cm long nozzle and a 5 cm long connector. Carefully fire polish all cut edges.

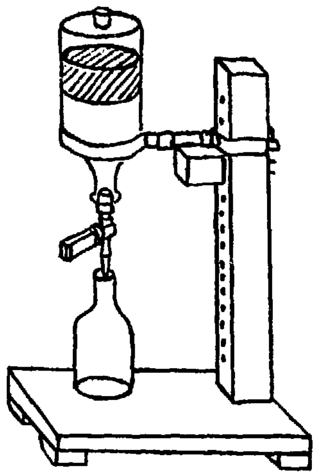


Fit the glass connector into, but not through, the one-hole rubber stopper (C). Insert the other end into the rubber tubing (E), and connect the rubber tubing to the nozzle. Fit the stopper into the neck of the bottle.

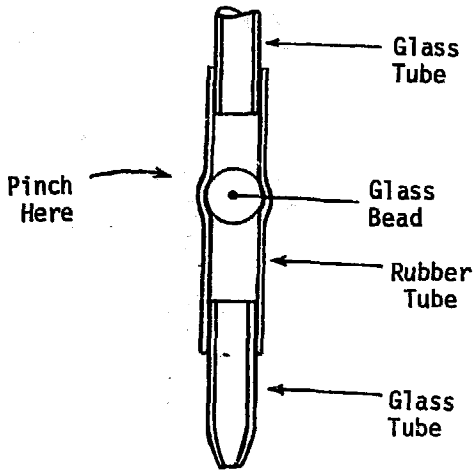
Construct a wooden pinch clamp (IV/A4) and use it to close the rubber tubing.

c. Notes

(i) The separatory funnel is used to separate two liquids that do not mix. With the delivery tube closed, the mixture of liquids is poured into the funnel through the hole at the top, (bottom of bottle). The funnel is then sealed and shaken vigorously for several seconds. Then the funnel is secured in a ring stand (IV/B4) or other appropriate support and allowed to rest undisturbed until the liquids separate into layers. The lower liquid is then drained through the delivery tube by opening the pinch clamp. In order to allow the funnel to drain properly, the stopper must be removed from the top.



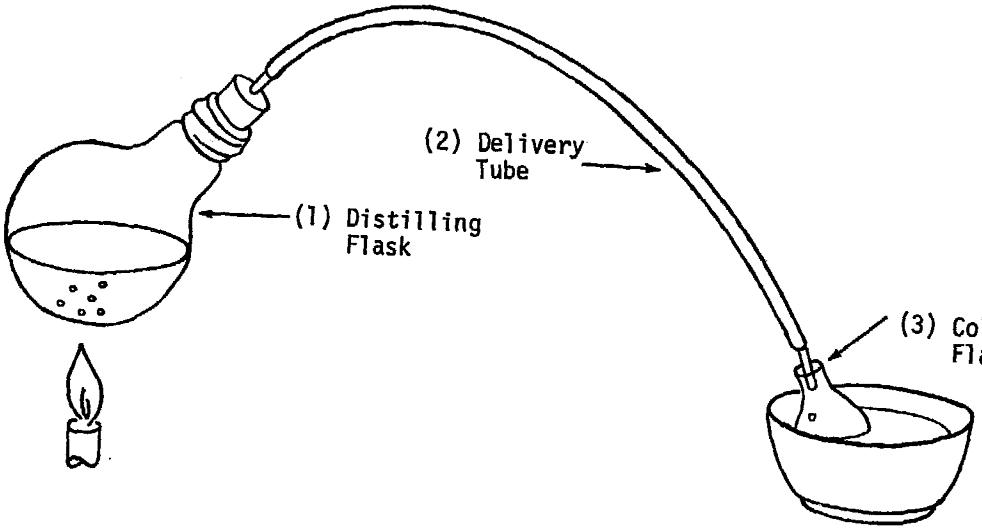
(ii) A glass bead just slightly larger than the internal diameter of the rubber tubing may be used in place of the pinch clamp. Push the bead into the rubber tubing before inserting the glass nozzle. The bead will seal the rubber tube. To dispense liquid from the funnel, squeeze the tube between thumb and forefinger at the location of the bead.



Cross Section

B. DISTILLATION APPARATUS

B1. Simple Distillation Apparatus



a. Materials Required

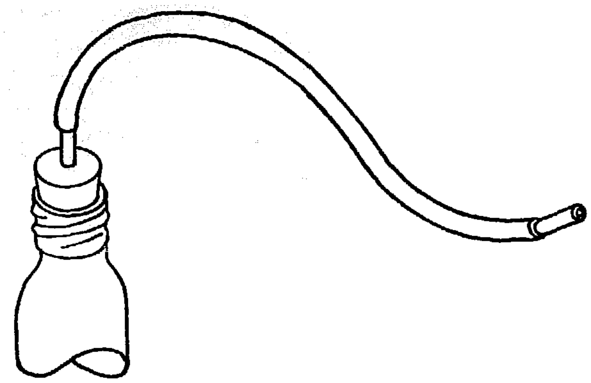
Components	Qu	Items Required	Dimensions
(1) Distilling Flask	1	Flask (A)	Capacity approximately 200 ml
	1	1-Hole Rubber Stopper (B)	To fit flask (A)
(2) Delivery Tube	2	Glass Tubing (C)	0.7 cm diameter, 5 cm long
	1	Rubber or Plastic Tubing (D)	1 cm diameter, approximately 60 cm long
(3) Collecting Flask	1	Flask or Bottle (E)	Capacity approximately 200 ml

b. Construction

(1) Distilling Flask

Fit the light bulb flask (A) or other flask with the one-hole rubber stopper (B).

(2) Delivery Tube



Support the flask in a stand, (IV/B4, B5, or B6).

Insert a short piece of glass tubing (C) into the stopper in the flask. Attach the other end of the glass tube to a long piece of rubber or plastic tubing (D). Insert another short piece of glass tubing (C) into the other end of the rubber or plastic tubing.

(3) Collecting Flask

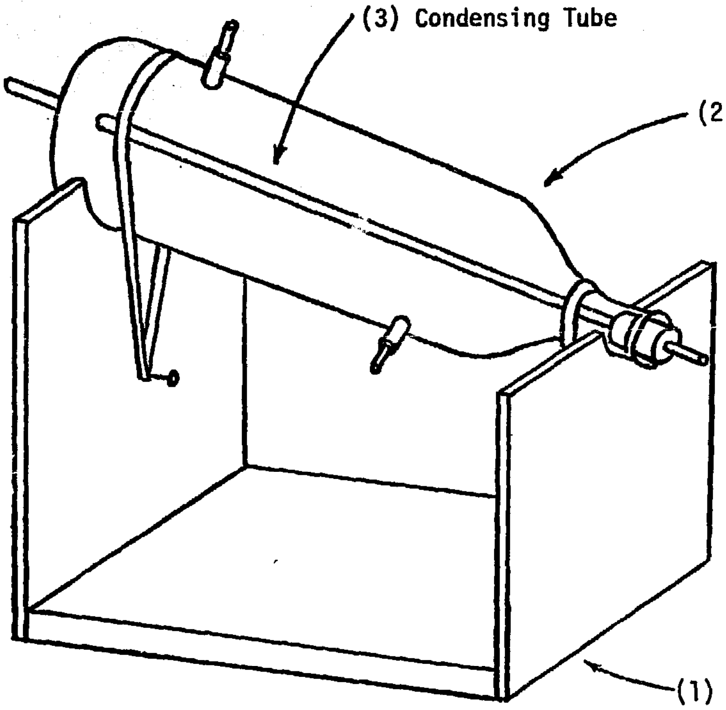
Place a flask (E) or jar in a bowl or pan of cool water and lead the free end of the delivery tube into the flask.

c. Notes

(i) A sample of a liquid--impure water, for example--to be distilled is placed in the distilling flask, and the stopper is inserted into the flask. The liquid is heated until it boils. As the liquid boils, its vapor travels through the delivery tube and is cooled enough by air surrounding the tube to condense and drip into the collecting flask. The water in the bowl helps cool the condensed liquid still more, as it is quite hot when first collected.

(ii) This simple apparatus is ideal for student participation in simple distillation operations involving small volumes of liquids.

B2. Condenser

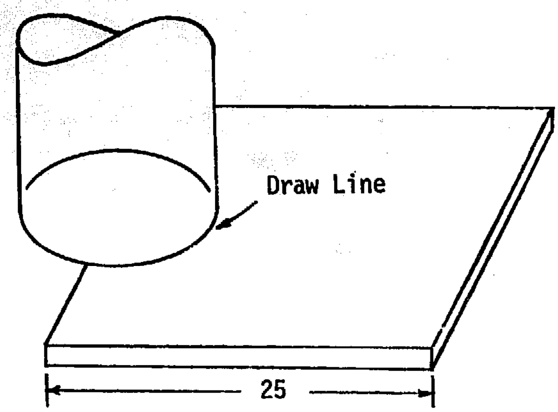


a. Materials Required

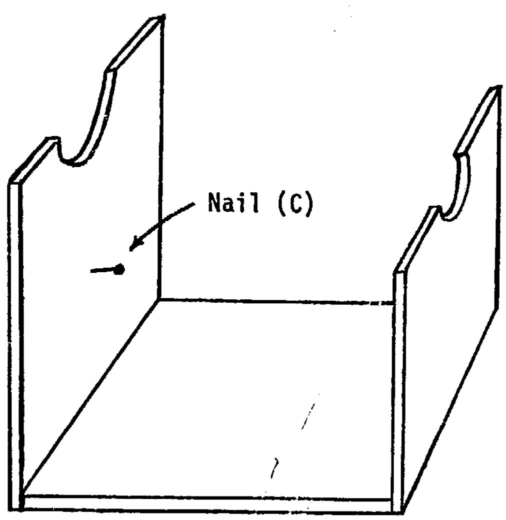
Components	Qu	Items Required	Dimensions
(1) Stand	2	Wood (A)	18 cm x 15 cm x 1 cm
	1	Wood (B)	25 cm x 15 cm x 1 cm
	2	Nails (C)	3 cm long
	2	Rubber Bands (D)	5 cm x 9 cm
(2) Water Jacket	1	Plastic or Glass Bottle (E)	Capacity approximately 1-2 liters
	1	1-Hole Rubber Stopper (F)	To fit bottle (E)
	2	Rubber Tubing (G)	1 cm diameter, 3 cm long
	2	Glass Tubing (H)	0.7 cm diameter 10 cm long
(3) Condensing Tube	1	Glass Tubing (I)	0.7 cm diameter, 10 cm longer than bottle

c. Construction

(1) Stand



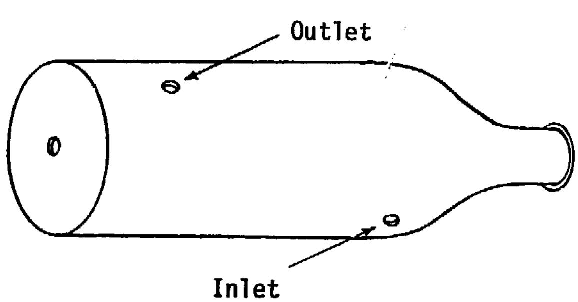
Trace around the base of the bottle (E) on the larger piece of wood (B) as shown. Cut along the traced line.



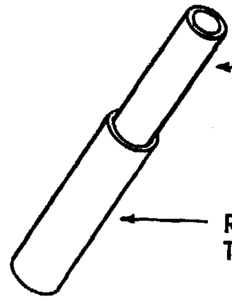
In a similar fashion, make a small semicircular cutout to accommodate the neck of the bottle (E) in one of the smaller pieces of wood (A).

Nail the two sections with cutouts to the third (A) to form the stand. Drive a nail (C) into each upright to anchor the rubber bands (D) that hold the water jacket in place.

(2) Water Jacket



Take a plastic bottle (E) if possible, a glass bottle if necessary. Drill three holes approximately 1 cm in diameter in the bottle as illustrated.



Fit each short piece of glass tubing (H) into a piece of rubber tubing (G). Insert each piece of rubber tubing into one of the holes in the side of the bottle. Seal with epoxy resin if necessary to make sure that the seal is watertight.

Fit the mouth of the bottle with a one-hole rubber stopper (F).

(3) Condensing Tube

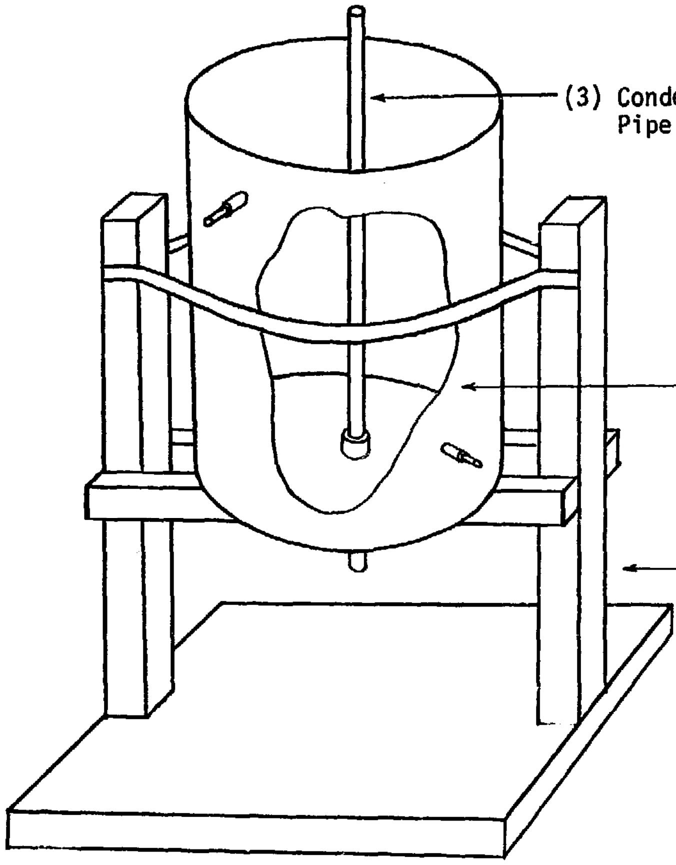
Insert a long glass tube (I) through the hole in the base of the bottle, all the way through the bottle, and through the rubber stopper to the outside again.

Rest the bottle in the stand with the base higher than the neck and the inlet tube below the outlet tube. Loop the rubber bands (D) around the base and neck of the bottle to secure it in position.

c. Notes

(i) To use this condenser, fasten a rubber or plastic tube from the flask in which a liquid is being boiled to the upper end of the condensing tube (that end protruding from the bottom of the bottle). Another tube, from a cold water source, is connected to the inlet (lower) tube, and a third rubber or plastic tube is attached to the outlet and led to a drain. As hot gas flows through the condensing tube, it is cooled by the water jacket and condenses, to drip as a liquid from the lower end of the condensing tube where it can be collected in a beaker.

B3. Water Still



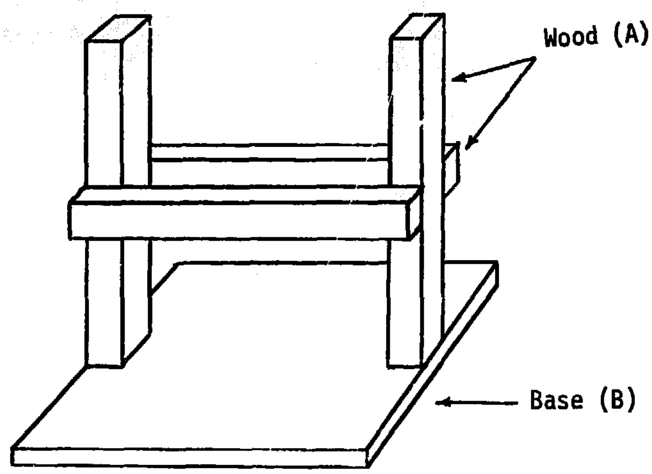
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame Support	4	Wood (A)	4 cm x 5 cm x 25 cm
	1	Wood (B)	2 cm x 16 cm x 25 cm
(2) Water Jacket	2	Metal Strapping (C)	1.5 cm x 28 cm
	1	Large Tin Can (D)	Capacity approximately 1-1.5 kg
	2	Rubber Tubing (E)	1 cm diameter, 5 cm long
	2	Glass Tubing (F)	0.7 cm diameter, 5 cm long
(3) Condensing	1	Copper Pipe (G)	1 cm outside diameter, 5 cm longer than can height
	1	1-Hole Rubber Stopper (H)	Approximately 2.5 cm diameter (large end)

1	Glass Tubing (I)	0.7 cm diameter, 5 cm long

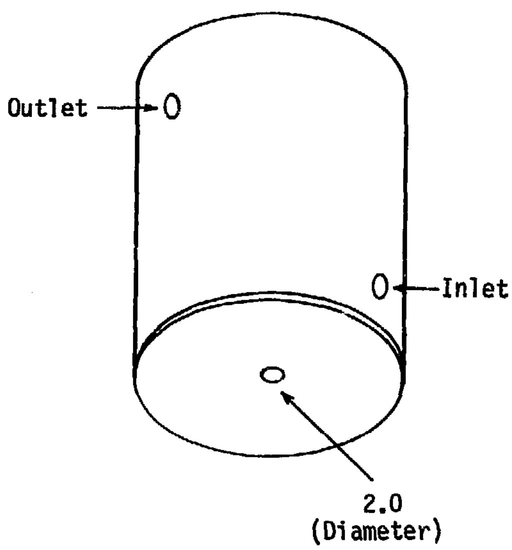
b. Construction

(1) Frame Support

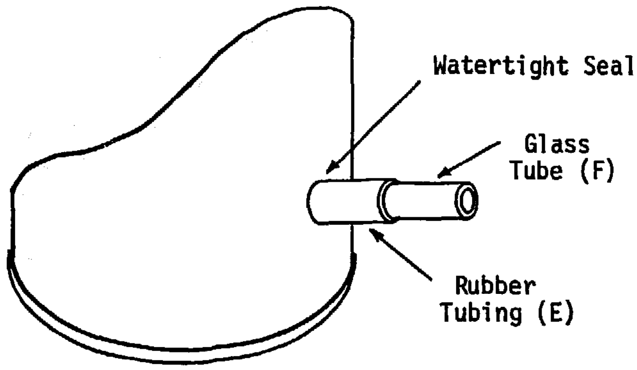


Nail two pieces of wood (A) to a flat piece (B) to form a base and uprights. Then nail two more pieces of wood (A) to the outsides of the uprights, as shown, to form supports for the can.

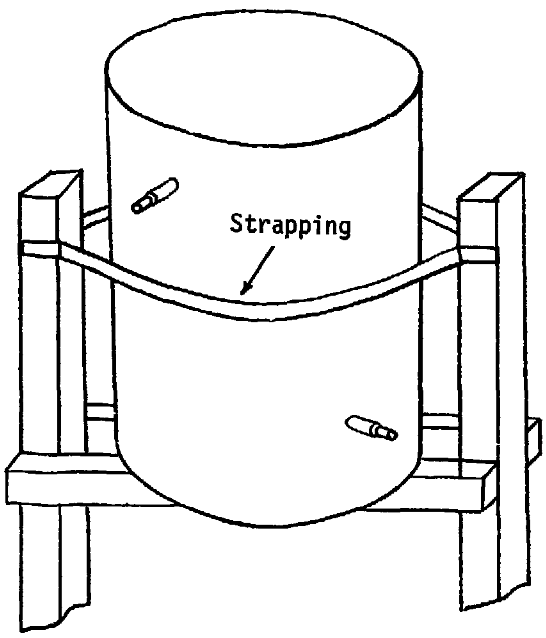
(2) Water Jacket



Cut a hole approximately 2 cm in diameter in the center of the bottom of the can (D). Crimp the cut edges inward. Cut a smaller hole, not quite 1 cm in diameter, in the side of the can near the bottom, to accommodate the inlet tube. Cut another small hole, not quite 1 cm in diameter, in the side of the can near the top, for the outlet tube.



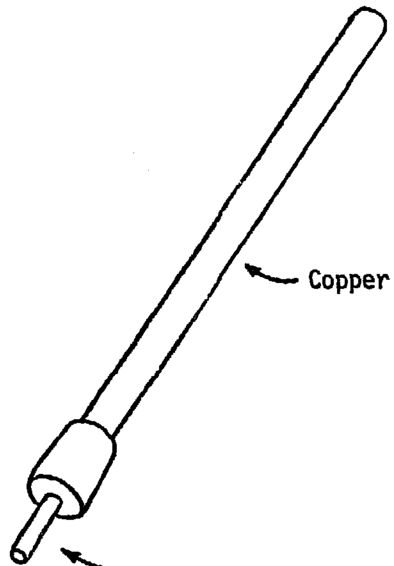
Insert each short piece of glass tubing (F) into a short piece of rubber tubing (E). Insert each rubber tube into one of the two small holes in the can. If the rubber tubes do not fit snugly by themselves, make a watertight seal with candle wax or epoxy resin.



Set the can in place in the frame support. To secure it in position, nail two pieces of strapping (C) to the frame support, one on each side of the can.

(3) Condensing Pipe

Choose a one-hole rubber stopper (H) that tightly seals the hole in the bottom of the water jacket can. Insert a short piece of glass tubing (I) part way through the stopper, from the large end. Insert the copper pipe (G) into the stopper from the other end.



Insert the condensing pipe into the water jacket can through the hole in the bottom of the can. Push the stopper tightly into the hole from the outside. Seal with candle wax or epoxy resin, if necessary, to produce a watertight seam.

c. Notes

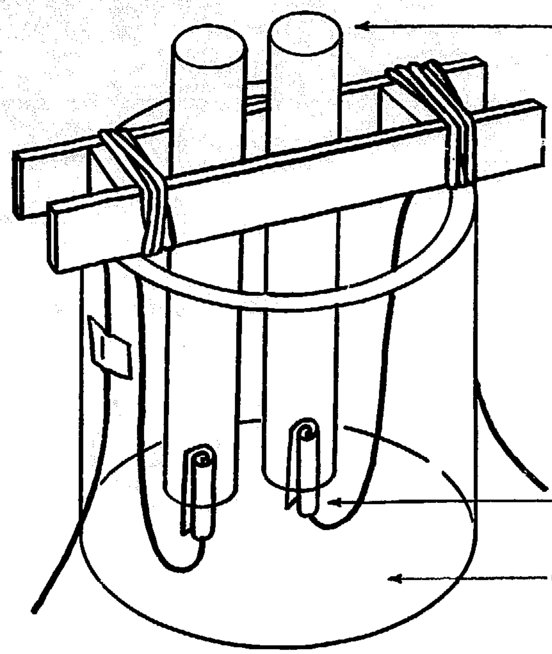
(i) A plastic or rubber tube from a water source is attached to the inlet tube, and another tube is attached to the outlet tube and led to a drain. A plastic or rubber tube from the container in which water is boiled is connected to the free end of the copper condensing pipe. Water vapor flowing through this tube will condense and drip from the glass delivery tube at the bottom of the still, where it can be collected.

(ii) This still is suitable for continuous operation, in order to produce distilled water for class use. In such a case, a large kettle should be used for boiling the water, and a plastic or rubber tube can be attached to the delivery tube and led to a storage container.

(iii) The size of the frame support for this still is determined by the size of the can used for the water jacket. Its dimensions will vary, according to the size of the can used.

C. ELECTRIC SEPARATOR

C1. Electrolysis Apparatus



a. Materials Required

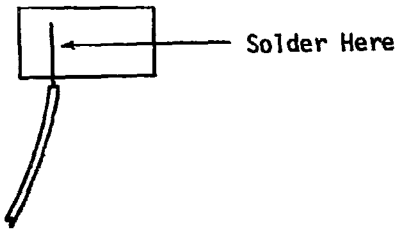
Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Jar (A)	Approximately 100-200 ml capacity
(2) Electrodes	2	Stiff Wire, Insulated (B)	Approximately 0.1 cm diameter, 25 cm long
	2	Thin Copper Sheet (C)	1.5 cm x 3.0 cm
	2	Masking or Adhesive Tape (D)	2 cm x 4 cm
(3) Collecting Tube	2	Test Tubes or Vials (E)	Approximately 1.5 cm diameter, 10 cm long
(4) Frame Support	2	Wood Strips (F)	0.2 cm x 2 cm x 15 cm
	2	Wood Blocks (G)	Approximately 2 cm x 2 cm x 1.3 cm
	2	Rubber Bands (H)	Approximately 0.2 cm x 4 cm

b. Construction

(1) Container

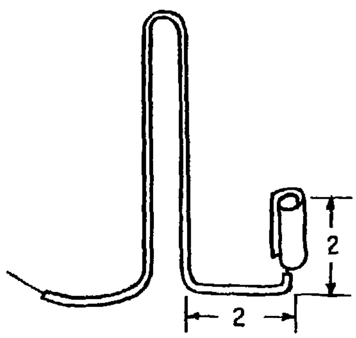
Choose a small glass jar (A) with a capacity of 100 - 200 ml, or cut off the top of a jar to make a container of appropriate size.

(2) Electrodes

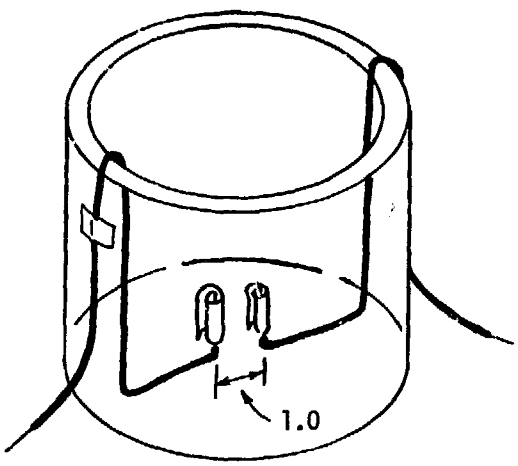


Strip about 1.5 cm of the insulation off each end of the stiff, insulated wire (B). Solder one end of each wire to a piece of the copper sheet (C), as shown.

When the solder has cooled, roll the copper sheet (C) into a spiral plate.



Bend each of the stiff wires (B) as illustrated. Make the large loop long enough to fit over the lip of the container (A) when the flat 2 cm portion of the wire is resting on the bottom of the container.



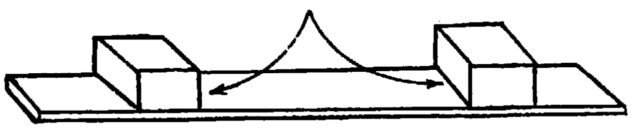
Place the electrodes at opposite sides of the container. Adjust the bends, if necessary, so that the plates of the electrodes are about 1 cm apart. Secure the wires to the outside of the container with tape.

(3) Collecting Tubes

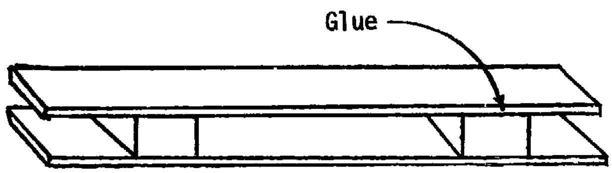
For the collecting tubes (E), use small glass or plastic test tubes or vials that are slightly taller than the height of the container (A).

(4) Frame Support

For the frame support, use two thin, flexible wooden strips (F) about twice as long as the diameter of the container. Cut two small wooden blocks (G) just slightly narrower than the diameter of the collecting tubes.



Glue the two blocks to one of the strips, about 5 cm apart.



Glue the other strip to only one of the blocks, as shown.

Hold the rubber bands (H) aside until the apparatus has been set up [see Note (i)].

c. Notes

(i) This apparatus is used to separate water into oxygen and hydrogen, which are collected in the tubes. The container is filled with water sufficient to cover the terminals by less than 1 cm. A little vinegar or washing soda ($Na_2CO_3 \cdot 10H_2O$) is added to the water to increase its conductivity. The collecting tubes are filled with the same acidic (vinegar) or basic (Na_2CO_3) solution. Then, with the open end sealed with a thumb or forefinger, each tube is inverted and placed into the container. The open end of the tube must be placed below the surface of the solution before it is uncovered. Then, without being lifted out of the solution, each tube is placed over one of the electrodes.

The frame support may be placed around the two collecting tubes. It is secured tightly around the tubes with rubber bands at each end. With the tubes thus supported, the frame is rested on the top of the container and the tubes are carefully adjusted so that the open ends do not rest on the bottom of the container, but are about 1 cm above the bottom and below the surface of the solution in the container.

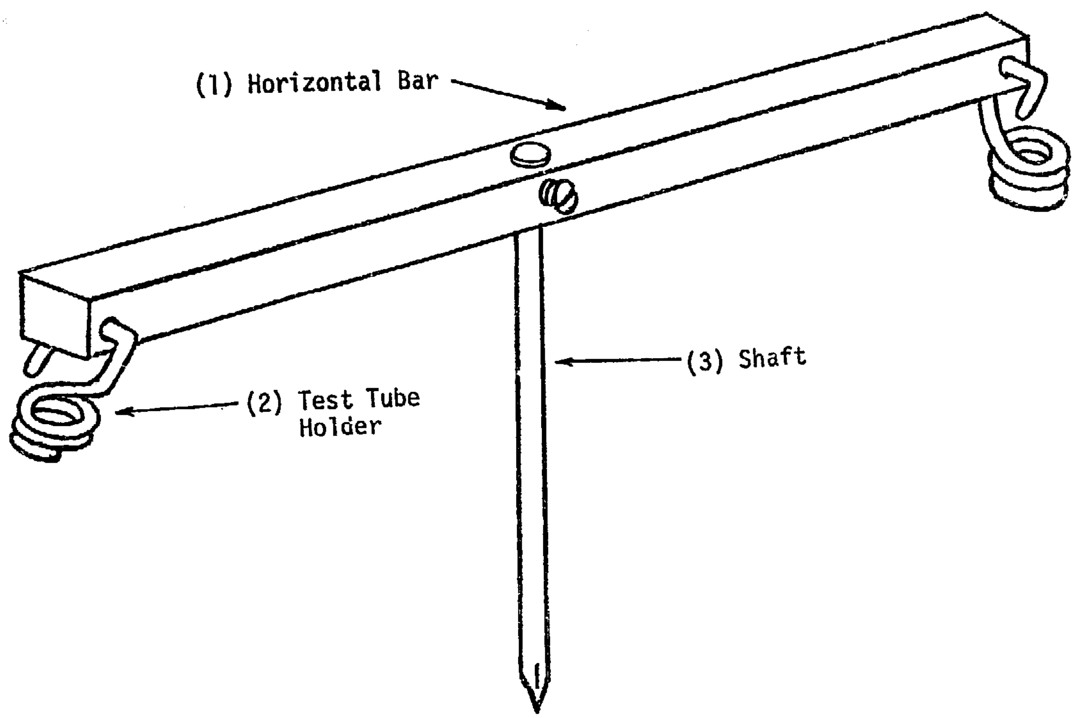
When the free ends of the electrodes are connected to three or more 1.5 volt cells connected in series, sufficient current passes through the solution to break down the water. Hydrogen is the gas generated at the negative plate (cathode) and collected in the tube placed over that plate. Oxygen is generated at the positive plate (anode) and is collected approximately one half as rapidly as hydrogen.

(ii) This apparatus is quite suitable for student use in the laboratory, as it is simple to set up and requires little current. With three or more 1.5 volt cells, the gases are evolved rapidly and the tubes can be filled in about 20 - 30 minutes.

(iii) Several factors enhance the efficient operation of this apparatus. The small volume of solution used and the proximity of the plates reduce the amount of resistance in the system and allow it to function on low current. If the plates are cleaned after each use, the apparatus will also function more efficiently.

D. CENTRIFUGAL SEPARATORS

D1. Hand Drill Centrifuge

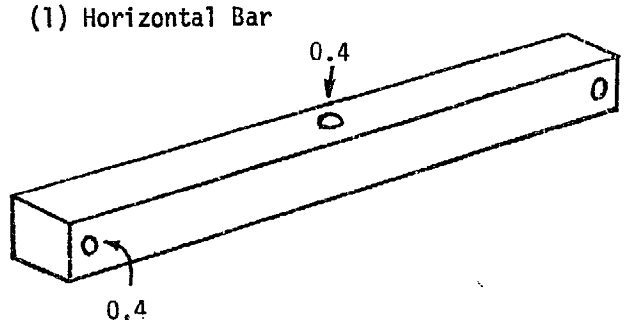


a. Materials Required

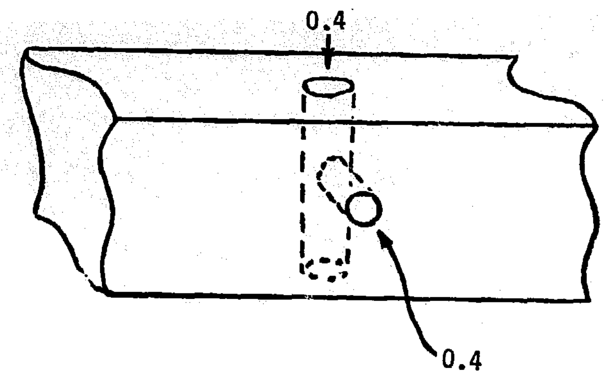
Components	Qu	Items Required	Dimensions
(1) Horizontal Bar	1	Wood (A)	2 cm x 2 cm x 32 cm
(2) Test Tube Holder	2	Stiff Wire (B)	Approximately 0.2 cm diameter, 30 cm long
(3) Shaft	1	Nail (C)	0.5 cm diameter, 18 cm long
	1	Bolt (D)	Approximately 0.5 cm diameter, 2 cm long

b. Construction

(1) Horizontal Bar

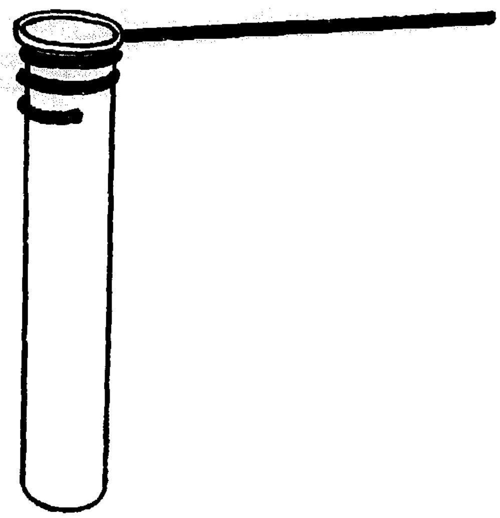


Drill holes, approximately 0.4 cm in diameter, at each end of the wooden bar (A). Drill a hole through the center of the bar, as shown. Make the diameter of this hole slightly smaller than the diameter of the nail (C) used for the shaft.

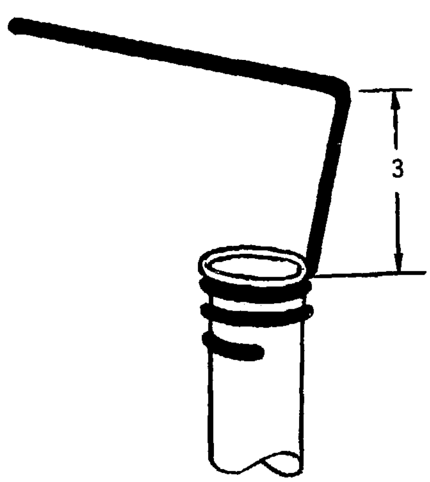


Then, drill a hole perpendicular to and intersecting the hole in the center of the bar. Make the diameter of this hole slightly smaller than the diameter of the bolt (D) used to hold the shaft in place.

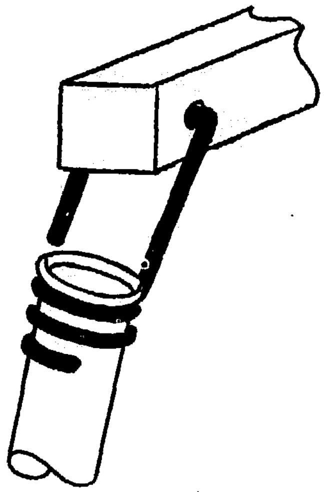
(2) Test Tube Holder



Take a test tube of the size that will be used in the centrifuge. Wind one piece of heavy, stiff wire (B) (coat hanger wire, for example) around the test tube two or three times. Make the coil very snug around the test tube so that the test tube lip will not slip through it. Leave a straight portion of about 8 - 9 cm at the top of the coil.



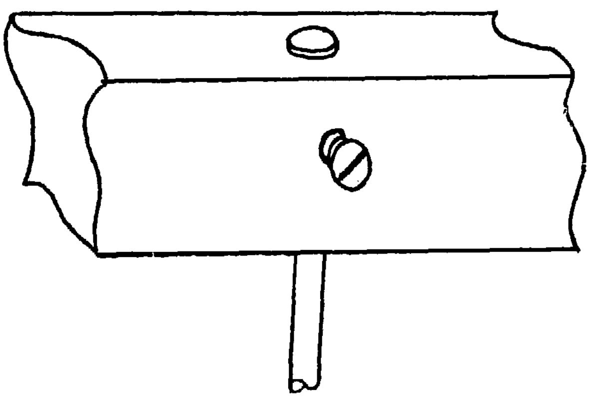
Bend the straight portion of the wire at an angle to the rest of the coil as shown. About 3 cm from the coil, bend the wire again, at right angles to the upright portion.



Fit the free end of the wire into one of the end holes in the horizontal bar. Check to see that the fit is loose enough for the holder to swing easily. Then bend the excess wire down, as shown, to secure the holder in the horizontal bar.

Repeat this procedure for the construction of the second test tube holder.

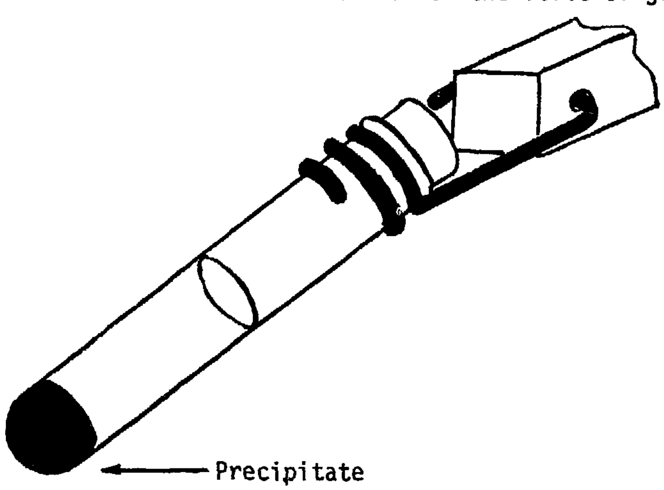
(3) Shaft



Carefully thread the short bolt (D) into the center, horizontal hole in the horizontal bar. Then unscrew it halfway. Fill the nail hole (vertical hole) with epoxy glue and tap the nail (C) into the hole. Tighten the bolt against the nail and coat the threads of the bolt with epoxy glue.

c. Notes

(i) A precipitate formed by a chemical reaction in a test tube will eventually settle to the bottom because of the force of gravity acting upon it. The time required for a given precipitate to settle is dependent on several factors; among these are the volume, density, and particle size of the precipitate. Spinning such material in a test tube in a centrifuge reduces this duration by creating a strong centrifugal force, which causes the heavier precipitate to settle to the the



outside of the centrifuge. When the test tube holders are free to pivot outward, as in this centrifuge, the test tubes will assume a nearly horizontal position when the centrifuge is in rapid motion. Thus, the bottom of the test tube becomes the "outside" of the centrifuge, and precipitate is pulled to the bottom of the tube.

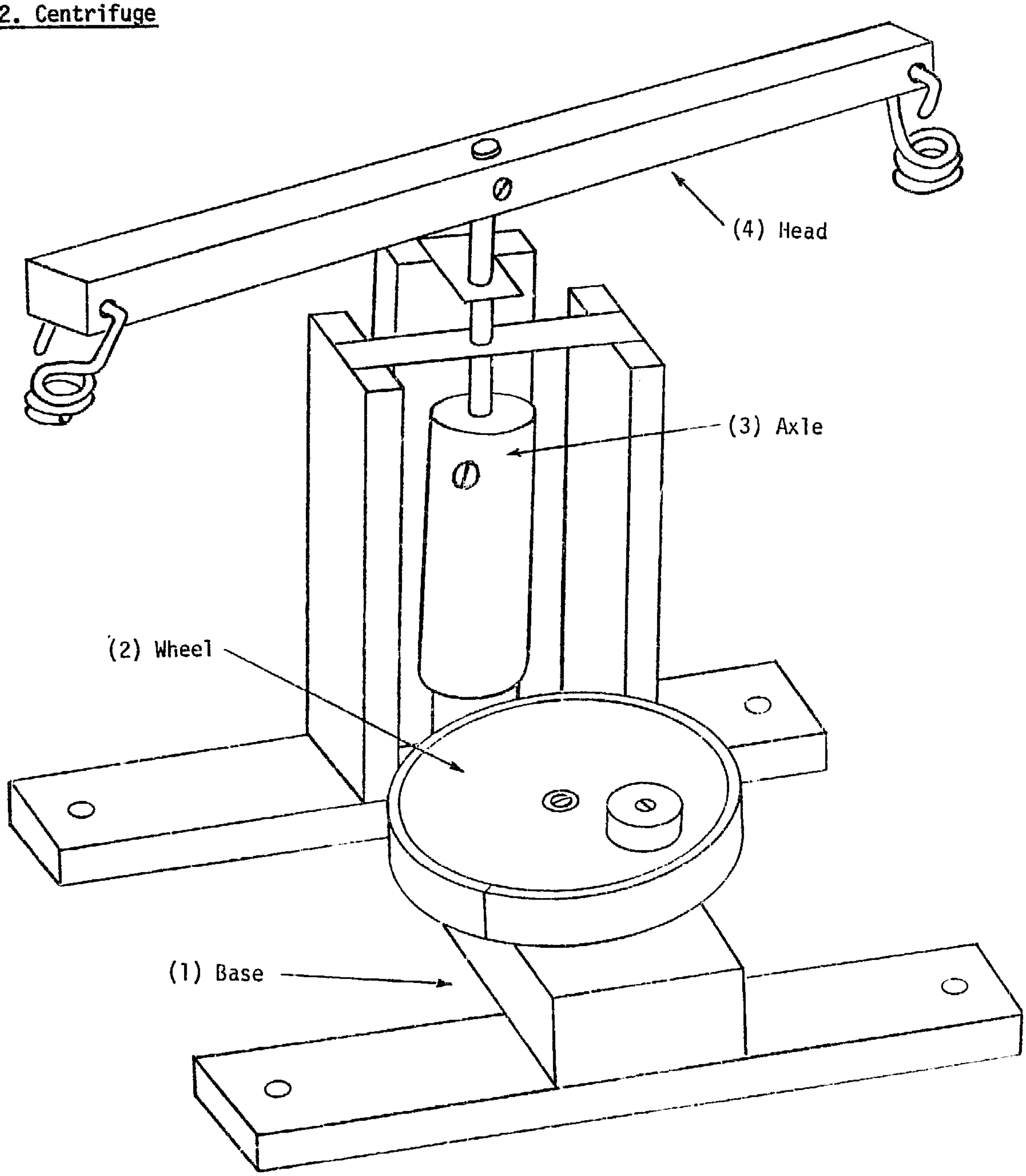
(ii) To use this centrifuge, place an appropriately sized test tube containing material to be centrifuged through one of the wire holders. To balance the centrifuge, place a test tube with an equal volume of water in the other holder. Take care to insure that the test tubes are securely held in place by the holders. Seal both test tubes with corks or stoppers to prevent spillage. Fix the end of the shaft firmly in a hand drill. Clamp the drill handle tightly in a heavy vise, stand at arm's length from the drill, and turn the handle of the drill. The centrifuge will spin, causing the precipitate to collect at the bottom of the test tube. To stop the centrifuge, let go of the drill handle and allow the centrifuge to continue to spin until it comes to a gentle stop. Another way to stop the centrifuge is to turn the drill handle more and more slowly until it is brought to a gentle stop. Sudden stops, which will shake up the precipitate, are to be avoided.

(iii) If a vise is not available, the drill may be held at arm's length from the body while the centrifuge is spun.

(iv) This centrifuge is capable of being spun at 300 - 500 revolutions per minute. It was tested with several precipitates, such as $CaCO_3$ and $AgNO_3$, and was found to reduce settling time from several hours (gravity) to less than one minute.

(v) This centrifuge, whether clamped in a drill or held at arm's length, must be used with extreme care since the test tubes swing close to the user. A safer, more permanent centrifuge, which incorporates this centrifuge as its rotating assembly, is described in the following section.

D2. Centrifuge



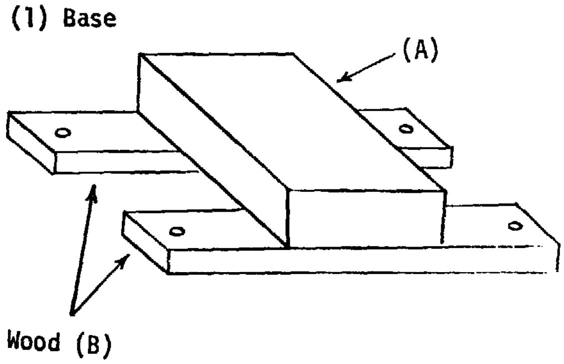
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	4 cm x 9 cm x 30 cm
	3	Wood (B)	2 cm x 5 cm x 30 cm
	2	Wood (C)	2 cm x 5 cm x 25 cm

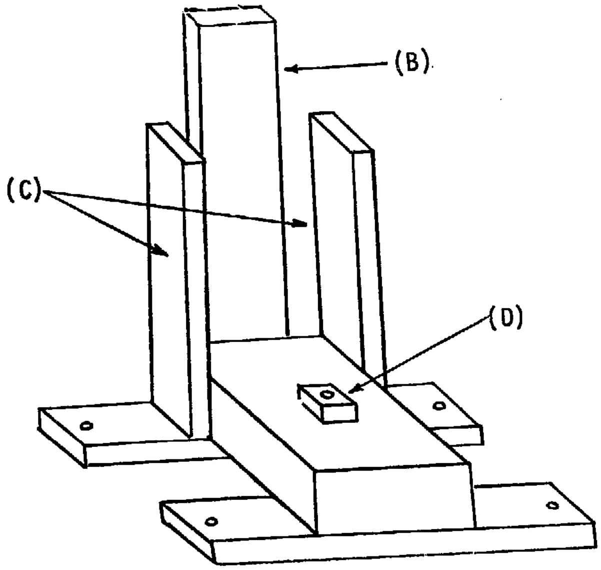
	1	Wood (D)	Approximately 3 cm x 3 cm x 1 cm
(2) Wheel	1	Wood (E)	1 cm x 15 cm x 15 cm
	1	Wooden Spool (F)	Approximately 3 cm x 3 cm x 3 cm
	2	Washers (G)	Approximately 0.8 cm inside diameter, 2.0 cm outside diameter
	1	Screw (H)	Approximately 0.6 cm diameter, 6.0 cm long
	1	Screw (I)	Approximately 3 cm long
	1	Rubber Strip (J)	1 cm x 50 cm
(3) Axle	1	Wood (K)	4 cm x 4 cm x 16 cm
	1	Wooden Spool or Dowel (L)	3 cm diameter, 3.5 cm long
	3	Finishing Nails (M)	Approximately 5 cm long
	1	Screw (N)	Approximately 0.6 cm diameter, 6.0 cm long
	2	Washers (O)	Approximately 0.8 cm inside diameter, 1.5 cm outside diameter
	1	Nail (P)	0.5 cm diameter, 18 cm long
	1	Bolt (Q)	Approximately 0.5 cm diameter, 2 cm long
	1	Rubber Strip (R)	3.5 cm x 10 cm
	2	Metal Strapping (S)	11 cm x 1 cm
(4) Head	1	Wood (T)	2 cm x 2 cm x 32 cm
	2	Stiff Wire (U)	Approximately 0.2 cm diameter, 30 cm long
	1	Bolt (V)	Approximately 0.5 cm diameter, 2 cm long

b. Construction

(1) Base

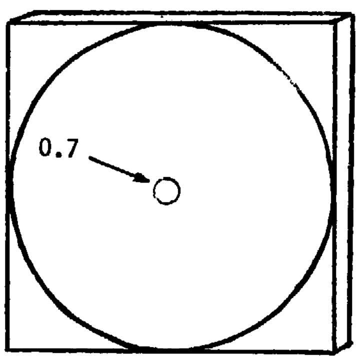


With nails or glue and screws, secure the thick piece of wood (A) to two pieces of wood (B) as shown to form the feet and bottom of the base. Drill a hole approximately 0.5 cm in diameter at each end of the feet (B).



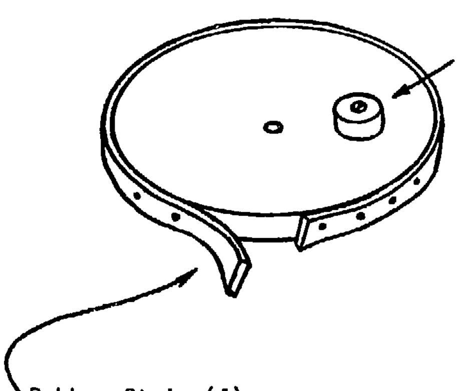
Next, nail or glue and screw the third piece (B) to the bottom of the base, in an upright position as shown. Secure the two shorter uprights (C) in position as shown. Glue the small piece of wood (D) to the center of the horizontal board. When the glue has dried, drill a hole about 0.5 cm in diameter through the small piece of wood (D) and a centimeter or so into the base (A).

(2) Wheel



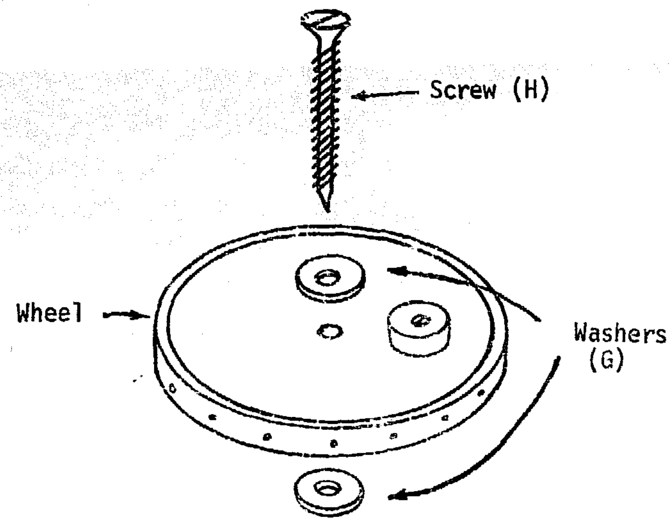
Wood (E)

Inscribe a circle in the thin wooden square (E). Carefully cut out the circle. Drill a hole, 0.7 cm diameter, through the center of the circle.



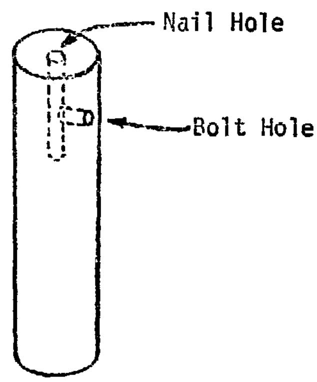
Fasten the strip of rubber sheeting (J) (e.g., from a tire inner tube) to the circumference of the wheel with glue and small nails with heads.

With the shorter screw (I), fasten the wooden spool (F) loosely to the wheel about halfway between the center and edge of the wheel. The handle must be free to rotate around the screw.

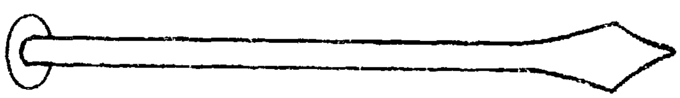


Mount the wheel to the base by inserting the long screw (H) through a washer (G), through the wheel, then through the second washer (G). The holes in the wheel and washers should be slightly larger in diameter than the screw (H). Finally, turn the screw firmly into the small piece of wood (D) on the horizontal board of the base. Make certain that the wheel will rotate freely around the screw without wobbling.

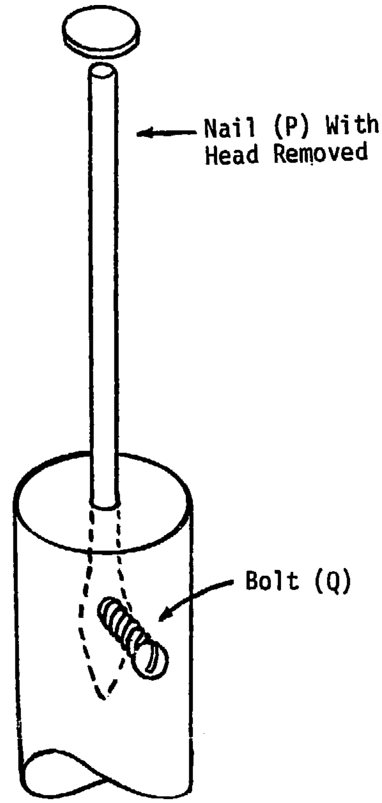
(3) Axle



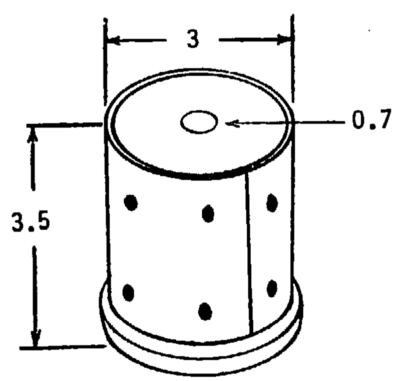
For the upper section of the axle, use the wooden block (K) or dowel. Drill a hole approximately 0.4 cm in diameter and approximately 5 cm deep into the center of one end of the block. Then drill a second hole, about 2.5 cm from the end, at a right angle to and intersecting the first hole. Make the hole about 0.4 cm in diameter, or just a little smaller than the bolt (Q) which is to be threaded into it.



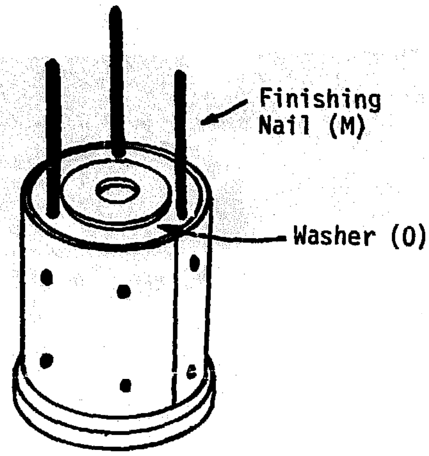
Flatten the end of a large nail (P) by hammering it on a metal block or anvil.



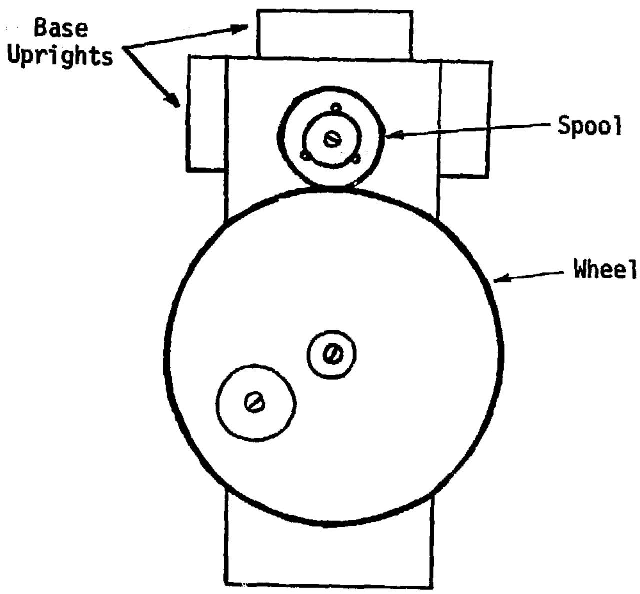
Carefully thread the bolt (Q) as far as possible into the bolt hole in the axle, then unscrew it halfway. Fill the nail hole with epoxy glue, and tap the nail (P) into the hole. Tighten the bolt against the nail, then coat its threads with epoxy glue. Finally, cut the head off the nail.



For the lower section of the axle, use a wooden spool (L) from which the thread has been removed, or a 3 cm diameter dowel. Cut the spool or dowel to a height of about 3.5 cm. Fasten a strip of rubber sheet (R) around the outside, just as for the wheel. Enlarge the hole in the spool to about 0.7 cm diameter.

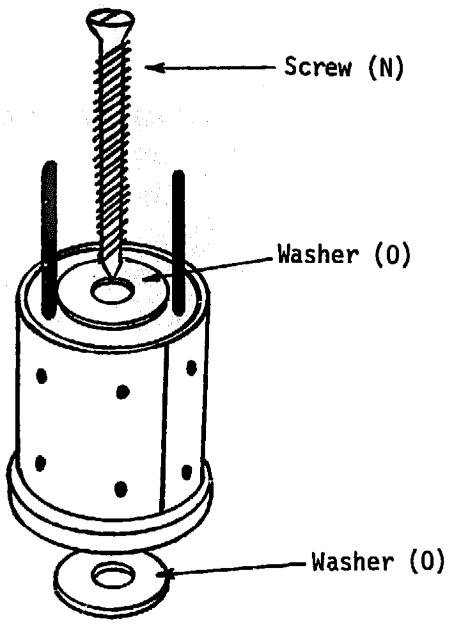


Fit one washer (O) on the top of the spool, aligning the holes of spool and washer. Drive three small finishing nails (M) into the top of the spool, outside the washer. Let approximately 3 cm of nails protrude from the top of the spool, and cut off their heads.

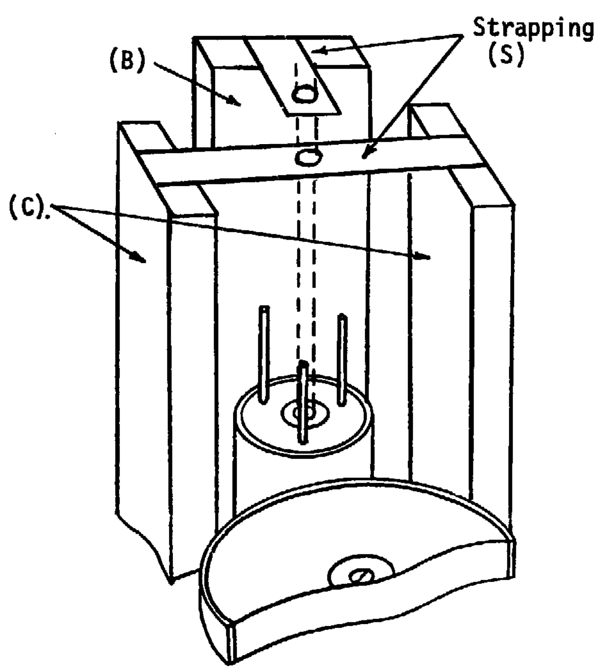


Overhead View of Base, Wheel and Axle Location

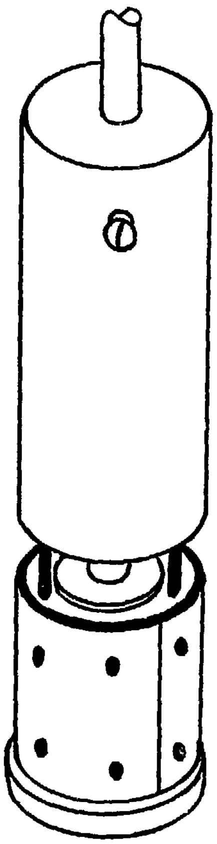
Locate the position of the axle by setting the spool on the horizontal board (A) of the base such that the rubber strip on the spool presses firmly against the rubber strip on the wheel. Mark the position of the center of the spool, and drill a small hole at that position.



Mount the spool (L) on the horizontal board (A) of the frame by passing a long screw (N) through the washer (O) and spool (L); then through a second washer (O), and into the hole in the base. Turn the screw firmly into the horizontal board, so that the spool is free to rotate. In addition, the edge of the wheel must rub the edge of the spool firmly enough so that when the wheel turns, the spool also rotates.



Construct strapping braces for the axle as follows: Drill a hole 0.8 cm in diameter in the center of one of the pieces of metal strapping (S). Nail this piece to the two shorter uprights (C) of the base such that the hole in the strapping is directly over the center of the spool on the base below. Drill a similar hole near one end of the other piece of strapping (S), and nail it, as shown, to the taller upright of the base (B) such that its hole is directly over the hole in the strapping below it. Trim off any excess.



Slip the nail end of the upper section of the axle through the holes in the strapping braces. Rest the other end of the upper section evenly on the tops of the three nails in the spool, and then drive the upper section into the nails with a hammer so that the spool and upper section will form a continuous solid piece. However, do not drive the upper section so far down that its end will hit the top of the screw and prevent the entire axle from turning. If this operation has been done correctly, the axle will turn when the wheel is rotated.

(4) Head

Prepare the horizontal bar and test tube holders according to directions given for the Hand Drill Centrifuge, VI/D1, using the wood (T) and stiff wire (U). Secure the nail of the axle to the centrifuge head according to directions given in VI/D1 with the bolt (V).

c. Notes

(i) The centrifuge should be bolted or clamped to the table top before using.

(ii) To use this piece of apparatus, the substance to be centrifuged is placed in an appropriately sized test tube. A second test tube is filled with an equal amount of material to be centrifuged or an equal volume of water. Each test tube is placed in one of the holders and checked to see that they will not slip out through the holder. Both test tubes are sealed with stoppers. Stand at arm's length from the centrifuge and turn the wheel, first slowly, then more and more rapidly. The tubes will be spun about in a nearly horizontal position. Do not try to stop the centrifuge suddenly by holding the wheel stationary; either let go of the wheel and allow the centrifuge to come to a gentle stop, or turn the wheel more and more slowly until the centrifuge is brought to a gentle stop.

(iii) Matched pairs of test tube holders of various sizes may be constructed and used interchangeably in the same centrifuge head, if desired.

(iv) When the wheel of this centrifuge is turned rapidly, about 150 turns per minute, for example, the centrifuge head spins at nearly 500 revolutions per minute.

VII. GAS GENERATORS

The apparatus used in the production of gases has been placed in two sections, one of which contains the complete apparatus for gas generation while the second section contains two devices useful in collecting gases.

A. GAS GENERATORS

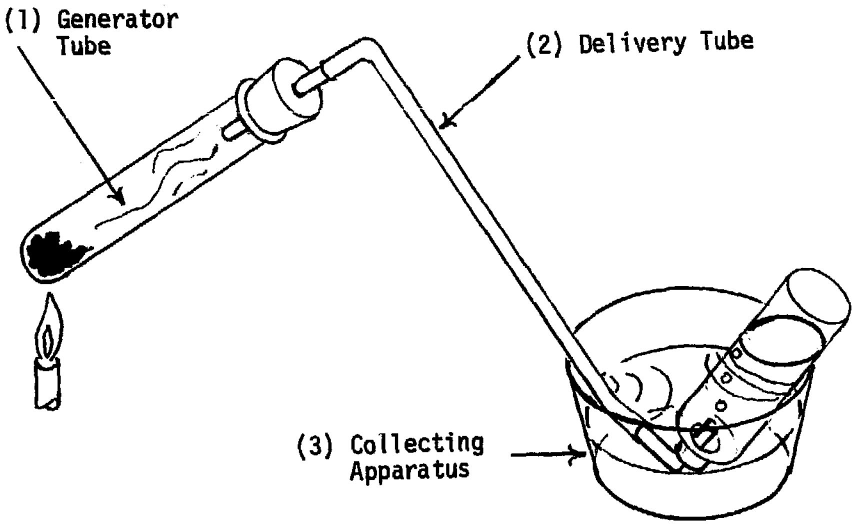
Three types of generators will be given: simple devices for which no special equipment is required; and an inexpensive version of Kipp's gas generator.

B. ACCESSORIES

Included here are the beehive shelf and metal sheet shelf.

A. GAS GENERATORS

A1. Simple Gas Generator and Collecting Apparatus



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Generator Tube	1	Test Tube or Flask (A)	Capacity at least 50 ml
	1	1-Hole Rubber Stopper (B)	To fit generator tube (A)
(2) Delivery Tube	1	Glass Tubing (C)	0.5 cm diameter, 5-10 cm long
	1	Rubber or Plastic Tubing (D)	To fit glass tubing (C and E), 30 cm long
	1	Glass Tubing (E)	0.5 cm diameter, 15-25 cm long
(3) Collecting Apparatus	1	Test Tube, Flask, or Bottle (F)	Capacity at least 50 ml
	1	Bowl or Pan (G)	250 ml or greater capacity

b. Construction

(1) Generator Tube

For the generator tube, use a hard-glass test tube or flask suitable for heating (A). Secure test tube in a slanted position with an appropriate clamp or support (IV/B5 or B6).

Fit the generator tube with a one-hole rubber stopper (B).

(2) Delivery Tube

Insert the shorter glass tube (C) through the one-hole rubber stopper. Connect the rubber or plastic tubing (D) to the free end of the glass tube (C). Bend the longer glass tube (E) at a 90° angle or less, and connect it to the flexible tubing (D).

(3) Collecting Apparatus

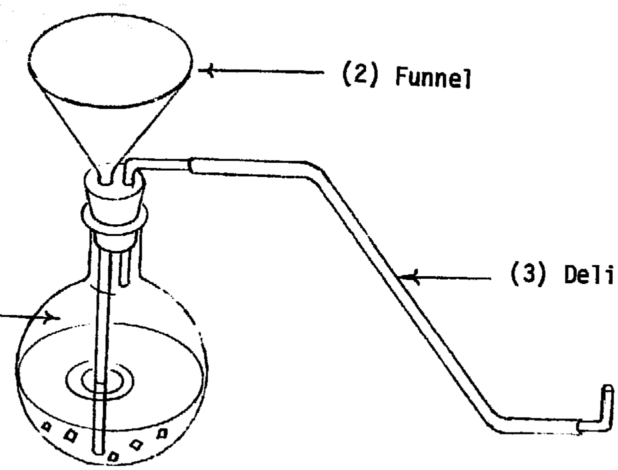
Select a large test tube, flask, or bottle (F). Fill with water, cover the opening, and invert in a bowl or pan of water (G) so that the water is held in the bottle (F). Uncover the opening and place the free end of glass tubing (E) into the mouth of the collecting tube.

c. Notes

(i) This apparatus is suitable for student use in generating small amounts of gases which are insoluble or only slightly soluble in water.

(ii) Small amounts of reactants are placed in the generator tube and carefully heated (if heating is required). The gas generated passes through the delivery tube, and is collected by displacing the water in the collecting tube.

A2. Flask Generator



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Generator Flask	1	Flask or Bottle (A)	250 ml capacity or larger
	1	2-Hole Rubber Stopper (B)	To fit flask (A)
(2) Funnel	1	Long-necked Funnel (C)	Approximately 10 cm diameter (large end)
(3) Delivery Tube	2	Glass Tubing (D)	0.5 cm diameter, 15-25 cm long
	1	Plastic or Rubber Tubing (E)	To fit glass tubing, approximately 30 cm long

b. Construction

(1) Generator Flask

Support the flask or bottle (A), if necessary, in a suitable support. Fit the flask with a two-hole rubber stopper (B).

(2) Funnel

Select a funnel (C) with a sufficiently long neck to reach nearly to the bottom of the flask (A). Carefully push the funnel neck through one of the holes in the stopper (B).

(3) Delivery Tube

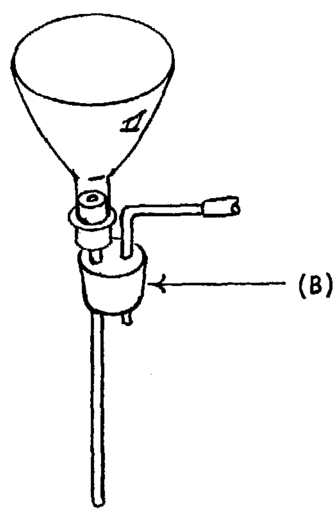
Make a 90° bend in each piece of glass tubing (D). Connect these with flexible tubing (E). Insert one of the glass tubes into the second hole of the rubber stopper (B).

c. Notes

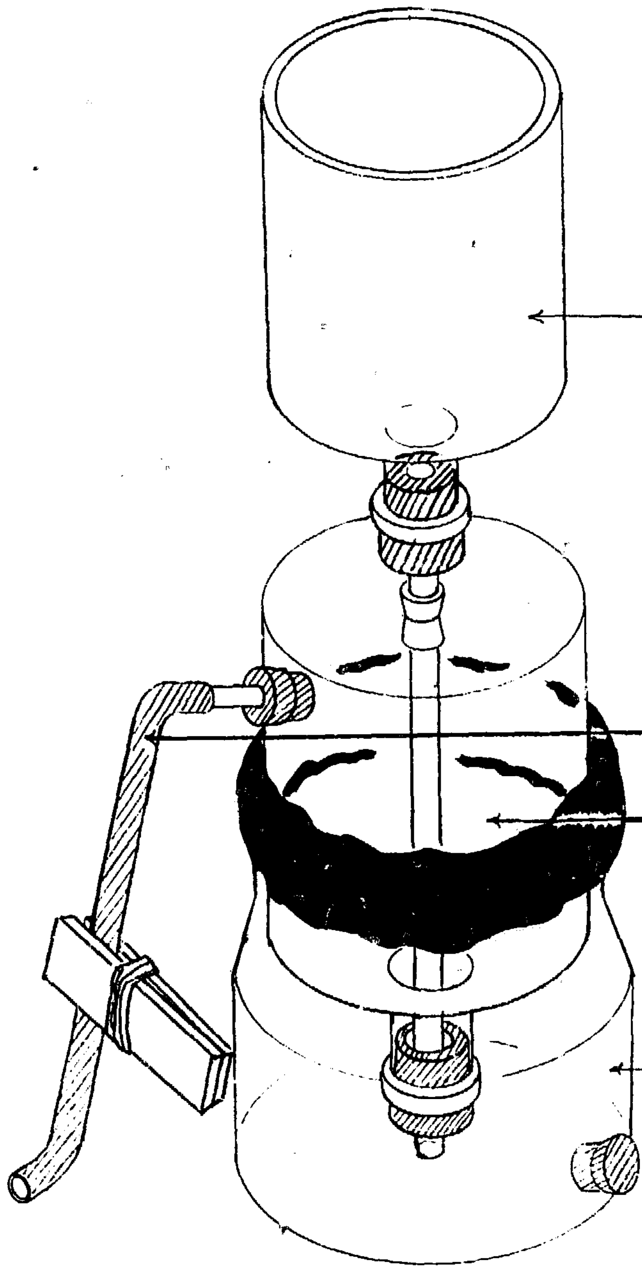
(i) This apparatus is used in conjunction with the collecting apparatus just as described in the previous section (VII/A1).

(ii) This device is generally chosen when the gas generating reaction involves a solid (such as zinc) and a liquid (such as dilute sulfuric or hydrochloric acid). The solid is placed in the bottom of the generator flask, then the rest of the apparatus is placed in position. When the collecting bottle is in place, the liquid reagent is added through the funnel. Thus, the reaction does not begin until the apparatus is sealed. Additional liquid can be added to the flask without dismantling the apparatus.

(iii) If a funnel made from a cut-down bottle is used (V/A3), it will be necessary to adapt the construction of this item slightly. Connect such a funnel to the flask (A) with a long piece of glass tubing running through the stopper (B) and a one-hole stopper fitted into the funnel.



A3. Kipp's Generator *



*Adapted from C. S. Rao (Editor), Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968), pp 174-175.

a. Materials Required

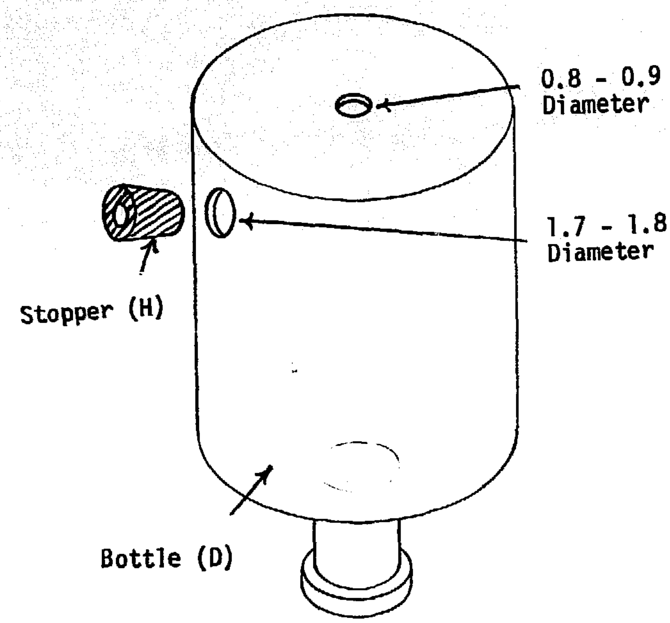
Components	Qu	Items Required	Dimensions
(1) Acid Container	1	Glass Jar (A)	Capacity approximately 500 ml
	1	Rubber Stopper (B)	Approximately 2.0 cm diameter (large end)
	--	Plasticine (Modeling Clay) or Pitch (C)	4 cm x 4 cm x 4 cm
(2) Reaction Flask	1	Glass Bottle (D)	Capacity approximately 500 ml
	1	1 or 2-Hole Rubber Stopper (E)	To fit bottle (D)
	1	Glass Tubing (F)	Approximately 0.7 cm diameter, 30 cm long
	1	Rubber Tubing (G)	1.0 cm diameter, 3 cm long
	1	1-Hole Rubber Stopper (H)	Approximately 2.0 cm diameter (large end)
(3) Gas Delivery Tube	1	Glass Tubing (I)	0.7 cm diameter, 5 cm long
	1	Rubber Tubing (J)	1.0 cm diameter, 30 cm long
	1	Pinch Clamp (K)	(IV/A4)
(4) Funnel	1	Glass Bottle (L)	Capacity approximately 1 liter
	1	1-Hole Rubber Stopper (M)	To fit bottle (L)

b. Construction

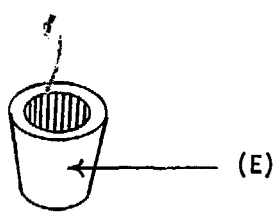
(1) Acid Container

Select a low, wide-mouth jar with a capacity of about 500 ml (A). Drill a hole in the side of the jar, just above the bottom, (I/E2). Enlarge the hole, by filing with a round file, to a diameter of 1.7 - 1.8 cm. Seal this hole with a solid rubber stopper (B).

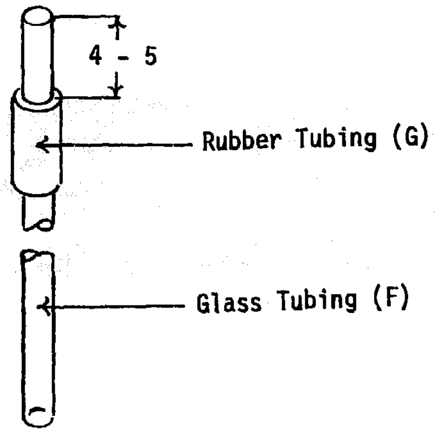
(2) Reaction Flask



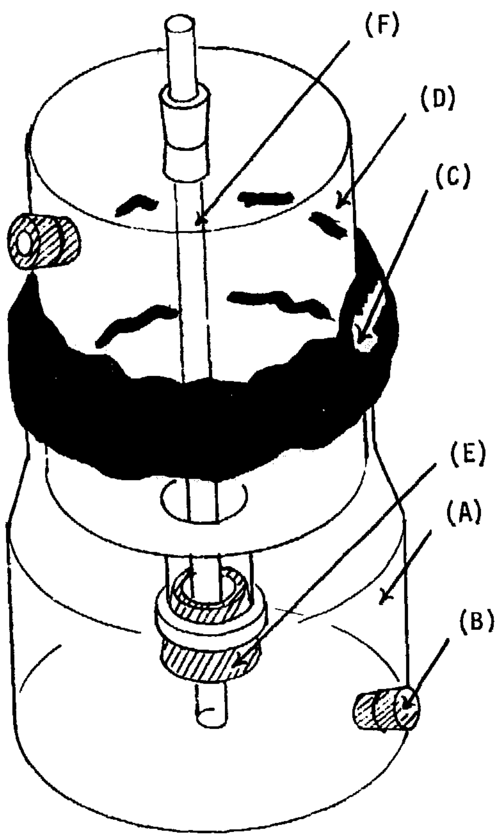
For the reaction flask, choose a narrow-necked bottle (D) that will just fit into the neck of the acid container (A). Drill a hole in the center of the bottom of the bottle (D), and enlarge the hole to a diameter of 0.8 - 0.9 cm. Drill a second hole in the side near the bottom. Enlarge this hole to a diameter of 1.7 - 1.8 cm. Fit a one-hole rubber stopper (H) into the side hole.



Select a stopper (E) that fits the neck of the bottle (D). If it is a one-hole stopper with a round file, enlarge the hole in the stopper to about two to three times its normal diameter. Fit this stopper into the neck of the bottle. If a two-hole stopper is available, make no alterations, and fit the stopper into the neck of the bottle (D).



Fire polish (I/D4) both ends of the glass tubing (F). Insert one end into the short length of rubber tubing (G). Allow 4 - 5 cm of glass tubing (F) to protrude beyond the rubber tubing (G).



Insert the long end of the glass tubing (F) into the bottle (D), from the bottom. Fit the end through the enlarged hole of the stopper (E), and carefully push and twist until the rubber tubing (G) around the glass tightly seals the hole in the bottom of the bottle (D).

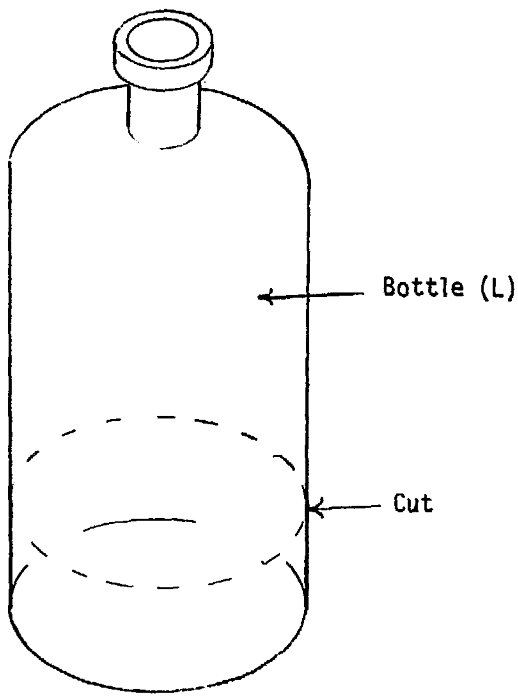
Set the reaction flask (D), neck down, into the neck of the acid container (A). Adjust and cut the glass tubing (F), if necessary, so its lower end is about 0.5 cm from the bottom of the acid container (A).

Roll the modeling clay (plasticine) (C) into a long cylinder and wrap it around the seam between reaction flask (D) and acid container (A). Press the clay firmly in place to make an airtight seal.

(3) Gas Delivery Tube

Insert a short piece of glass tubing (I) into the stopper in the side of the reaction flask. Attach rubber tubing (J) to the other end of the glass tube. Use a wooden pinch clamp (K) (IV/A4) or other suitable clamp to close the rubber tubing.

(4) Funnel



Construct a large funnel with a capacity equal to that of the acid container by cutting off the bottom third of a narrow-necked bottle (L) (I/F2). Smooth the rough cut edge of the funnel with emery cloth. Select a one-hole rubber stopper (M) to fit the funnel neck. Insert the glass tube (F) from the reaction flask (D) into the stopper (M).

Invert the funnel (L) and fit its neck tightly over the stopper (M).

Support the funnel in a ring stand (IV/B5) or other suitable holder.

c. Notes

(i) To complete the gas generating apparatus, the gas delivery tube of the Kipp's Generator must be connected to a suitable collection device such as that described in VII/A1, or the aspirator described in V/A8.

(ii) The solid reactant, such as zinc chips, is added to the reaction flask (D) through the hole in the side. The solid will sit, for the most part, on the stopper (E) in the neck of the flask. The stopper (H) and gas delivery tube are then securely replaced in the reaction flask, and all connections and seals are checked to insure that they are gastight. Then the liquid reagent, such as 6M hydrochloric acid, is poured into the funnel (L).

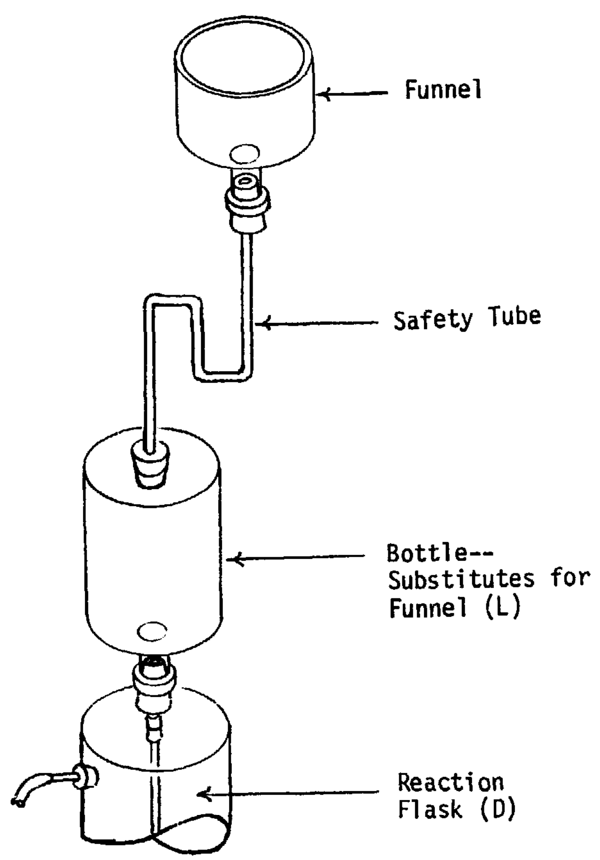
When the pinch clamp (K) is removed from the gas delivery tube, the acid will flow into the acid container (A). As the acid level rises above the neck of the reaction flask (K), it will flow into the reaction flask through the enlarged or second hole of the stopper (E) and will react with the solid to produce a gas (hydrogen, in this example). The gas will pass through the delivery tube to the collecting vessel.

(iii) The reaction can be stopped without removing any of the reactants or dismantling the equipment. When the gas delivery tube is closed with the pinch clamp, the pressure of the gas accumulating in the reaction flask will force the acid out of the reaction flask and back into the acid container until it is no longer in contact with the solid. Some of the acid will also be forced back up the glass tube and into the funnel. The funnel must therefore be large enough to safely contain a large volume of acid that might be backed up.

To restart the reaction, the delivery tube is opened, and acid again flows into the acid container and reaction flask to evolve more gas.

(iv) This device is suitable for evolving large quantities of a gas for class use, or as a demonstration. It should be possible to build a larger model, but experimentation with the size relationships between the funnel, reaction flask, and acid container will be necessary.

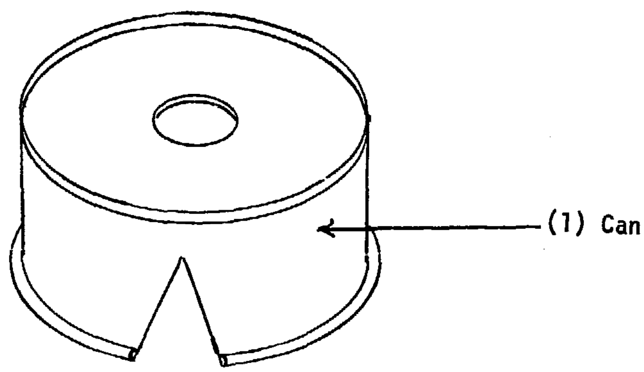
(v) If the Kipp's Generator is to be employed for continuous classroom use, a safety tube and funnel may be substituted for the large funnel to prevent the escape of unpleasant or undesirable acid fumes. A piece of glass tubing, approximately 0.7 cm diameter and 35 - 40 cm long, is bent as shown. This is connected, by means of a rubber stopper at the upper end, to a funnel. A bottle with a hole drilled in the bottom is substituted for the large funnel (L), and the lower end of the safety tube is connected to this bottle with a one-hole rubber stopper or short piece of rubber tubing.



The whole apparatus must be supported in a stand or frame of some kind.

B. ACCESSORIES

B1. Beehive Shelf



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Tin Can (A)	9 cm diameter x 5 cm high

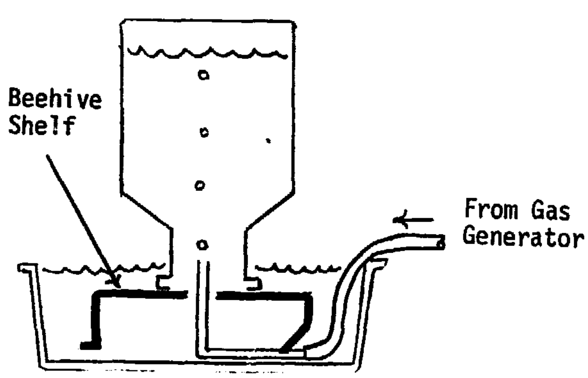
b. Construction

(1) Tin Can Shelf

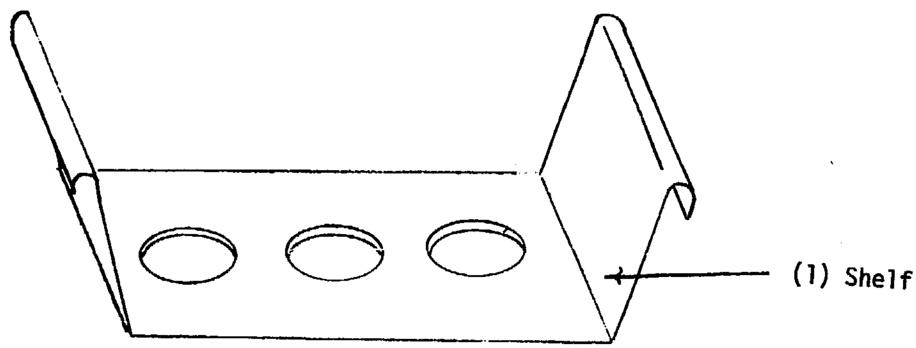
Select a short tin can with one end removed (A). Cut a V-shaped notch about 1 cm high in the side of the can. Drill a hole 1.5 cm in diameter in the center of the end of the can. Varnish the can.

c. Notes

(i) The beehive shelf is placed in the bottom of a pan of water. A gas collecting tube or jar, filled with water as described in VII/A1, is inverted on the shelf, with the mouth of the jar over the hole in the shelf. The gas delivery tube is then inserted through the notch of the shelf, up through the hole, and into the neck of the collecting jar.



B2. Metal Sheet Shelf



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Shelf	1	Metal Sheet (A)	Approximately 0.05 cm thick, 8 cm x 30 cm

b. Construction

(1) Metal Sheet Shelf

Cut the metal sheet from heavy aluminum sheeting or a tin can. Cut three holes, 1.5 cm in diameter, in the sheet (A) as shown. Bend the edges up as shown. Finally, make curved bends approximately 1 cm from each end.

c. Notes

(i) This shelf may be hung from the sides of a rectangular pan measuring from 12 to 20 cm wide. The shelf must be covered with water. Collecting bottles, filled with water, are inverted over the holes and set on the shelf.

VIII. METALWARE AND CLEANER

A. METALWARE

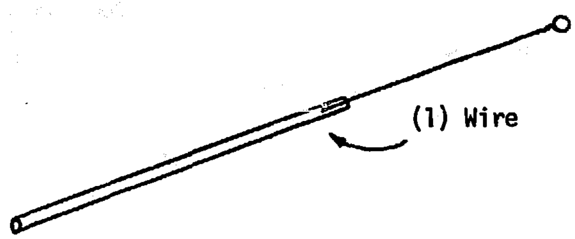
The items in this section are small pieces of metalware which can be constructed from scrap strapping, wire and the like. Items which can be improvised from normal household items, such as knives, have not been included.

B. CLEANER

This item can be used to clean the test tubes utilized in chemistry.

A. METALWARE

A1. Flame Test Wire



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Wire	1	Transfer Loop	BIOL/VII/A3

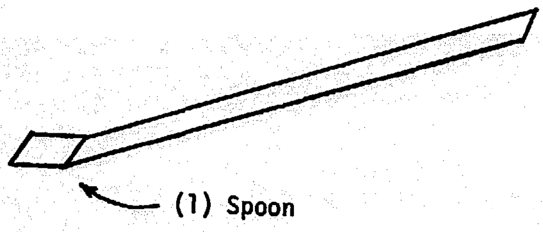
b. Construction

(1) Wire — See BIOL/VII/A3 for construction details.

c. Notes

(i) Use this wire to flame test compounds. Simply get a small amount of the chemical caught in the wire loop and hold it in a hot flame to observe the color of the flame.

A2. Deflagrating "Spoon"

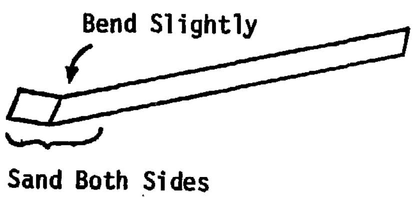


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Spoon	1	Metal Strapping (A)	About 10 cm x 3 cm

b. Construction

(1) Spoon



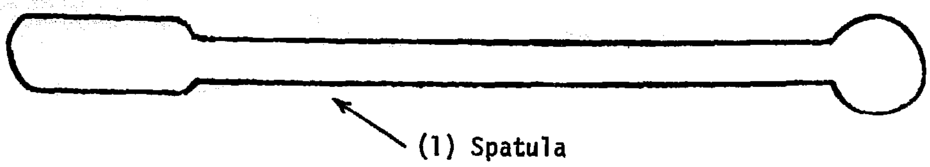
Carefully sand off all the paint from one end of the metal strapping (A) so that there is only bare metal. Make a slight bend in this end about 1.0 cm from the end.

c. Notes

(i) To use the deflagrating spoon, place a small amount of the chemical to be heated on the bent portion of the strapping. Hold the spoon in a holder (e.g., IV/A4), and hold the chemical in the flame of a burner until it burns or melts. The deflagrating spoon is used mainly in doing flame tests on unknown compounds.

(ii) When the end of the spoon becomes contaminated, either clean it with sand-paper or simply cut it off, sand the new end, and bend it as before.

A3. Spatula

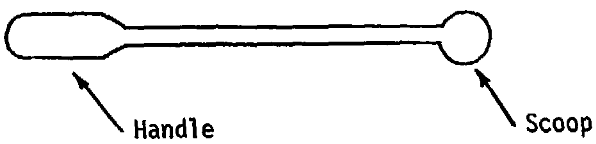


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Spatula	1	Tin Can or Strapping Wire (A)	20.0 cm long, 3.0 cm wide

b. Construction

(1) Spatula



Cut a piece of tin can metal (A) or a piece of wire strapping to the desired length and width. Cut the metal to the shape illustrated.

Make a depression in the scoop by hammering a steel ball in the circle.

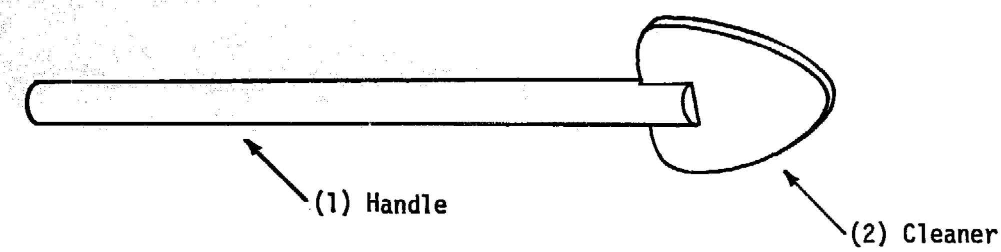
Depress the center of the handle slightly for easier handling.

c. Notes

(i) This spatula may be converted to a deflagrating spoon by bending the handle backward at a 90° angle with the shaft and bending the scoop forward at a 90° angle with the shaft.

B. CLEANER

B1. Test Tube Cleaner or Spatula

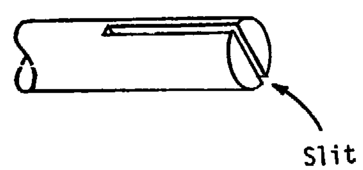


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Handle	1	Wooden Dowel (A)	25 cm long
(2) Cleaner	1	Piece of Rubber Inner Tube (B)	5 cm x 5 cm

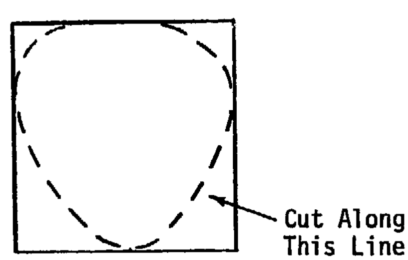
b. Construction

(1) Handle



Use a piece of wooden dowel (A) about 25 cm in length. Make a slit about 2.0 cm long in the center of one end of the handle.

(2) Cleaner



Cut a triangular piece of rubber (B) about 5.0 cm long from a discarded inner tube. Insert this in the slit made in the handle. Drive a small nail through the handle and cleaner to hold them in place, if necessary.

IX. HEATERS AND DRYERS

The apparatus in this section has been divided into two categories, as follows:

A. DRYERS

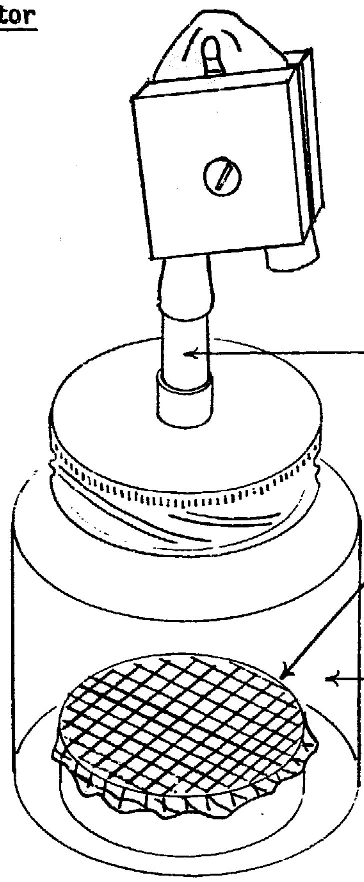
Dryers are devices used to remove the moisture content from chemical compounds.

B. HEATER

This is a device that is intended to produce a heat intense enough to incinerate precipitates.

A. DRYERS

A1. Dessicator



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Jar (A)	Capacity 200 ml or more
	1	Lid (B)	To fit jar (A)
(2) Dryer	1	Small Tin Can (C)	To fit inside jar (A)
	1	Wire Mesh (D)	To cover tin can (C)
	--	Calcium Chloride or Silica Gel (E)	--
(3) Tubing	1	Rubber Tubing (F)	1 cm diameter, 15 cm long
	1	Glass Tube (G)	0.7 cm diameter, 5 cm long
	1	Screw Clamp or Pinch Clamp (H)	(IV/A4 or A5)

b. Construction

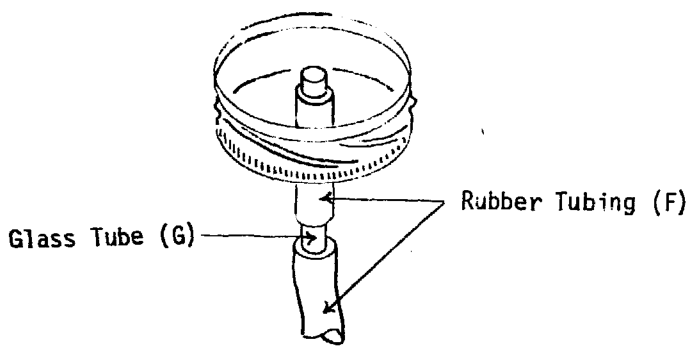
(1) Container

Select a jar (A) with a screw top (B) and a very wide mouth. Cut a hole slightly less than 1.0 cm in diameter in the center of the jar lid (B).

(2) Dryer

Take a short tin can (C) which fits easily into the jar, or cut a taller can to a height of 2 - 3 cm.

Place a drying agent, such as calcium chloride ($CaCl_2$) pellets or silica gel (C) in the can. Cover the can with wire mesh (D) and set it in the bottom of the jar (A).

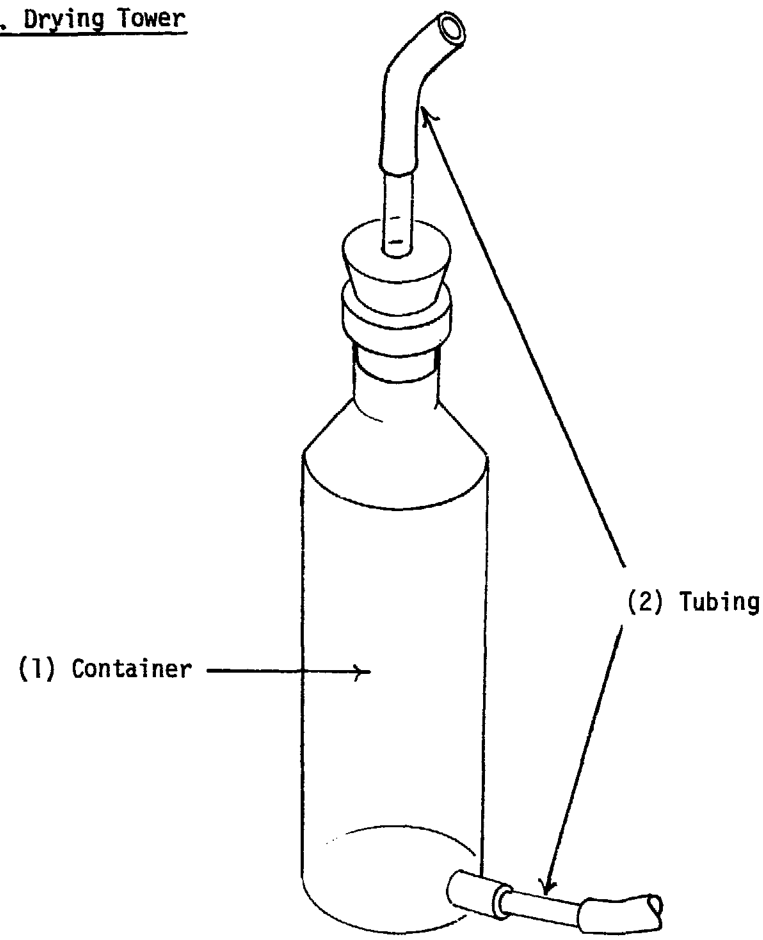


Cut a section of about 3 cm from the piece of rubber tubing (F). Insert one end of the glass tube (G) all the way into this short piece of rubber tubing. Insert the other end of the glass tube (G) into the longer section of rubber tubing. Push the shorter piece of rubber tubing, with the glass tube inside, into the hole in the top of the jar lid (B). Seal the tubing into the hole in the jar with cement, if necessary, to make an airtight seam. Seal the long rubber tube with a pinch clamp (IV/A4) or screw clamp (IV/A5).

c. Notes

(i) Powders or substances to be kept free of moisture are placed in containers inside the dessicator, and the top is sealed. The rubber and glass tube arrangement permits a partial vacuum to be formed in the dessicator if it is used in conjunction with a vacuum pump.

A2. Drying Tower



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Glass Bottle (A)	Capacity approximately 300-400 ml
	1	1-Hole Stopper (B)	To fit bottle (A)
(2) Tubing	3	Rubber Tubing (C)	1 cm diameter, 5 cm long
	2	Glass Tubing (D)	0.7 cm diameter, 5 cm long

b. Construction

(1) Container

Drill a hole just slightly smaller than 1.0 cm in the side of the bottle (A) near the bottom (I/E2). Fit the bottle (A) with a one-hole cork or rubber stopper (B).

(2) Tubing

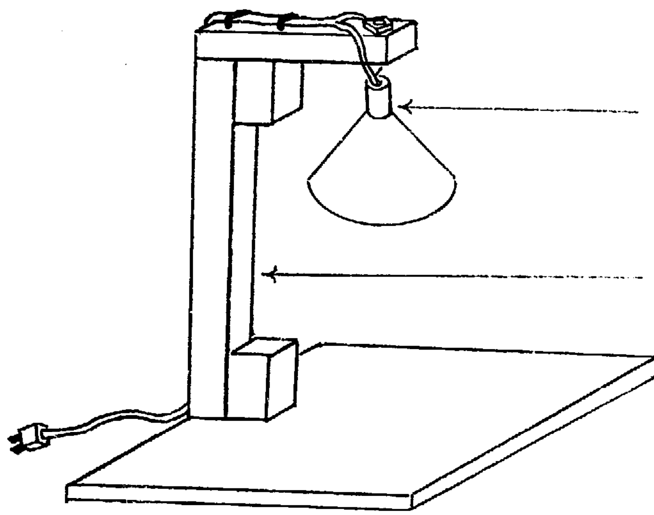
Insert one of the pieces of glass tubing (D) into the one-hole stopper, and push a piece of rubber tubing (C) on to the other end of the glass tube.

Insert one piece of rubber tubing (C) into the hole in the bottle (A), and cement it in place to make an airtight seal. Push the second piece of glass tubing (D) into the rubber tubing (C), and connect the last piece of rubber tubing (C) to the glass tube (D).

c. Notes

(1) This apparatus is used in removing moisture from gases. For example, moisture can be eliminated from H_2, O_2, N_2, Cl_2, and SO_2 by filling the drying tower with calcium chloride or other drying agent and connecting it by means of the tubing connections at top and bottom, between the gas generator and collecting device. As the gas passes through the drying tower, moisture is absorbed by the drying agent.

A3. Electric Lamp Dryer

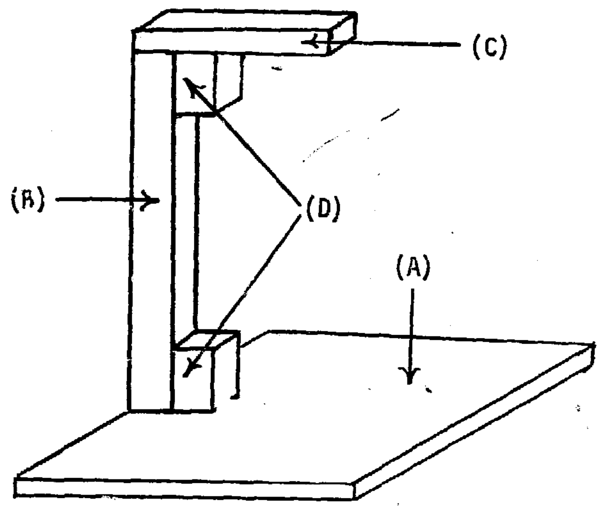


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support	1	Wood (A)	30 cm x 30 cm x 1 cm
	1	Wood (B)	1 cm x 2 cm x 32 cm
	1	Wood (C)	1 cm x 2 cm x 18 cm
	2	Wood (D)	4 cm x 4 cm x 2 cm
(2) Lamp	1	Lamp Socket (E)	--
	1	Insulated Electrical Cord and Plug (F)	--
	1	Incandescent Bulb (G)	100 watts
	4	Large Staples or Thin Nails (H)	--
	1	Bolt (I)	Approximately 0.8 cm x 3 cm
	1	Nut (J)	To fit bolt (I)
	1	Wire Mesh (K)	20 cm x 20 cm
	1	Thin Wire (L)	15 cm
	1	Aluminum Foil (M)	20 cm x 20 cm

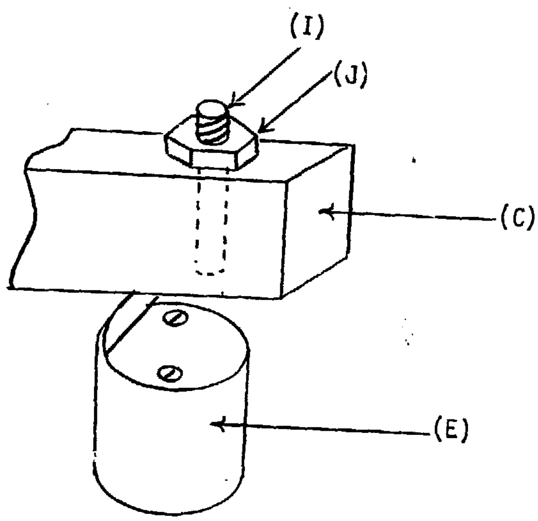
b. Construction

(1) Support



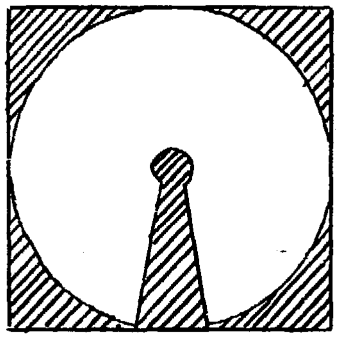
Construct the support as illustrated. Use glue and screws to secure the parts (A), (B), (C), and (D) to one another.

(2) Lamp

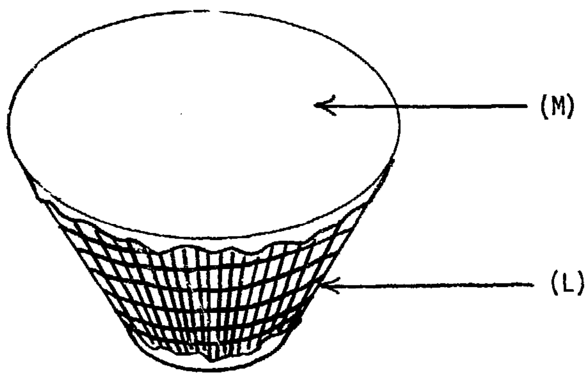


Secure the lamp socket (E) to the top horizontal bar (C) with the nut (J) and bolt (I).

Attach the electrical cord, with plug attached (F), to the socket (E). Run the wire along the top bar (C) and down the back of the vertical support (B). Secure the cord in position with large staples (H), bent nails, or tape.



From the wire mesh (K), cut a circle. Cut out and remove the shaded portion as shown. Cut a similar but slightly larger shape from the aluminum foil (M). Curve the wire mesh (K) into a cone with an open end that will fit over the base of the incandescent bulb (G), and secure the cut edges together by threading the thin wire (L) in and out of the wire mesh.



Cover the inside of the wire mesh cone (K) with the foil (M), shiny side to the inside of the cone. Secure the foil reflector (M) to the wire mesh (L) by bending the foil edges around the wire mesh cone.

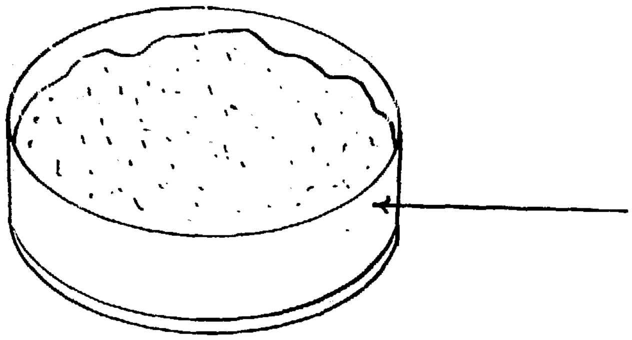
Slip the small end of the reflector over the neck of the bulb (E) and screw the bulb into the socket (E).

c. Notes

(i) The light provides a heat source for drying precipitates which are placed in shallow containers, watch glasses (V/A5) or petri dishes (V/A6).

(ii) Experimentation in the use of the dryer might include varying the size of the reflector, distance of the bulb from the material, wattage of bulb and number of bulbs used.

A4. Sand Bath



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Can	1	Large Tin Can (A)	15-20 cm diameter
	--	Sand (B)	--

b. Construction

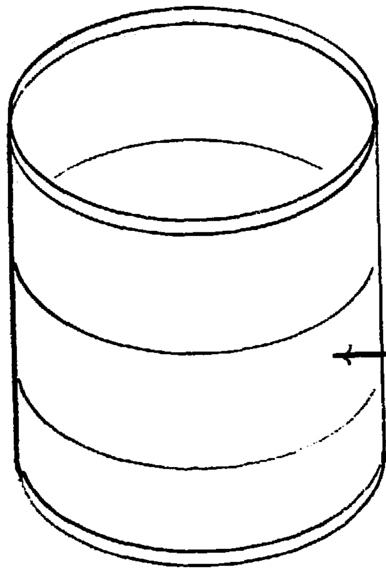
(1) Can

Use a large, shallow tin can (A) as a container, or cut a larger can to a height of about 5 cm. Fill the container with sand (B).

c. Notes

(1) Solutions or precipitates that must be evaporated or dried slowly may be placed in shallow containers, watch glasses, or petri dishes which are rested on the sand. The sand bath is then rested on a tripod (IV/B3), heating stand (IV/B4) or other suitable support and slowly heated with an alcohol or gas burner.

A5. Water or Steam Bath



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Tin Can (A)	Capacity approximately 150-300 ml

b. Construction

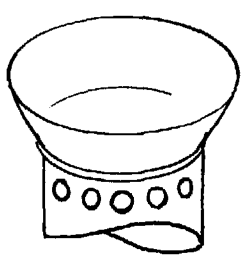
(1) Container

Use an empty, clean tin can (A) for the container. Fill it about 2/3 full of water.

c. Notes

(i) Use of the water bath is a safe way to heat materials that must not, for technical or safety reasons, be heated above about 100°C. Test tubes containing material to be heated are placed in the water bath. The water bath is rested on a suitable support and heated with an alcohol or gas burner. Materials heated in the test tubes will be heated to a temperature not higher than the boiling point of the water.

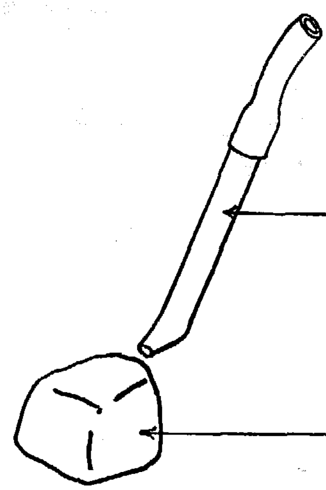
(ii) The water bath may be converted to a steam bath by the addition of a row of holes punched or drilled around the can near the top. The can is filled about 1/3 full of water, and a petri dish (V/A6) or watch glass (V/A5) containing material to be heated is rested on top.



The steam bath is rested on a suitable support and heated; as the water boils, the steam will heat the material in the petri dish or watch glass and will be able to escape through the holes in the top of the can.

B. HEATER

B1. Blowpipe for Charcoal Block



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Blowpipe	1	Rubber Tubing (A)	Approximately 1.0 cm diameter, 10 cm long
	1	Glass Tubing (B)	Approximately 0.7 cm diameter, 20 cm long
(2) Charcoal Block	1	Charcoal Block (C)	--

b. Construction

(1) Blowpipe

Heat the glass tubing (B) near one end and bend it slightly as shown. Then heat it again, just past the bend, in order to draw it out to form a nozzle.

Fit the rubber tubing (A) over the other end of the glass tube (B).

(2) Charcoal Block

Use a lump of charcoal (C) as a heat source.

c. Notes

(i) This item is used to create a concentrated heat source by blowing through the blowpipe onto the charcoal ember.

X. MOLECULAR MODELS

Four types of models to assist in the instruction and understanding of molecular structure are described.

A. SPACE-FILLING MODELS

These roughly represent relative sizes and positions of atoms within a molecule.

B. SKELETAL MODELS

These models more accurately represent atomic radii and bond angles than do those in the previous section.

C. CRYSTAL MODELS

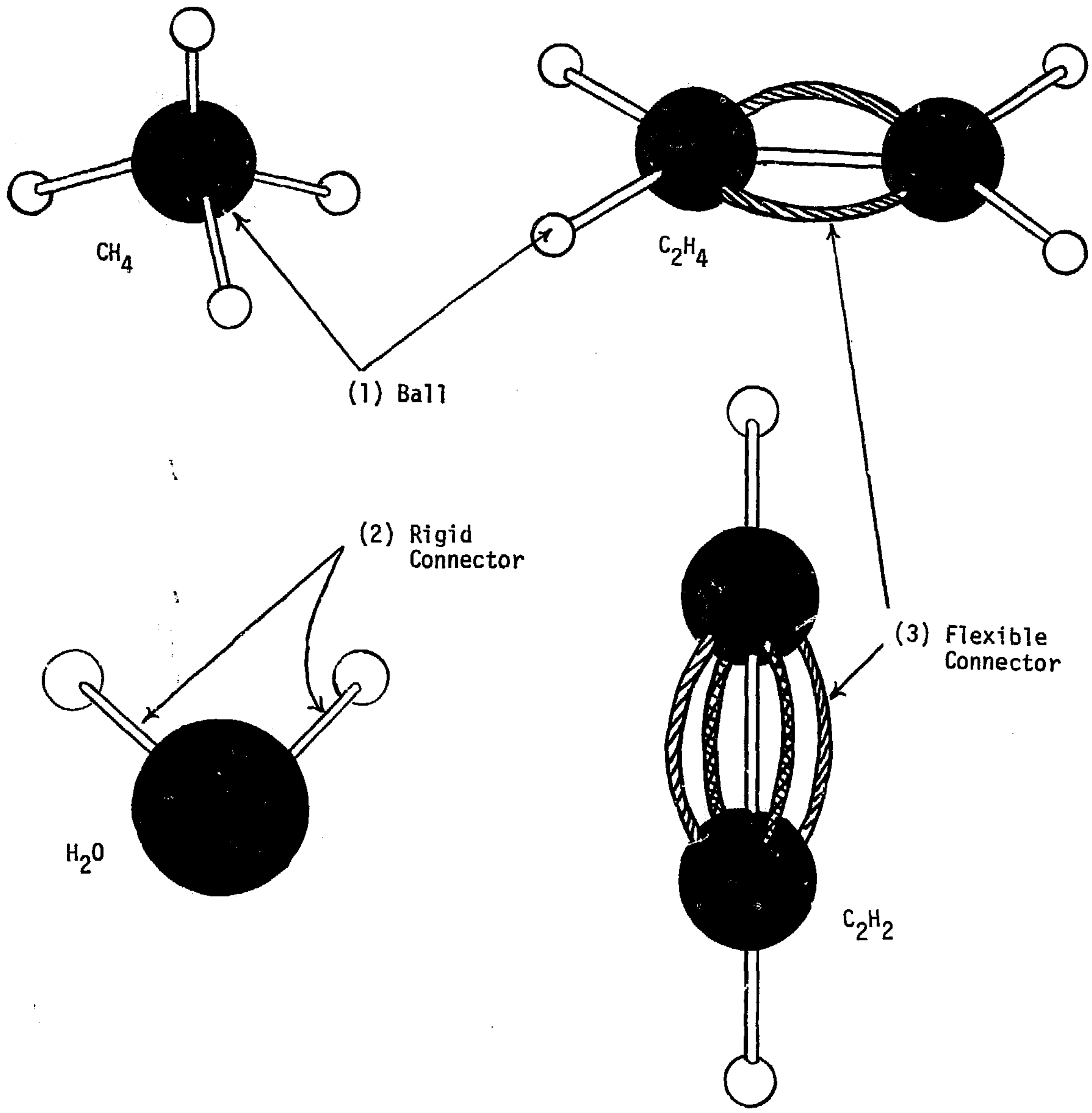
These are three-dimensional models that represent shape and atomic packing within crystals.

D. KINETIC-MOLECULAR MODEL

This two-dimensional model demonstrates the kinetic theory of matter.

A. SPACE-FILLING MODELS

A1. Ball-and-Stick Models



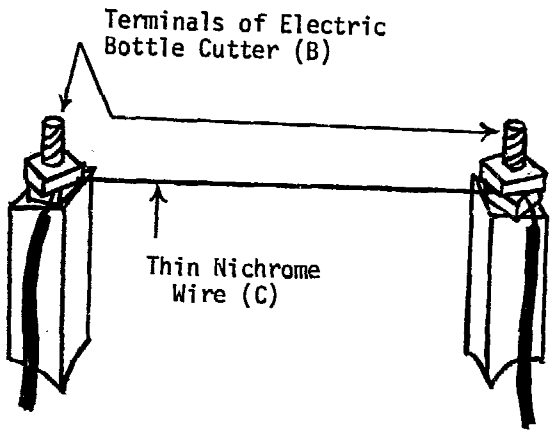
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Ball	1	Block of Styrofoam Plastic or Foam Polystyrene (A)	Approximately 4 cm x 10 cm x 10 cm
	1	Electric Bottle Cutter (B)	(I/F2)
	1	Thin Nichrome Wire (C)	0.02 cm diameter, 35 cm long

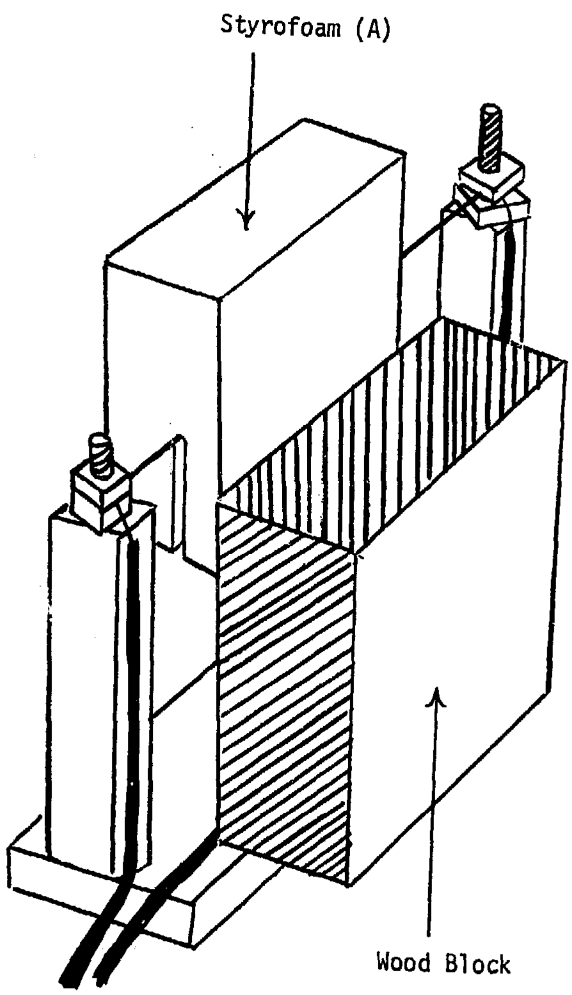
(2) Rigid Connector	1	Box of Toothpicks (D)	Approximately 250
(3) Flexible Connector	1	Package of Pipe Cleaners (E)	Approximately 25

b. Construction

(1) Ball



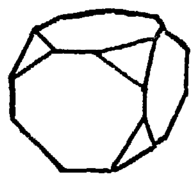
Construct the electric bottle cutter (B) according to directions given in (I/F2). Substitute the thin nichrome wire (0.02 cm diameter) for that described and stretch it tightly between the terminals. Connect the terminals to a six volt battery or a transformer that steps line current down to about six volts.



Form the styrofoam (A) into small balls. First, cut the block into cubes, determining the sizes according to the element each represents:

H - 1.5 cm on a side
C - 3 cm " " "
O - 3 cm " " "
Si - 4 cm " " "

To cut a precise straight line, brace a large wooden block against the base of the bottle cutter, with one edge as far from the taut wire as the width of the desired cut. Push the styrofoam block (A) down on the hot, taut wire to slice it, holding it against the wooden block which acts as a guide.



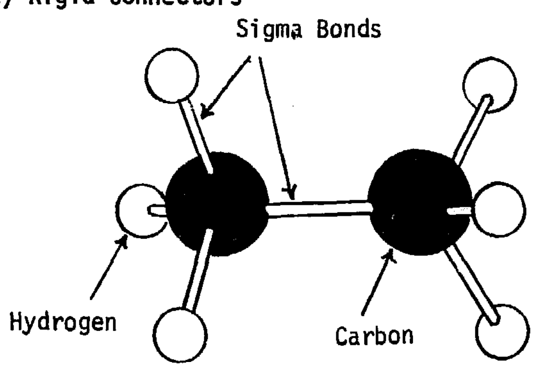
Carefully cut the corners off each cube to approach the shape of a sphere.

Last, shape the trimmed cubes with the fingers more exactly into spheres.

For clarity in the finished models, paint the balls with tempera (poster paint) to which a small amount of dissolved soap has been added. Use the following colors to represent:

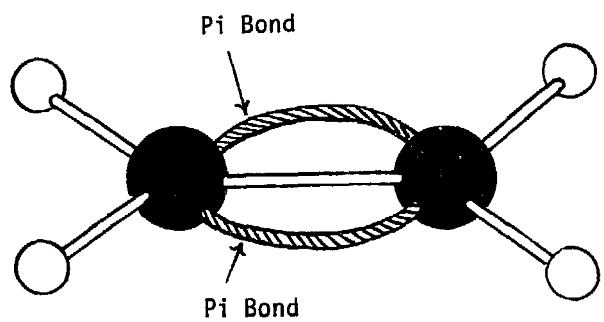
H - white
C - black
O - red

(2) Rigid Connectors

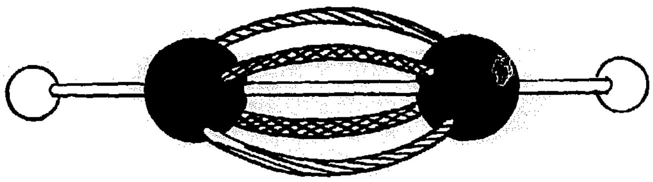


Stick toothpicks (D) into the styrofoam balls to represent sigma bonds between atoms, as in the ethane molecule (C_2H_6) represented here.

(3) Flexible Connectors



Use pairs of pipe cleaners (E) cut to approximately 5 cm lengths to represent pi bonds between atoms, as in the ethene (ethylene; C_2H_4) molecule represented here.



When triple bonds (one sigma and two pi bonds) are to be represented, dye the two pairs of pipe cleaners different colors for clarity. This diagram represents a molecule of ethyne (acetylene; C_2H_2).

c. Notes

(i) If commercially manufactured styrofoam or foam polystyrene balls are easily available, they may be substituted for the hand-made balls described here.

(ii) The scale of approximate sizes of the balls used in these models is based on the atomic radii for stable compounds listed in the Periodic Table of the elements, for example:

Element	Atomic Radius in Angstroms	Approximate Ratio
C	0.77	2
N	0.75	2
O	0.73	2
H	0.32	1

(iii) If styrofoam or foam polystyrene is not available, modeling clay (plasticine) may be used for the balls and painted appropriate colors. However, once the clay balls are painted, repeated puncturing of them with toothpicks will disfigure them. Thus, it is recommended that they be used only to make permanent demonstration models.

(iv) Pipe cleaners or match sticks may be substituted for the toothpicks if desired.

(v) A kit for teacher use should contain:

2 dozen balls representing Carbon
2 dozen " " Hydrogen
2 dozen " " Oxygen
1 dozen " " Halogens
1 dozen " " Nitrogen
1 dozen " " Sulfur
several dozen each straight and flexible connectors.

This would provide sufficient materials for constructing demonstration models in the classroom. The same quantities listed above would be adequate for laboratory use for from one to four students.

(vi) The use of molecular models in the study of chemistry can enhance the students' understanding of and ability to predict the various properties and interactions of elements and compounds. These ball and stick models illustrate, roughly, the relative bond angles, sizes and positions of atoms within a molecule in a clear and simple form. They are not, however, scale representations of bond lengths or atomic molecular sizes and shapes. In order to demonstrate the mathematical relations of electrons in a given molecule, it will be necessary to employ a different style model, that which is described in the next section.

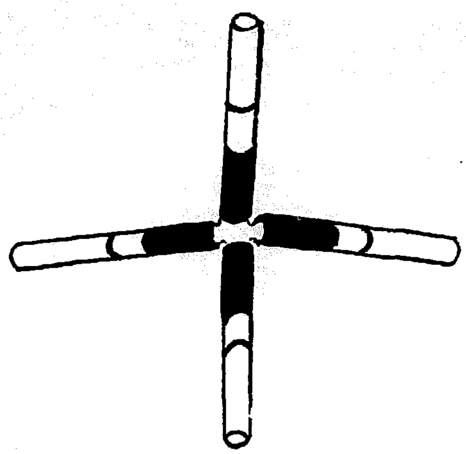
(vii) The color code * used in these models is as follows:

Hydrogen - white
Carbon - black
Oxygen - red
Nitrogen - blue
Sulfur - dark yellow
Flourine - light green
Chlorine - dark green
Bromine - orange
Iodine - brown
Phosphorous - violet
Silicon - light yellow

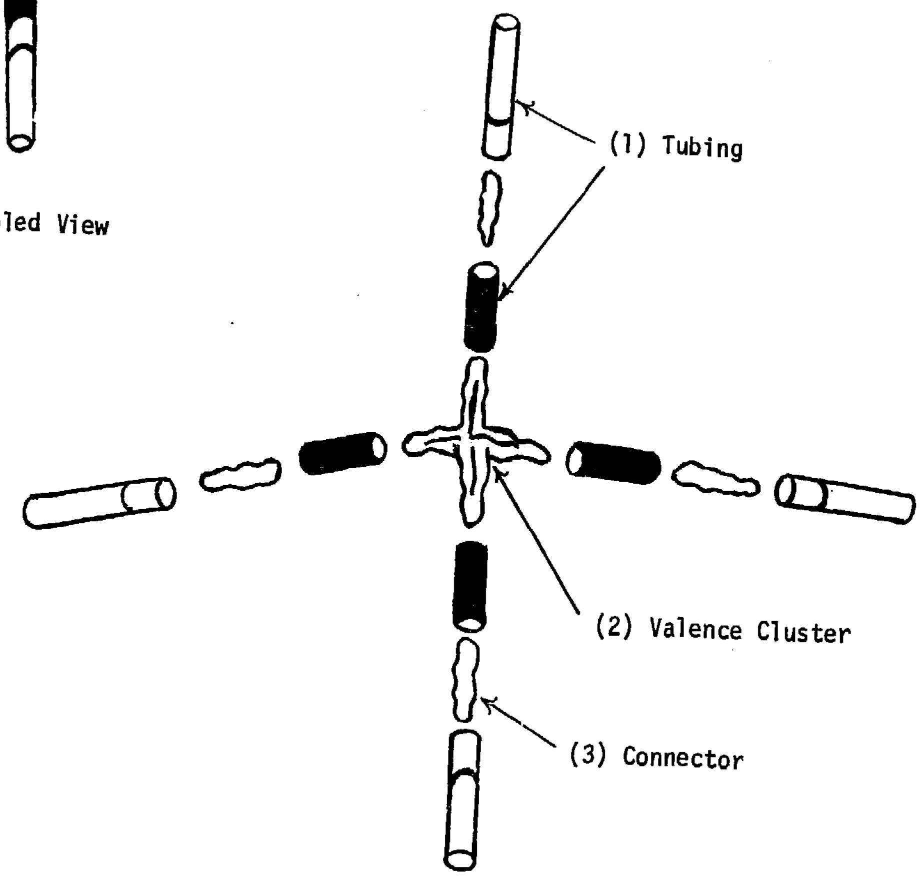
*From the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, Portland, Oregon: Portland Project Committee, (1971, p 17.

B. SKELETAL MODELS

B1. Molecular Model Units*



Assembled View



Exploded View

*Adapted from George C. Brumlik, Edward J. Barrett, and Reuben L. Baumgarten, "Framework Molecular Models," Journal of Chemical Education, XLI (1964), pp 221-223.

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Tubing	--	Milk Straws (Paper or Plastic) (A)	0.4 cm diameter, approximately 20 cm long
	--	Tempera (Poster) Paints (B)	Black, white, red, yellow, green, blue, orange
(2)	--	Pipe Cleaners (C)	--
(3) Connector	--	Pipe Cleaners (D)	--
	--	Finishing Nails (E)	Approximately 0.1 cm diameter, 1.5 cm long
	--	Soft Iron Wire (F)	Approximately 0.05 cm diameter

b. Construction

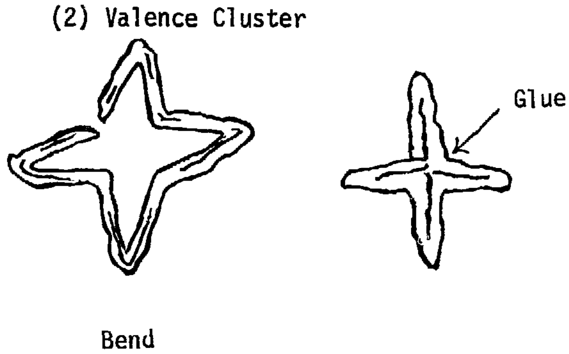
(1) Tubing

Mix a small amount of liquid or dissolved soap with the tempera paints (B) to reduce their surface tension. Using this mixture, paint several milk straws (A) according to the atom they are to represent:

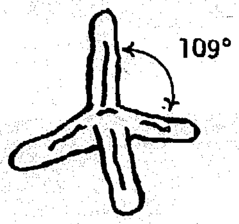
Carbon - black
Hydrogen - white
Oxygen - red
Nitrogen - blue
Sulfur - dark yellow
Bromine - orange
[Consult Note (ii) for additional colors.]

Cut the straws into various lengths depending upon the scale used and bond represented.

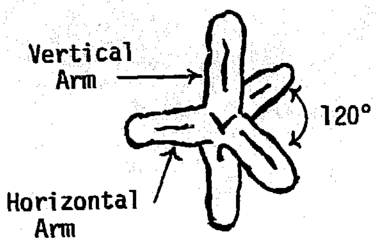
(2) Valence Cluster



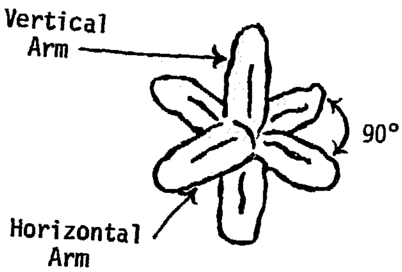
Bend a pipe cleaner (C) into the shape desired, and glue the joint in the middle. When the glue has dried, adjust the angles of the arms of the connector to suitable angles.



Make tetrahedral (4 arms) shapes with the angles of the arms at about 109°.

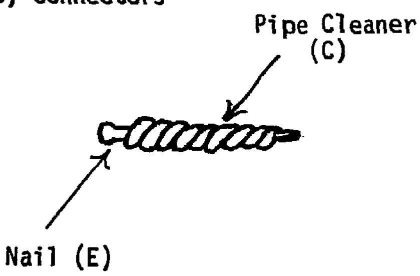


Make trigonal bipyramid (5 arms) shapes. Arrange the angles between the three horizontal arms to 120°. Adjust the two vertical arms at right angles to the horizontal arms.

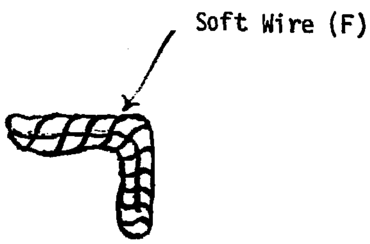


Construct octahedrons (8-pointed). Adjust the angles between the four horizontal arms to 90°. Arrange the two vertical arms at right angles to the horizontal arms.

(3) Connectors



Construct straight connectors to represent bonds between atoms by wrapping a pipe cleaner (C) around a nail (E). Vary the length of pipe cleaner used according to the tightness desired.



To make angular connectors to be used to complete various structures, bend a pipe cleaner (C) in half. Then wrap soft wire (F) around the pipe cleaner and bend the assembly to a 90° angle.

c. Notes

(i) These units can be used to build models of almost any molecule. The valence clusters represent atomic nucleii, the intersection of the arms representing the center of the atom. The tetrahedral (4-armed) valence cluster depicts bond angles of approximately 109°, for sp^3 hybridized orbitals or atoms with eight electrons in their valence shell. The five-armed valence cluster can depict sp^2 hybridization, with 120° bond angles, for atoms engaged in π (pi) bonds, as well as d sp^3 hybridization, with 90° and 120° bond angles for atoms with ten atoms in their valence shell. The six-armed valence cluster can represent sp hybridization with bond angles near 180°, or d^2sp^3 hybridization for atoms with twelve electrons in their valence shell. The straight connector depicts σ (sigma) bonds between like or unlike atoms.

Electrons, whether bonded or unshared, are represented by the straws, color coded and cut to scale.

The straws in a completed molecular model represent covalent radii of bonding atoms, and van der Waals radii in the non-bond direction.

(ii) Below are charts* to guide the coloring and cutting of straws to represent covalent radii or van der Waals radii. Any convenient scale may be used to simulate the Ångstrom unit (Å) measurements of these forces. For example, a scale of 10 cm/Å produces large models ideal for lecture demonstrations, while a scale of 2 cm/Å yields smaller models suitable for student use.

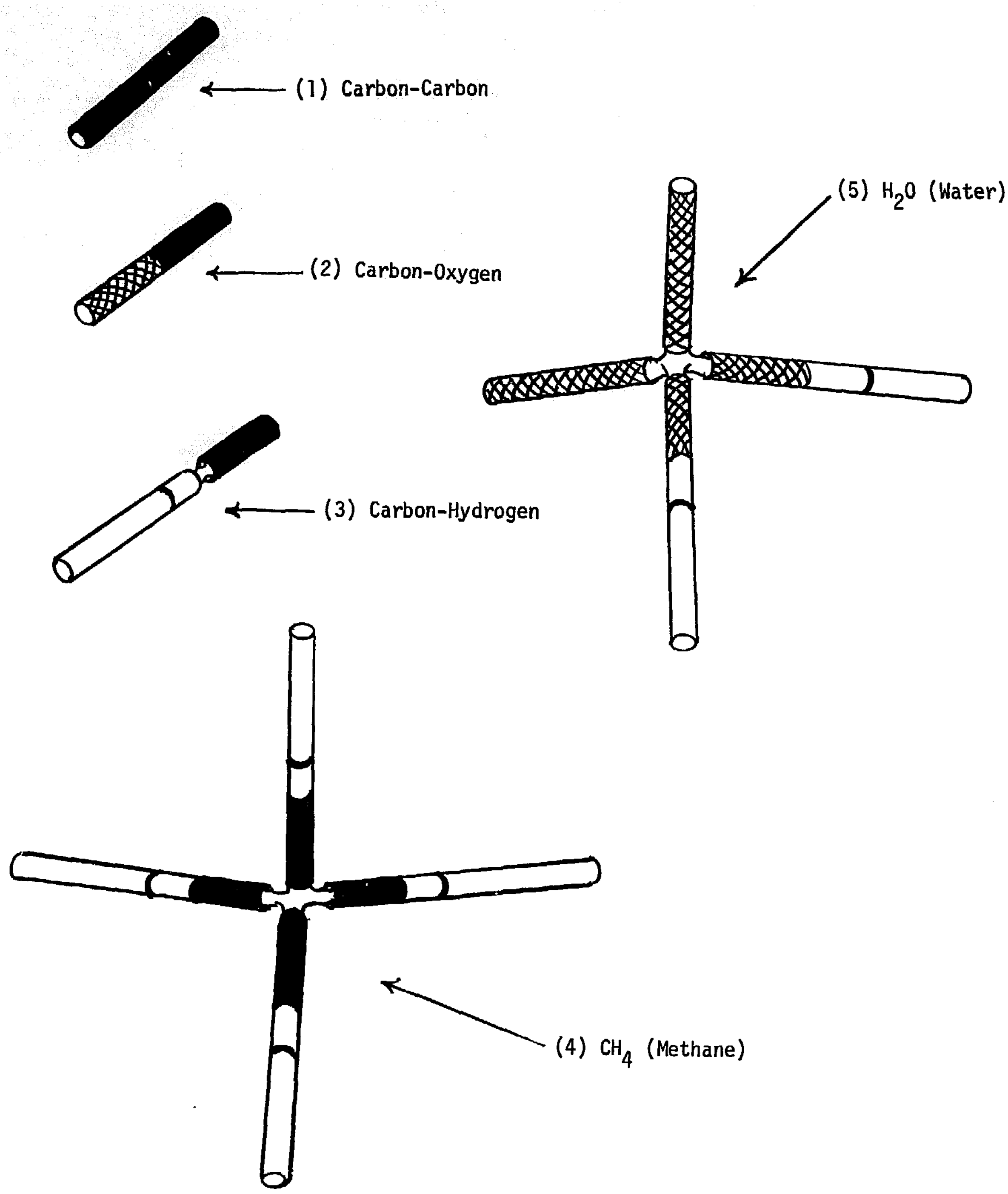
Bond	Atomic Covalent Radii (Å)	Length of Straw in cm (Scale: 10 cm/Å)	Length of Straw in cm (Scale: 2 cm/Å)	Color of Straw
C - single	0.77	7.7	1.5	
C - double	0.67	6.7	1.3	black
C - triple	0.60	6.0	1.2	
O - single	0.74	7.4	1.5	
O - double	0.62	6.2	1.2	red
O - triple	0.55	5.5	1.1	
N - single	0.74	7.4	1.5	
N - double	0.62	6.2	1.2	blue
N - triple	0.55	5.5	1.1	

*Adapted from the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, (Portland, Oregon: Portland Project Committee, 1971), pp 8-18.

Bond (single)	Atomic Covalent Radii (Å)	Length of Straw in cm (Scale: 10 cm/Å)	Length of Straw in cm (Scale: 2 cm/Å)	Color of Straw
H	0.30	3.0	0.6	white
F	0.64	6.4	1.3	light green
Si	1.17	11.7	2.3	light yellow
P	1.10	11.0	2.2	violet
S	1.04	10.4	2.1	dark yellow
Cl	1.00	10.0	2.0	dark green
Br	1.14	11.4	2.3	orange
I	1.33	13.3	2.7	brown

Atom	Van der Waals Radii (Å)	Length of Straw in cm (Scale: 10 cm/Å)	Length of Straw in cm (Scale: 2 cm/Å)	Color of Straw
H	1.2	12.0	2.4	white
O	1.40	14.0	2.8	red
F	1.35	13.5	2.7	light green
S	1.85	18.5	3.7	dark yellow
Cl	1.80	18.0	3.6	dark green
Br	1.95	19.5	3.9	orange
I	2.15	21.5	4.3	brown
N	1.5	15.0	3.0	blue
P	1.9	19.0	3.8	violet

B2. Single Bond Structures*



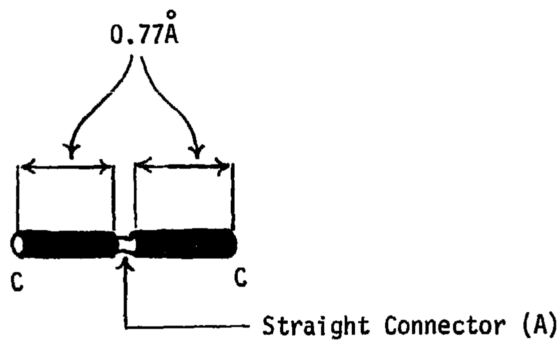
*Adapted from the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, (Portland, Oregon: Portland Project Committee, 1971), pp 19-28.

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Carbon-Carbon	1	Straight Connector (A)	X/B1
	2	Black Straws (B)	1.5 cm
(2) Carbon-Oxygen	1	Straight Connector (C)	X/B1
	1	Black Straw (D)	1.5 cm
	1	Red Straw (E)	1.5 cm
(3) Carbon-Hydrogen	1	Straight Connector (F)	X/B1
	1	Black Straw (G)	1.5 cm
	1	White Straw (H)	3.0 cm
(4) CH_4 (Methane)	1	4-armed Valence Cluster (I)	X/B1
	4	Carbon-Hydrogen Bonds (F,G,H) [see (3) above]	4.5 cm
(5) H_2O (Water)	1	4-armed Valence Cluster (J)	X/B1
	2	Red Straws (K)	1.5 cm
	2	Red Straws (L)	2.8 cm
	2	White Straws (M)	3.0 cm
	2	Straight Connectors (N)	X/B1

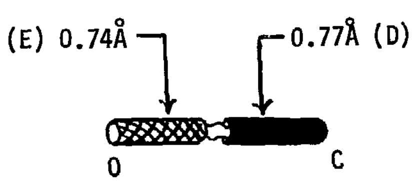
b. Construction

(1) Carbon-Carbon



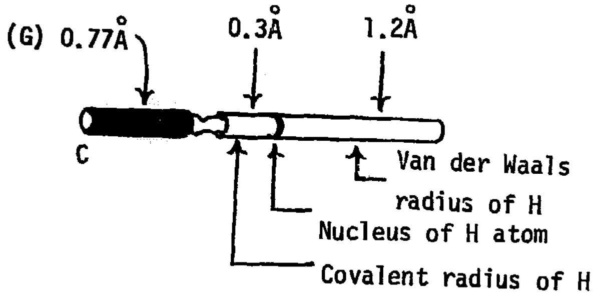
To represent this single covalent bond between like atoms, cut two black straws (B) to a scale representation of the single bond covalent radius of carbon (X/B1), Note (ii). For example, cut the straws to 1.5 cm for a scale of 2 cm/Å. Join these two straws with a straight connector (A).

(2) Carbon-Oxygen



To construct this model of a single covalent bond between unlike atoms, cut one black straw (D) to represent the single bond covalent radius for carbon (1.5 cm, for example) and a red straw to represent the single bond covalent radius for oxygen (E) (1.5 cm). Connect these two straws with a straight connector (C).

(3) Carbon-Hydrogen

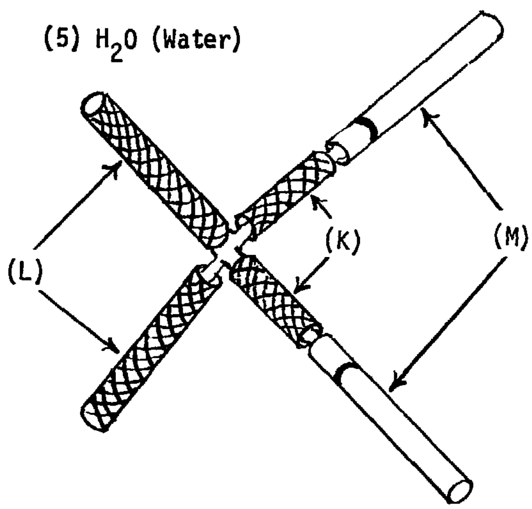


Construct the carbon-hydrogen bond to include a representation of the van der Waals radius for hydrogen. Cut one black straw (G) to indicate the single bond covalent radius for carbon. Cut one white straw (H) to show the covalent radius of H (0.6 cm) plus the van der Waals radius of H (2.4 cm). Draw a line around the white straw at the intersection of these two values to indicate the position of the hydrogen nuculeus, then join the black and white straws with a straight connector (F).

(4) CH_4 (Methane)

Construct four carbon-hydrogen bonds (F,G,H) as described above. Join them all together at the carbon end by sliding each onto an arm of the four-armed valence cluster (I) and pushing all the straws together so that the connectors do not show.

(5) H_2O (Water)



Cut two red straws (L) to represent the van der Waals radius of O (2.8 cm). These will represent two unshared electron pairs. Cut two red straws (K) to indicate the single bond covalent radius of O (1.5 cm). Use a straight connector (N) to join each of these with a white straw (M) representing the covalent and van der Waals radii of H (3.0 cm). Connect the two red straws and two O - H bonds with a four-armed connector (J) as illustrated.

c. Notes

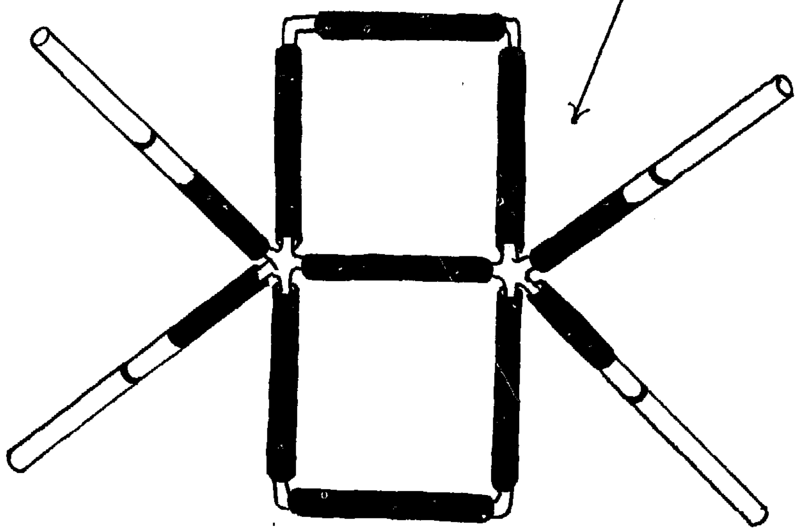
(i) Single covalent bonds between like atoms, such as the carbon-carbon bond, may also be represented by one straw, appropriately colored, cut to twice the covalent radius. Thus, the carbon-carbon bond would be represented by one black straw, 3 cm long.

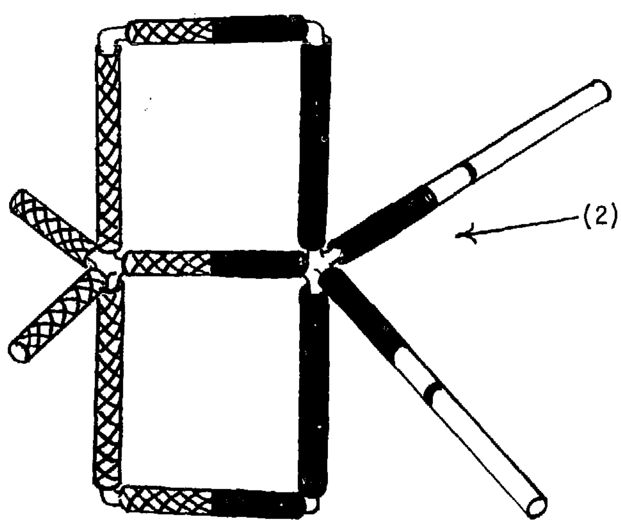
(ii) Unlike the space-filling models of X/Al, these models do not show molecular shape. The shape of the constituent atoms within a molecule must be imagined; the scale and orientation of the parts of the model show bond lengths, bond angles, and bond thicknesses in reasonably accurate scale.

(iii) These skeletal molecular models are based on atomic orbital geometry, which deals with the behavior of electrons in paths, or orbitals, in the space around the nucleus of an atom. For a complete discussion of electrons, nucleii, and orbitals, consult recent chemistry texts, such as Chemical Bond Approach Project, Chemical Systems, (Webster Division McGraw-Hill Book Company, 1964), Chapter 10.

B3. Double Bond Structures*

(1) $H_2C = CH_2$
(Ethene)

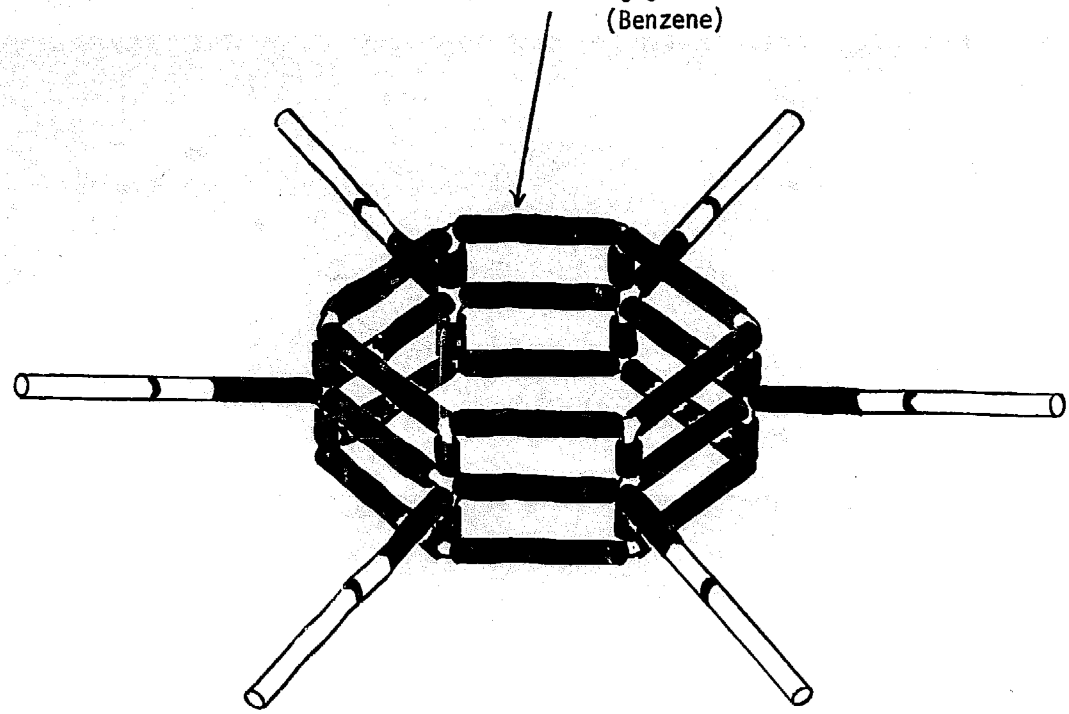




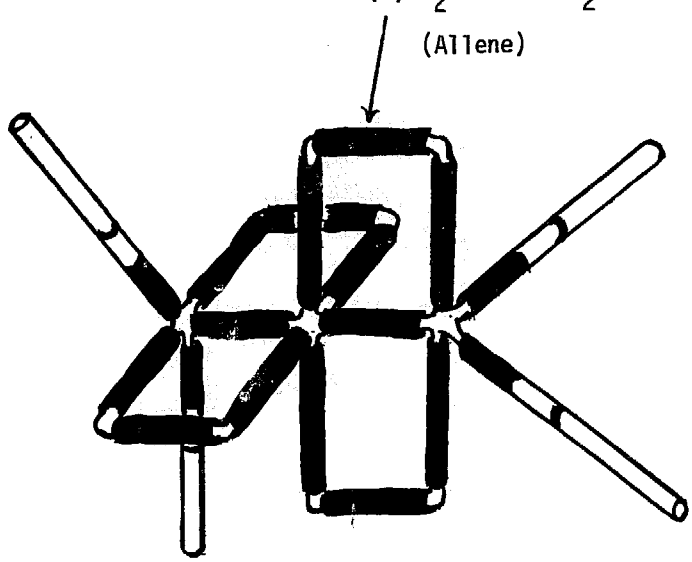
(2) $H_2C = O$
(Formaldehyde)

*Adapted from the Portland Project Committee, Teacher Guide, Chemistry of Living Matter, (Portland, Oregon: Portland Project Committee, 1971) pp 28-36.

(3) C_6H_6
(Benzene)



(4) $H_2C = C = CH_2$
(Allene)



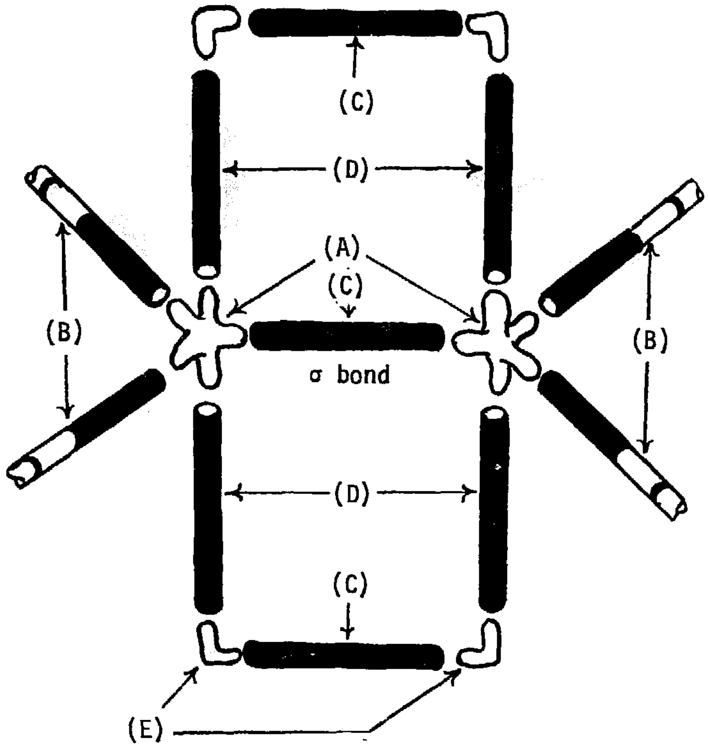
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) $H_2C{=}CH_2$ (Ethene)	2	5-armed Valence Clusters (A)	X/B1
	4	C-H Bonds (B)	4.5 cm
	3	Black Straws (C)	2.6 cm
	4	Black Straws (D)	3.0 cm
	4	Angular Connectors (E)	X/B1
(2) $H_2C{=}O$ (Formaldehyde)	2	5-armed Valence Clusters (F)	X/B1
	4	Angular Connectors (G)	X/B1
	2	C-H Bonds (H)	4.5 cm
	3	Red Straws (I)	1.2 cm
	3	Black Straws (J)	1.3 cm
	2	Red Straws (K)	3.0 cm
	2	Black Straws (L)	3.0 cm
	2	Red Straws (M)	1.5 cm
	3	Straight Connectors (N)	X/B1
(3) C_6H_6 (Benzene)	18	5-armed Valence Clusters (O)	X/B1
	6	C-H Bonds (P)	4.5 cm
	18	Black Straws (Q)	2.6 cm
	12	Black Straws (R)	3.0 cm
(4) $H_2C{=}C{=}CH_2$ (Allene)	2	5-armed Valence Clusters (S)	X/B1
	1	6-armed Valence Clusters (T)	X/B1
	4	C-H Bonds (U)	4.5 cm
	6	Black Straws (V)	2.6 cm
	8	Black Straws (W)	3.0 cm
	8	Angular Connectors (X)	X/B1

b. Construction

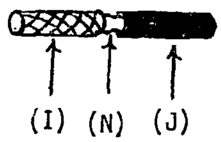
(1) $H_2C{=}CH_2$ (Ethene)

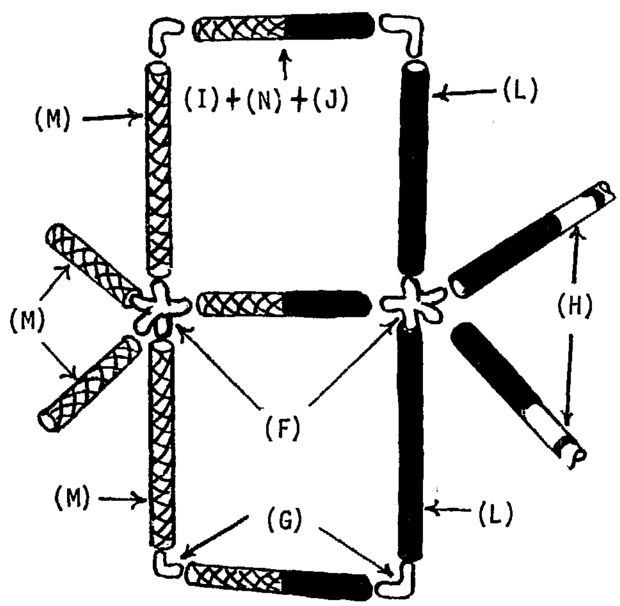
First construct four C-H bonds (B) (X/B2). Then complete the $H_2C{=}CH_2$ molecule as shown. Use three 2.6 cm black straws (C) to represent double bond formation between like atoms. The central black straw (C)



represents the σ bond. The two outside sections of black straws (C) represent the two arms of the π bond, the thickness of which is shown by the four 3.0 cm black straws (D). Their length represents the single bond covalent radius of carbon.

(2) $H_2C=O$ (Formaldehyde)

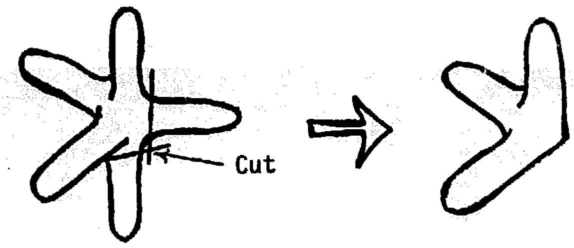




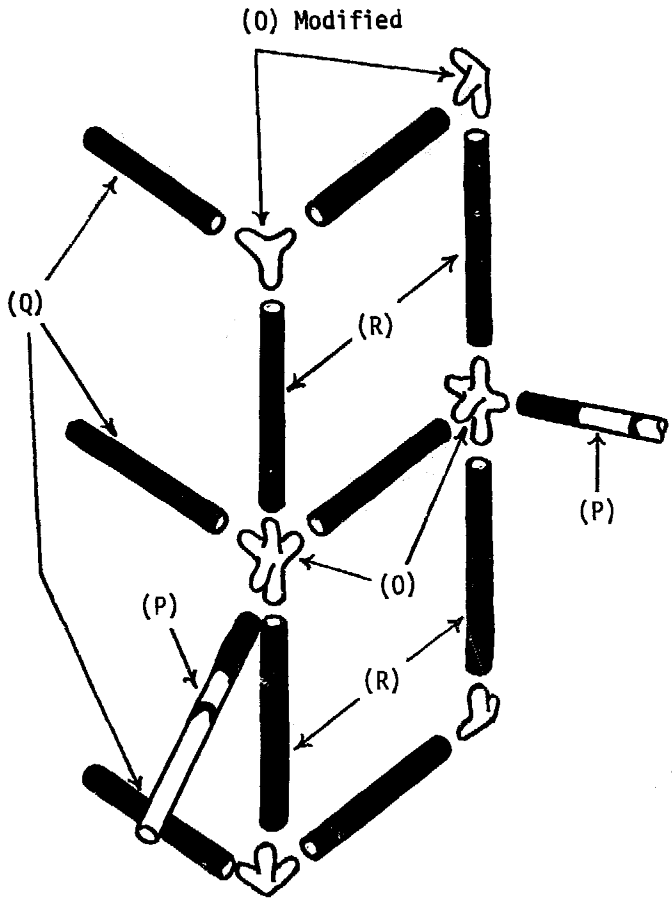
Construct this model showing double bond formation between like atoms. First, construct three C=O bonds representing the double bond radii C (J) and O (I), as shown. Make two C-H bonds (H) (X/B2).

Use the 5 armed valence clusters (F) and angular connectors (G) to join the straws. Indicate the thickness of the π bond by red straws on the oxygen side, black straws on the carbon side.

(3) C_6H_6 (Benzene)

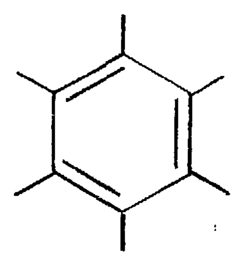


Cut off and discard one horizontal and one vertical arm from each of twelve 5-armed valence clusters (O) to form 3-cornered clusters.



One corner, exploded view

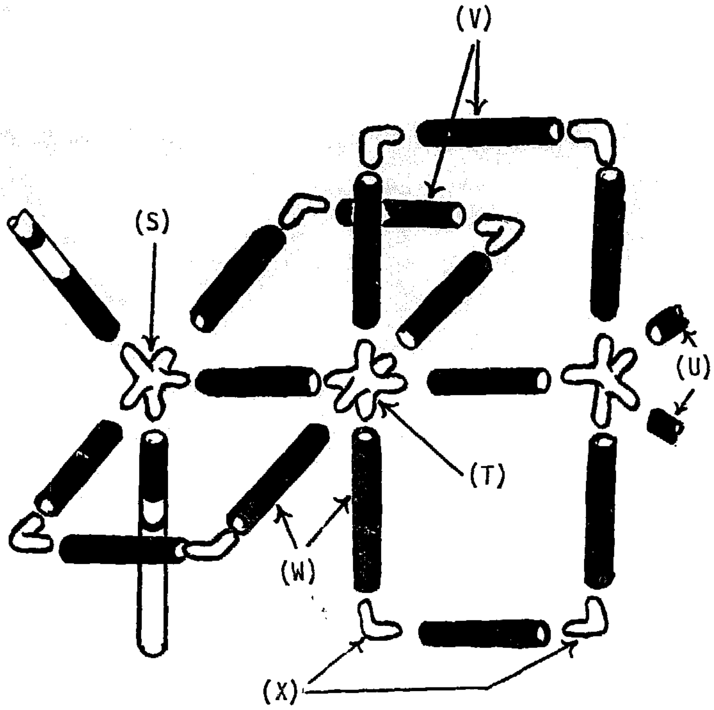
Make six C-H bonds (X/B2) (P). Construct the three layered model as shown. Use the twelve 3.0 cm black straws (R) to represent the thickness of the π bonds (twice the single covalent radius of carbon). Use the eighteen 2.6 cm black straws (Q) to represent the bond lengths (twice the double covalent bond radius of carbon). The shared-bond aspect of the ring structure often pictured:



is represented in the model by the three-layered structure.

(4) $H_2C{=}CH_2$ (Allene)

Construct four C-H bonds (U). Use one 6-armed valence cluster (T), as well as two 5-armed clusters (S), to connect the the components of the H_2C-C-CH_a (allene) molecule.



Place the 6-armed cluster (T) as shown to indicate that the middle carbon atom is π bonded to each of the side carbons.

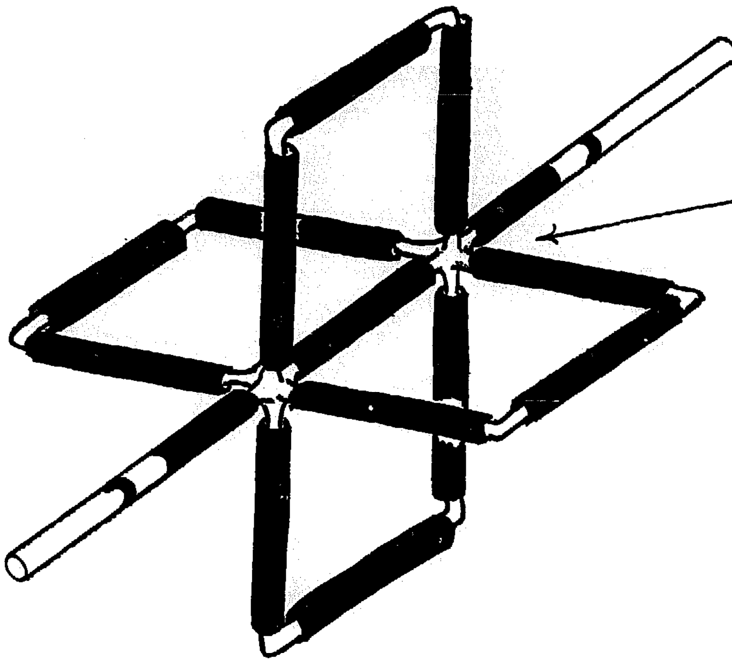
c. Notes

(i) These four examples of double bond models illustrate some of the complex double bond forms that can be built. By applying the principles thus illustrated, it should be possible to construct almost any simple or complex double bonded molecule.

(ii) Because the forces holding two nucleii together in a double bond are greater than those in a single bond, the nucleii are closer together. Thus, the straws representing the C=C or C=R covalent distance are shorter than those representing the C-C or C-R distance.

(iii) In the H_2O=O (formaldehyde) molecule, the slightly longer tubing representing the π bond thickness at the carbon atom than at the oxygen atom indicates a certain strain on the double bond. The covalent radius of oxygen is used to model the unbonded electrons, rather than the van der Waals radius as in the model of water, because the C=O bond "pulls" or distorts the oxygen electron cloud. C=N bonds may be constructed just as C=C and C=O bonds; blue tubing represents N.

B4. Triple Bond Structure*



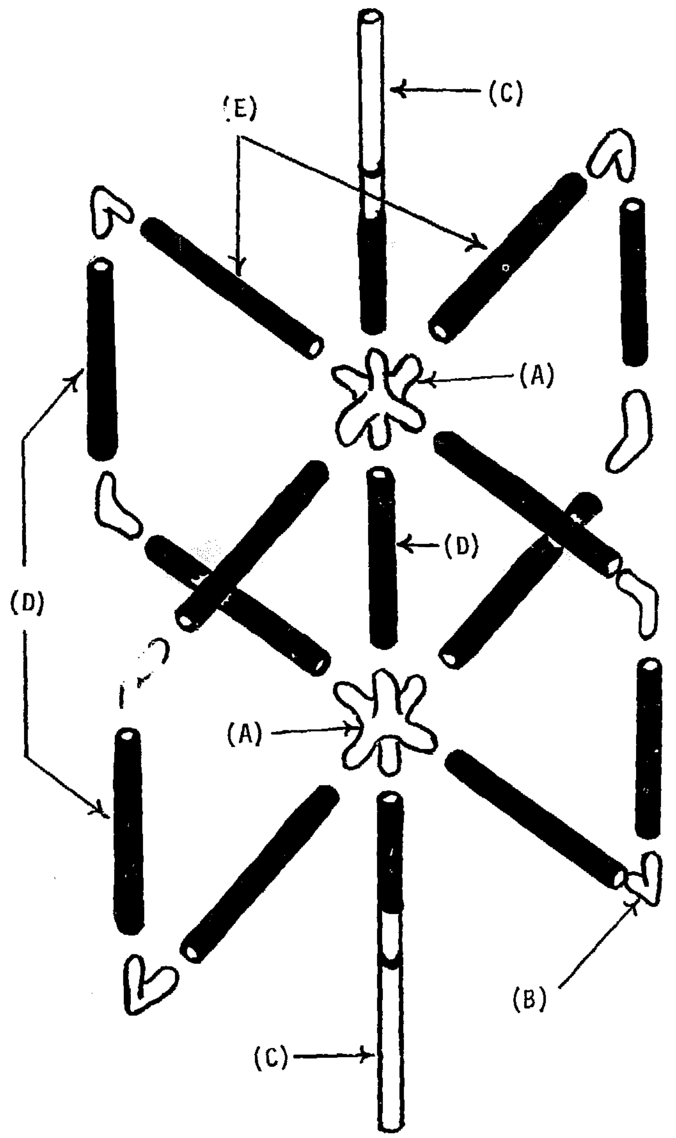
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) HC=CH (Acetylene)	2	6-armed Valence Clusters (A)	X/B1
	8	Angular Connectors (B)	X/B1
	2	C-H Bonds (C)	4.5 cm
	5	Black Straws (D)	2.4 cm
	8	Black Straws (E)	3.0 cm

*Adapted from the Portland Project Committee, Teacher Guide, Chemistry of Living Matter,(Portland, Oregon: Portland Project Committee, 1971), pp 36-37.

b. Construction

(1) HC=CH (Acetylene)



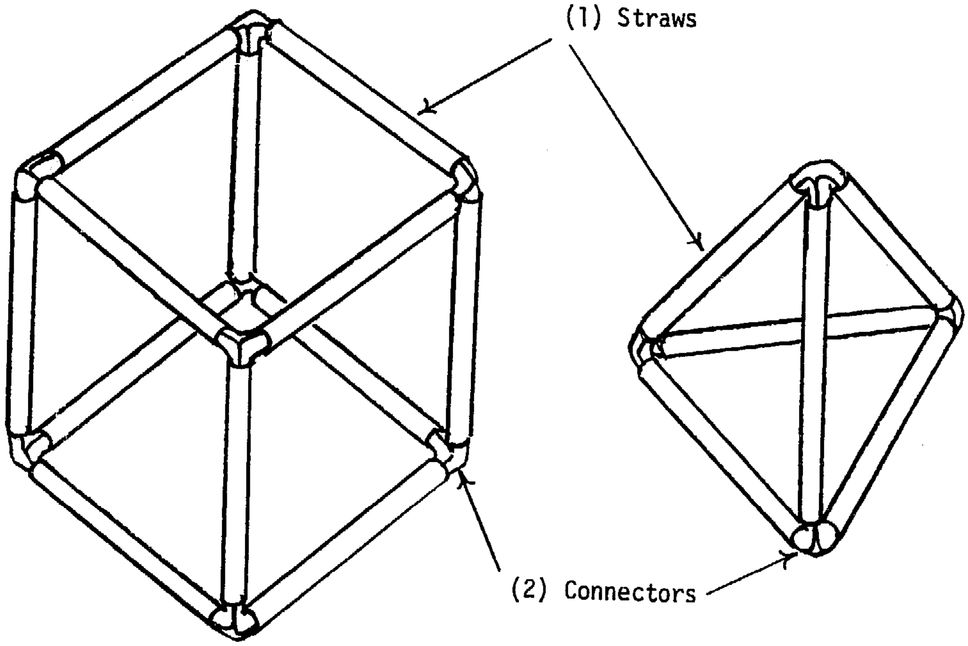
First make two C-H bonds (C) (X/B2). Then use two 6-armed valence clusters (A) and eight angular connectors (B) to connect the parts of the HC=CH (acetylene) molecule as shown. The 2.4 cm black straws (D) indicate the length of the triple bond, and are cut to represent twice the triple covalent bond radius for carbon. Bond thickness is indicated by the 3.0 cm straws (E) or twice the single bond radius for carbon.

c. Notes

(i) Because the forces holding two nucleii together in a triple bond are stronger even than those of a double bond, the nucleii are closer together. Thus, the straws representing the C=R covalent distance are shorter than those representing the C=R distances. Nucleii involved in sp hybridization with triple bond formation are represented in the model by the 6-armed sp valence cluster.

(ii) In the HC=CH (acetylene) model, the central carbon-carbon bond represents the σ bond. The four outside sections of black straws represent two double-armed π bonds.

B5. Geometric Structures*



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Straws	--	Paper or Plastic Milk Straws (A)	Approximately 0.4 cm diameter
	--	Pipe Cleaners (B)	Approximately 3 cm long

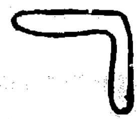
b. Construction

(1) Straws

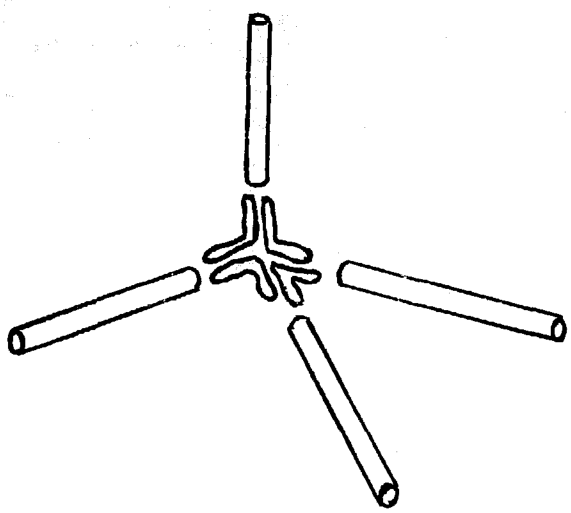
Cut the straws (A) to any convenient length, 5 cm, for example. Paint the straws, if desired, with poster (tempera) paints to which a small amount of dissolved soap has been added.

*Adapted from D.C. Hobson and C. V. Platts, "Milk-Straw Molecular Models," School Science Review, CLXIII (1966), pp 694-701.

(2) Connectors



Bend the cut pipe cleaners (B) to form right angles.



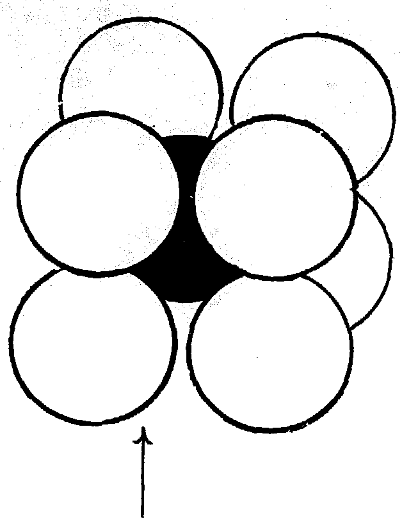
Insert the pipe cleaners (B) into the straws (A), as shown, to form secure connections.

c. Notes

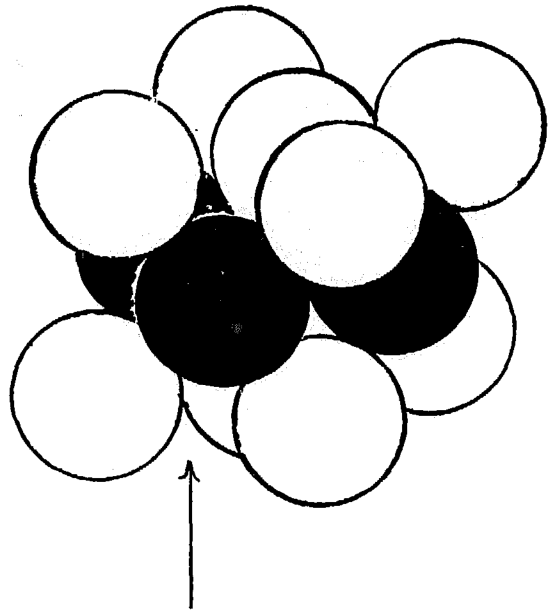
(i) By selecting appropriate numbers of straws and connectors, a variety of geometric forms may be built.

C. CRYSTAL STRUCTURE MODELS

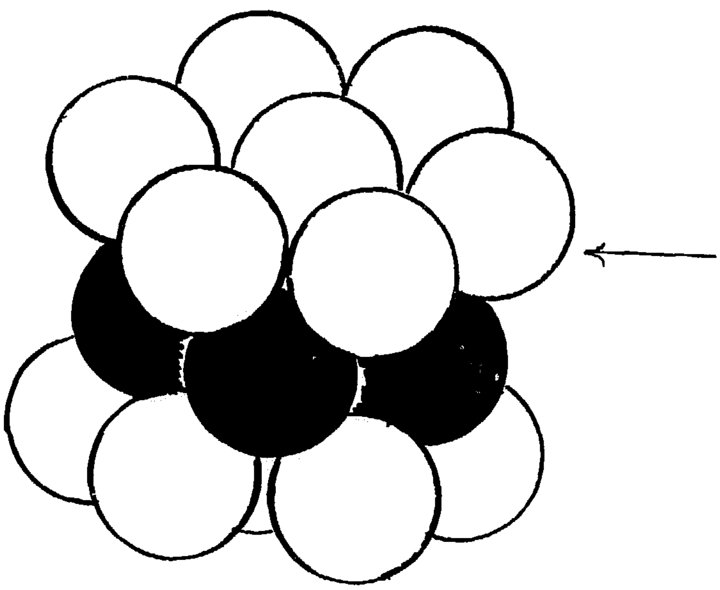
C1. Crystalline Packing Models*



(1) Body-Centered Cubic Unit Cell



(2) Face-Centered Cubic Unit Cell



(3) Closely-Packed Hexagonal Unit Cell

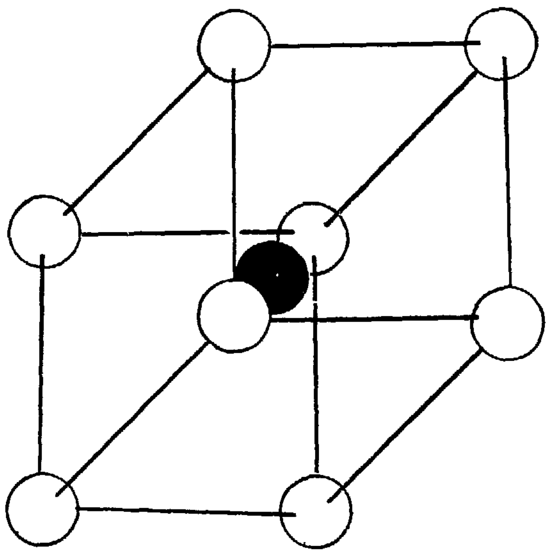
*Adapted from J. W. Coakham, W. Evans, and H. Nugent, "Introducing Crystal Structures," School Science Review, CLXXIV (1969), pp 61-71.

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Body-Centered Cubic Unit Cell	9	Styrofoam or Foam Polystyrene Spheres (A)	Approximately 4 cm diameter
(2) Face-Centered Cubic Unit Cell	14	Styrofoam or Foam Polystyrene Spheres (B)	Approximately 4 cm diameter
(3) Closely-Packed Hexagonal Unit Cell	17	Styrofoam or Foam Polystyrene Spheres (C)	Approximately 4 cm diameter

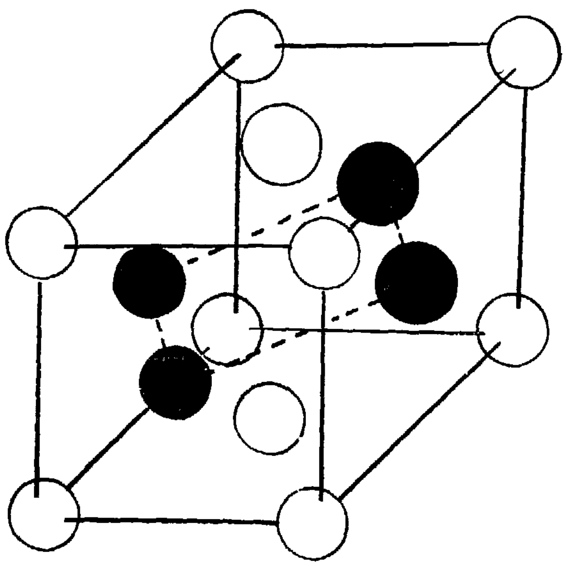
b. Construction

(1) Body-Centered Cubic Unit Cell



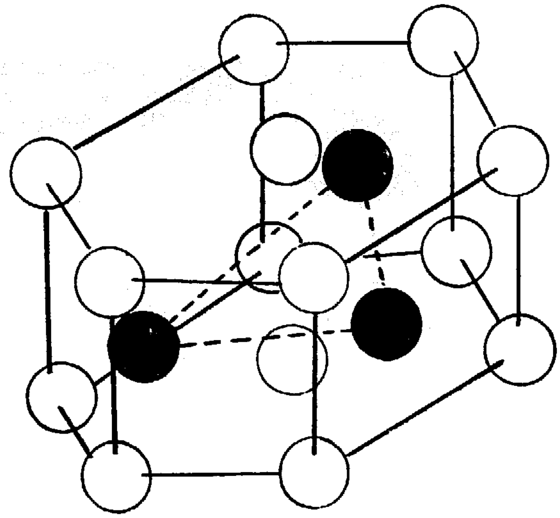
Make the spheres (A) from styrofoam or foam polystyrene (X/B1) or purchase spheres from a commercial source. Use the nine spheres to represent the atoms of the crystal according to the "exploded" diagram. Place four spheres in the top and bottom layers, and one in the middle. Use toothpicks, pipe cleaners, match sticks, or cement to hold the spheres together.

(2) Face-Centered Cubic Unit Cell



Use this exploded diagram as a guide for building the face-centered cubic unit cell from 14 spheres (B). Place five spheres in both top and bottom layers, and four spheres in the middle layer.

(3) Closely-Packed Hexagonal Unit Cell

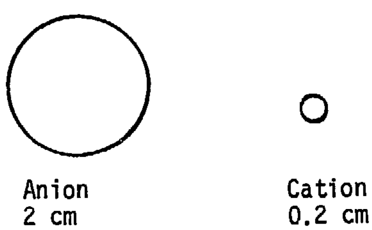


Use seventeen spheres (C) as illustrated to build the closely-packed hexagonal unit cell. Place seven spheres in the top and bottom layers, with three in the middle layer.

c. Notes

(i) The models described demonstrate three-dimensional patterns found in crystals of metals, where the atoms are all of one size and the bonding forces are equal in all directions. As with previous models, the use of molecular models aids the student in both understanding the structure and predicting the characteristics of the substances studied.

(ii) If it is necessary to construct crystal models showing different ion sizes, smaller or larger styrofoam spheres may be used. For example, ionic crystal models may be constructed using spheres 2 cm in diameter for anions, and 0.2 cm diameter for cations.

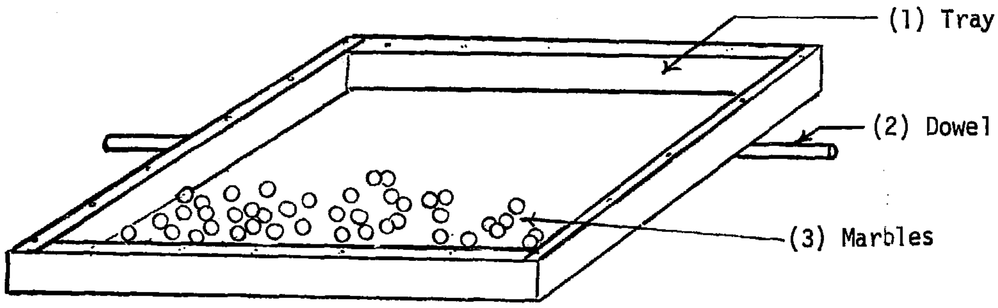


(iii) These models may be also used to demonstrate such aspects of crystal structures as coordination number, most closely-packed planes and Miller Indeces.

(iv) For further discussions on the application of these models to the study of the molecular structure of crystals, consult J. W. Coakham, W. Evans, and H. Nugent, "Some Aspects of Crystal Structure, Part I," School Science Review, CLXXIX, pp 339-350.

D. KINETIC-MOLECULAR MODEL

D1. Kinetic Theory Model*



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Tray	1	Wood (A)	1 cm x 30 cm x 30 cm
	2	Wood (B)	2 cm x 2 cm x 26 cm
	2	Wood (C)	2 cm x 2 cm x 30 cm
(2) Dowel	1	Wooden Dowel (D)	Approximately 1.5 x 40 cm
(3) Marbles	250	Marbles or Glass Beads (E)	Approximately 1.0-1.5 cm diameter
	5	Marbles or Glass Beads (F)	Larger than the others

b. Construction

(1) Tray

Nail or glue the four wood strips (B and C) to the flat wood square (A) to form a tray. Varnish the tray inside and out to provide a slick inside and outside surface.

(2) Dowel

Select a dowel (D) to support one end of the tray.

(3) Marbles

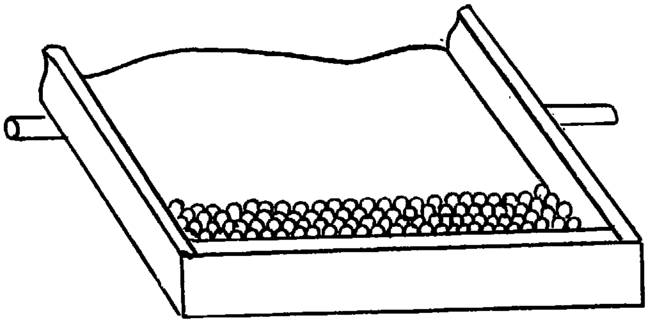
Place the marbles or plastic or glass beads (E) in the tray. Use all of them to represent the molecules in a solid or liquid. Use only 40 - 50,

*Adapted from I. D. Taylor, "Kinetic Theory Models," School Science Review, CLXIII (1963), pp 780-783.

plus the few larger marbles (F), to represent the molecules in a gas.

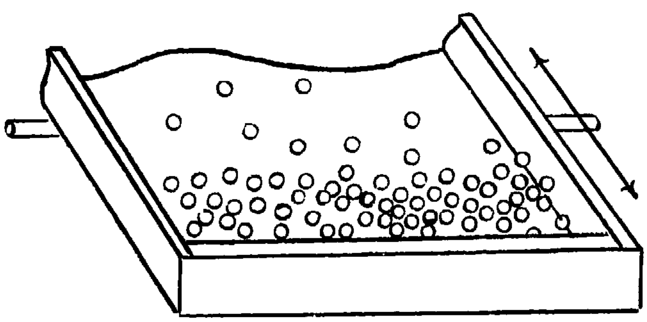
c. Notes

(i) To demonstrate, two-dimensionally, the kinetic activity of molecules in matter, place all the marbles in the tray. Rest one end of the tray on the dowel so that the marbles all roll to the opposite end, packing into a regular structure with each marble, or "molecule" touching six neighbors.



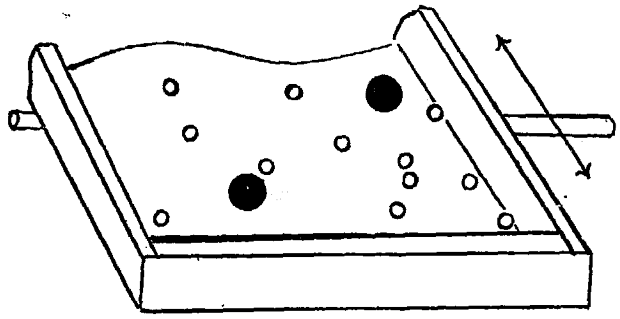
(ii) When the tray is at rest, none of the "molecules" move, representing the theoretical condition of matter at absolute zero. When the tray is gently agitated back and forth, the "molecules" begin to vibrate and to show "thermal expansion". They occupy a larger volume, but generally retain the same relative position. Occasionally a few molecules jump clear of the surface, representing the slight vapor pressure of a solid.

(iii) As the tray is agitated still harder, with greater amplitude, the "solid" "melts" with the "increase in temperature" (increase in kinetic energy). The molecules slip out of place, the volume increases, and more molecules jump away from the surface.



By slowing down the rate and amplitude of vibration, the "liquid" can be converted back to a "solid". Slowing the vibration gently represents gradual cooling and results in a regular structure. If, however, the vibration suddenly ceases, rapid cooling is demonstrated. The resulting "solid" shows an irregular structure with many imperfections.

(iv) For a demonstration of a "gas", most of the molecules are removed, and the tray is agitated more rapidly than for the "solid" or "liquid". All the



molecules move rapidly and randomly about, traveling large distances before colliding with one another. A few larger marbles, added to the "gas", move with small, irregular, jerky motions, representing the Brownian motion of dust or smoke particles in air.

(v) If a clean glass tray and overhead projector is available, the model may be projected on a screen for a large class to see. The "molecules" show on the screen as shadows.

XI. CHROMATOGRAPHIC APPARATUS

Chromatography, a powerful analytical technique of recent development, may be performed with relatively simple apparatus. It is based upon the differential migra tion of solutes in a liquid or solid medium and maybe used for both qualitative and quantitative analysis of solutions.

A. QUALITATIVE CHROMATOGRAPHIC APPARATUS

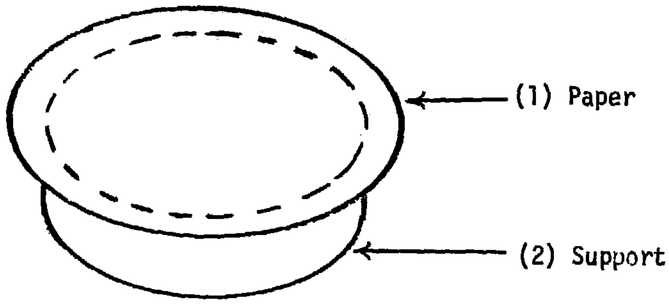
This section includes chromatographic devices employing paper as the stationary medium and briefly describes a few techniques for using these devices to identify the components of a mixture.

B. QUANTITATIVE CHROMATOGRAPHIC EQUIPMENT

This section describes a device that allows for the separation of the components of a mixture as well as the recovery of individual components for further experimentation or purification.

A. QUALITATIVE CHROMATOGRAPHIC APPARATUS

A1. Horizontal Paper Chromatography Device



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Paper	1	Filter Paper (A)	Approximately 10 cm diameter or larger
(2) Support	1	Petri Dish (B)	Slightly smaller than filter paper

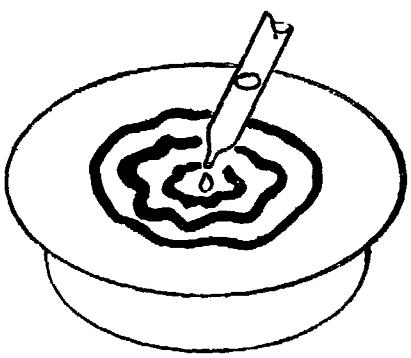
b. Construction

(1) Paper — Use a circle or square of filter paper (A) as the medium for the chromatogram.

(2) Support — Select a petri dish or other shallow container (B) just slightly smaller than the paper (A) on the support (B).

c. Notes

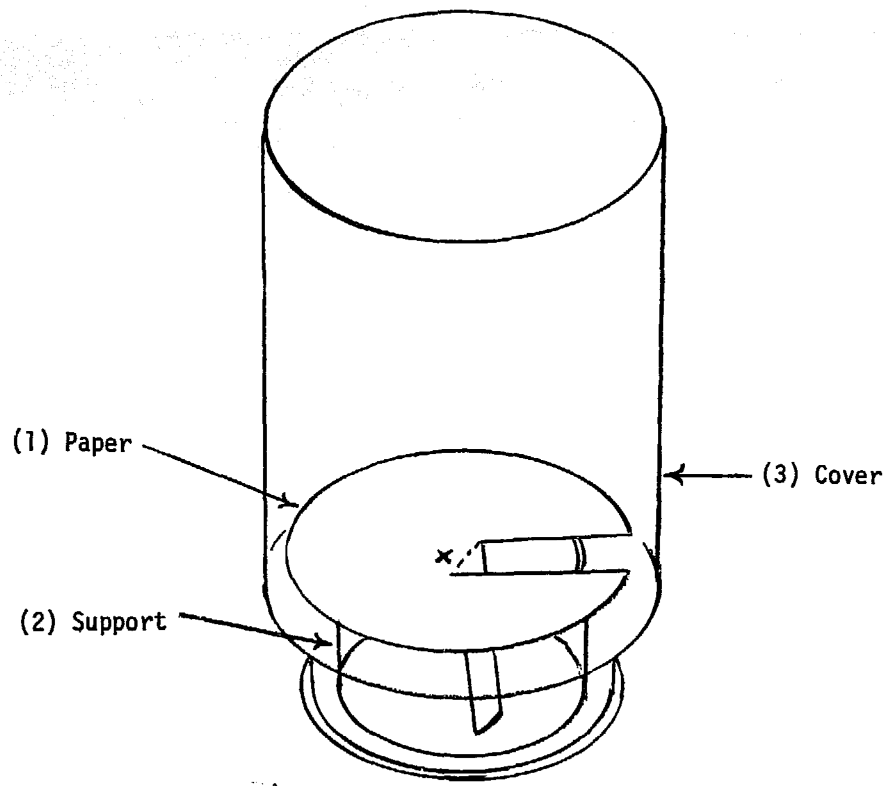
(i) This apparatus can be set up almost instantaneously for rapid, qualitative work. A drop of a colored solution to be analyzed is placed in the center of the paper. Then, successive, small drops of the eluting solvent are dropped on top of the original drop. The solution spreads radially, and as separation of components occurs, concentric rings of color will appear on the paper.



(ii) As an example of a test solution, a drop of black or blue-black, washable ink may be used. The eluting solvent in this case could be water, methanol (methylated spirits) or 70% ethanol.

(iii) Chromatography paper, white paper towels, blotting paper, newsprint paper, or other white or light-colored, coarse-grained paper may be substituted for the filter paper (A).

A2. Horizontal Paper Chromatography Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Paper	1	Filter Paper (A)	Approximately 10 cm diameter or larger
(2) Support	1	Cup or Jar (B)	Slightly smaller than filter paper
(3) Cover	1	Glass Jar or Bowl (C)	To cover paper and support

b. Construction

(1) Paper

Take a circle or square of filter paper (A) or suitable substitute and cut a tongue across the paper to within about 1 cm of the center of the

*Adapted from A. V. Jones, "Chromatography for Junior Schools," School Science Review, CLXXIX: (1970), 298-300.

paper. Bend the tongue down at a right angle to the paper (A).

(2) Support

Select a small cup or jar (B) just slightly smaller than the paper (A). Rest the paper (A) on the jar (B) with the paper tongue extended into the jar.

(3) Cover

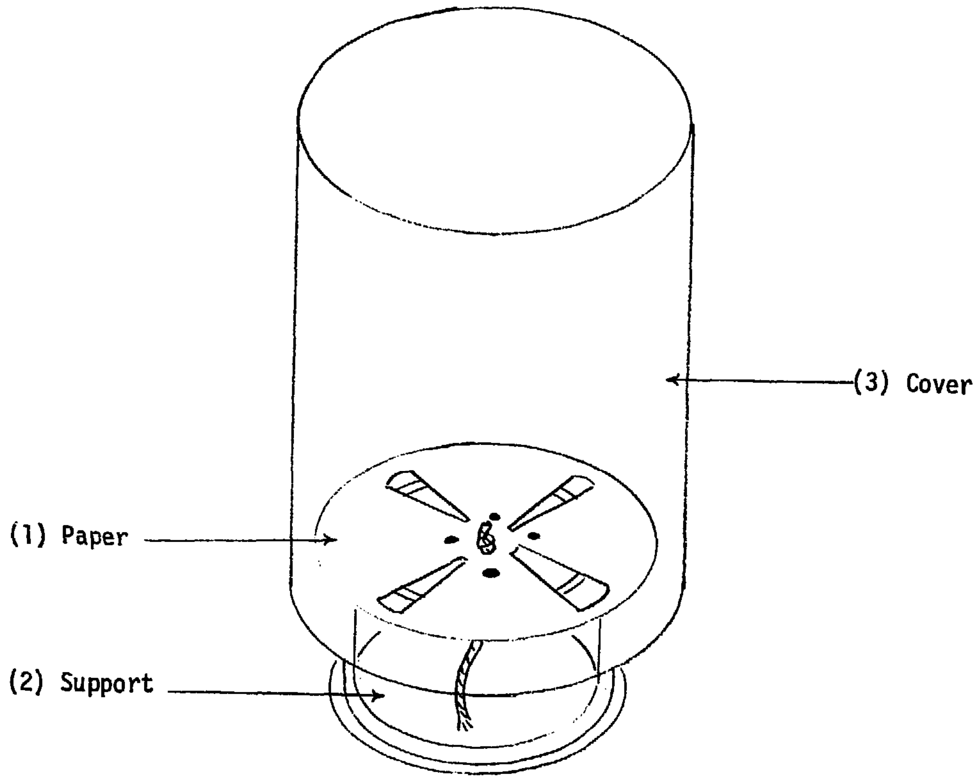
Select a large glass jar or bowl (C) to cover the support and paper. Invert the cover to enclose the other two components.

c. Notes

(i) This apparatus, while only slightly more complex than that in the previous section, has the added advantage that, once set up, it may be left to stand for some time. A spot of test solution (e.g., ink or a concentrated extract made from plant flowers, leaves, stems, or roots) is placed at the center of the paper (A). Then the small jar (B) is filled to within about 2 cm of the top with solvent (e.g., water or alcohol). When the paper tongue is placed in the solvent, the liquid will soak up the tongue to the test spot, and beyond. The components of the test solution separate out, in rings, as the solvent progressively soaks the paper. Covering the apparatus with a bowl or jar (C) helps prevent evaporation of the solvent before it has had time to soak the paper.

(ii) The experiment continues until the solvent front reaches to within about 1 cm of the edge of the paper, or until it is apparent that it has stopped moving. The paper is then removed from the apparatus and rapidly dried, using the drying lamp (IX/A3), a fan, or other source of dry heat or moving air.

A3. Horizontal Paper Chromatography Device *

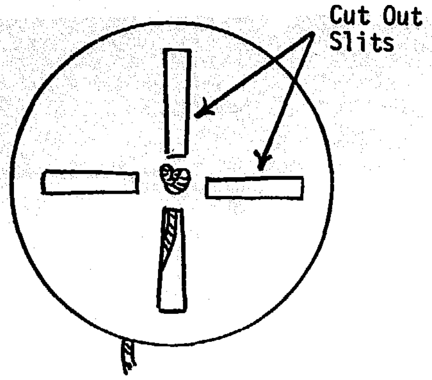


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Paper	1	Filter Paper (A)	Approximately 10 cm diameter or larger
	1	String (B)	Approximately 0.2 cm diameter, 5-10 cm long
(2) Support	1	Cup or Jar (C)	Slightly smaller than filter paper (A)
(3) Cover	1	Glass Bowl or Jar (D)	To cover paper (A) and support (C)

b. Construction

(1) Paper



Take a circle or square of filter paper (A) or suitable substitute and cut several slits radiating from the center as shown. Punch a small hole in the center and secure a piece of string (B) with a knot, to act as a wick.

(2) Support

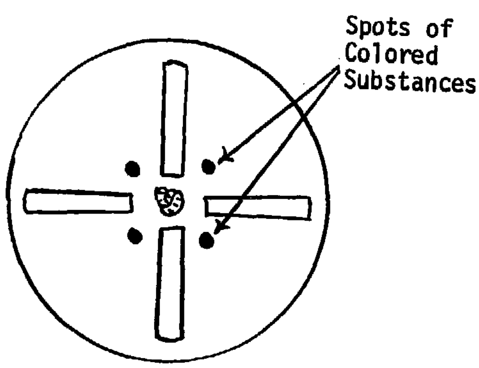
Select a small cup or jar (C) just slightly smaller than the paper (A). Rest the paper (A) on the rim of the jar (B) so that the string wick (C) extends into the jar.

(3) Cover

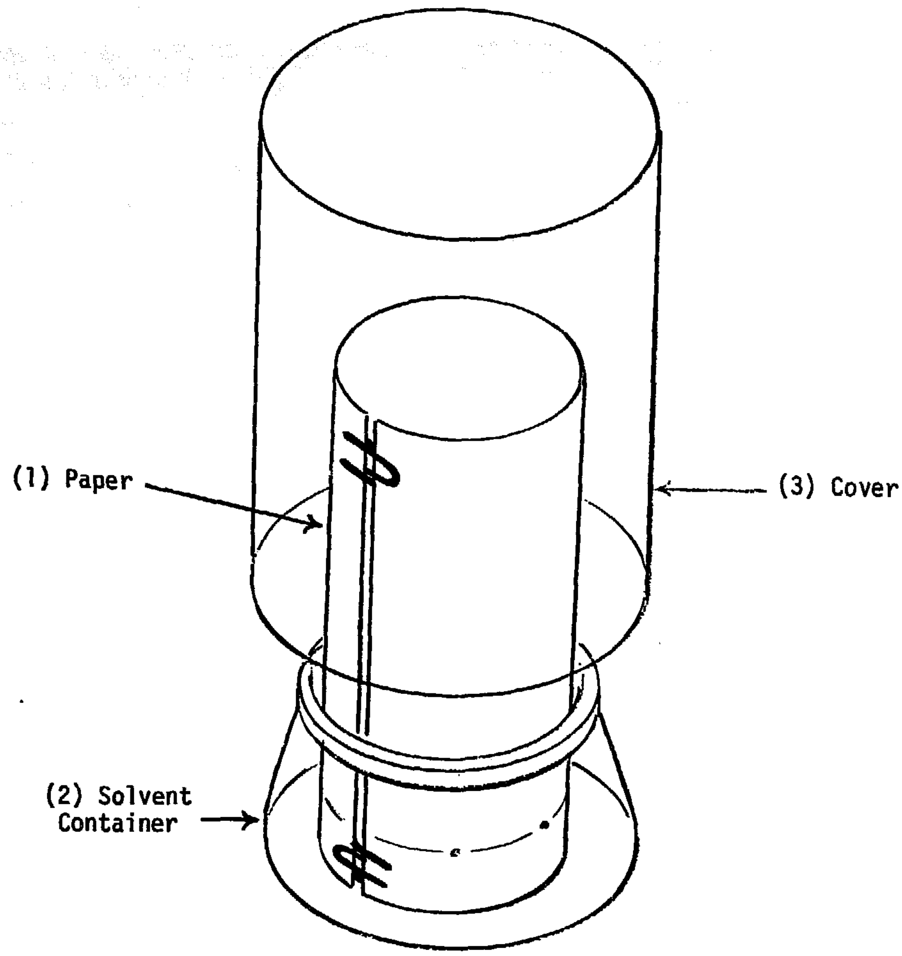
Select a large glass jar or bowl (D) to cover the support and paper. Invert the cover to enclose the other components.

c. Notes

(i) This apparatus is used in the same fashion as the preceding device. However, the slits in the paper allow for more than one colored substance or test solution to be used simultaneously. The spots are placed inside the "V" of the slits, which prevent the colors from merging.



A4. Vertical Paper Chromatography Equipment

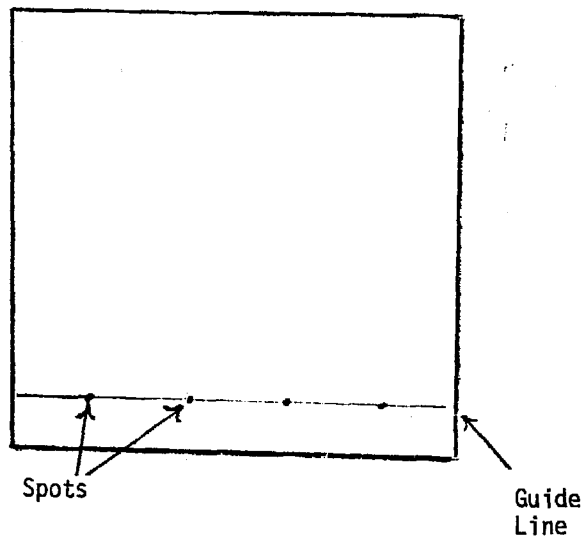


a. Materials Required

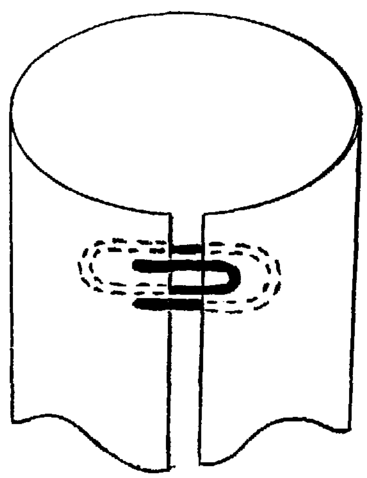
Components	Qu	Items Required	Dimensions
(1) Paper	1	Chromatography Paper (A)	Approximately 15 cm x 15 cm
(2) Solvent	1	Beaker, Bowl or Jar (C)	To contain paper (A) when rolled into tube
(3) Cover	1	Glass Jar or Bowl (D)	To fit on or over Solvent Container (C)

b. Construction

(1) Paper



With a pencil, draw a faint line approximately 2 - 3 cm from one edge of the paper (A). Use this line as a guide for locating the spots of solution or solutions to be tested. Make the spots as small as possible and about 2 cm apart.



Roll the paper (A) loosely into a tube. Secure the edges together with the paper clips (B) such that the edges do not touch or overlap.

(2) Solvent Container

Set the rolled paper (A) into the beaker, bowl, or jar (C) and pour solvent into the container (C) to a height of about 1 cm.

(3) Cover

Rest a large glass jar or bowl (D) on or over the solvent container (C) to prevent evaporation of the solvent.

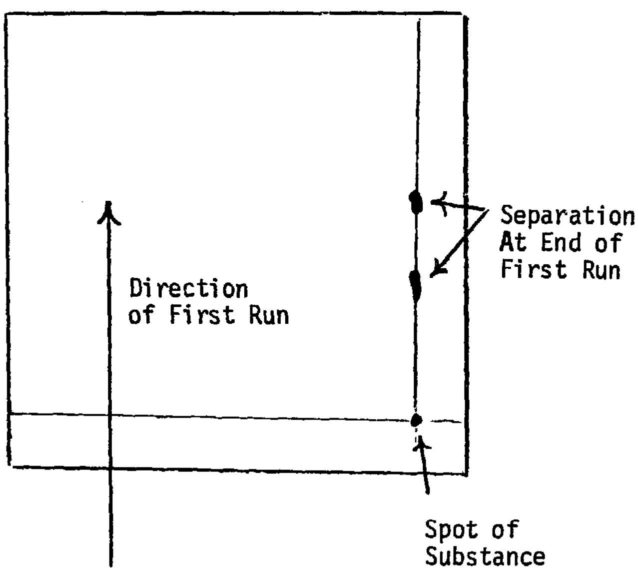
c. Notes

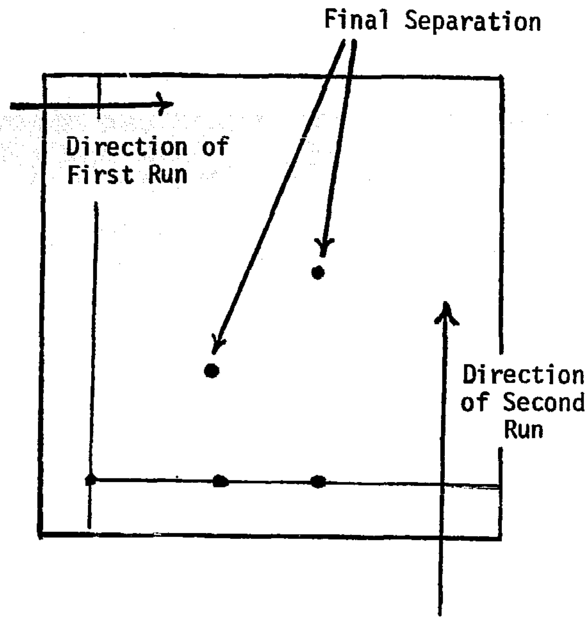
(i) If chromatography paper is not available, white paper toweling or blotting paper may be substituted.

(ii) When this apparatus is in use, the solvent front migrates up the paper, (by capillary action) resulting in the separation of the components of the test spot. This is allowed to continue until it has reached to within several cm of the top of the paper or until it is apparent that the solvent front will move no further (when the rate of capillary action is in equilibrium with the rate of evaporation). The paper is then removed from the apparatus and dried, and the final locations of the color spots may be circled with pencil for easy identification.

(iii) This apparatus is also suitable for performing separation of colorless substances, as long as the completed chromatogram can be treated in some way to make visible the final location of the component of the substances. For example, proteins, while generally colorless, may separate in this fashion. The dried chromatogram is then sprayed with a ninhydrin solution, which reacts with the amino acids in their final locaticns, making them visible as bluish spots or smudges.

(iv) It is possible, with this apparatus, to submit a substance to chromotographic separation by two different solvents on the same sheet of paper. To run such a two-dimensional chromatogram, a spot of the substance is placed at the intersection of two lines drawn on the paper and treated as described above, with one solvent. At the end of the first run, the chromatogram is removed from the apparatus and dried.

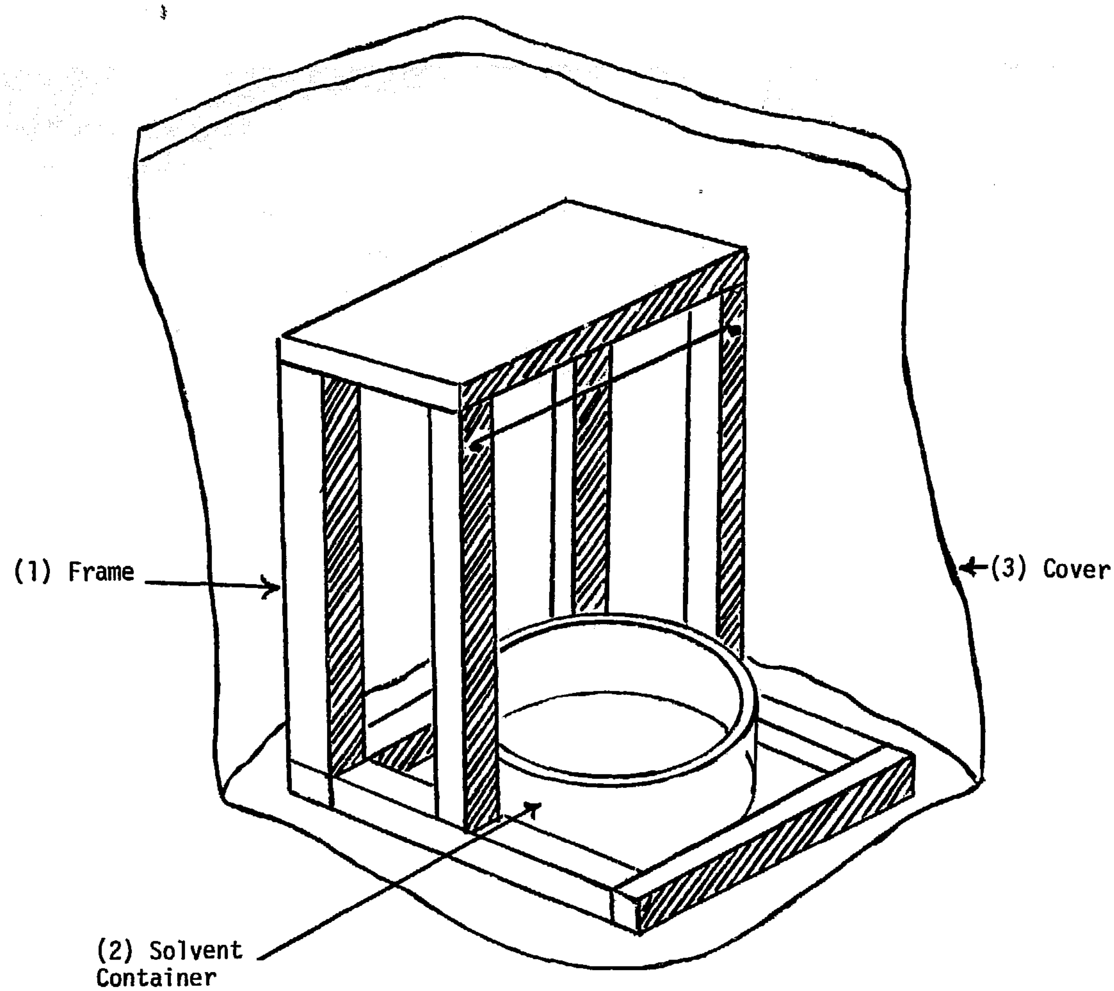




Then the paper is rotated 90° and again rolled into a tube, with the first separation at the bottom edge of the tube. This tube is run a second time with a second solvent. Thus, it is possible to effect a more complete separation than is possible with one solvent alone.

(v) A complete discussion of techniques and substances appropriate to chromatographic separation is beyond the scope of this guidebook. For further information, texts and resources on biochemistry, chemistry, and chromatography should be consulted.

A5. Vertical Strip Paper Chromatography Equipment

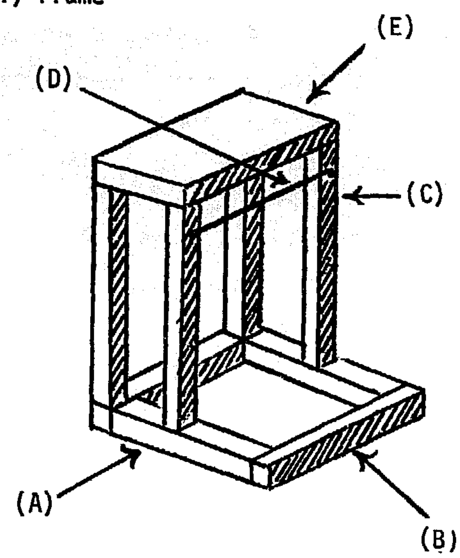


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Frame	2	Wood (A)	1 cm x 1 cm x 8 cm
	2	Wood (B)	1 cm x 1 cm x 10 cm
	4	Wood (C)	1 cm x 1 cm x 20 cm
	1	Wood or Masonite (D)	6 cm x 10 cm x 0.2 cm
	1	Thin, Stiff Wire (E)	Approximately 11 cm long
(2) Solvent	1	Cup or Jar (F)	Approximately 4 cm high, to fit inside frame
(3) Cover	1	Plastic Bag (G)	To fit loosely over frame

b. Construction

(1) Frame



With nails and glue, secure the frame parts (A), (B), (C), and (D) as shown. Secure the wire (E) to the frame, about 2 cm from the top, with two small nails.

(2) Solvent Container

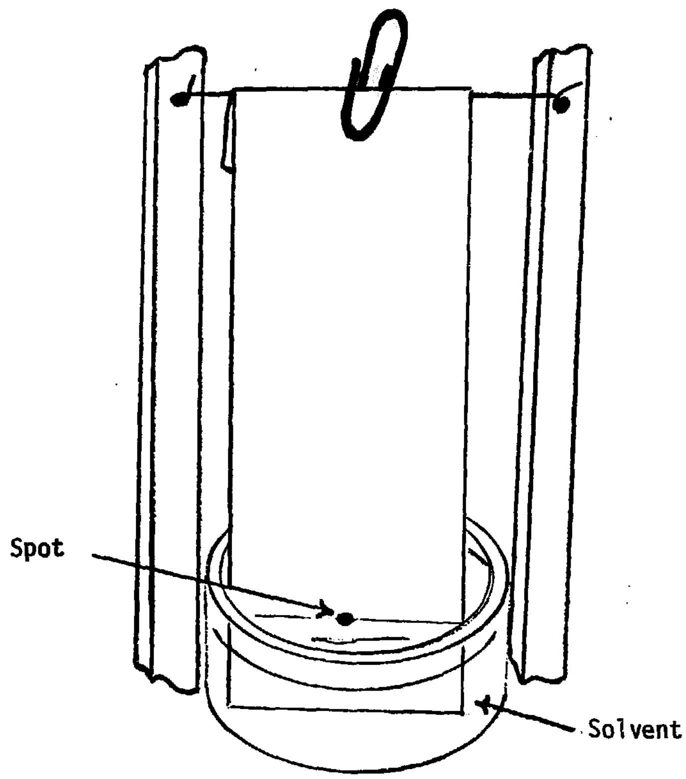
Select a shallow cup or jar (F) that will fit inside the frame. If necessary, cut a tall jar down to a height of 3 - 4 cm (I/F2).

(3) Cover

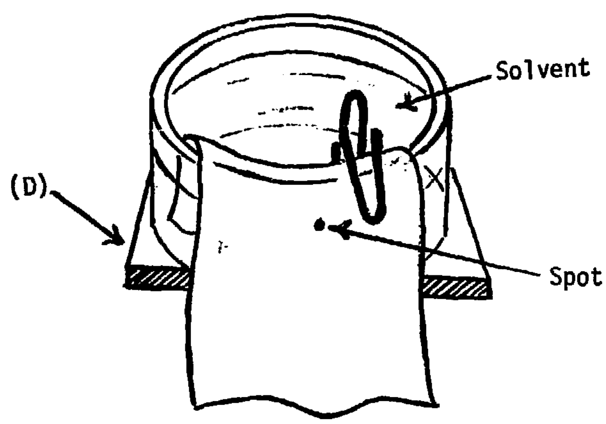
Select a plastic bag (G) that will fit loosely over the frame. It may be held in place by clipping it with a clothespin to a clamp or ring that is supported about 10 cm above the frame on the ring and burette stand (IV/B5) or other suitable support. Alternatively, a frame to support the bag may be constructed out of stiff (e.g., coat hanger) wire.

c. Notes

(i) This frame may be used to support a strip of chromatography paper or suitable substitute for either ascending or descending chromatographic operations. For ascending operations, the solvent container (F) remains at the bottom of the frame. The Paper strip, with one end just touching the solvent, is hung from the wire with a paperclip The spot or spots of substance to be separated is located at the lower end of the strip, just above the solvent. The apparatus should be kept covered by the plastic bag (G) during the course of the experiment to keep solvent evaporation to a minimum.



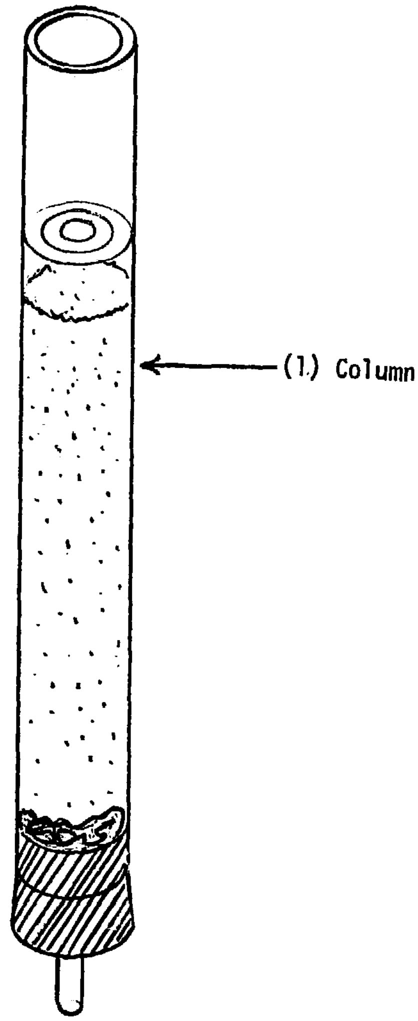
(ii) In order to use the frame for descending operations, the solvent container (F) is placed on the top shelf (D). The paper strip is then hung from the solvent container, held in place with a paper clip or clothespin, and with a short piece folded over to dip into the solvent. The spot is located near the top of the strip, outside the solvent container. The solvent front then moves down the paper in the course of the experiment.



(iii) If a sufficiently large jar is available, it may be used as a cover in place of the plastic bag (G).

B. QUANTITATIVE CHROMATOGRAPHIC EQUIPMENT

B1. Liquid-Column Apparatus

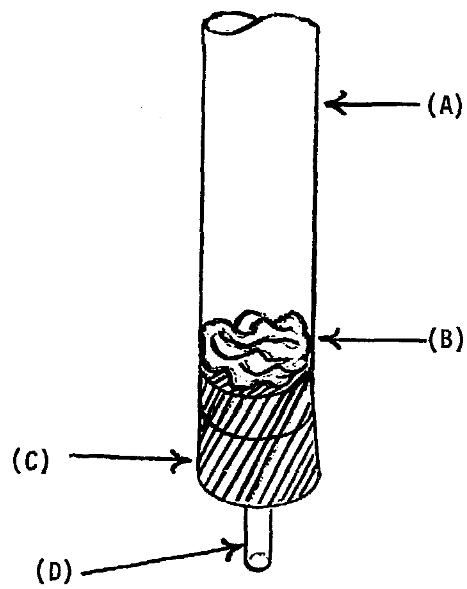


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Column	1	Glass Tube (A)	Approximately 1.5 cm outside diameter, 25 cm long
	1	Cotton or Glass Wool (B)	--
	1	1-Hole Stopper (C)	To fit tube
	1	Glass Tubing (D)	Approximately 0.5 cm diameter, 5-10 cm long
	--	Silica Gel (E)	28-200 mesh

b. Construction

(1) Column



Fire polish both ends of the glass tube (A) to eliminate sharp edges. Push a small wad of cotton or glass wood (B) about 1 cm into one end as a plug.

Insert the small glass tube (D) into the stopper (C) and push the stopper into the large glass tube (A), and support the column in a vertical position in a burette clamp (IV/B5) or other suitable support.

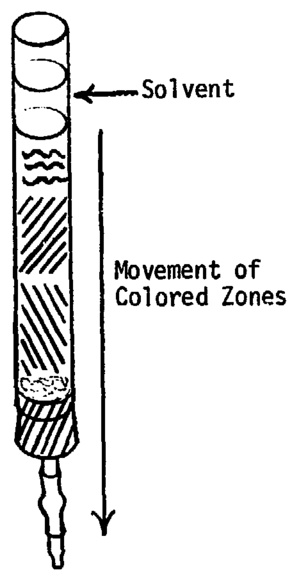
To pack the column with the stationary medium, make a slurry with several grams of the silica gel (E) and water. Pour this slurry into the top of the column, and allow the water to drain through the small glass tube (D), while the moist silica gel is retained by the plug (B). If necessary, pour additional slurry into the column until about 15 cm of the column is packed with silica gel and about 1 cm of water remains on top of the silica gel. If desired, the packing operation may be hastened by applying slight suction, by means of the suction-filter flask (VI/A4) coupled with a suction pump, aspirator (V/A8) or other source of suction.

c. Notes

(i) The flow of liquid through the column may be controlled, if desired, by the addition of a stopcock, or flexible rubber tubing coupled with a pinch clamp (IV/A4) or glass bead (III/B1). A glass nozzle may also be added to the free end of the flexible tubing.

(ii) To use this apparatus, the water remaining on the column is allowed to drain until less than 1 cm remains to cover the silica gel. Then a small quantity of a solution of colored material to be tested, in a concentrated form, is gently pipetted on to the medium. The desired solvent is then added to the column, and the column is allowed to drain slowly, using either gravity or very slight suction.

As the solvent moves down the column, carrying the substance with it, separation will occur, as indicated by colored zones appearing on the medium. As additional solvent is added to the column, the zones themselves will migrate down the column; if sufficient solvent is added, each zone, consisting of a specific component of the substance tested, may be washed off the column and recovered separately.



(iii) In addition to separating components of a substance and washing them down the column with one solvent, it is possible to use additional solvents to wash down a component or components that do not migrate at all with the first solvent. To do this, allow the column to drain until less than 1 cm of the first solvent remains on top of the medium, then add the second solvent to the column and proceed with the washing as described above.

(iv) Other interesting results may be obtained by reversing the order of solvents used, in successive runs, with the same test substance. For example, alcohol and water are two solvents that may be used, in either order, to separate a mixture of vegetable dyes or ink.

(v) One of the chief advantages of the liquid-column method of chromatographic separation over paper chromatography is that the components of the substance tested are recovered individually for use in further experiments or in quantitative determinations. For example, a measured quantity of the test substance, in a known concentration, is added to the column, and the solvent used and the solutions recovered are measured. Then the components eluted are submitted to volumetric or gravimetric quantitative analysis to determine the proportion of each component present in the original sample.

(vi) Substances other than 28 - 200 mesh silica gel, and solvents other than alcohol or water, may be used in liquid-column chromatography. Further experimentation, as well as research into the technical literature on chromatography, is suggested for the development of this technique. A useful reference for this purpose is Erich Heftmann, Chromatography, Second Edition, (New York: Reinhold Publishing Corporation, 1967).

XII. MULTIPURPOSE SYRINGES

Many chemical techniques and experiments are readily performed using disposable plastic syringes. Some of these uses will be described in this section, and the devices have been grouped according to the concepts they illustrate. In addition to those uses given here, syringes can also be used in column chromatography, ion exchange devices, and other areas in chemistry.

A. TECHNICAL DEVICES

Two items of use in the chemistry laboratory are included here.

B. GAS STUDIES APPARATUS

Included here are several ways in which syringes may be used in studying the production, collection, and properties of gases.

C. DIFFUSION APPARATUS

Diffusion of both gases and liquids can easily be studied with the aid of plastic syringes.

D. OXIDATION APPARATUS

This section describes a number of devices used in the study of oxidation reactions.

E. ANALYTICAL APPARATUS

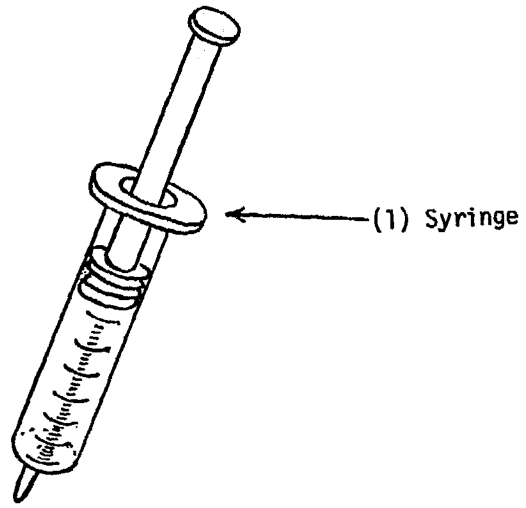
These devices are used in experiments to determine chemical formulae, structures, and molecular weight.

F. CONDUCTANCE APPARATUS

The variation in conductivity of different solutions can be studied with the aid of several devices which are fairly easily constructed with disposable syringes.

A. TECHNICAL DEVICES

A1. Dropper/Pipette



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringes	1	Plastic Disposable Syringe (A)	Capacity 10-50 ml

b. Construction

(1) Syringe

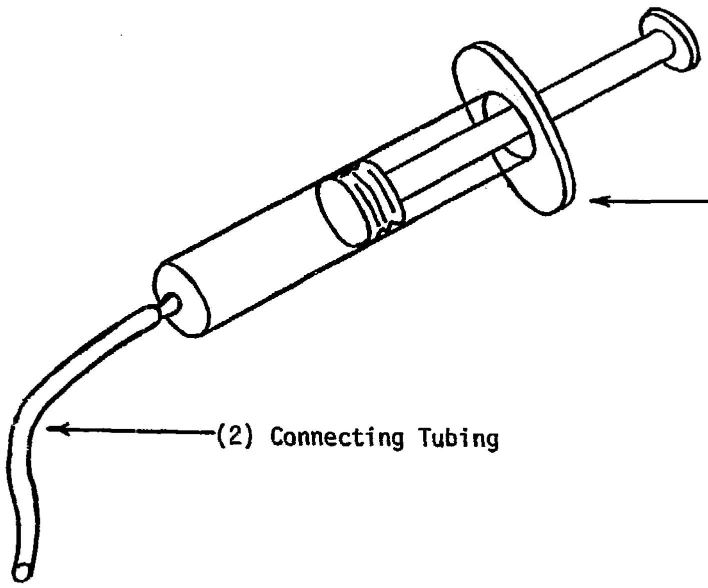
Select a calibrated, plastic disposable syringe (A) with a volume appropriate for the desired use.

c. Notes

(i) In the smaller sizes, disposable syringes make excellent droppers with an advantage being that the amount dispensed is measurable. Similarly, they can be used for the same purposes for which pipettes are used. In the larger sizes, syringes can substitute for burettes in titration experiments. Finally, syringes may be utilized in calibrating improvised flasks, beakers, etc., of unknown capacity.

(ii) Placing a medium-sized diameter needle (inside diameter approximately 0.03 cm) on the syringe nozzle will allow solutions to be carefully and accurately delivered, drop by drop.

A2. Pump



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 20 ml
(2) Connecting Tube	1	Plastic or Rubber Tubing (B)	Approximately 10 cm long, diameter to fit syringe nozzle (A)

b. Construction

(1) Syringe

Take a plastic, disposable syringe (A) with a volume appropriate for the desired use.

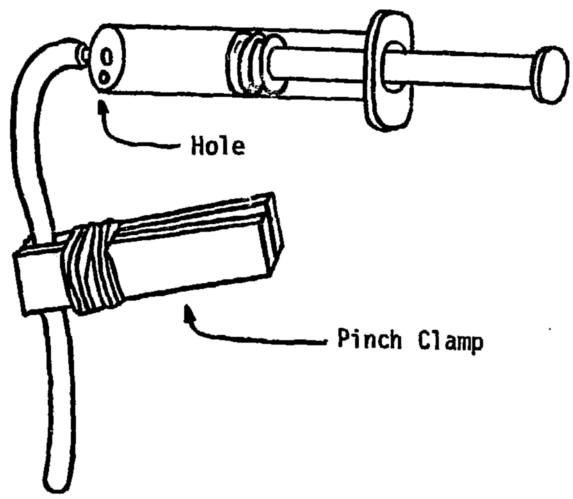
(2) Connecting Tubing

Attach a length of plastic or rubber tubing (B) to the syringe nozzle when the pump is to be used in hard-to-reach places.

c. Notes

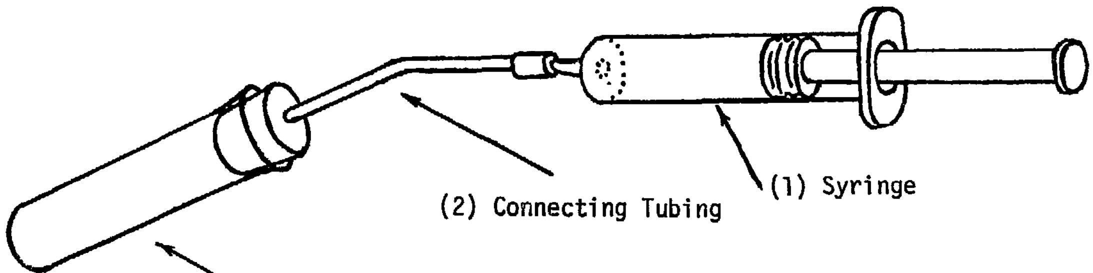
(i) To use the pump, connect the tubing to the object from which gas or liquid is to be removed. Withdraw the plunger to draw gas or liquid into the syringe. Then remove the tubing from the object or container, direct the tubing into an appropriate container or waste receptacle, and depress the plunger to expell the gas or liquid through the tubing.

(ii) With two modifications, the syringe may be used to provide continuous pumping action without removing the tubing from the object from which substances are pumped. Make a small hole in the base of the syringe barrel with a drill or hot wire, and add a pinch clamp (IV/A4) to the tubing to close it off. In use, the tubing is connected to the object from which gas or liquid is to be removed. Then the pinch clamp is removed from the tubing and the hole in the syringe barrel is covered with a finger. The plunger is withdrawn to draw material into the syringe. To expell the contents of the syringe through the hole, the tubing is closed with the pinch clamp, the hole is uncovered, and the plunger is depressed.



B. GAS STUDIES APPARATUS

B1. Gas Production and Collection Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity 10-50 ml
(2) Connecting Tube	1	Rubber or Plastic Tubing (B)	2 cm long, diameter to fit syringe nozzle (A)
	1	Glass Tubing (C)	Approximately 0.5 cm diameter, 10 cm long
(3) Reaction Chamber	1	Hard Glass Test Tube or Flask (D)	Capacity 20-100 ml
	1	1-Hole Stopper (E)	To fit test tube or flask (D)

b. Construction

(1) Syringe

Select a plastic, disposable syringe (A) of appropriate capacity.

(3) Connecting Tubing

Connect the short piece of flexible rubber or plastic tubing (B) to the syringe nozzle.

Heat the glass tubing (C) sufficiently to bend it to a slight angle (about 30°). Connect

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 19.

one end of the glass tubing to the rubber or plastic tubing (B).

(3) Reaction Chamber

Seal a hard glass test tube or flask (D) (capacity from 20 to 100 ml, depending on the desired use) with a one-hole stopper (E). Use a rubber stopper if caustic materials are to be used in the apparatus. Insert the free end of the glass tubing into the hole in the stopper.

c. Notes

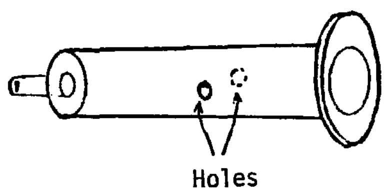
(i) This simple reaction apparatus, suitable for either lecture demonstration or student laboratory use, may be employed in a number of ways. In the simplest qualitative experiments, the use of the syringe allows liquids to be introduced into the reaction chamber where they react with solids or other liquids. A number of gases can be produced using this or similar devices. For example, injecting a 3% solution of hydrogen peroxide from the syringe into a suspension of dried yeast and water in the test tube will yield oxygen gas. Also, injecting a concentrated solution of baking soda from the syringe into vinegar will yield carbon dioxide. Finally, injecting vinegar into water and a piece of magnesium ribbon will cause hydrogen gas to be liberated. The gas liberated will collect in the syringe, pushing the plunger out as more and more gas is given off. Turning the plunger slightly will assure that the gas is at atmospheric pressure.

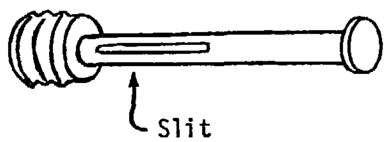
(ii) This apparatus may also be used for quantitative studies in the above reactions. The solid reactants must be carefully weighed or measured, and the use of the syringe allows very precise amounts of liquids to be introduced into the reaction chamber. The volume of the gas evolved may be read from the syringe. The change in volume of gas in the syringe may be plotted against time to give a measure of the rate of reaction. In addition, the volume of gas liberated may also be plotted as a function of temperature and/or the concentration of one or more of the reactants used.

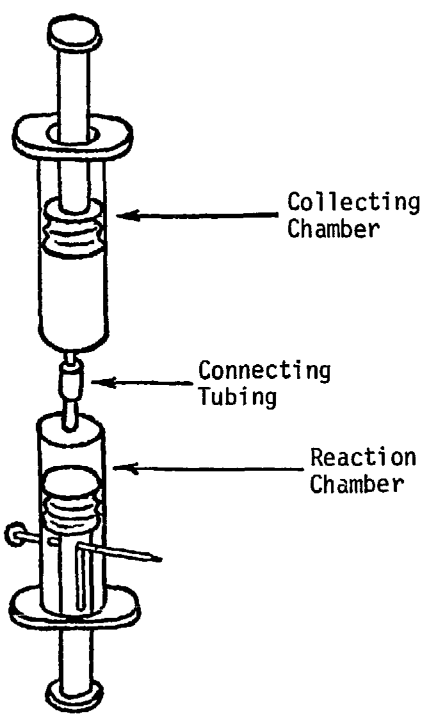
(iii) In a third type of experiment using this apparatus, solids which give off gases when heated are placed in the test tube, and the gas is collected in the syringe. Begin with the syringe plunger fully depressed, and as the gas is evolved, it will push the plunger back, giving a quantitative measure of the amount of gas produced. In using this device, clamps to hold both the test tube and syringe are needed. As an example, red lead can be heated in the test tube, and the gas evolved collected in the syringe. It should be noted, however, that this will spoil the test tube. Instead, potassium permanganate can be used, and no spoilage of the test tube will occur. However, some asbestos wool must be put in the upper end of the test tube to prevent pieces of the potassium permanganate from entering the syringe.

(iv) The experiments based on the use of this apparatus are adapted from Nuffield O-Level Chemistry, Collected Experiments, (London: Longmans/Penguin Books, 1967), pp 9, 229-231, 297-299.

(v) If a glass reaction chamber is not available or is not desired, a second syringe, the same size as the first but slightly modified, may be substituted. First, with a hand drill or hot nail or wire, bore two holes, approximately 0.3 cm in diameter, opposite each other about halfway along the length of the barrel. With a drill and saw or hot nail, make a slit in the syringe plunger as shown. Push the plunger into the syringe, and lock it in place by inserting a nail approximately 0.3 cm wide and 5 cm long through the holes in the barrel and slit in the plunger. Place in the lower syringe a small piece of material which will react with the liquid to be placed in the upper syringe. Replace the plunger in the lower syringe, insert the nail stop, and depress the plunger until the nail prevents further movement. Draw a quantity of liquid into the upper syringe, and fasten the two together with the short piece of tubing. Next, inject all of the liquid into the lower syringe and



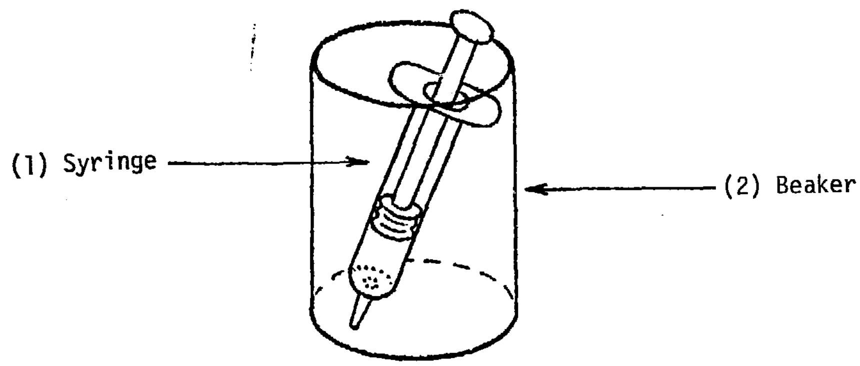




leave the upper syringe plunger in the depressed position. As gas is given off in the lower syringe, it will expand and push out the plunger of the upper syringe until the upper syringe is filled with gas or the reaction stops. Solids and liquids which can be used as outlined to produce gases include animal charcoal and hydrogen peroxide (to form oxygen), metals and dilute acids, carbonates and acids.

(vi) The above modification is based on a design by Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 30-31.

B2. Micro-Generator *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Disposable Plastic Syringe (A)	Capacity 10-50 ml
(2) Beaker	1	Glass Jar or Beaker (B)	To accommodate syringe as shown

b. Construction

(1) Syringe

Select a plastic, disposable syringe (A) of a size appropriate to the amount of gas desired.

(2) Beaker

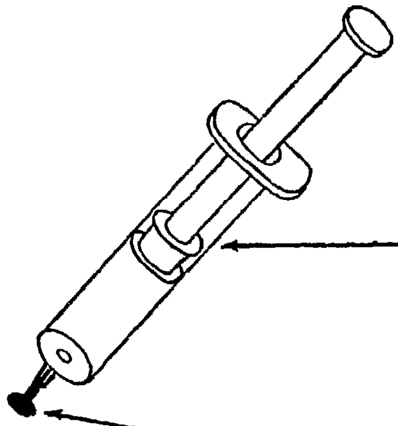
Select a glass jar or beaker (B) such that the syringe can be rested in it more or less vertically.

c. Notes

(i) As an example of its use, the micro-generator can be employed to generate hydrogen sulphide gas (H_2S). Simply place a small piece of ferrous sulphide in the syringe, and put a small amount of dilute hydrochloric acid in the beaker. Draw a portion of the acid up into the syringe until it touches the ferrous sulphide, and leave the syringe resting in the beaker. The gas will collect in the syringe, above the acid. If desired, the needle may be reattached to the syringe when it comes time to bubble the gas through a test solution.

*Adapted from L. A. George, "Two Further Uses for Disposable Syringes," School Science Review, CLXX (1968), 113.

B3. Gas Solubility Device/Reaction Rate Chamber



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 25 ml
(2) Plug	1	Nail (B)	To fit syringe nozzle (A)

b. Construction

(1) Syringe — Take a plastic, disposable syringe (A) of 25 ml or other desired capacity.

(2) Plug — Use the nail (B) to completely seal the syringe after a substance has been drawn into it.

c. Notes

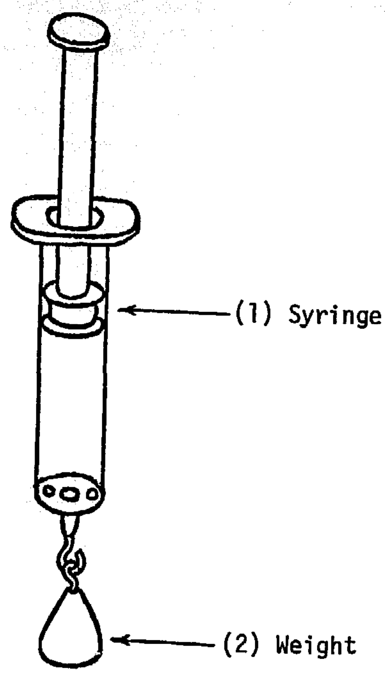
(i) A number of simple solubility experiments may be done with syringes that can be sealed airtight. For example, the syringe may be half filled with cold water, with the plunger just above the water level. Seal the nozzle, and when the plunger is withdrawn further, air will be seen to bubble out of the water. This same demonstration may be repeated with distilled water, or cold water through which CO_2, O_2, N_2, etc., have been bubbled. A slightly more sophisticated demonstration involves water through which CO_2 has been bubbled for about five minutes. When a small amount of bromothymol blue is added, the solution will be yellow. Add this to a sealed syringe, and as the plunger is withdrawn, CO_2 will bubble out and the color of the solution will change to pale green. If the syringe is shaken, the CO_2 will be redissolved, and the solution will once again be yellow. The experiment may be tried repeatedly.

(ii) A single syringe can also be used to illustrate the effect of pressure on solubility. Attach a short length of rubber tubing to the nozzle, and also attach a clamp or piece of wire to the rubber tube which can be used to close the tube. Fill the syringe half full of water, and fill the remainder of the barrel with CO_2. Shake the syringe vigorously, then hold the tube under water, release the clamp (or loosen the wire), and note the rise in water level in the syringe. Repeat the experiment, but depress the syringe plunger while shaking it. There will be a noticeable difference in the rise of the water level.

(iii) The above experiments have been adapted from Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 35-37.

(iv) Another experiment that can be performed with the sealed syringe involves the relationship between reaction rate and pressure. Fill the syringe partially with vinegar and add sodium bicarbonate. Carbon dioxide will be given off, and this reaction can be speeded up or slowed down and stopped by decreasing or increasing the internal pressure with the plunger, respectively. This experiment is based on Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 6.

B4. Charles' Law: Volume/Temperature Device *

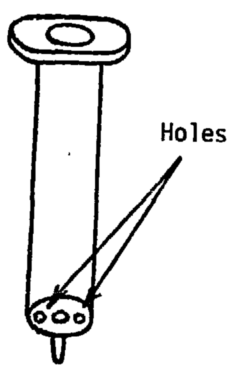


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity 35 ml
	1	Small Eyed Screw (B)	To seal syringe nozzle (B)
(2) Weight	1	Lead Sinker or Weight (C)	Approximately 30 g

b. Construction

(1) Syringe



Make two small holes in the bottom of the syringe barrel (A) with a hand drill or hot wire.

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 32.

Screw a small, eyed screw (B) into the syringe nozzle to seal the nozzle and to provide an attachment for the weight (C).

(2) Weight

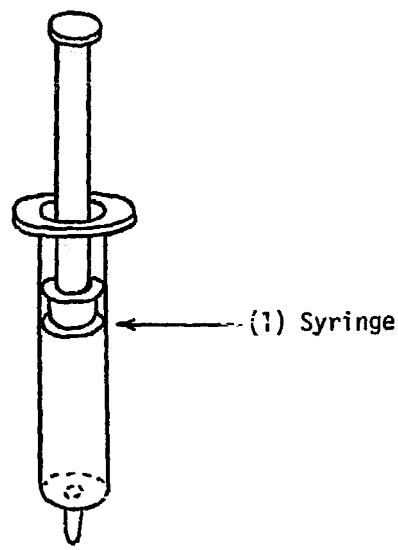
Hang a lead sinker (C) or other suitably sized weight (approximately 30 g) from the eyed screw.

c. Notes

(i) With the plunger set so that a 35 cc volume of air is trapped in the syringe barrel, the device is put into a container of hot water. Water will be seen to enter the syringe barrel as the expanding air leaves it through the small holes (the effect will be more visible if a drop of vegetable dye is placed in the nozzle depression before beginning). Varying amounts of water will enter the syringe depending upon the water temperature. Good quantitative data can be gotten by comparing the water temperature with the amount of water entering the syringe (or the air volume of the syringe after the water enters). The device should be removed from the water to return the air volume to its original reading for each temperature/pressure reading.

C. DIFFUSION APPARATUS

C1. Liquid Diffusion Device



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 50 ml

b. Construction

(1) Syringe

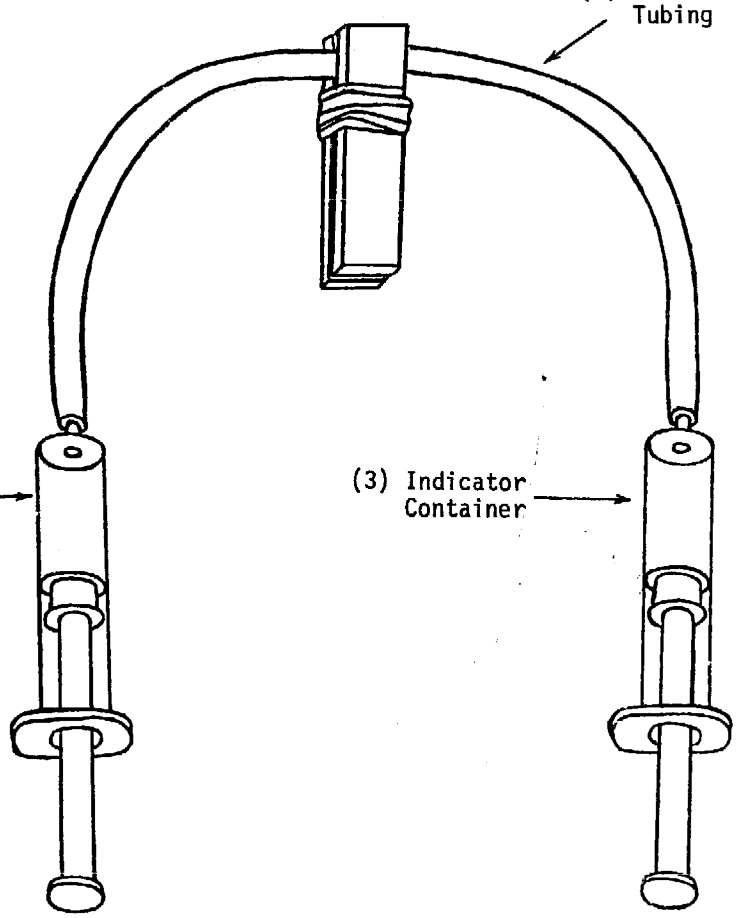
Select a plastic, disposable syringe (A) of a large capacity (35 - 50 ml, for example).

c. Notes

(i) To use this device to study diffusion of liquids, fill the syringe almost completely with cold water. Then, draw a small amount of colored solution into it and let the syringe stand. Diffusion should be complete after two or three days. Colored solutions which work well include potassium permanganate and copper sulphate.

(ii) This experiment has been adopted from Andrew Farmer, "The Disposable Syringe: Additional Experiment," School Science Review, CLXXVIII (1970), 60.

C2. Gas Diffusion Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Gas Container	1	Plastic Disposable Syringe (A)	Capacity approximately 25 ml
(2) Connecting Tubing	1	Rubber or Plastic Tubing (B)	Approximately 15 cm long, diameter to fit syringe nozzles
	1	Pinch Clamp (C)	IV/A4
(3) Indicator Container	1	Plastic Disposable Syringe (D)	Capacity approximately 25 ml
	--	Indicator Solution (E) (Limewater or Litmus Solution)	Approximately 5 ml

*Adapted from Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 35.

b. Construction

(1) Gas Container

Select a plastic, disposable syringe (A) of about 25 ml capacity.

(2) Connecting Tubing

Use a length of flexible tubing (B) to connect the two syringes together. Make a pinch clamp (C) or use another suitable clamp to close the tubing.

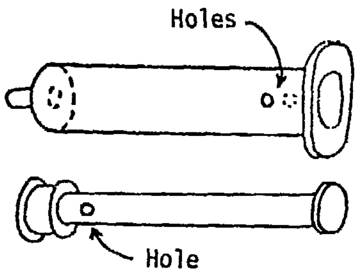
(3) Indicator Container

Select a plastic, disposable syringe (D) with the same capacity as that used for the gas container. Fill it with the indicator solution (E).

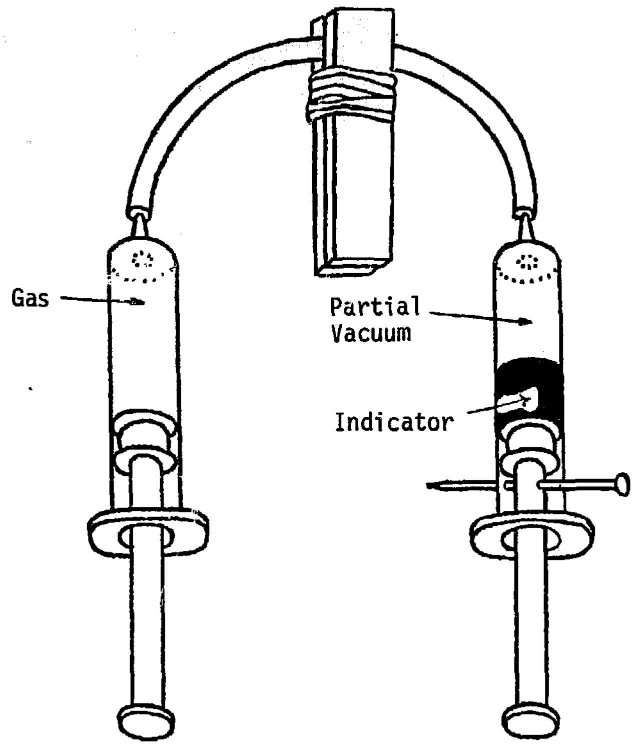
c. Notes

(i) Place an indicator solution (e.g., limewater) in the indicator container. A gas (e.g., CO_2) is collected in the gas container syringe and the two syringes are connected by the tubing. When the clamp is released, the gas will diffuse until it reaches the indicator solution and causes a reaction (white precipitate when CO_2 meets limewater). The time taken for the gas to diffuse may be measured.

(ii) A slight modification of the indicator container will allow a comparison of gas diffusion rates in air and in a partial vacuum. This is done by making two holes opposite each other near the mouth of the syringe barrel with a hand drill or heated nail. Then one hole is made in the plunger, as shown. The holes should be made so that a nail can be pushed through the barrel and plunger.

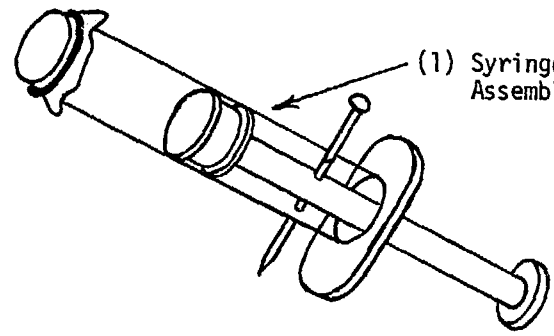


To repeat the above experiment with a partial vacuum, the nail is removed from the indicator syringe and several ml of indicator solution are drawn into the syringe. Then the tubing, closed by the clamp, is attached to the syringe. With the clamp in place the plunger is pulled back, to create a partial vacuum, and the nail is pushed through the syringe barrel and plunger to hold the plunger in position. Gas is collected in the other syringe and allowed to diffuse to the indicator solution, and the time taken is compared to the results of the first experiment.



D. OXIDATION APPARATUS

D1. Oxidation Indicator: Membrane Type *

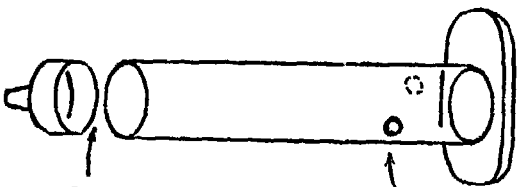


a. Materials Required

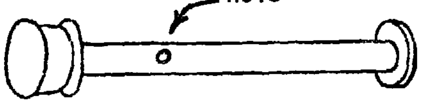
Components	Qu	Items Required	Dimensions
(1) Syringe Assembly	1	Plastic Disposable Syringe (A)	Capacity 25-50 ml
	1	Nail (B)	Approximately 0.2 cm diameter, 4 cm long
(2) Membrane	1	Thin Sheet Rubber (C)	Approximately 5 cm x 5 cm
	1	Rubber Band or Thin Wire (D)	--

b. Construction

(1) Syringe Assembly



Take a medium to large capacity (25 - 50 ml) plastic, disposable syringe (A). Cut off the end of the barrel near the nozzle. Then, with a hand drill or hot nail, make two holes approximately 0.3 cm in diameter opposite each other near the mouth of the barrel.



In the same fashion, make one hole in the stem of the plunger, near the plug, as shown.

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 6.

Insert the plunger into the syringe barrel, and push the nail (B) through the holes in the barrel and plunger to fix the plunger in position.

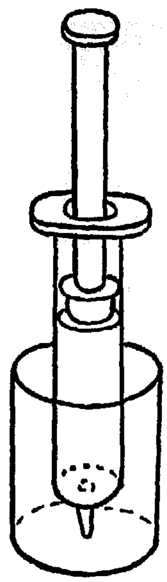
(2) Membrane

Cut a 5 cm x 5 cm square of thin sheet rubber (C) (from a toy balloon, for example). Stretch it over the open end of the syringe barrel and secure it in place with a rubber band (D) or length of thin wire.

c. Notes

(i) This simple device will give a visual indication that oxidation is taking place. For example, if wet steel wool or a piece of cotton soaked in alkaline pyrogallol [Note (i) XII/D4] is inserted into the barrel of the syringe and the plunger fixed in place with the nail, as the material reacts with the oxygen in the air the pressure inside the syringe will gradually be lowered. This can be seen since the rubber sheet will be pulled further and further into the syringe.

D2. Oxidation Indicator: Displacement Type *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 35 ml
(2) Beaker	1	Jar or Beaker (B)	To support syringe

b. Construction

(1) Syringe

Select a plastic, disposable syringe (A) of medium to large capacity (35 - 50 ml). No modifications are necessary.

(2) Beaker

Choose a small glass jar (B), beaker, or other container that will support the syringe, as shown.

c. Notes

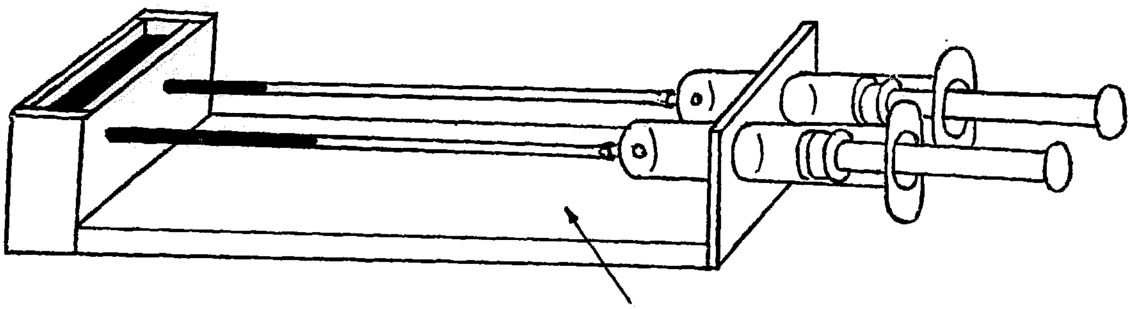
(i) Place a portion of wet steel wool (it may have to be washed in vinegar to remove the anti-rust coating) in the syringe barrel and position the plunger

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 2.

so that some predetermined air volume is trapped in the syringe. Place the syringe into a small amount of water in the beaker so that the nozzle is under water. As the steel wool reacts with the oxygen in the air, pressure inside the syringe will drop and water will be drawn up into the syringe barrel. Dyeing the water with non-fast vegetable dye will make the visual display more evident.

Cotton wool or other absorbent material soaked with alkaline pyrogallol [Note (i) XII/D4] may be substituted for the wet steel wool.

D3. Oxidation Rate Indicator *



(1) Indicator

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Indicator	1	Respirometer	BIOL/VIII/D1(1)

b. Construction

(1) Indicator

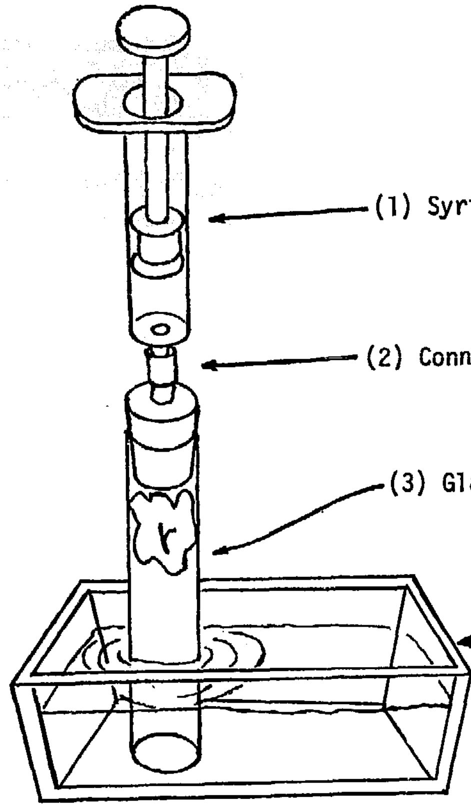
Construct this item according to directions given for the Respirometer, BIOL/VIII/D1(1).

c. Notes

(i) Begin operation of this device by fastening the plastic tubing to the reservoir and to the nozzles of the syringes. Fill the reservoir with water which has been colored with non-fast vegetable dye. Items which react with oxygen in the air, including wet steel wool, white phosphorus, or alkaline pyrogallol (soaked cotton wool), are placed in the barrel of one syringe, where they react, removing oxygen from the trapped air. This results in a lowering of pressure which causes the colored water to be drawn from the reservoir into the clear tubing. The second syringe serves as a control, containing only air. The rate of the reaction can be judged from the speed with which the water column moves toward the syringe.

*Adapted from Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 11.

D4. Stoichiometry Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Capacity 10 ml or more
(2) Connecting Tube	1	Rubber or Plastic Tubing (B)	To fit syringe
	1	Glass Tubing (C)	0.5 cm diameter, 2 cm long
(3) Glass Tube	1	Glass Tubing (D)	2-3 cm diameter, 10 cm long
	1	1-Hole Stopper (E)	To fit large tubing
	--	Cotton (Cotton Wool) (F)	--
(4) Water Container	1	Pan or Tray (G)	Capacity approximately 1 liter

*From Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 19.

b. Construction

(1) Syringe

Select as many plastic, disposable syringes (A) of the same capacity (approximately 10 ml) as desired.

(2) Connecting Tubing

Connect the short rubber or plastic tubing (B) to the syringe nozzle. Connect the free end of the rubber or plastic tube to the short piece of glass tubing (C).

(3) Glass Tubing

Seal one end of a large diameter glass tube (D) with a one-hole stopper (E) and insert the glass tube (C) into the hole in the stopper.

Push a small wad of cotton (F) (cotton wool) into position near the top of the glass tube, below the stopper.

(4) Water Container

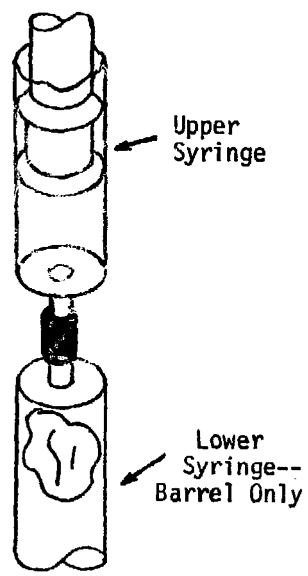
For the water container, use a pan, tray, jar, or beaker (G) into which the desired number of syringe assemblies can be filled.

c. Notes

(i) An alkaline pyrogallol solution must be prepared for use with this apparatus. Put 10 g powdered pyrogallol [1, 2, 3 -- trihydroxybenzene, $C_6H_3(OH)_3$] and 2 g sodium hydroxide (NaOH) pellets into a small flask or test tube. Add about 30 ml H_2O. Tightly cap the container and shake it until all the solid dissolves. Avoid stirring the container to introduce air, as the alkaline solution will rapidly absorb oxygen and become useless for the experiment.

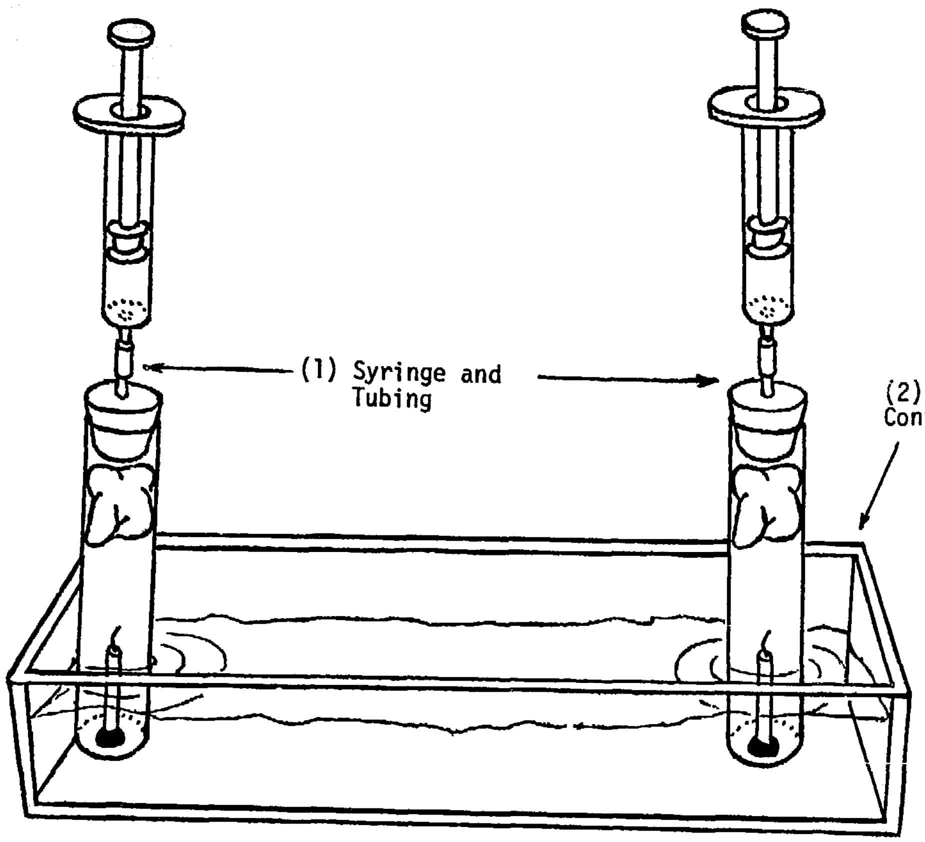
(ii) For experimentation in stoichiometry, several of these syringe assemblies need to be set up. Each should have an identical amount of the pyrogallol solution (or other reducing agent) in the syringe. Place all the devices open end down in the water container. Inject varying amounts of the pyrogallol (for example, 0.5, 1, 1.5 ... 10 ml) into the glass tube where it will be absorbed in the cotton. The pyrogallol will then react with the oxygen in the air in the tube, and continue to react until either the pyrogallol or oxygen is consumed. As oxygen is removed from the air, pressure in the tube will fall, and water will be drawn up into it from the trough. The height of the water in the tube then becomes a measure of the amount of oxygen consumed, and will be seen to be proportional to the amount of pyrogallol used, until the upper limit is reached.

(iii) If glass tubes are not available, syringe barrels may be substituted. A short piece of plastic or rubber tubing is used to connect the upper syringe and lower syringe barrel, which is used in an inverted position.



E. ANALYTICAL APPARATUS

El. Air Composition Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe and Tubing	2	Stoichiometry Device (A)	XII/D4, Components (1), (2), and (3)
(2) Water Container	1	Pan or Tray (B)	Approximately 1 liter
	--	Limewater (C)	--
	2	Modeling Clay (D) (Plasticine)	Small wads
	2	Candles (E)	Approximately 0.5 cm diameter, 5 cm long

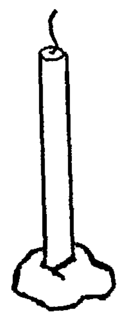
*From Paul D. Merrick, Experiments with Plastic Syringes, (San Leandro, California: Educational Science Consultants, 1968), p 20.

b. Construction

(1) Syringe and Tubing

Prepare two syringe and tubing (A) assemblies, as described for the Stoichiometry Device (XII/D4).

(2) Water Container



Support each candle (E) in a small wad of modeling clay (D), about 5 - 10 cm apart on the bottom of the pan or tray (B). The clay wad must be smaller than the diameter of the glass tube used.

Pour sufficient limewater (C) into the pan or tray to cover the wad of clay and 1 cm or so of the candles.

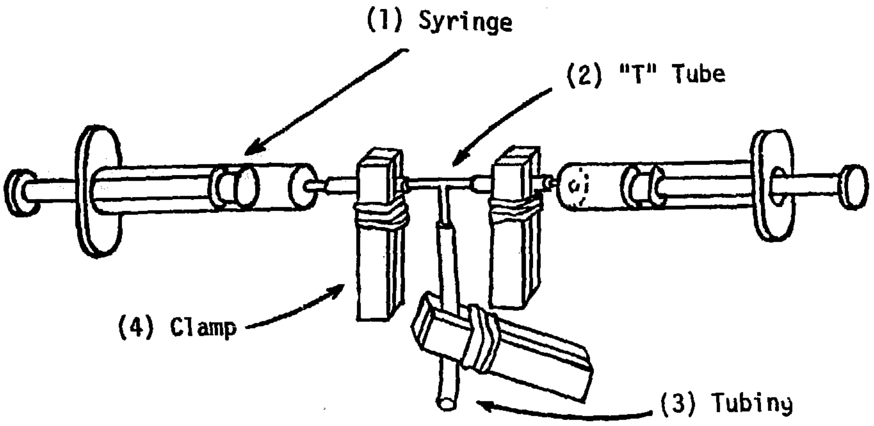
c. Notes

(i) To investigate the proportion of oxygen in the air, an alkaline pyrogallol solution, prepared according to instructions in XII/D4, is required. Each syringe should contain an equal amount of the pyrogallol solution (5 ml, for example).

(ii) When the syringe assemblies, with alkaline pyrogallol solution in each syringe, and the candles in the limewater have been prepared, light one candle. After a few seconds, place one of the syringe assemblies over each candle. Allow them to stand for about five minutes after the burning candle goes out to allow the limewater to remove CO_2 from the air in its tube. At this time, limewater will have risen into the tube to compensate for the lost CO_2. Mark this level of limewater with a wax pencil or felt-tipped marker.

Using a syringe pump (see XII/A2), remove air from the other tube until the limewater rises to the same level in the second tube as it had in the first. Mark this level, also. Now, inject alkaline pyrogallol from the syringes onto the cotton wads. This will react with the oxygen in the air, and remove all of it if enough pyrogallol is used. The water level in each tube will have risen. The amount of rise in the first tube (the one containing the candle) will be compared to the amount of rise in the second tube. Also, the change in trapped air volume in both tubes should be noticed. By doing this, it will be found from the first tube that the burning candle removes only about 25% of the oxygen in the air, while the change in volume in the second tube will show that air is about 21% oxygen.

E2. Gas Reaction Chamber *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	2	Plastic Disposable Syringe (A)	Capacity 50 ml
(2) "T" Tube	1	Glass "T" Tube (B)	Approximately 0.5 dm diameter
(3) Tubing	3	Rubber Tubing (C)	To fit syringe nozzle, approximately 8 cm long
(4) Clamp	3	Pinch Clamp (D)	IV/A4

b. Construction

(1) Syringe

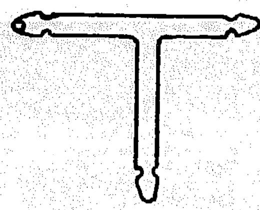
Select two 50 ml plastic, disposable syringes (A). Secure the syringes in a horizontal position by appropriate supports.

(2) "T" Tube

Use a glass or metal "T" tube (B) with three outlets. If available, a three-way valve (stopcock) may be substituted for the clamps and "T" tube.

*Adapted from Nuffield O-Level Chemistry, Collected Experiments, (London: Longmans/ Penguin Books, 1967), p 237.

(3) Tubing



Connect the two syringes to the "T" tube with two short pieces of rubber tubing (C). Use a third piece of tubing (C) to connect the apparatus to a source of gas.

(4) Clamp

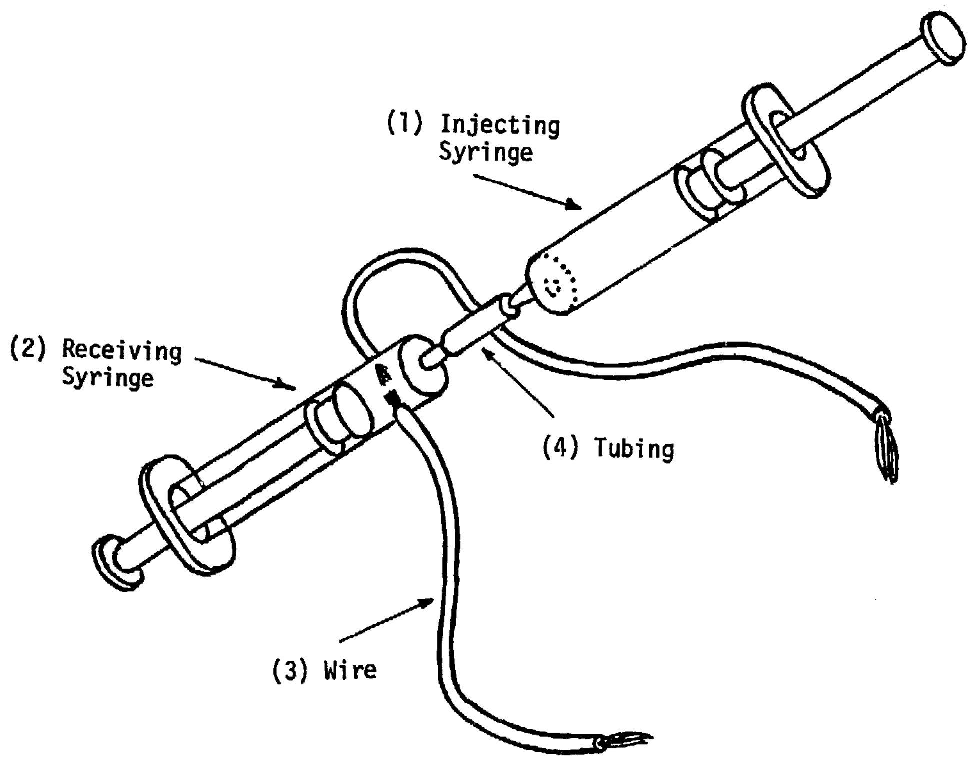
Use three pinch clamps (D) or other suitable clamps to close each section of tubing.

c. Notes

(i) To determine the number of gram-molecules of hydrogen chloride that react with one gram-molecule of ammonia, set up the apparatus as shown in the main illustration. Using the correct combination of open and closed clamps, fill one syringe with dry ammonia gas, empty it, and repeat one or two more times to "flush" the syringe. Follow the same procedure with the other syringe using dry hydrogen chloride. Then, fill the first syringe with 40 cc of the dry ammonia and fill the second with 50 cc of the dry hydrogen chloride. With the two syringes open to each other but closed to the atmosphere, inject the hydrogen chloride into the syringe of ammonia. The two gases will react, forming ammonium chloride. That about 10 cc of hydrogen chloride remains unreacted is shown by passing the gas over damp indicator paper. Thus, 40 cc of ammonia reacts with 40 cc of hydrogen chloride.

F. CONDUCTANCE APPARATUS

F1. Conductance Device *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Injecting Syringe	1	Plastic Disposable Syringe (A)	Capacity approximately 35 ml
(2) Receiving Syringe	1	Plastic Disposable Syringe (B)	Capacity approximately 35 ml
(3) Wire	2	Insulated Wire (C)	Approximately 0.3 cm diameter, 50 cm long
(4) Tubing	1	Plastic or Rubber Tubing (D)	To fit syringe nozzles, 2 cm long

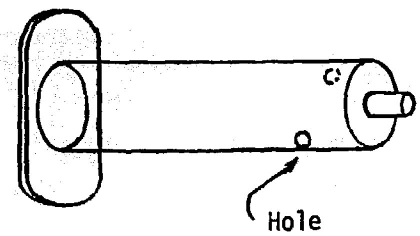
b. Construction

(1) Injecting Syringe

Use a 35 ml plastic, disposable syringe (A), with no modifications, for this component.

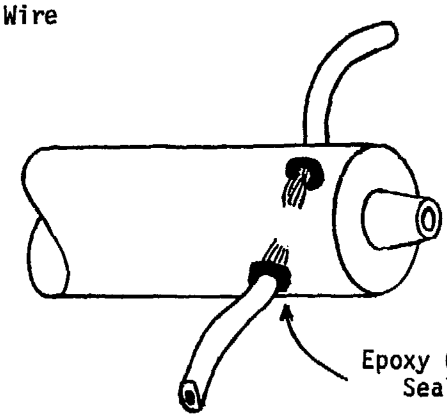
*Adapted from Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 32-34.

(2) Receiving Syringe



Take a 35 ml plastic, disposable syringe (B) and with a hand drill or hot wire make two holes, approximately 0.2 cm in diameter, opposite each other near the base of the barrel.

(3) Wire



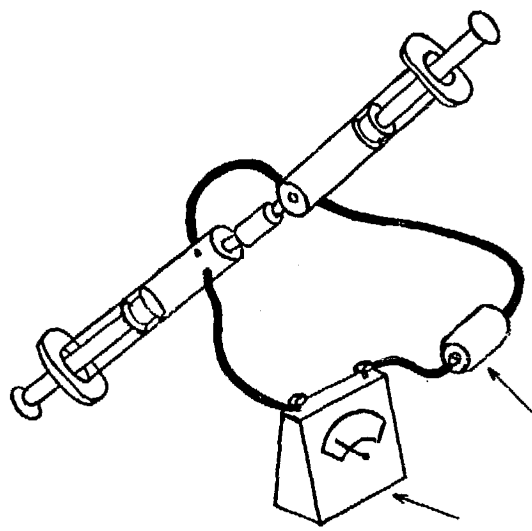
Remove about 1.0 cm of insulation from each end of both wires (C). Insert one bare end of each wire through the holes in the syringe barrel (B). Seal the holes with epoxy glue, taking care to see that no epoxy covers the bare wire inside the syringe barrel.

(4) Tubing

Connect the two syringes together with a short piece of plastic or rubber tubing (D).

c. Notes

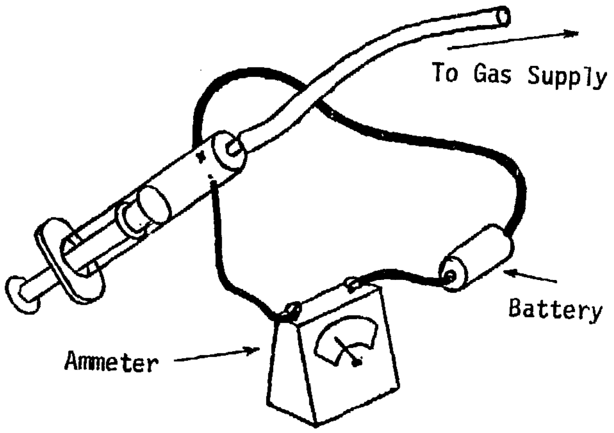
(i) This apparatus may be used to investigate the variation of conductance as two solutions are mixed. The wires are connected in series to a 1.5 volt cell and an ammeter as shown. One liquid is placed in the receiving syringe, another in the injecting syringe, and the current is measured on the ammeter. Then the solution in the injecting syringe is gradually fed into the receiving syringe, and any changes in the current are noted. Conductance, the reciprocal of resistance, may be calculated from the



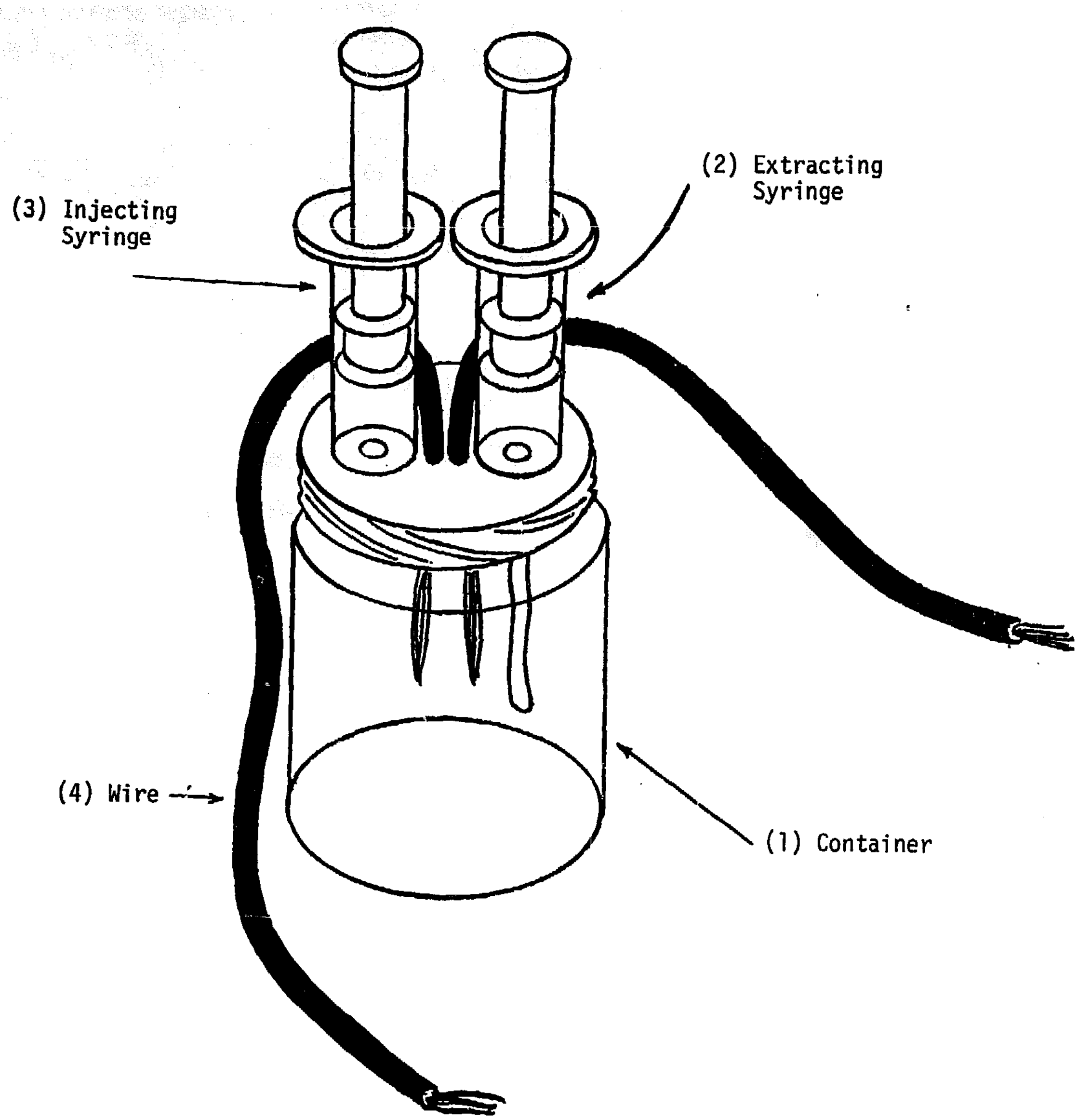
current and voltage: $R = \frac{E}{I}$ $\quad$ $mhos = \frac{1}{R}$

(ii) Solutions which may be tested in this apparatus include water in the receiving syringe and salt solution or HCl solution in the injecting syringe; dilute H_2SO_4 in the receiving syringe and $Ba(OH)_2$ solution in the injecting syringe; and dilute HCl in the receiving syringe with NaOH in the injecting syringe.

(iii) This device, with one modification, may also be used to investigate the variation of conductance as a gas is bubbled into a solution. The injecting syringe is removed and replaced with a section of plastic or rubber tubing that connects the remaining syringe to a gas source. For example, the syringe is filled with a limewater solution, and the current is noted on the ammeter. Then CO_2 is passed through the limewater, and the change in current as well as the change in color of the solution can be seen. Phenolphthalein can also be added to the limewater initially, and the color change from red to clear will indicate the neutralization has occurred.



F2. Constant Volume Conductance Device



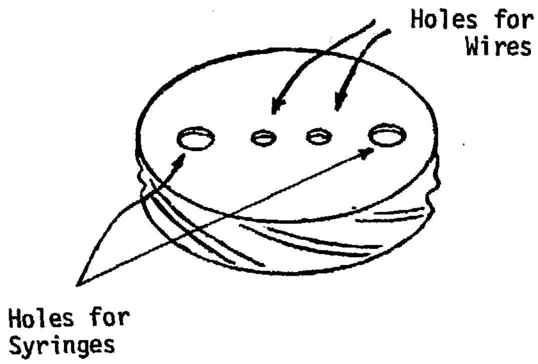
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Jar with Lid (A)	Capacity approximately 200-250 ml
(2) Extracting Syringe	1	Plastic Disposable Syringe (B)	Capacity approximately 20 ml
	1	Rubber or Plastic Tubing (C)	Diameter to fit syringe nozzle; length, about 1 cm shorter than jar height

(3) Injecting Syringe	1	Plastic Disposable Syringe (D)	Capacity approximately 20 ml
(4) Wire	2	Insulated Wire (E)	Diameter 0.3 cm, 50 cm long

b. Construction

(1) Container



Puncture four holes in the jar lid (A). Make the two outside holes about 0.5 cm in diameter to accommodate the syringe (B,D) nozzles. Make the two inner holes about 1 - 2 cm apart and 0.4 cm in diameter, to accommodate the insulated wire (E).

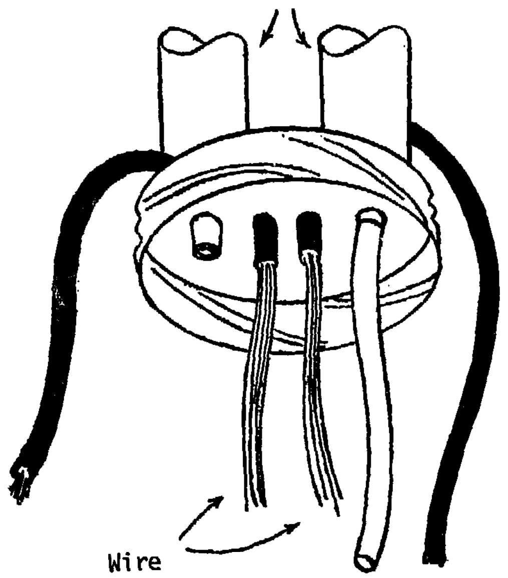
(2) Extracting Syringe

Push the nozzle of a plastic, disposable syringe (B) through one of the outer holes in the jar lid. Attach the rubber or plastic tubing (C) to the syringe nozzle from the inside of the lid.

(3) Injecting Syringe

Push the nozzle of a second plastic, disposable syringe (D) through the other outer hole in the jar lid.

(4) Wire



Strip 5 - 7 cm of insulation from one end of each wire (E). Push each stripped end of wire through the inner holes in the jar lid, from the outside of the lid. Allow about 8 - 9 cm of each wire to extend from the inside of the lid.

c. Notes

(i) In order to use this apparatus to investigate variations in the conductance of a solution as its composition (but not its volume) is changed, the wires from the container must be connected, in series, to a 1.5 volt battery and an ammeter. [See diagram, Note (i), XII/F1.] A solution, such as water, is placed in the container. A second solution (concentrated salt solution, for example) is placed in the injecting syringe and the lid placed on the jar. Current is measured; then a measured amount of solution from the injecting syringe is added to the container, the solution mixed well, and volume of solution equal to that added to the container is withdrawn with the extracting syringe so that the electrode depth is unchanged. Current is again measured, and conductance calculated as described in Note (i), XII/F1.

(ii) This equipment is adopted from Andrew Farmer, "The Disposable Syringe--A Rival to the Test Tube?," School Science Review, CLXXIV (1969), 34-35.

BIBLIOGRAPHY

A number of texts have proved to be extremely valuable references to the Inexpensive Science Teaching Equipment Project, and these are listed below.

American Peace Corps, Science Teachers' Handbook, (Hyderabad, India: American Peace Corps, 1968).

This handbook contains many ideas for improvising science teaching equipment.

Association for Science Education, The School Science Review, (London: John Murray).

A quarterly journal containing articles on science experiments and equipment in all the sciences at all school levels.

Association for Science Education, The Science Master's Book, Part 2 (Chemistry) Series 1-4, (London: John Murray).

These materials, selected from The School Science Review, describe apparatus and experiments for a wide range of chemistry activities.

Coulson, E. H.; A. E. J. Trinder, and Aaron E. Klein, Test Tubes and Beakers: Chemistry for Young Experimenters, (Garden City, New York: Doubleday and Company, Inc., 1971).

This book describes simple apparatus and experiments for youngsters in a home laboratory.

Bowker, M. K., and A. R. D. Hunt, Making Elementary Science Apparatus, a Handbook for Teachers in Tropical Areas, (London: Thomas Nelson and Sons, Ltd., 1968).

This book outlines instructions for construction and use of inexpensive, elementary science apparatus.

The Portland Project Committee, Teacher Guide, Chemistry of Living Matter, Energy Capture, and Growth, (Portland, Oregon, U.S.A.: The Portland Project Committee, 1971).

This guide is one of a three-year sequence integrating biology, chemistry, and physics into one secondary science program. Student guides are also available.

Richardson, John S., and G. P. Cahoon, Methods and Materials for Teaching General and Physical Science, (New York, Toronto, and London: McGraw-Hill Book Company, Inc., 1951).

This guide describes investigations and laboratory techniques for secondary level physics and chemistry.

United Nations Educational, Scientific, and Cultural Organization, UNESCO Source Book for Science Teaching, (Paris: UNESCO, 1962).

This book, recently revised, contains many simple ideas for teaching science at a relatively elementary level.

In addition to the above texts, the materials from a large number of projects in the files of the International Clearinghouse on Science and Mathematics Curricular Developments at the University of Maryland have also been particularly valuable. Further details of these projects may be found in:

The Seventh Report of the International Clearinghouse on Science and Mathematics Curricular Developments, 1970. (College Park, Maryland, U.S.A.: University of Maryland, 1970).

This is a source of information on curriculum projects throughout the world, and indicates materials available, project directors, publishers, etc. The Eighth Report will be available in late 1972.

GUIDEBOOK TO CONSTRUCTING INEXPENSIVE SCIENCE TEACHING EQUIPMENT

Volume III: Physics

Inexpensive Science Teaching Equipment Project
Science Teaching Center
University of Maryland, College Park
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U.S.A.

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FOREWORD

History

The Inexpensive Science Teaching Equipment Project was initiated by Dr. J. David Lockard, and got underway under his direction in the summer of 1968. Originally entitled the Study of Inexpensive Science Teaching Equipment Worldwide (IS-TEW or IS-2 Study), the Project was to (1) identify laboratory equipment considered essential for student investigations in introductory biology, chemistry and physics courses in developing countries; (2) improvise, wherever possible, equivalent inexpensive science teaching equipment; and (3) produce designs of this equipment in a Guidebook for use in developing countries. Financial support was provided by the U.S. Agency for International Development through the National Science Foundation.

The initial work of the Project was undertaken by Maria Penny and Mary Harbeck under the guidance of Dr. Lockard. Their major concern was the identification of equipment considered basic to the teaching of the sciences at an introductory level. An international survey was conducted, and a list of equipment to be made was compiled. A start was also made on the writing of guidelines (theoretical designs) for the construction of equipment.

Work on the development of the Guidebook itself got underway in 1970, with the arrival of Reginald F. Melton to coordinate the work. Over 200 guidelines were completed during the year by Donald Urbancic (Biology), Chada Samba Siva Rao and John Delaini (Chemistry), and Reginald Melton (Physics). Full use was made of project materials from around the world which were available in the files of the International Clearinghouse on Science and Mathematics Curricular Developments, which is located in the Science Teaching Center of the University of Maryland. The guidelines were compiled into a draft edition of the Guidebook which was circulated in September, 1971, to some 80 science educators around the world for their comments and advice.

The work of constructing and developing equipment from the guidelines, with the subsequent production of detailed designs, began in a limited way in 1970, the major input at that time being in the field of chemistry by Chada Samba Siva Rao, who was with the project for an intensive two-month period. However, the main work of developing detailed designs from the guidelines was undertaken between 1971 and 1972 by John Delaini (Biology), Ruth Ann Butler (Chemistry) and Reginald Melton (Physics). Technical assistance was given by student helpers, with a special contribution from David Clark, who was with the project for a period of 18 months.

Thanks are due to those graduates, particularly Samuel Genova, Melvin Soboleski and Irven Spear, who undertook the development of specific items of equipment while studying at the Center on an Academic Year Institute program; to student helpers, especially Don Kallgren, Frank Cathell and Theodore Mannekin, who constructed the equipment; and to Dolores Aluise and Gail Kuehnle who typed the manuscripts.

Last, but not least, special acknowledgement is due to those individuals, and organizations, around the world who responded so willingly to the questionnaires in 1968 and to the draft edition of the Guidebook in 1971.

The Guidebook

The designs presented in the Guidebook are based on the premise that many students and teachers in developing countries will wish to make equipment for themselves. This does not mean that students and teachers are expected to produce all their own apparatus requirements. It is recognized that teachers have specific curricula to follow, and that "class hours" available for such work are very limited. It is also recognized that teachers, particularly those in developing countries, are not well paid, and often augment their salaries with supporting jobs, thus placing severe limits on the "out-of-class hours" that are available for apparatus production.

However, in designing equipment for production by students and teachers, two factors have been kept in mind. One, project work in apparatus development can be extremely rewarding for students, bringing both students and teachers into close contact with the realities of science, and relating science and technology in the simplest ways. Two, it is not difficult for cottage (or small scale) industries to adapt these designs to their own requirements. The Guidebook should therefore not only be of value to students and teachers, but also to cottage industries which may well be the major producers of equipment for schools.

Although all the designs in the Guidebook have been tested under laboratory conditions in the University of Maryland, they have not been tested in school situations nor produced and tested under local conditions in developing countries. It is therefore recommended that the designs should be treated primarily as limited resource materials to be subjected to trial and feedback. It is suggested that the first time that an item is constructed it should be made precisely as described in the Guidebook, since variations in the materials, or the dimensions of the materials, could alter the characteristics of the apparatus. However, once this item has been tested the producer is encouraged to make any number of modifications in the design, evaluating the new products against the original.

Before producing new equipment in quantity, it is recommended that educators with experience in the field of science education should be involved in determining how best to make use of the Guidebook. They will wish to relate the apparatus to their own curriculum requirements, and, where necessary, prepare relevant descriptions of experiments which they recommend should be undertaken using the selected apparatus. They will want to subject the experiments and related equipment to trials in school situations. Only then will they consider large-scale production of apparatus from the designs in the Guidebook. At this stage educators will wish to control the quality of apparatus production, to train teachers to make the best use of the new apparatus, and to insure that adequate laboratory conditions are developed to permit full utilization of the apparatus. Too often in the past apparatus has sat unused on many a classroom shelf, simply because the teacher has been untrained in its usage, or the laboratory facilities have been inadequate, or because the apparatus available did not appear to fit the requirements of the existing curriculum. Such factors are best controlled by educators in the field of science education in each country. Clearly the science educator has a crucial role to play.

Apparatus development, like any aspect of curriculum development, should be considered as a never ending process. This Guidebook is not presented as a finished product, but as a part of this continuing process. There is no doubt that the designs in this book could usefully be extended, descriptions of experiments utilizing the apparatus could be added, and the designs themselves could be improved. No extravagant claims are made concerning the Guidebook. It is simply hoped that it will contribute to the continuing process of development.

TOOLS AND RAW MATERIALS

The raw materials required to make specific items of equipment are indicated at the beginning of each item description. However, there are certain tools and materials which are useful in any equipment construction workshop, and these are listed below.

Tools

Chisels, Wood

3, 6, 12, 24 mm
(i.e., 1/8", 1/4", 1/2", 1")

Cutters

Bench Shears: 3 mm (1/8")
Glass Cutter
Knife
Razor Blades
Scissors: 200 mm (8")
Snips (Tinmans), Straight: 200 mm (8")
Snips (Tinmans), Curved: 200 mm (*")
Taps and Dies: 3 to 12 mm (1/8" to 1/2") set

Drills and Borers

Cork Borer Set
Countersink, 90^{o}
Metal Drill Holder (Electrically Driven), Capacity 6 mm (1/4")
Metal Drills: 0.5, 1, 2, 3, 4, 5, 6, 7 mm
(i.e., 1/32", 1/16", 3/32", 1/8", 5/32", 3/16", 7/32", 1/4") set
Wood Brace with Ratchet: 250 mm (10")
Wood Augur, Bits: 6, 12, 18, 24 mm
(i.e., 1/4", 1/2", 3/4", 1")

Files, Double Cut

Flat: 100 mm, 200 mm (4", 8")
Round: 100 mm, 200 mm (4", *")
Triangular: 100 mm (4")

Hammers

Ball Pein: 125, 250, (1/4, 1/2 lb)
Claw 250 g (1/2 lb)

Measuring Aids

Caliper, Inside
Caliper, Outside
Caliper, Vernier (may replace above two items)
Dividers: 150 mm (6"), Toolmakers
Meter, Electrical (Multipurpose - volts, ohms, amps, etc.)
Meter Stick
Protractor
Scriber

Measuring Aids (Continued)

Set Square
Square, Carpenter's: 300 mm (12") blade
Spoke Shave: 18 mm (3/4")
Wood Smoothing Plane

Pliers

Combination: 150 mm(6")
Needle Nose: 150 mm (6")
Side Cutting: 150 mm (6")
Vise Grips

Saws, Metal

300 mm (.2") blades

Saws, Wood

Back Saw: 200, 300 mm (8", 12")
Coping Saw: 200 mm (8")
Cross Cut: 600 mm (24")
Hand Rip: 600 mm (24")
Key Hole Saw: 200 mm (8")

Screw Drivers

100 mm (4"), with 2 and 3 mm tips
150 mm (6"), with 5 mm tip
200 mm (8"), with 7 mm tip

Vises

Metal Bench Vise: 75 mm (3")
Wood Bench Vise: 150 mm (6")

Miscellaneous

Asbestos Pads
Goggles, Glass
Oil Can: 1/2 liter (1 pint)
Oil Stone, Double Faced
Punch, Center
Sandpaper and Carborundum Paper, Assorted grades
Soldering Iron: 60 watts, 100 watts

Raw Materials

Adhesives

All Purpose Cement (Elmers, Duco)
Epoxy Resin & Hardener (Araldite)
Rubber Cement (Rugy)
Wood Glue (Weldwood)
Cellophane Tape
Plastic Tape
Masking Tape

Electrical Materials

Bulbs with Holders: 1.2, 2.5, 6.2 volts
Dry Cells: 1.5, 6 volts
Electrical Wire: Cotton or Plastic covered
Fuse Wire: Assorted
Lamps: 50, 75, 100 watts
*Magnet Wire: #20, 22, 24, 26, 28, 30, 32, 34
Nichrome Wire: Assorted
Parallel Electrical Cording
Plugs
Switches

Glass and Plastic

Acrylic (Plastic) Sheets: 2 cm and 2.5 cm thick
Plates, Glass
Tubes, Glass: 3, 6 mm (1/8", 1/4") internal diameter

Hardware

Bolts and Nuts, Brass or Steel; 3 mm (1/8") diameter: 12, 24, 48 mm (1/2", 1", 2") lengths
Nails: 12, 24 mm (1/2", 1") lengths
Screws, Eye
Screws, Wood: 12, 18, 24, 26 mm (1/2", 3/4", 1", 1 1/2") lengths
Thumbtacks
Washers (Brass and Steel): 6, 9 mm (1/4", 5/16") diameter
Wingnuts (Steel): 5 mm (3/16")

Lumber

Boxwood (Packing Case Material)
Hardboard: 6 mm (1/4") thick
Kiln Dried Wood: 2.5 x 15 cm (1" x 6") cross section
1.2 x 15 cm (1/2" x 6") cross section
Plywood: 6, 12 mm (1/4", 1/2") thickness
Wood Dowels: 6, 12 mm (1/4", 1/2") thickness

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* U. S. Standard Plate numbers are used in this book to indicate the gauge of different wires. Where wires are referenced against other numbering systems appropriate corrections should be made in determining the gauges of materials required. The following comparison of gauges may be of interest:

Standard	Diameter of #20 Wire
Brown & Sharp	0.08118
Birmingham or Stubs	0.089
Washburn & Moen	0.0884
Imperial or British Standard	0.0914
Stubs' Steel	0.409
U. S. Standard Plate	0.09525

Metal Sheets

Aluminum: 0.2, 0.4 mm (1/100", 1/64") thickness.
Brass: 0.4, 0.8 mm (1/64", 1/32") thickness.
Galvanized Iron: 0.4 mm (1/64") thickness.
Lead: 0.1 mm (1/250") thickness.
Spring Steel, Packing Case Bands

Metal Tubes:

Aluminum, Brass, Copper: 6, 12 mm (1/4", 1/2") internal diameter.

Metal Wires

Aluminum: 3 mm (1/8") diameter
Coathanger: 2 mm (1/16") diameter
*Copper: #20, 24
Galvanized Iron: 2 mm (1/16") diameter
*Steel: #20, 26, 30.

Paint Materials

Paint Brushes
Paint Thinner
Varnish
Wood Filler

Miscellaneous

Aluminum Foil
Cardboard Sheeting
Containers (Plastic or Glass)
Corks (Rubber or Cork)
Grease
Hinges: Assorted
Machine Oil
Marbles
Mesh (Cotton, Nylon, Wire)
Modelling Clay (Plasticene)
Paper Clips
Pens: Felt (Marking Pens)
Pins and Needles
Rubber Bands
Soldering Lead
Soldering Paste
Spools
Steel Wool
Straws
String (Cord, Cotton, Nylon)
Styrofoam
Syringes: Assorted
Wax (Paraffin)

*See footnote on previous page.

I. BALANCES

The balances presented have been divided into three categories:

A. ELEMENTARY BALANCES

These are relatively crude, but extremely easy to make, even for elementary students, and serve as an excellent introduction to an understanding of balances.

B. EXPERIMENTAL BALANCES

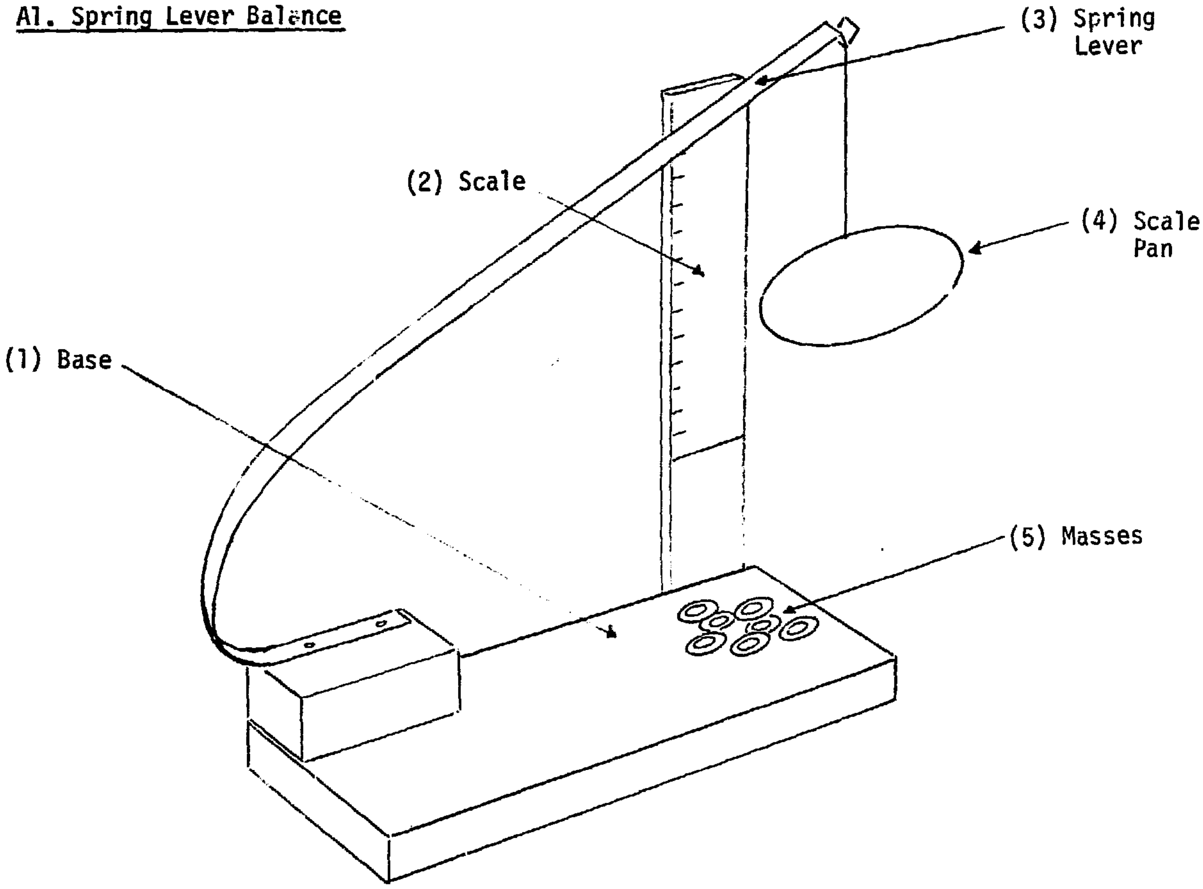
These are somewhat more exact and are useful for undertaking investigations into the properties of balance.

C. FUNCTIONAL BALANCES

These are relatively sophisticated and designed primarily for functional usage.

A. ELEMENTARY BALANCES

A1. Spring Lever Balance



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	13 cm x 6 cm x 1.5 cm
	1	Wood (B)	5 cm x 2.5 cm x 2.5 cm
(2) Scale	1	Wooden Strip (C)	20 cm x 2 cm x 0.5 cm
	1	White Paper (D)	15 cm x 2 cm
(3) Spring Lever	1	Packing Case Steel Band (E)	30 cm x 1.2 cm x 0.02 cm
(4) Scale Pan	1	Galvanized Iron Wire (F)	50 cm length, #24
	1	Aluminum Sheet (G)	5.5 cm x 5.5 cm x 0.02 cm approximately
(5) Masses	--	Washers (H)	--

b. Construction

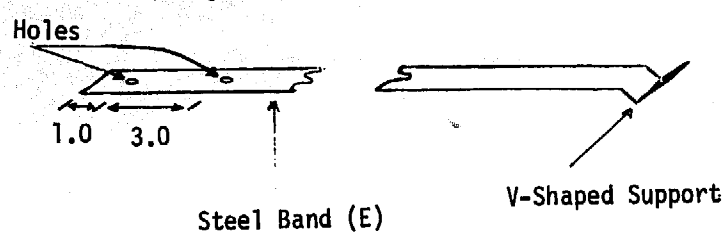
(1) Base

Attach wood (B) to one corner of wood (A) to support the spring lever above the base.

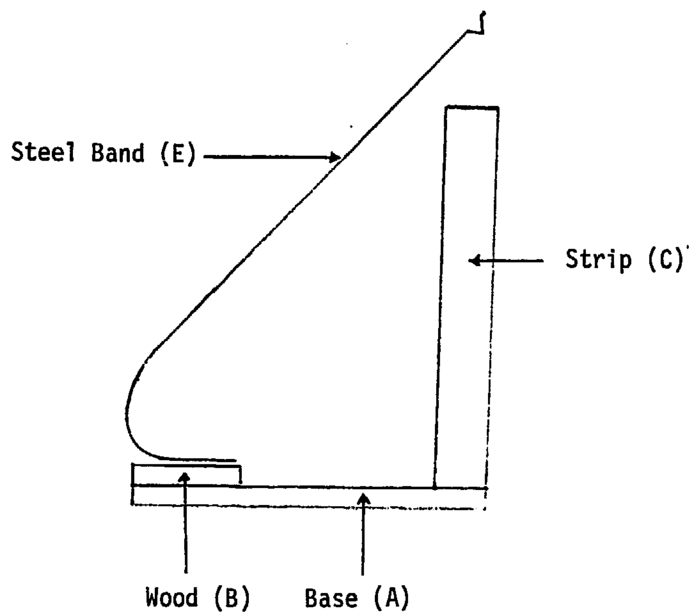
(2) Scale

Attach strip (C) vertically to the adjacent corner of the base. Glue a strip of white paper (D) to the top front surface of strip (C) to serve as a scale.

(3) Spring Lever

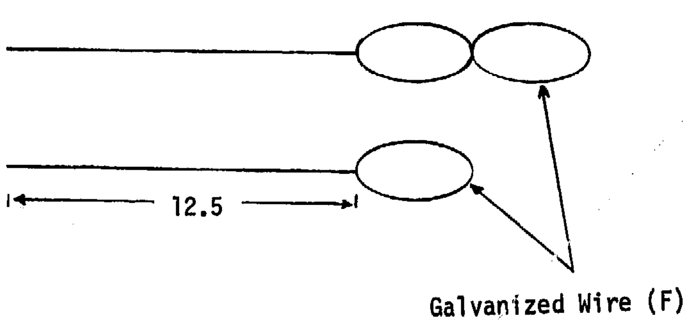


Take packing case steel band (E) and make a small V-shape at one end to hold the scale pan support wire. Drill two holes in the other end to take two small nails.

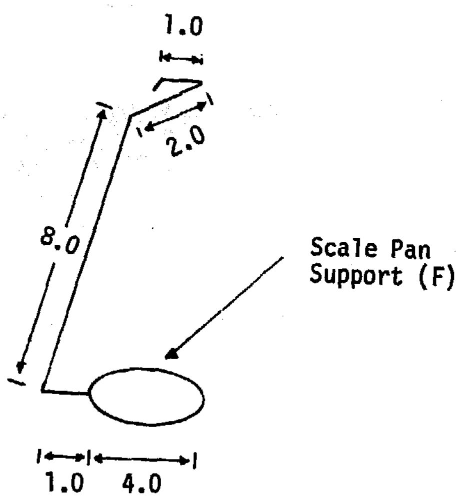


Attach the drilled end of band (E) to the top of block (B) on the base with two small nails. Bend the band smoothly over to form an elongated C-shape as indicated.

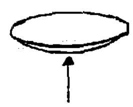
(4) Scale Pan



Take the galvanized iron wire (F) and make it into a double strand 25 cm long. Use half of the new length to form a "figure 8" in the wire.



Fold one loop on top of the other, and then bend the remaining straight portion of the wire to the shape indicated. You now have a scale pan support which may be attached to the spring lever.


Pan (G)

Make the pan itself from the aluminum sheet (G). Hammer it at the center to create a saucer shaped pan. Sit the pan on the loop of the scale pan support.

(5) Masses

Such items as nails, washers and paper clips may be used for masses.

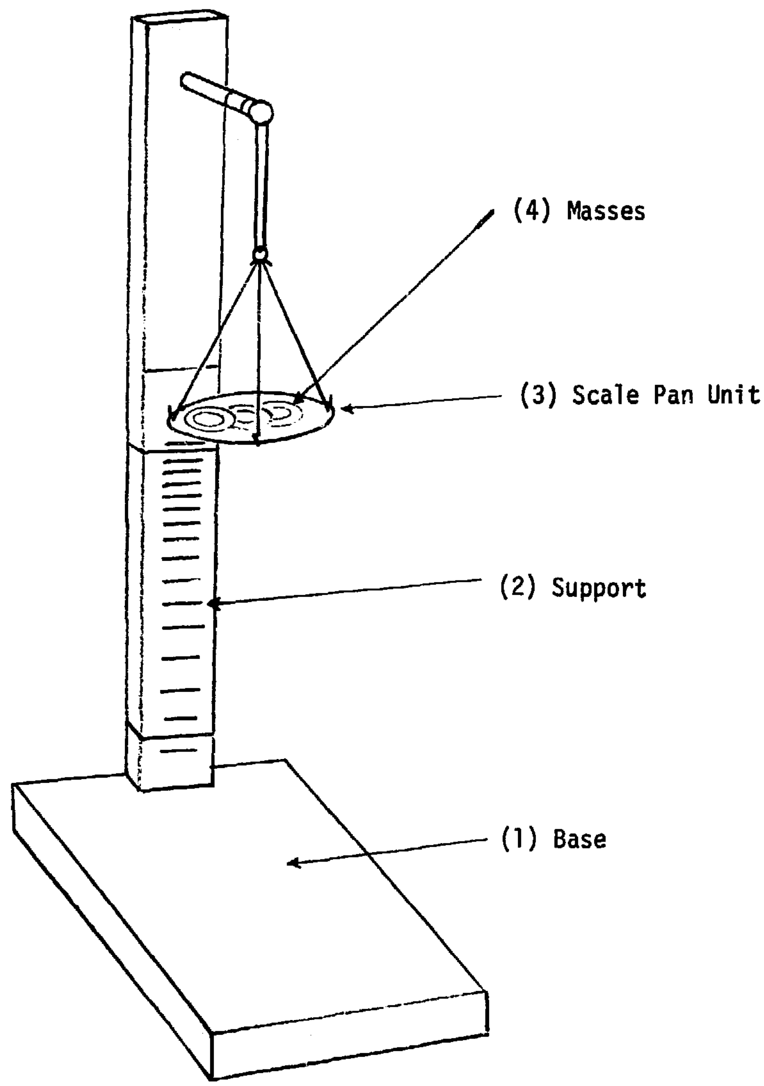
c. Notes

(i) Note the point of intersection between the spring lever and the left side of the scale, and record the position with a temporary zero mark. Determine the elastic limit of the spring lever by adding successively larger masses to the scale pan, and noting on each occasion whether the spring returned to the same zero point on removing the masses from the pan. In this particular case it was noted that the elastic limit was reached with a mass of 33 g.

(ii) Note the new zero point on the scale with a permanent mark. This will be slightly below the temporary mark due to the spring being subjected to a force which extended it slightly beyond its elastic limit. Now add masses 1 g at a time calibrating the scale accordingly up to 20 g.

(iii) A more sensitive balance, weighing from 0 to 10 g, may be made in an identical fashion by using half the width of packing case band as the spring lever. Such a balance made here was found to have an elastic limit of 27 g, and was readily calibrated as described above.

A2. Rubber Band Balance



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	15 cm x 10 cm x 1.5 cm
(2) Support	1	Wood Strip (B)	45 cm x 4 cm x 2 cm
	2	Screws (C)	2.5 cm long
	1	White Paper (D)	30 cm x 4 cm
	2	Rubber Bands (E)	--

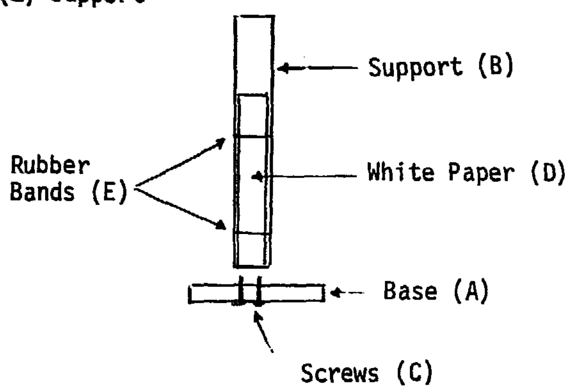
(3) Scale Pan Unit	1	Nail (F)	7 cm long approximately
	1	Rubber Band (G)	--
	1	Galvanized Wire (H)	#20, 3 cm long
	1	Aluminum Sheet (I)	6 cm x 6 cm x 0.02 cm
	3	Wire (J)	#24, 9 cm long
	1	Adhesive Tape (K)	10 cm x 1 cm
(4) Masses	--	Washers	--

b. Construction

(1) Base

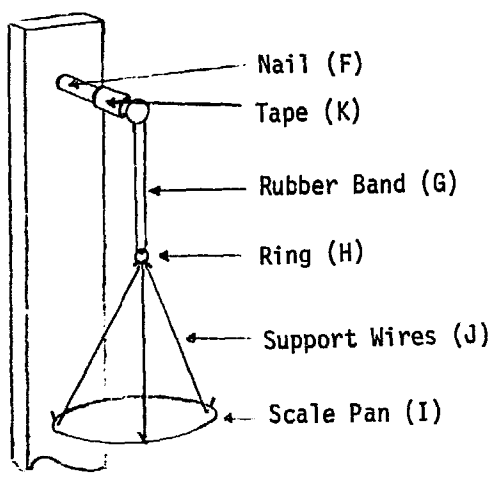
Use wood (A) to serve as the base.

(2) Support



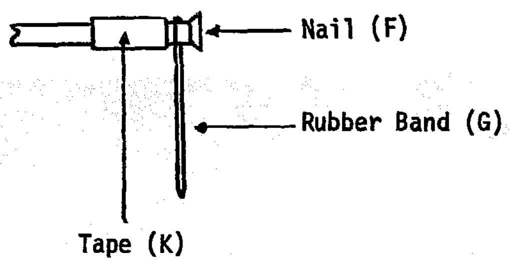
Attach wood strip (B) vertically to the base with two screws (C). Attach the plain white paper (D) to the front of the vertical support (B) with rubber bands (E).

(3) Scale Pan Unit



Drive nail (F) horizontally into top of the vertical support, and suspend a rubber band (G) from its end. Take the galvanized wire (H) and bend it into the shape of a ring which can be suspended from the rubber band.

Hammer the aluminum sheet (I) at its center so as to create a saucer shape, thus producing a reasonable scale pan. Use a hammer and nail to produce three small holes near the perimeter of the pan. Suspend the pan from the ring by means of the three lengths of wire (J) bent over at both ends to form suitable hooks.



To prevent the rubber band sliding backwards and forwards on the supporting nail a length of adhesive tape (K) should be wrapped around the nail so as to leave a groove between the tape and the end of the nail, the rubber band being held in position in the groove.

(4) Masses

Such items as nails, washers and paper clips may be used as masses.

c. Notes

(i) Note the point on the scale corresponding to the position of the unloaded scale pan. Determine the elastic limit of the rubber band by loading the scale pan with increasing masses, noting in each instance whether the unloaded pan returns to the same zero point on the scale. For the particular band used in this instance the elastic limit was reached with a mass of 235 g.

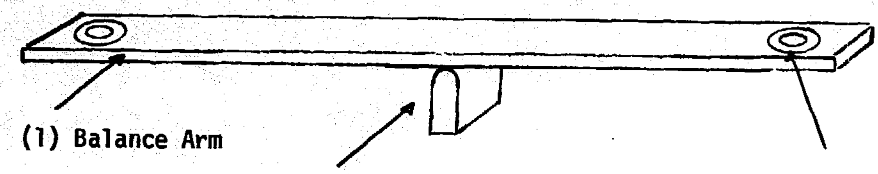
(ii) Check the zero position on the scale once more, making a permanent mark opposite the scale pan, then calibrate the scale by adding successive weights to the pan, keeping well within the elastic limits of the band.

(iii) A nonuniform scale will result.

(iv) The rubber band will deteriorate with time, and this will be particularly rapid in tropical countries. However, the band can easily be replaced and the scale recalibrated so long as the teacher has a suitable set of weights available.

(v) If the scale pan is suspended from two parallel elastic bands, instead of one, the range and the elastic limit will be increased. With two bands the elastic limit increased in this particular case to 550 g. However, it was noted that if masses of less than 500 g were left on the pan for any period of time there was still a tendency for the rubber band to be plastically deformed.

A3. Simple Beam Balance



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Balance Arm	1	Meter Ruler (A)	100 cm long
(2) Pivot	1	Wood (B)	4 cm x 4 cm x 2 cm
(3) Masses	--	Washers (D)	--

b. Construction

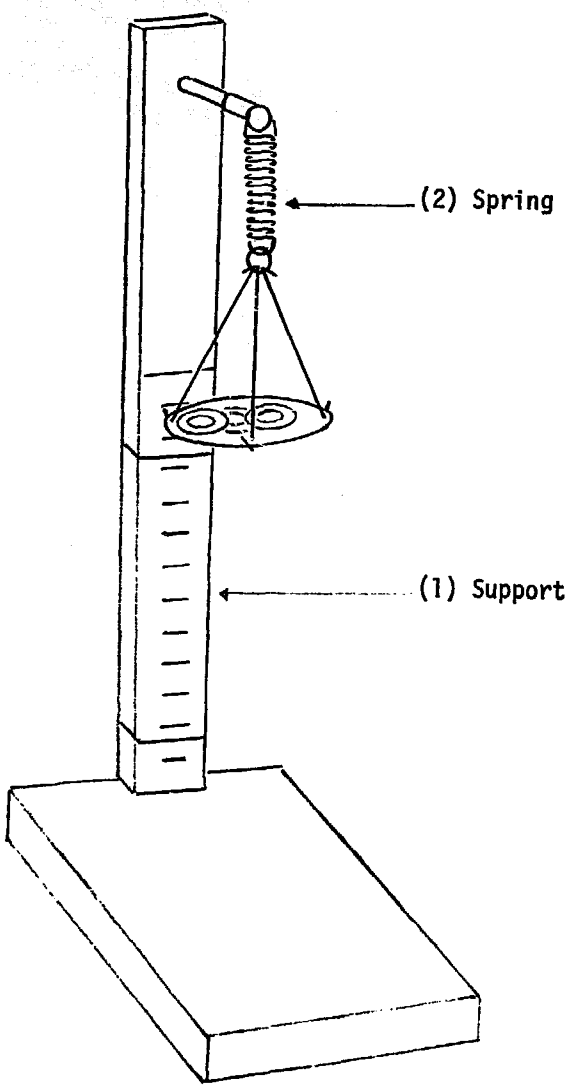
(1) Balance Arm — Use the meter ruler (A) as a balance arm.

(2) Pivot — Round off one end of the available piece of wood (B) with sandpaper.

(3) Masses — Use washers or heavy nuts (D) for masses.

B. EXPERIMENTAL BALANCES

B1. Extending Spring Balance



a. Materials Required

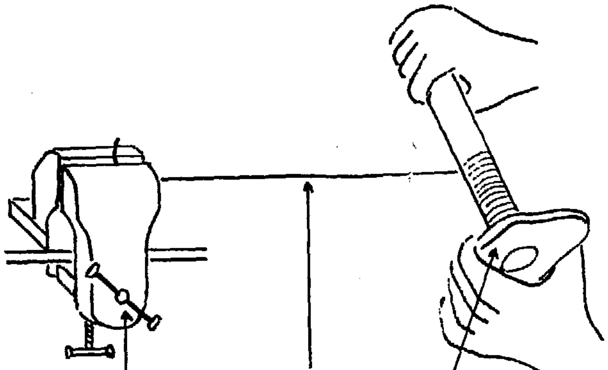
Components	Qu	Items Required	Dimensions
(1) Support	1	Rubber Band Balance (A)	I/A2
(2) Spring	1	Steel Wire (B)	0.09 cm diameter, 225 cm long

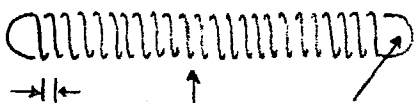
b. Construction

(1) Support

Make the support (A) in precisely the same way as the rubber band balance described

(2) Spring





under I/A2.

Take a length of steel wire (B) (e.g. piano wire) and fasten one end firmly in a clamp. Attach the other end to a cork borer or similar device (see notes). If the diameter of the axis of the cork borer used is 1.4 cm, the diameter of the resultant spring (when released) will approach 2 cm. Keeping the wire under tension wind some 30 turns of wire into the spring, each turn being separated from the next by about 0.1 cm. Use pliers to twist a loop in each end of the spring. Remove the rubber band which supports the scale pan in the rubber band balance (A), and replace it by the steel spring.

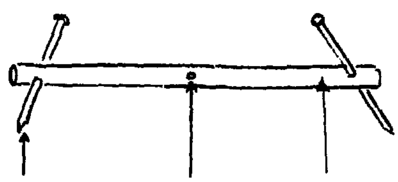
c. Notes

(i) Determine the elastic limit of the steel spring, and calibrate the balance in exactly the same way as for the rubber band balance.

(ii) With the materials described above the spring was extended until the scale pan touched the base of the apparatus without reaching the elastic limit of the spring. The scale was calibrated from 0 to 400 g (an extension of 19.6 cm), and it was noted that the resultant scale was uniform.

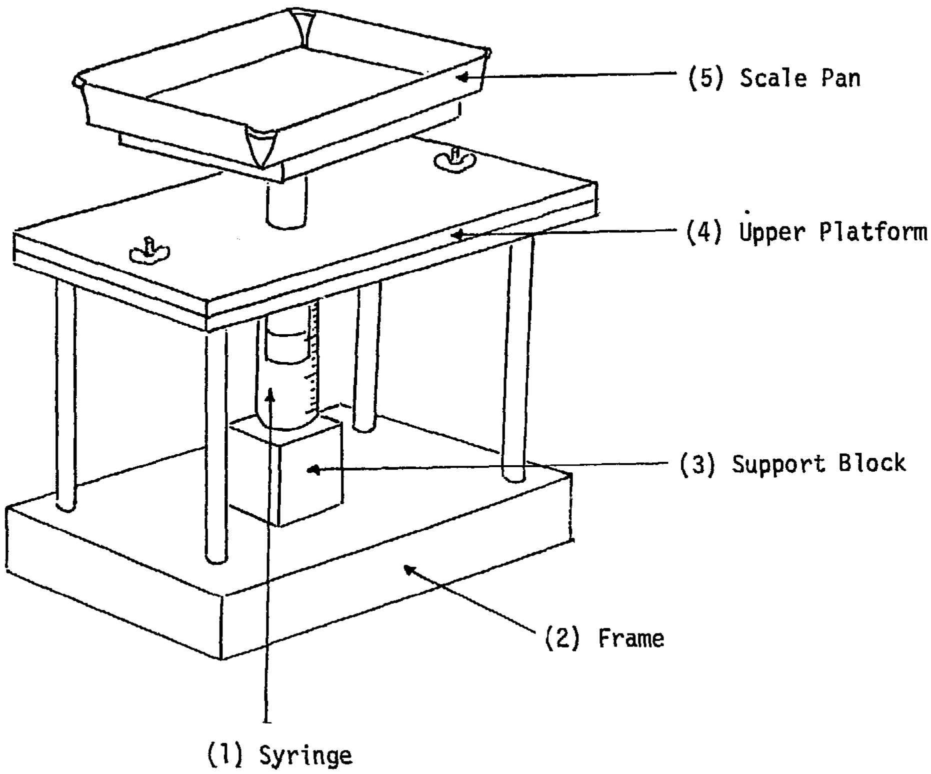
(iii) A more sensitive, or weaker, spring may be made by using thinner wire or by making the diameter of the spring greater.

(iv) A very convenient winding device for the spring is a wooden dowel (in this case 1.4 cm diameter, 30 cm long) with a hole (0.6 cm diameter) drilled at either end to take a nail about 10 cm long.



A small hole (diameter 0.2 cm) drilled through the center of the dowel holds the wire, and the latter may be wound into a spring in much the same way as with the help of the cork borer, in this case winding the wire spring onto the wooden dowel which is turned with the help of the protruding nails.

B2. Compression Spring Balance



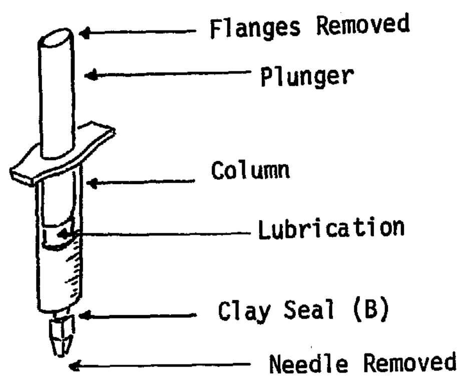
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Syringe (A)	Column length approximately 6.4 cm, internal diameter approximately 1.3 cm
	--	Modelling Clay (B)	--
(2) Frame	1	Wood (C)	14 cm x 9 cm x 2 cm
	1	Wood (D)	14 cm x 9 cm x 0.7 cm
	4	Wooden Dowels (E)	12 cm long, 1 cm diameter
(3) Support Block	1	Wood (F)	2 cm x 2 cm x L cm, where L is dependent on length of syringe
(4) Upper Platform	1	Wood (G)	14 cm x 9 cm x 0.07 cm
	2	Bolts (H)	2 cm long, 0.3 cm diameter
	2	Wing Nuts (I)	0.3 cm diameter

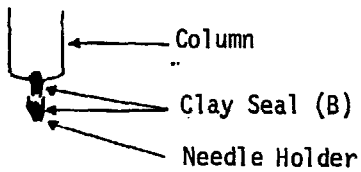
(5) Scale Pan	1	Galvanized Wire (J)	32 cm long, 0.4 cm diameter
	1	Aluminum Sheet (K)	12 cm x 12 cm x 0.05 cm
	1	Wood (L)	5 cm x 5 cm x 2 cm

b. Construction

(1) Syringe

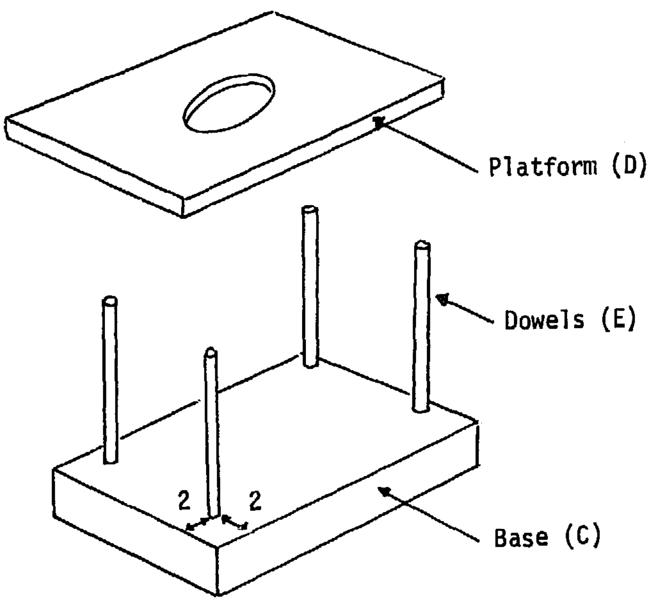


Take the disposable plastic syringe (A) and remove the needle and the top flanges. Remove the plunger from the column, and smear the end of the plunger with petroleum jelly thus insuring a well lubricated plunger, and a good airtight seal.



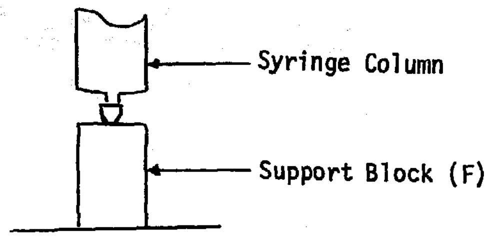
Insert the plunger about 1 cm into the column, and then seal off the open end of the column with modelling clay with the help of the metal needle holder.

(2) Frame



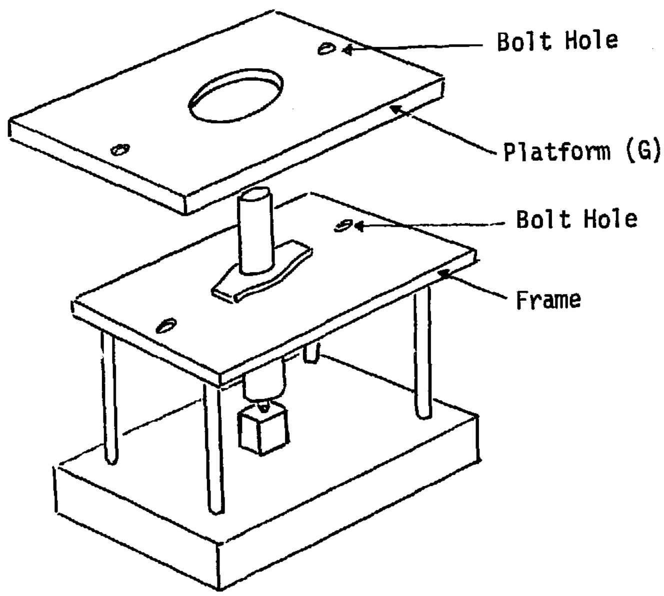
Make the base of the frame from wood (C) drilling holes (1 cm diameter) at the corners to take the dowels (E). Use wood (D) as a platform, drilling holes (1 cm diameter) at each corner to take the dowels. Attach the base and platform together by means of the four dowels, fixing the latter firmly in position with wood cement. Drill a hole (1.4 cm diameter) through the middle of the platform, making it just large enough to take the plunger.

(3) Support Block



Insert the syringe column through the hole in the platform. It will hang suspended with a gap between the bottom of the syringe and the surface of the base. Cut a small support block (F) to fill this gap, and drill a small inset into the top of the block to hold the syringe firmly in position. (The block will also prevent the modelling clay seal in the bottom of the syringe being readily broken under pressure). Fasten the support block to the base with wood cement.

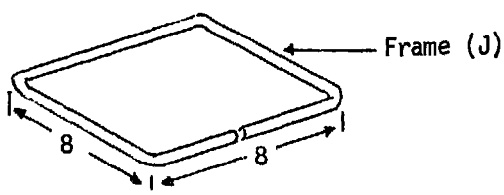
(4) Upper Platform



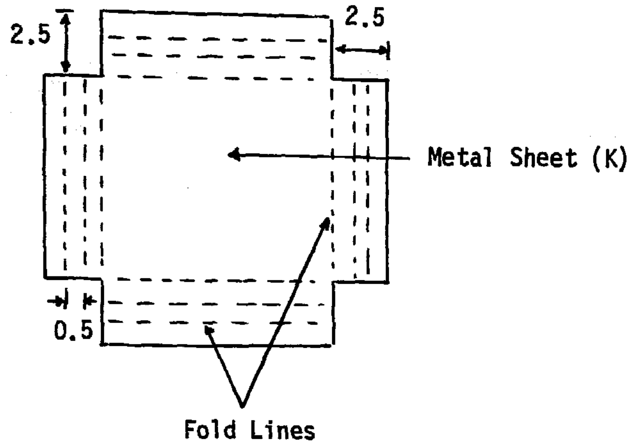
Make the upper platform from wood (G) to fit on top of the existing platform for the frame.

Drill a hole (diameter the same as that of the syringe plunger) in the middle of the upper platform, and slide the latter into position on the frame. Drill two bolt holes (0.3 cm diameter) through both platforms, and fasten them together by means of bolts (H) and wing nuts (I), thus holding the syringe firmly in position.

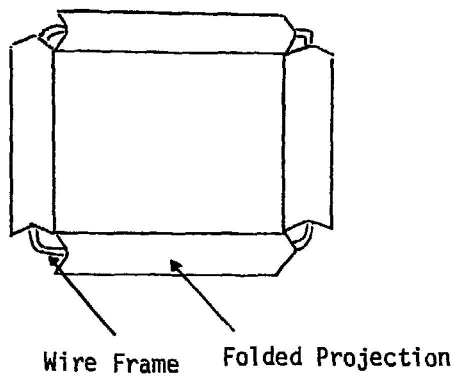
(5) Scale Pan

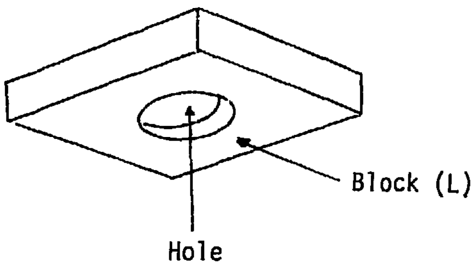


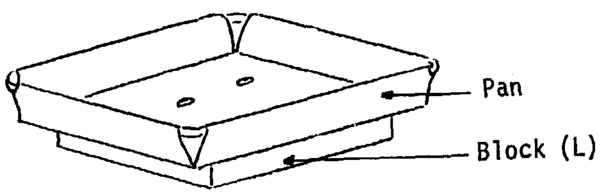
Make a frame for the scale pan out of aluminum or galvanized wire (J).



Cut the corners (2.5 cm x 2.5 cm) out of the aluminum sheet (K), and fold the projections as illustrated so that they may be bent over the wire frame to form a suitable scale pan.





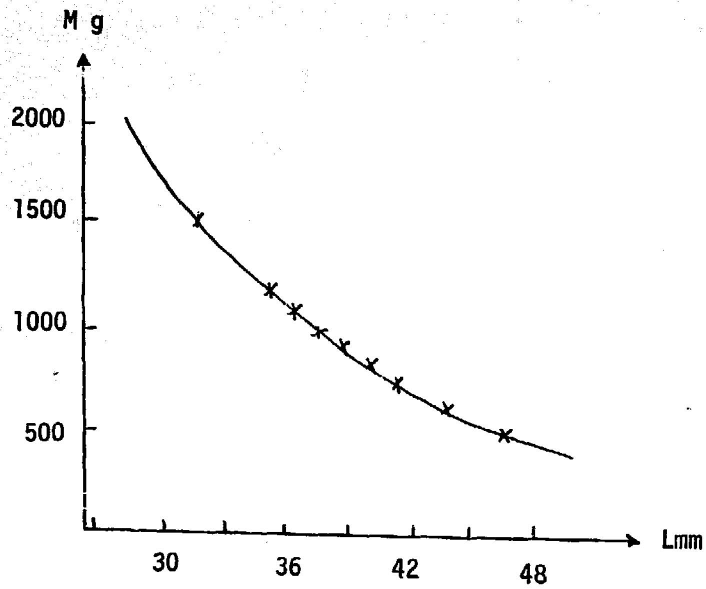


Take the wooden block (L), and drill a hole (the same diameter as the plunger, and 1.5 cm deep) into the middle of the block. Nail the scale pan squarely on to the undrilled surface of the block. Line the inside of the hole in the lower surface with wood filler. Lower the block onto the plunger. The latter will be held firmly within the hole once the wood filler dries.

c. Notes

(i) The balance may readily be calibrated with known weights by noting the length of the trapped air column for each given mass in the scale pan.

(ii) The variation of length of the air column with mass is not linear, as can be seen from the plot below showing the relationship of air column length (L) to the applied mass (M).

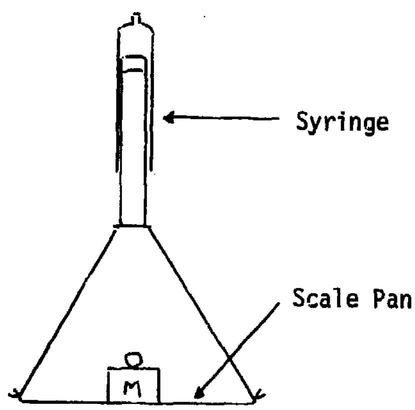


M g	L = mm
500	47.8
600	44.8
700	42.4
800	41.2
900	40.0
1000	38.8
1100	37.6
1200	36.4
1500	32.8
2000	28.0

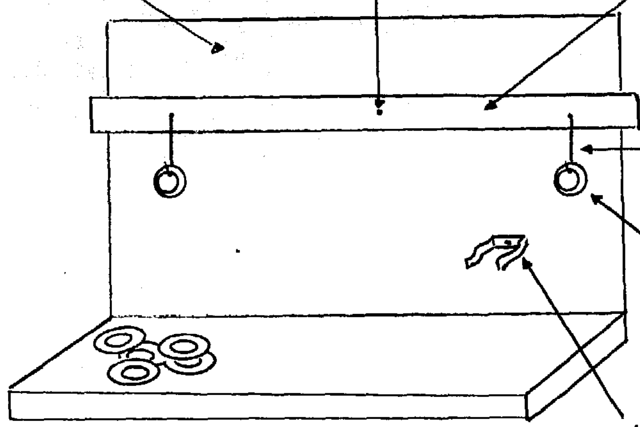
(iii) Because of friction between the plunger and the sides of the column, the syringe tends to be insensitive to weights of less than about 500 g, but it readily measures weights from this lower limit up to around 5,000 g.

(iv) The sensitivity of the balance appears to increase as the length and diameter of the syringe column increases.

(v) In designing new balances it would be of particular interest to consider the use of a syringe as an extension spring, as illustrated in the diagram. It would appear that this balance might have quite a different range and sensitivity from that of the compression spring balance.



B3. Pegboard Balance



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support Stand	1	Wood (A)	50 cm x 10 cm x 2 cm
	1	Pegboard (B)	50 cm x 35 cm x 0.3 cm
(2) Pivot	1	Wood (C)	8 cm x 3 cm x 1 cm
	1	Nail (D)	5 cm long, 0.3 cm diameter
	2	Bolts (E)	2 cm long, 0.3 cm diameter
	2	Wing Nuts (F)	0.3 cm internal diameter
(3) Balance Arm	1	Wood (G)	50 cm x 2.5 cm x 0.5 cm
	1	Aluminum Sheet (H)	2.5 cm x 2.0 cm x 0.02 cm
(4) Hooks	6	Paper Clips (I)	--
(5) Masses	20	Washers (J)	--
(6) Spring Clips	2	Packing Case Steel Bands (K)	8.5 cm x 1 cm x 0.02 cm
	2	Bolts (L)	1.5 cm long, 0.3 cm diameter
	2	Wing Nuts (M)	0.3 cm internal diameter

b. Construction

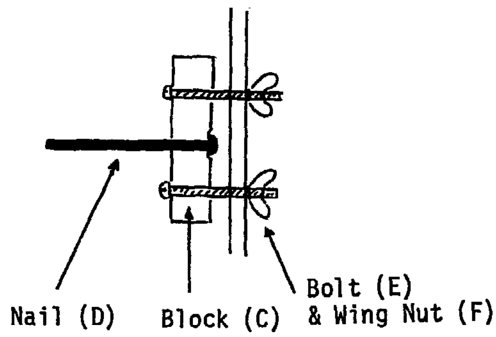
(1) Support Stand

Attach the sheet of pegboard (B) vertically on to wood (A) to make the support.

(2) Pivot

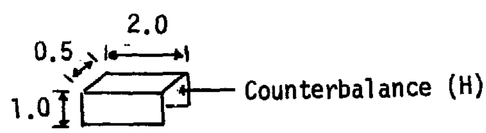
Drill a small hole (diameter 0.2 cm) through wood (C), and make a small inset over the hole. Drive nail (D) through the hole so that the nail head sits in the inset.

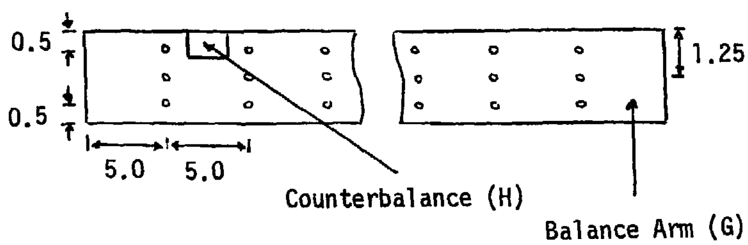
Drill two more holes (diameter 0.3 cm) through the wood, close to the edges, and use bolts (E) and wing nuts (F) to attach the block to the pegboard support stand. The newly attached pivot nail should be at the center of the pegboard and about 20 cm above the base.



(3) Balance Arm

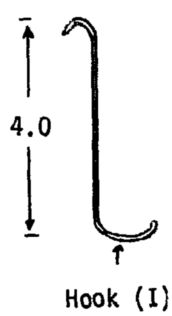
Make the balance arm out of wood (G). Drill holes (0.5 cm diameter) at regular intervals in the arm as illustrated, and balance the arm as required on the nail pivot. Take a sheet of aluminum (H) and bend it into a counterbalance. Set it in an appropriate position on the balance arm to correct any irregularity in the balance of the latter.





(4) Hooks

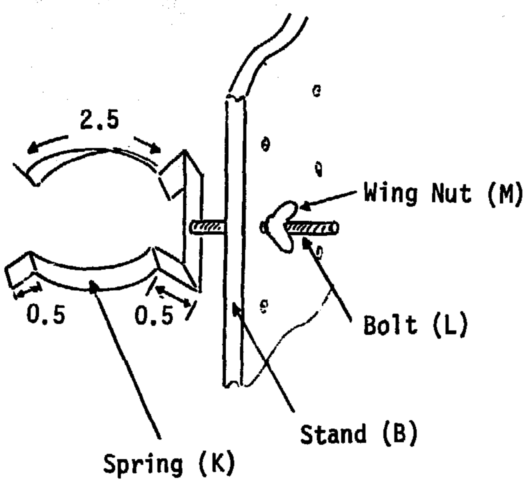
Make each hook by straightening out a paper clip (I), and cutting off a length of about 6 cm. Then bend the wire into the shape shown. Make six such hooks.



(5) Masses

Use heavy washers (J) or nuts for masses.

(6) Spring Clips

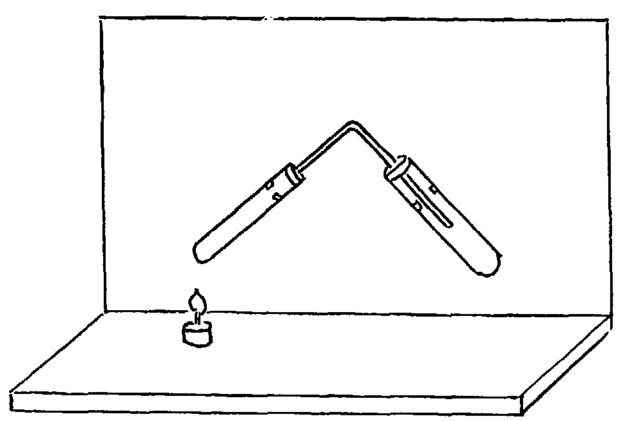


Take a length of packing case steel band (K) and drill a hole (diameter 0.3 cm) through its center. Then bend it as indicated into the form of a spring clip. This size of spring clip is suitable for a standard test tube. Attach this to the support stand with a bolt (L) and wing nut (M). Two identical spring clips should be made.

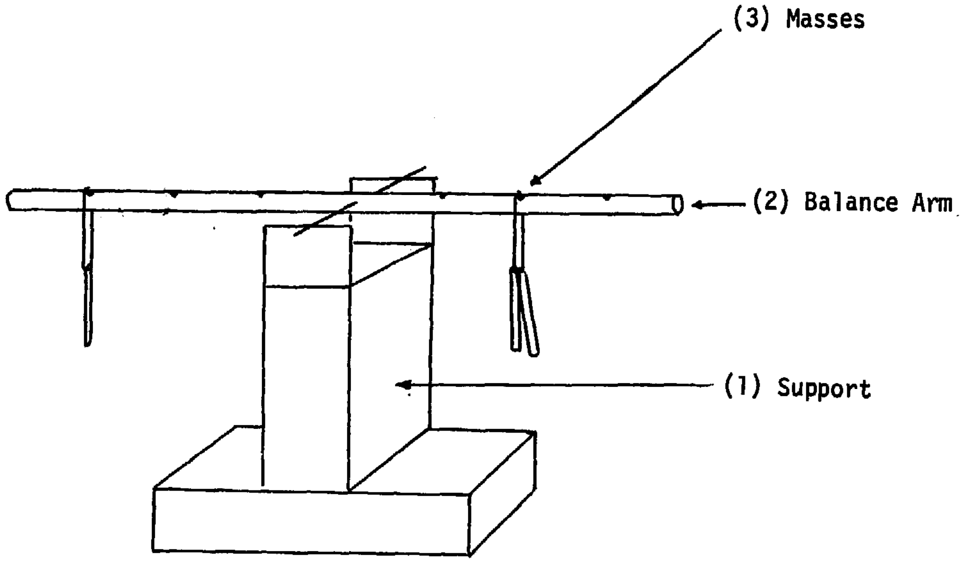
c. Notes

(i) The position of the pivot in the horizontal lever can be changed at will not only from one end of the lever to the other, but also from the lower edge of the lever to the upper edge (changing the sensitivity of the balance). The apparatus is particularly suitable for studying "moments".

(ii) With the help of the spring clips described the apparatus may be converted into a general support stand.



B4. Soda Straw Balance

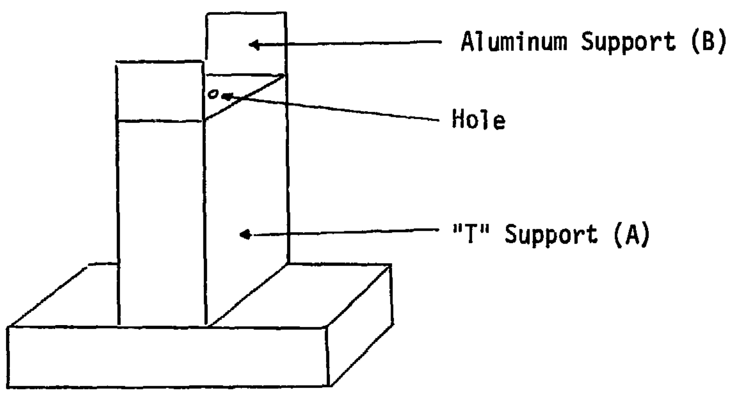


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support	2	Wood (A)	6 cm x 2 cm x 2 cm
	1	Aluminum Sheet (B)	6 cm x 2 cm x 0.02 cm
(2) Balance Arm	1	Soda Straw (C)	16 cm long approximately
	1	Needle (D)	3 cm long
(3) Masses	10	Paper Clips (E)	--

b. Construction

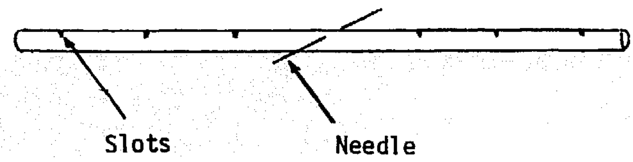
(1) Support



Screw, or nail, one block of wood (A) on to the other so as to form an inverted sheet (B) and bend this into a three sided support to sit on top of the inverted "T" support. Drill a small hole through the base of the aluminum sheet so that the latter may be attached to the wood support by means of a nail or screw.

(2) Balance Arm

Pierce the middle of the straw (C) with needle (D) making sure that the latter is close



to the top surface of the straw, thus lending stability to the balance arm. Use a razor blade to cut small V-shaped slots in the top surface of the straw at regular intervals of 2 cm. Balance the straw on top of the support.

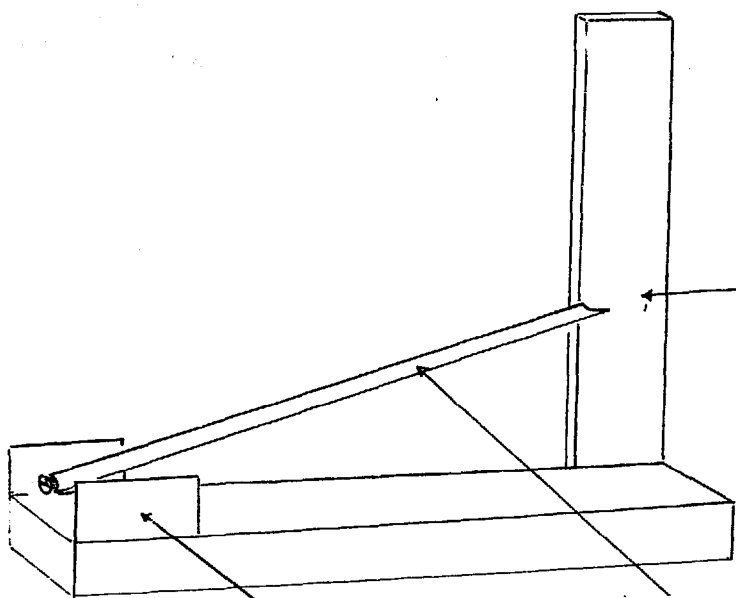
(3) Masses

Use the paper clips (E) as appropriate masses.

c. Notes

(i) This apparatus is suitable for individual student investigation of the principle of "moments".

B5. Microbalance

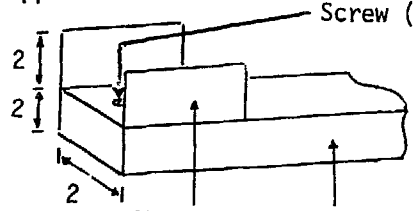


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support	1	Wood (A)	15 cm x 2 cm x 2 cm
	1	Screw (B)	1 cm long
	1	Aluminum Sheet (C)	6 cm x 2 cm x 0.02 cm
(2) Balance Arm	1	Straw	16 cm long approximately
	1	Bolt (E)	1 cm long approximately
	1	Needle (F)	3 cm long
(3) Scale	1	Wood Strip (G)	12 cm x 2 cm x 0.4 cm
	1	White Paper (H)	10 cm x 2 cm
	2	Rubber Bands (I)	--

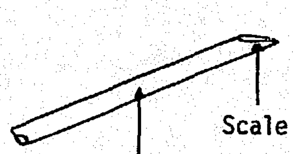
b. Construction

(1) Support



Bend the aluminum sheet (C) into a three sided support. Drill a hole (0.2 cm diameter) through the middle of the support base, and then attach the support to the end of wood (A) by means of a screw through the hole.

(2) Balance Arm



Take the straw (D) and select a short bolt (E) which fits tightly into the end of the straw. Screw the bolt partway into the straw. Cut the free end of the straw with a pair of scissors to make an appropriate scale pan in the balance arm. Pierce the straw near to the top surface, and sufficiently close to one end, with the needle (F) so that the latter will serve as a pivot. Balance the straw on the support. A few trials will be necessary to obtain a suitable position for the needle.

(3) Scale

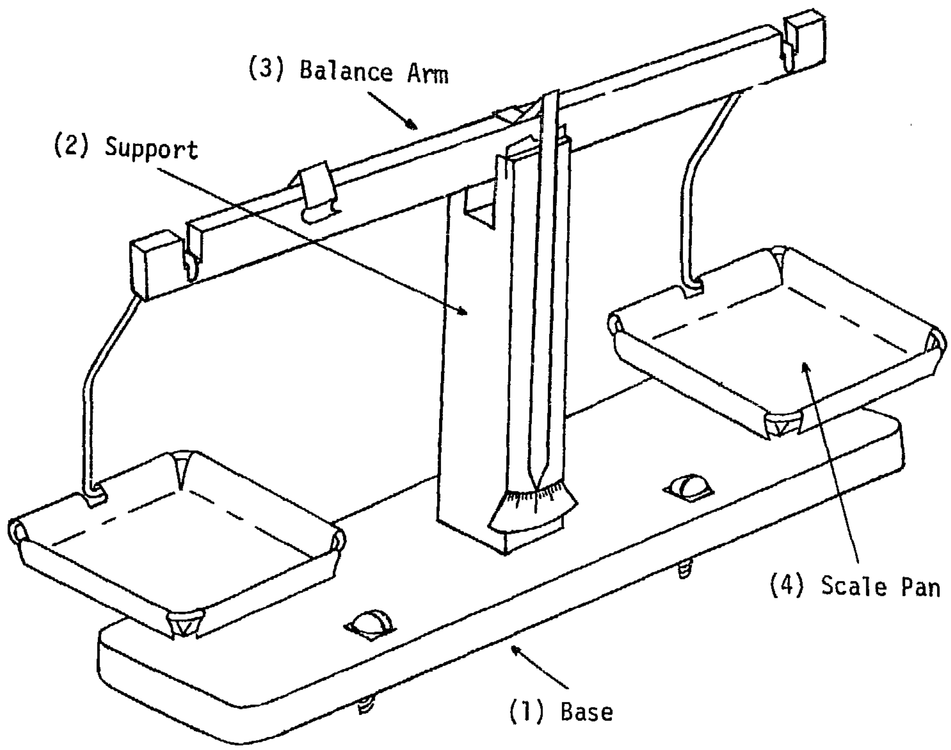
Nail the wood strip (G) vertically on to the end of the base (A), and attach the piece of white paper (H) to the front surface with rubber bands (I).

c. Notes

(i) The position of the pivot and screw should be adjusted so that the straw points toward the top of the scale. Assuming the weight of a large sheet of paper (or several sheets together) can be determined, calibration may be effected by placing a fraction of a sheet of paper (e.g. 1 square cm or less) on the soda straw scale pan, and noting the depression of the straw on the scale. This balance is sufficiently sensitive to determine the mass of extremely small bodies such as mosquitoes, strands of hair etc.

C. FUNCTIONAL BALANCES

C1. Equal Arm Balance ©



a. Materials Required

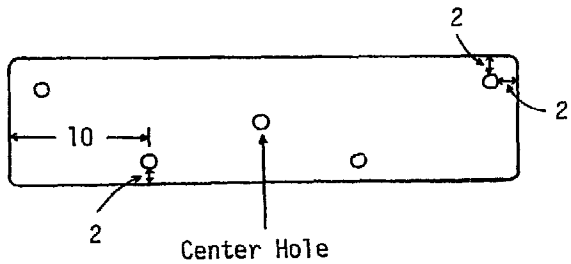
Components	Qu	Items Required	Dimensions
(1) Base	1	Softwood (A)	38 cm x 9 cm x 2 cm
	4	Bolts (B)	0.2 cm diameter, 3 cm long
	8	Nuts (C)	0.2 cm internal diameter
(2) Support	1	Screw (D)	3 cm long
	1	Wood (E)	15.5 cm x 3 cm x 2 cm
	1	Razor Blade (F) (Double Edge)	--

(3) Balance Arm	1	Wood (G)	38 cm x 2 cm x 0.5 cm
	1	Needle (H)	0.1 cm diameter, 5 cm long
	1	Aluminum Sheet (I)	19 cm x 0.5 cm x 0.5 cm
	1	Aluminum Sheet (J)	4 cm x 1.5 cm x 0.05 cm
(4) Scale Pans	2	Aluminum Wires (K)	50 cm long, 0.3 cm diameter
	2	Aluminum Sheets (L)	13.5 cm x 13.5 cm x 0.02 cm
	1	White Paper (M)	4 cm x 2 cm

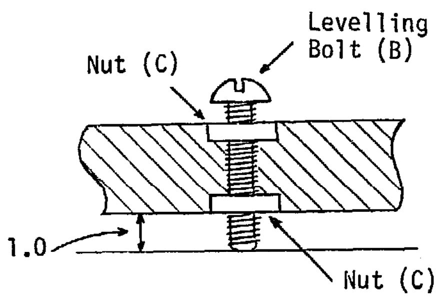
b. Construction

(1) Base

Make the base out of softwood (A). Drill four holes (diameter 0.3 cm) in the base to take the four levelling bolts (B). Inset the nuts (C) into the base above and below the holes by hammering the nuts into the wood surface. They may be fixed permanently in position with epoxy resin.



Base (A)



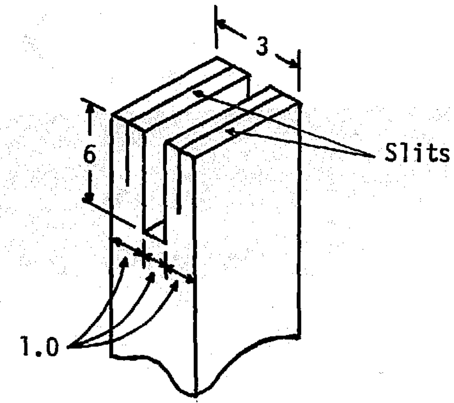
Side View

Two nuts (C) on each bolt (B) prevent the latter from wobbling, and permit easy hand adjustment of the bolt.

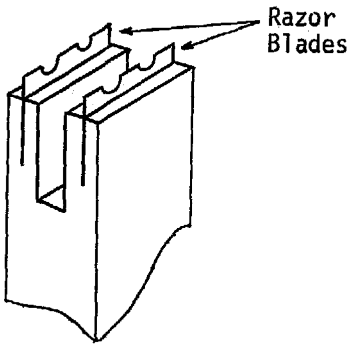
Bore an additional hole (approximately 0.2 cm diameter) at the center of the base to facilitate the attachment of the support.

(2) Support

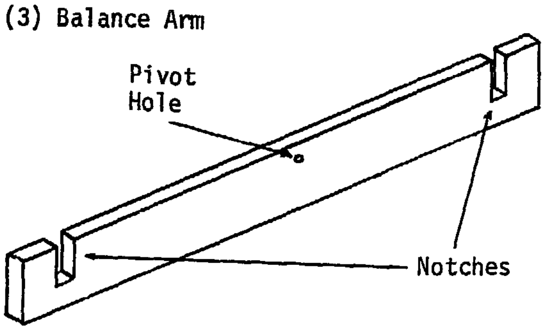
Cut the support to the shape shown from a piece of wood (E) and cut slots approximately 1 cm deep in the top surface with a saw. Attach the support to the base with the screw (D) inserted through the hole in the center of the base, making a strong junction with the help of wood cement. Then, cut the



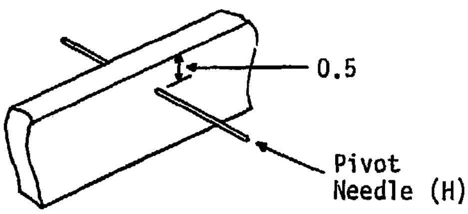
razor blade (F) in half, and, after smearing the cutting edges with epoxy resin, insert the cutting edges of the blades as deep as possible into the slits. The less the blades protrude above the wood the less the strain that is possible on the projecting blades.



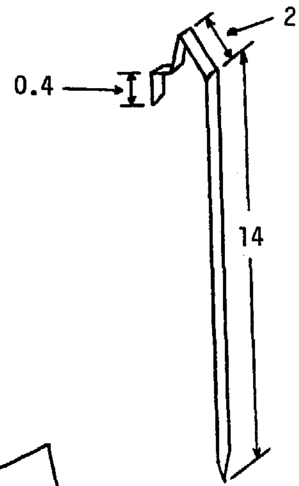
(3) Balance Arm



Make the balance arm out of softwood (G), cutting a notch (0.5 cm wide, 1.0 cm deep) at a distance of 1.5 cm from each end of the arm.

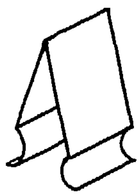


Drill a hole (0.1 cm diameter) horizontally through the middle of the arm at a distance of 0.5 cm from the top of the arm. Drive the steel needle (H) through the hole to serve as a pivot, and glue it permanently in position with epoxy resin.

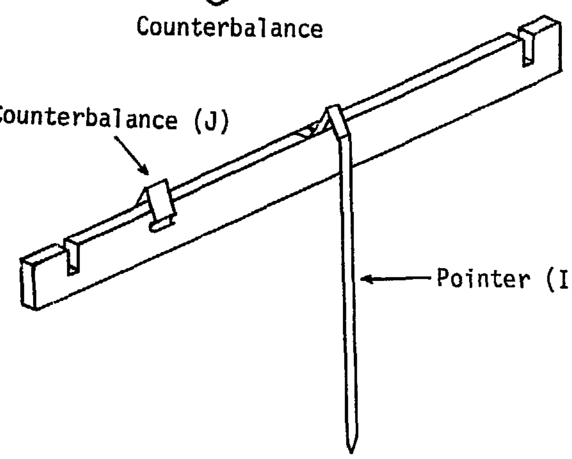


The needle must be sufficiently strong not to bend, even under heavy loads.

Take the sheet of aluminum (I) and bend it into the shape of a pointer as illustrated. Then attach the pointer to the middle of the balance arm.

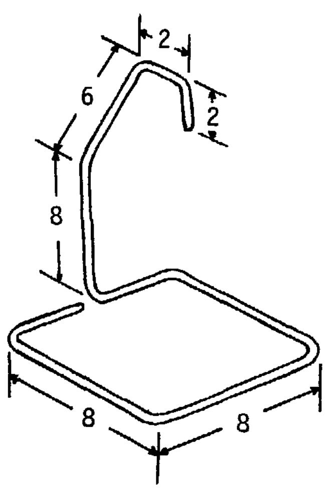


Counterbalance

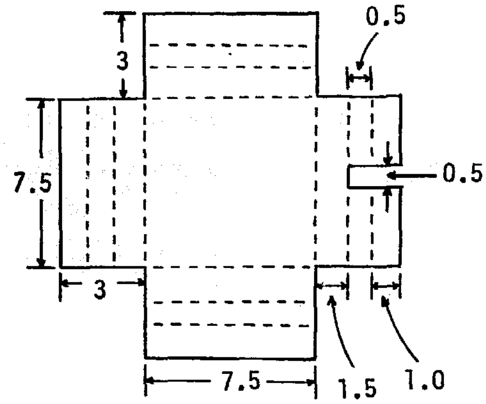


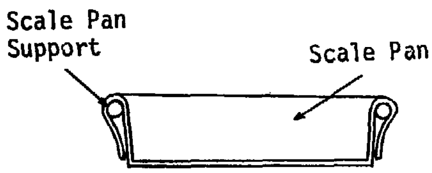
Complete the balance arm by making a small counterbalance from the sheet of aluminum (J), bending it to the shape indicated. Sit the counter-balance on the balance arm.

(4) Scale Pans



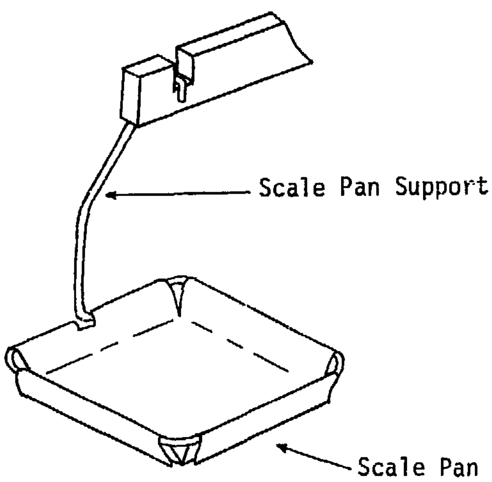
Take the length of aluminum or galvanized wire (K) and bend it into a support for the scale pan. Make an identical support in the same way, and suspend both supports from the notches in the balance arm.

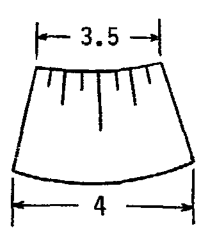




Cross Section

Make the scale pan from the sheet of aluminum (L). Cut squares (3 cm x 3 cm) from the sheet corners to make four projections on the sheet, and cut a slit in one of the projections as indicated. Fold the projections along the dotted lines converting the aluminum sheet into a scale pan with sides. Sit the scale pan on the framework of one of the support wires. Make a second scale pan in an identical manner.





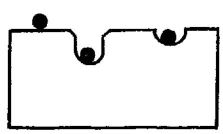
Make a small scale from a piece of white paper (M) by marking regular divisions (0.3 cm apart approximately) on the paper. Glue the scale to the support just behind the pointer so that when the balance arm is perfectly horizontal the pointer will be at the middle of the scale.

c. Notes

(i) The following table gives approximate values for the sensitivity of such a balance under varying loads. Sensitivity is measured as the number of milligrams required to cause the pointer to move one millimeter under the given load.

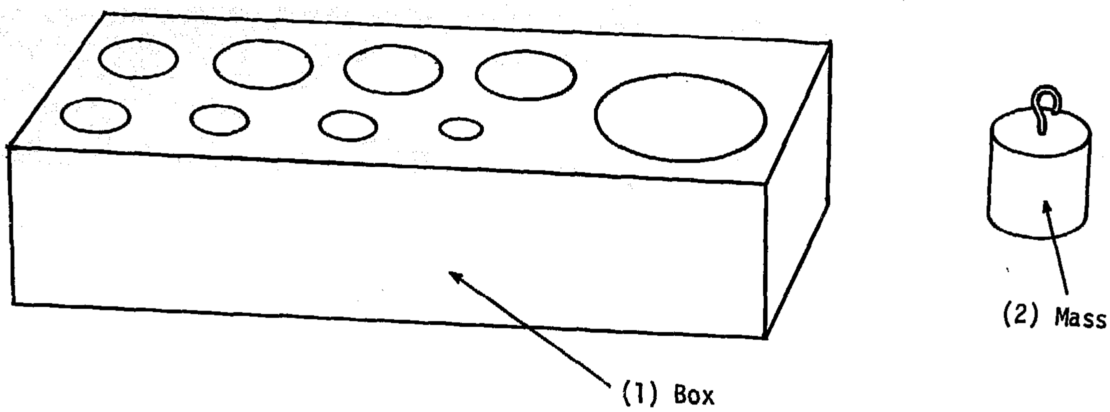
Load in Each Pan	Sensitivity
25 g	25 mg/mm
50 g	25 mg/mm
100 g	65 mg/mm
250 g	200 mg/mm
500 g	335 mg/mm

(ii) As seen in the illustration, the shape of the razor blade edge allows three different points to be used as fulcrums for the pivot needle. Sensitivity is found to be essentially the same at all three points for all weights.



(iii) The centering point of the pointer is very stable under varying weight loads. However, if the weights are shifted drastically in position in the pans (that is, off center) then shifts in the pointer position of up to 2 mm may be noted.

C2. Box of Masses ©

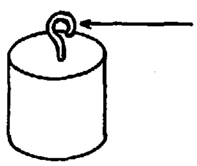


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Masses	1-3	Lead (A) (sheeting, etc.)	2 kg approximately
	9	Eye Screws (B)	--
(2) Box	1	Wood (C)	17 cm x 8 cm x 5 cm

b. Construction

(1) Masses



Take a box of wet sand, and use wooden dowels, or some such similar material, to make cylindrical molds in the sand according to the dimensions given below. Heat up some lead (A) in a can, and when it is molten pour it into the molds. Allow the lead to solidify and cool. Then screw into the top of each lead cylinder a cup screw (B) to serve as a handle.

The lead cylinders may then be filed down until each is the desired mass. The number of masses required, and the

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 9-10.

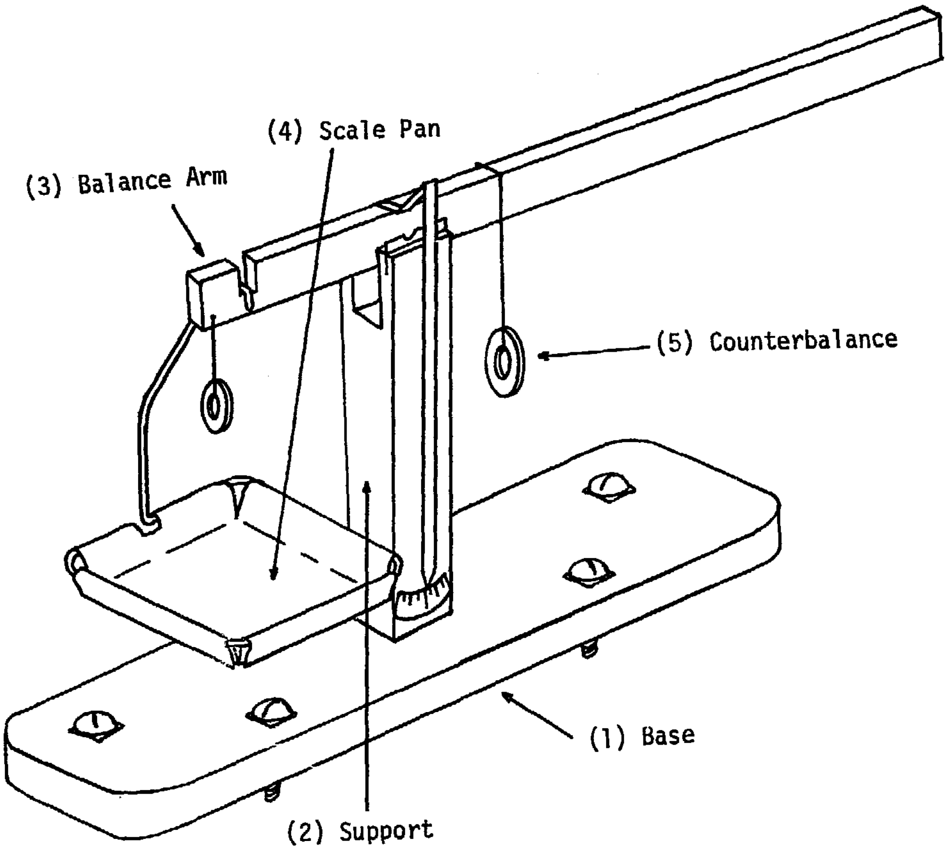
approximate size of each mold, is indicated below.

Qu	Weight	Diameter	Depth
1	500 g	3.8 cm	4.0 cm
3	200	2.4	4.0
1	100	2.4	2.0
1	50	2.4	1.0
2	20	1.2	2.0
1	10	1.2	1.0

(2) Box

Take the block of wood (C) and drill holes, the same size as the above molds, into the top surface. These will serve as suitable mass holders.

C3. Single Pan Balance



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Equal Arm Balance Base (A)	I/C1, Component (1)
(2) Support	1	Equal Arm Balance Support (B)	I/C1, Component (2)
(3) Balance Arm	1	Soft Wood (C)	42 cm x 2 cm x 0.5 cm
	1	Needle (D)	5 cm long
	1	Aluminum Sheet (E)	19 cm x 0.5 cm x 0.05 cm
(4) Scale Pan	1	Equal Arm Balance Scale Pan	I/C1, Component (4)
(5) Counterbalances	--	Washers (F)	Approximately 70 g total
	--	Washers (G)	Approximately 12 g total
	2	Paper Clips (H)	--

b. Construction

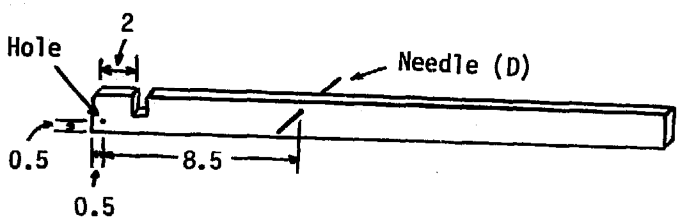
(1) Base

Make the base (Component 1) of the Equal Arm Balance (I/C1) and use it as the base (A) of of this item.

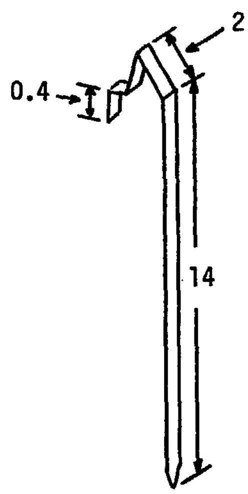
(2) Support

Make the support (Component 2) of the Equal Arm Balance (I/Cl) and use it as the support (B) of this item.

(3) Balance Arm



Make the balance arm from the soft wood (C). Drive the needle (D) horizontally through the arm 9 cm from one end and 0.5 cm from the top surface. Cut a notch (0.5 cm wide, 1.0 cm deep) in the top of the arm and drill a small hole (0.2 cm diameter) through the corner of the wood.



Take a sheet of aluminum (E) and bend it into the shape of a pointer as illustrated. Then attach the pointer to the arm just above the pivot.

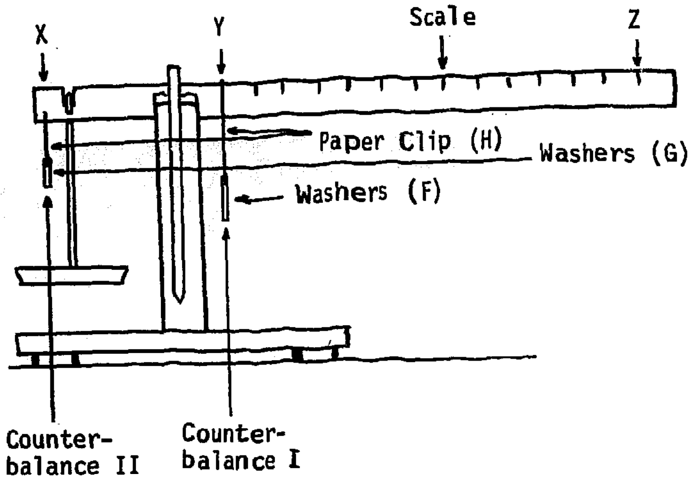
Sit the balance arm on top of the support so that the needle serves as a pivot.

(3) Scale Pan

Make the scale pan (Component 4) of the Equal Arm Balance (I/Cl), and suspend it from the notch in the balance arm.

(4) Counterbalance

If it is desired to use the balance to weigh the masses up to 300 g, a standard 300 g mass should be placed in the scale pan and washers (F) should be suspended from a paper clip (H) to make counterbalance (I).



Side View

The latter should be such that when it is suspended from the end of the balance arm (position Z) it will just balance the 300 g mass. (In this particular instance two washers weighing a total of 70 g were found to be ideal.)

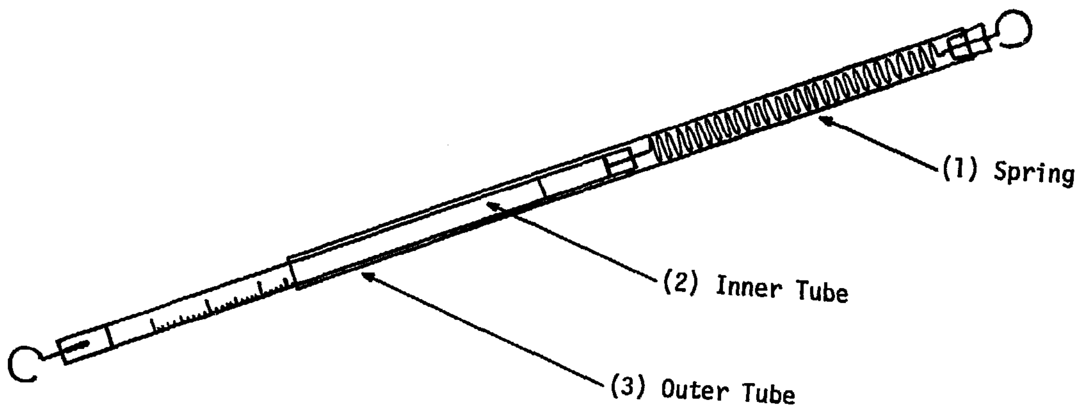
The counterbalance should then be moved to a suitable zero position (Y) on the arm. The balance arm will not remain horizontal. Therefore make a second counterbalance II from the small washers (G) such that when these are suspended from the end of the arm (position X) they will just balance the arm in a horizontal position with counterbalance I in the zero position (Y). (In this instance washers weighing a total of 12 g made a suitable counter-balance II).

You are now ready to calibrate the scale. Stick a piece of paper to the balance arm with adhesive tape to facilitate the marking of the scale. Then place standard masses (50, 100, 150, 200, 250, 300 g) in the scale pan, and in each instance determine the position of the counterbalance (I) which balances the arm. A uniform scale should be created, and this may be subdivided as desired.

c. Notes

(i) Alternative scales may be produced in an identical manner simply by altering the magnitude of counterbalance I (leaving the mass of counterbalance II the same as before). For example using only one washer (35 g) for counterbalance I a scale from 0 to 140 g was created on the same balance.

C4. Spring Balance ©



a. Materials Required

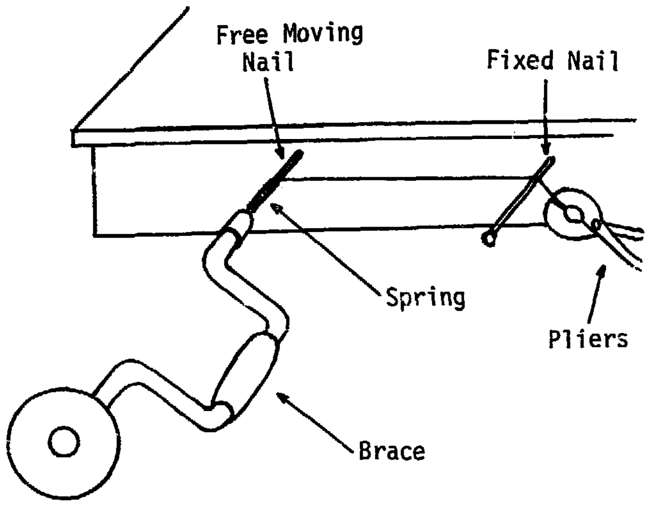
Components	Qu	Items Required	Dimensions
(1) Spring	1	Roll of Steel Wire (A)	#26 gauge (for 10 Newton Balance)
	1	Roll of Steel Wire (B)	#30 gauge (for 1 Newton Balance)
(2) Inner Tube	1	Hollow Aluminum Tube (C)	21 cm long, internal diameter 1 cm
	2	Wood Stoppers (D)	1 cm diameter, 2 cm long
	1	Cup Screw (E)	--
(3) Outer Tube	1	Hollow Aluminum Tube (F)	27 cm long, internal diameter 1.3 cm
	1	Wood Stopper (G)	1.3 cm diameter, 2 cm long
	2	Cup Screws (H)	--

b. Construction

(1) Spring

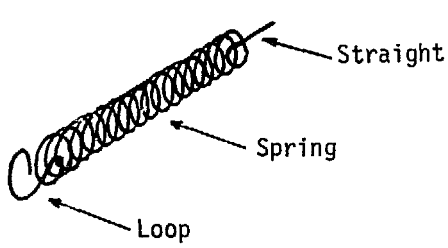
The most important factor in winding a spring is to keep the wire taut at all times, and for this the help of a

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 31-33.



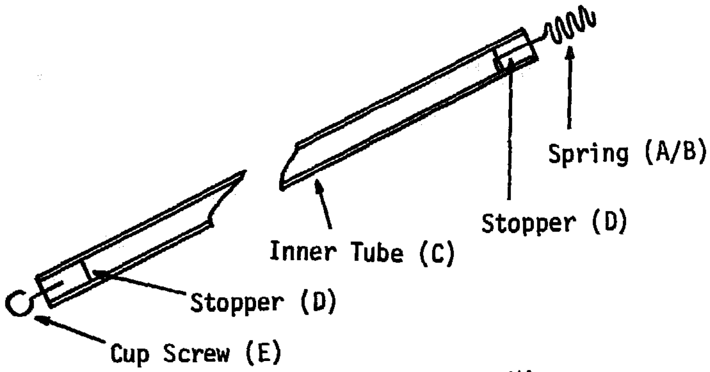
brace and two nails (10 cm long, 0.7 cm diameter) is invaluable. Drill a horizontal hole about 3 cm deep in the bench for the free moving nail, and about 20 cm to the right of this drive in a second (fixed) nail. Clamp one end of the wire (A/B) along with the head of the free nail in the jaws of the brace, and get your partner to hold the other end of the wire in the jaws of a pair of pliers, keeping the wire taut with the assistance of the fixed nail. Turn the brace, winding the wire firmly around the free nail. The spring may be close wound (each turn touching the next) or open wound (each turn separated from the next by a fixed distance). Although the wire is wound on a nail of diameter 0.7 cm, on release from tension it will tend to expand to about 1 cm diameter.

If a Newton balance is to be made take the #26 gauge steel wire (A) (diameter 0.07 cm) and open wind it (o.1 cm between each turn) into a spring approximately 8 cm long and 0.9 cm in diameter.



Make a loop on one end of the spring (using dog nosed pliers) and a straight piece on the other end.

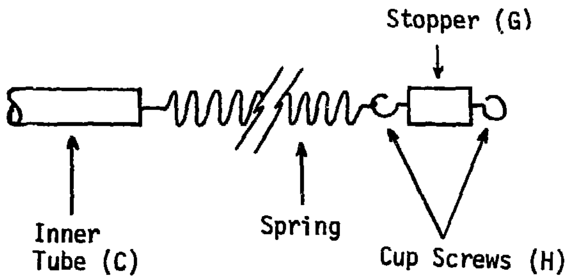
(2) Inner Tube



Cross Section View

Make two stoppers out of the wood (D). Fix a cup screw (E) into one of the stoppers and glue it permanently into one end of the aluminum tube (C). Drill a small central hole through the other stopper (D) and insert the straight end of the spring, bending the end over to hold it in position. Glue the stopper into the other end of the tube.

(3) Outer Tube



Detail

Make a wooden stopper (G) to fit one end of the hollow aluminum tube (F). Fix cup screws (H) in either end of the stopper, and attach the top of the spring to one of the cup screws.

Now take the combination of stopper, spring and inner tube, and lower it into the outer tube (F) until the stopper lodges in the top of the tube. Glue the stopper firmly into the tube.

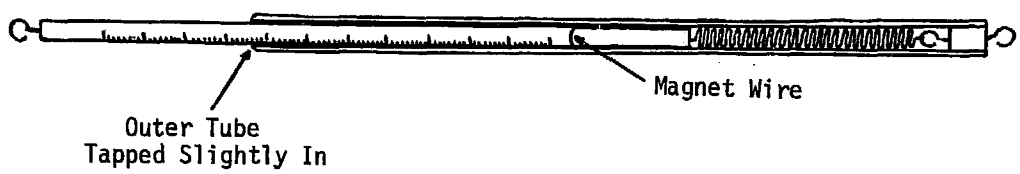
c. Notes

(i) To calibrate the 10 Newton spring, hold the balance vertically, and mark the inner tube opposite the lower end of the external tube (10 Newtons). Suspend 1,020 g from the spring and once again mark the inner tube opposite the lower end of the external tube. Then subdivide the distance between the two marks into 100 equal divisions, thus permitting the balance to read from 0.0 to 10.0 Newtons with an accuracy of 0.1 Newtons.

(ii) To calibrate the 1 Newton spring simply suspend a mass of 102 g from the balance and repeat the above process, calibrating the inner tube from 0.00 to 1.00 Newtons with an accuracy of 0.01 Newtons.

(iii) Spring balances are very easily damaged by over extension of the spring. It is therefore useful to make some simple device to prevent over stressing the spring.

One such method is to tie a piece of magnet wire (diameter 0.05 cm) around the inner cylinder, just above the final marking on the scale. If the lower perimeter of the outer tube is then tapped gently all around it, the magnet wire will be unable to move beyond this point, thus preventing over extension of the spring.



Cross Section

II. TIMING DEVICES

Timing devices have been divided into three groups according to the length of time intervals they would most conveniently measure. This categorization is somewhat arbitrary, and it follows that some devices could, under certain circumstances, exist in more than one category. The categories are defined as follows:

A. LONG INTERVAL TIMERS

The intervals to be measured may range from a day (month, year) down to an hour or minute.

B. MEDIUM INTERVAL TIMERS

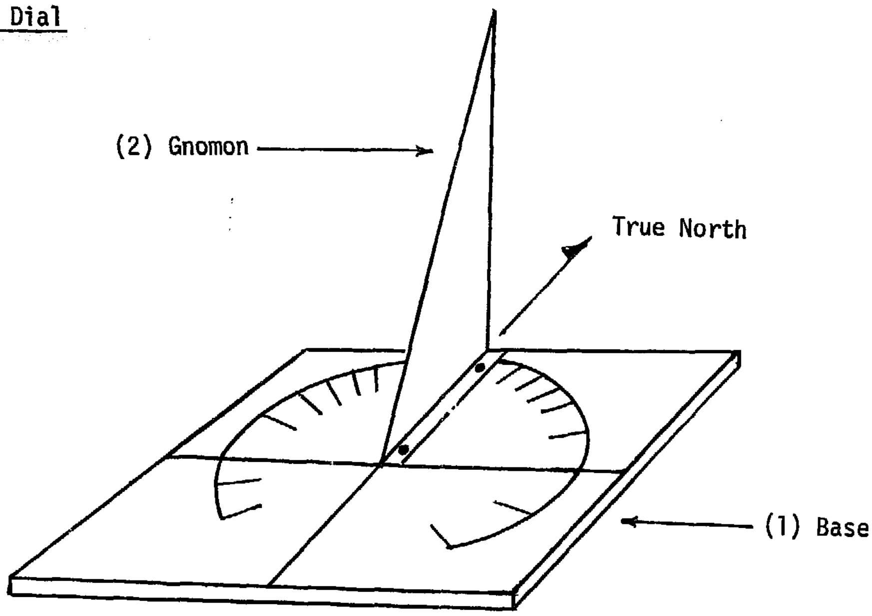
The intervals to be measured would range from minutes to seconds.

C. SHORT INTERVAL TIMERS

The intervals to be measured are subdivisions of a second.

A. LONG INTERVAL TIMERS

A1. Sun Dial

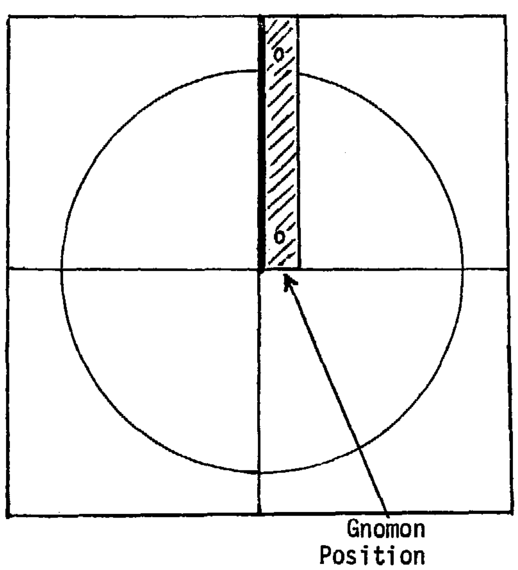


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	16 cm x 16 cm x 2 cm
(2) Gnomon	1	Metal Sheet (B)	10 cm x 8 cm x 0.1 cm

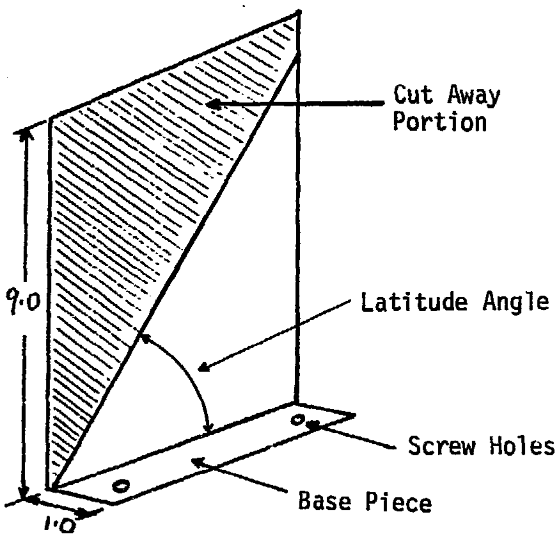
b. Construction

(1) Base



Cut the base from the wood (A). Use a felt pen to mark off the surface of the base into four equal portions. Draw a circle (diameter 7 cm) on the base with its center at the middle of the base.

(2) Gnomon



Make the gnomon from the metal sheet (B). Bend the end of the sheet at right angles to the sheet so as to form a base piece 1 cm wide. Drill two screw holes in the base piece. Note the latitude of your locality (e.g., 39° in Washington, D.C.) and mark out a right-angled triangle on the vertical portion of the metal sheet such that the sloping side of the triangle is inclined to its base at an angle equal to the latitude angle. Cut off the sheet above the sloping side. You now have a metal gnomon. Attach the gnomon to the base with screws.

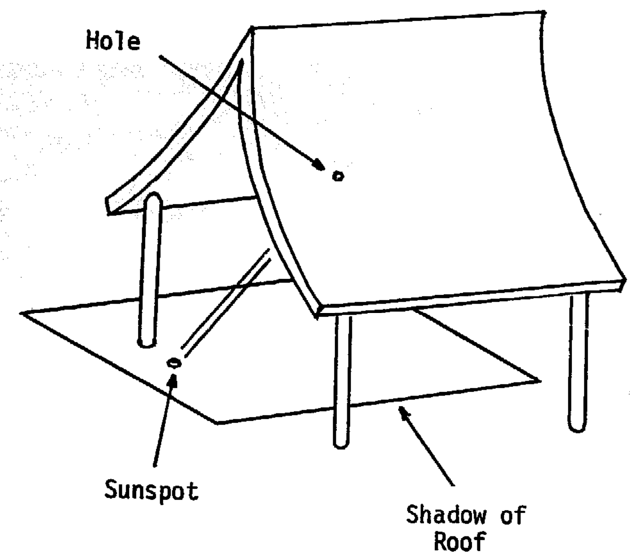
c. Notes

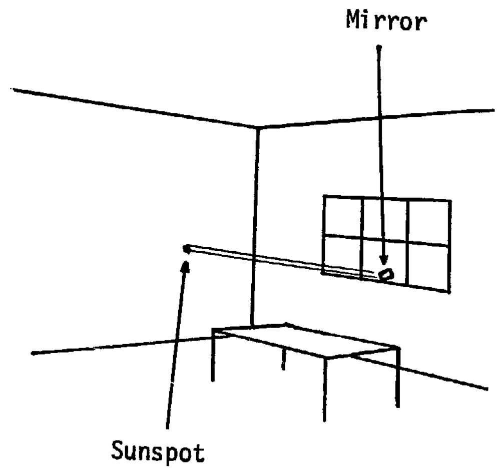
(i) The base of the apparatus should be placed on a horizontal surface with the plane of the gnomon in a true North-South plane, thus making the sloping side of the gnomon parallel to the Earth's axis. Calibrate the sun dial against a clock, marking in the positions of the shadow with a felt pen or paint.

(ii) At the North and South Poles the shadow will move through 15° every hour. Elsewhere the angle rotated per hour will be greater than 15° in the early morning and late evening, and less than 15° towards midday.

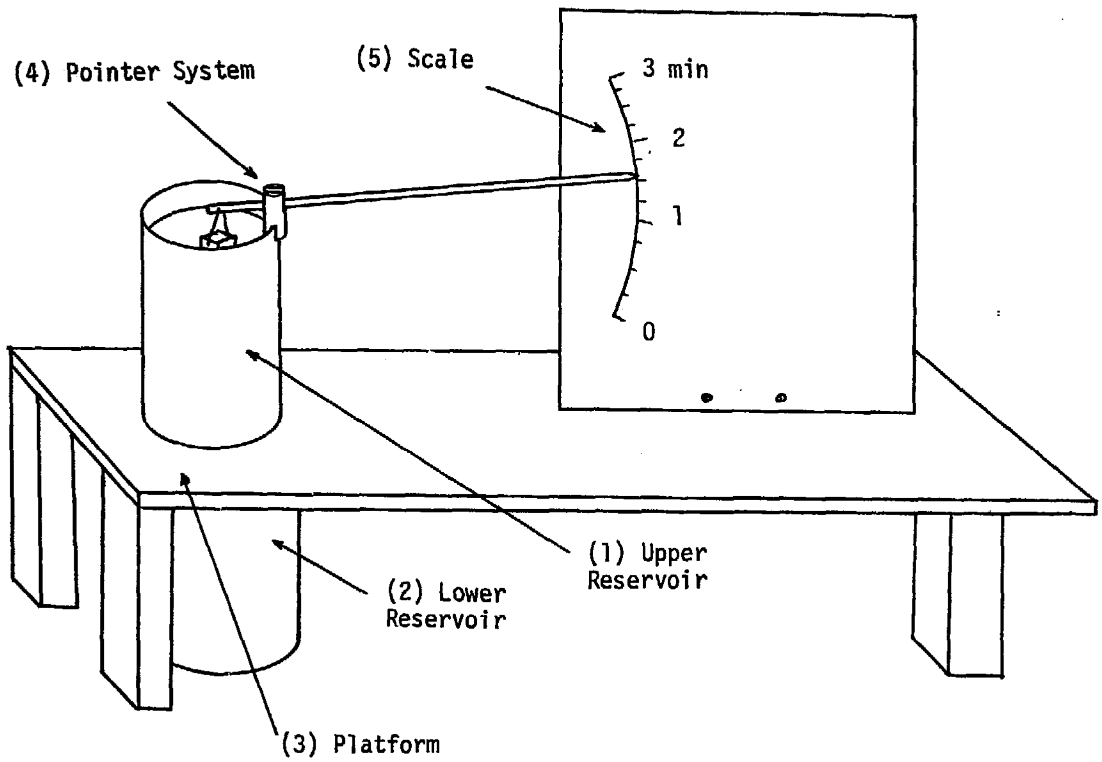
(iii) Since the rotation of the Earth is not exactly 24 hours, the sun will not appear to be due North (or South, as the case may be) at noon, Greenwich Mean Time. Each month it will therefore be noted that the sun dial deviates further and further from the conventional time. From 5 to 30 minutes deviation will be noted over a period of one month, depending on the season.

(iv) The apparent motion of the sun may be used in even simpler (but cruder) ways to record the passage of time. It is thus possible to note the motion of a spot of sunlight due to a ray of light passing through a hole in a roof, or due to a ray of light reflected from a mirror placed by a window. The distance moved by the sunspot in successive intervals of time on the same day will be noted to be surprisingly regular. (See sketches on next page.)


Hole
Sunspot
Shadow of
Roof


Mirror
Sunspot

A2. Water Clock



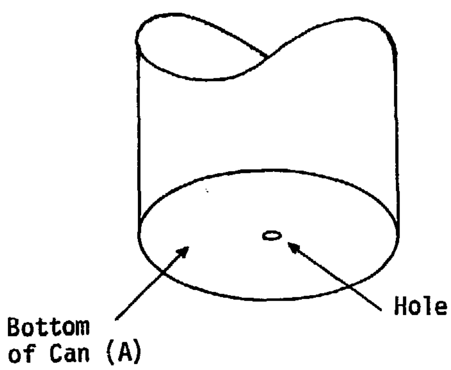
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Upper Reservoir	1	Can (A)	1 liter capacity
(2) Lower Reservoir	1	Can (B)	1 liter capacity
(3) Platform	1	Plywood (C)	50 cm x 15 cm x 1.0 cm
	3	Wood (D)	20 cm x 3 cm x 3 cm
(4) Pointer System	1	Wooden Dowel (E)	8 cm long, 2.5 cm diameter
	1	Wood Strip (F)	35 cm x 0.6 cm x 0.4 cm
	1	Nail (G)	0.2 cm diameter, 4 cm long
	4	Washers (H)	--
	1	Wood (I)	4 cm x 4 cm x 1 cm
	1	String (J)	--
	1	Eye Screw (K)	--

(5) Scale	1	Plywood (L)	40 cm x 30 cm x 0.5 cm
	1	Wood (M)	30 cm x 3 cm x 3 cm
	1	White Paper (N)	30 cm x 40 cm

b. Construction

(1) Upper Reservoir



Take the tin can (A) and drill a small hole (0.1 cm diameter for example) in the middle of the base.

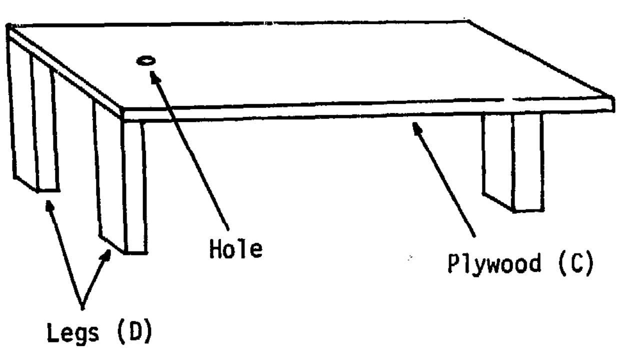
The bigger the can, and the smaller the hole, the greater will be the period of time for which the clock will run. This may be checked now by filling the can with water, and noting the time for it to drain.

If you wish to measure small intervals of time, you may increase the number of holes in the base of the can.

(2) Lower Reservoir

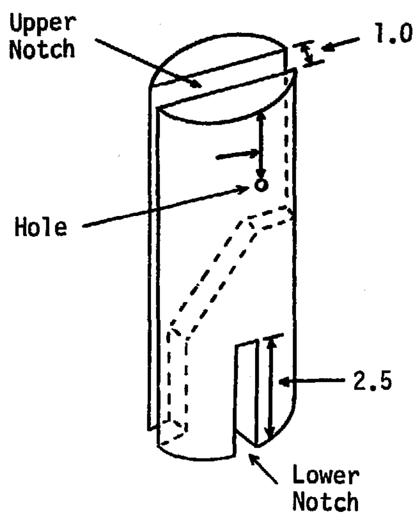
Use can (B) which should be of the same size as, or larger than, the can used for the upper reservoir.

(3) Platform

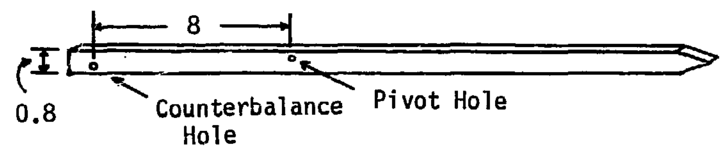


Take plywood (C) to make the platform, balancing this on the three legs (D) which should be sufficiently long to permit the lower reservoir to be moved under the platform without difficulty. Drill a hole (1 cm diameter) in one end of the platform. Place the upper reservoir over the hole in the platform and the lower reservoir underneath it so that water can run from the upper to lower reservoir.

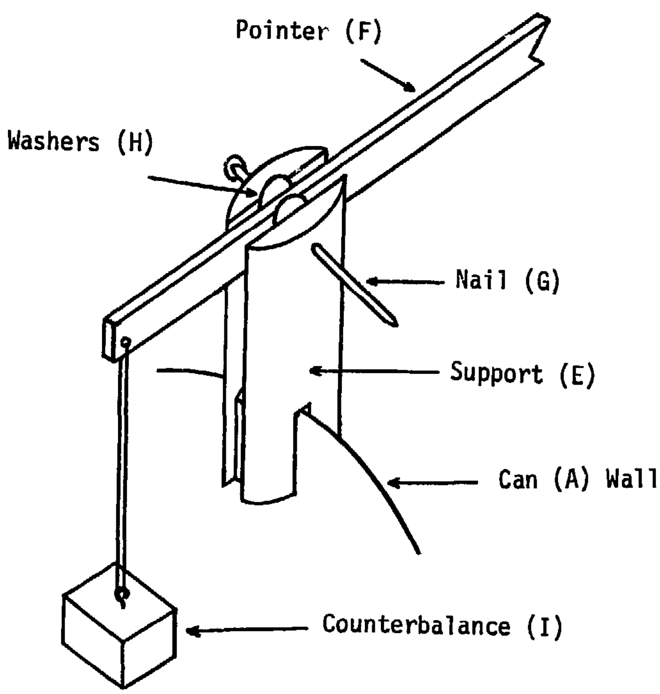
(4) Pointer System



Make a support from a wooden dowel (E) as indicated. Cut a lower notch in the support to enable it to sit on the side of the upper reservoir (A). Make an upper notch to permit the full movement of the pointer (E) to be attached. Drill a hole (0.2 cm diameter) horizontally through the upper part of the support to permit passage of the nail (G) to serve as the pivot for the lever.



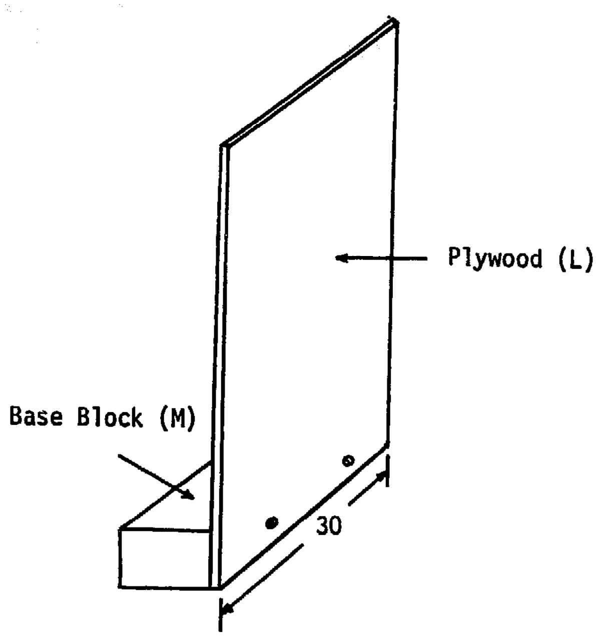
Make the pointer from a strip of wood (F). Drill a small hole (0.3 cm diameter) at one end of the pointer to take the string (J) from the counter-balance, and 8 cm away from this hole drill a second hole (0.3 cm diameter), close to the top surface of the pointer, through which the nail (G) is to be put as a pivot.



Balance the pointer on the newly made support by inserting the nail (G) through the appropriate holes in the support and pointer. Washers (H) should be placed either side of the pointer to serve as spacers. These prevent unwanted motion of the pointer on the pivot. The pivot may be fixed permanently in position in the support with the help of epoxy resin, since the pointer can move about the fixed axle on its own pivot hole.

Take the small block of wood (I), and attach it to the pointer by means of the string (J) and a screw (K) attached to the top of the block.

(5) Scale



Attach a sheet of plywood (L) to the block of wood (M) intended to hold the plywood in a vertical position. Sit the newly made scale on the platform just behind the end of the pointer, sufficiently close to avoid parallax problems in recording the movement of the pointer. Screw the base block (M) of the scale onto the platform. Use a white sheet of paper (N) attached to the surface of the plywood with thumbtacks to actually record a time scale.

Adjust the length of string (J) on the counterbalance so that when the upper reservoir is full of water the pointer will be set towards the bottom edge of the scale.

c. Notes

(i) The counterbalance should be wet all over prior to use so that it does not tend to sink deeper into the water as it is used.

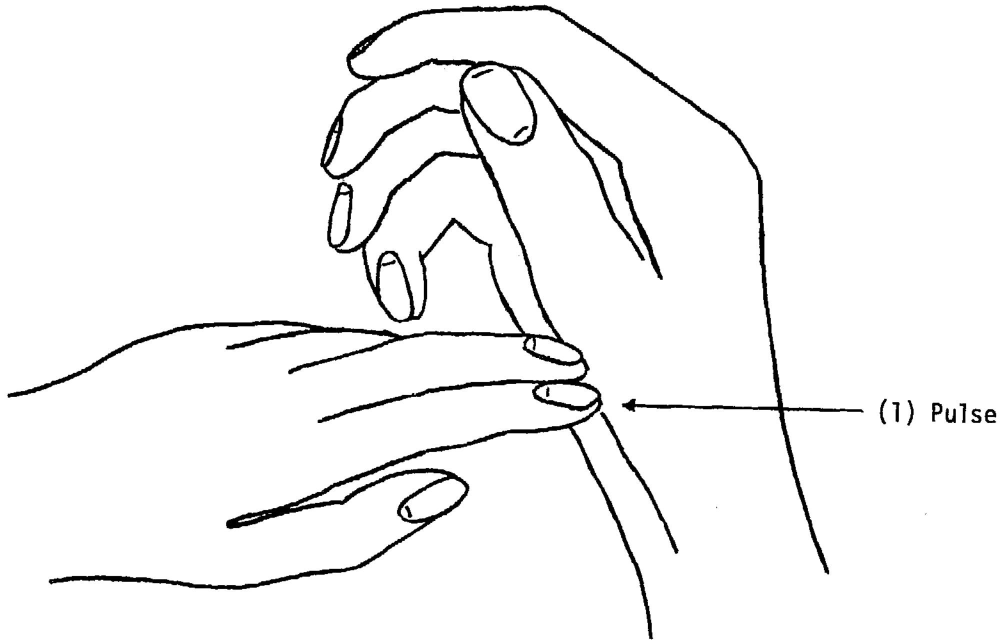
(ii) The water clock may be calibrated against a watch. The scale produced will not be linear since the water pressure over the hole in the base of the upper reservoir decreases as the water level drops. The initial rate of fall of water level is therefore greater than the final rate.

(iii) The clock will be found to be surprisingly reliable, observations being quite repeatable.

(iv) Using an upper reservoir of 1.3 liters, a depth of 19 cm and a base hole 0.15 cm diameter, a five-minute scale was very conveniently created. When the number of holes in the base was doubled the pointer traversed the scale in half the time (2 min 30 sec), and when the number of holes was increased to three the pointer traversed the scale in one third of the original time (i.e., in 1 min 40 sec).

B. MEDIUM INTERVAL TIMERS

B1. Pulse



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Pulses	--	--	--

b. Construction

(1) Pulse

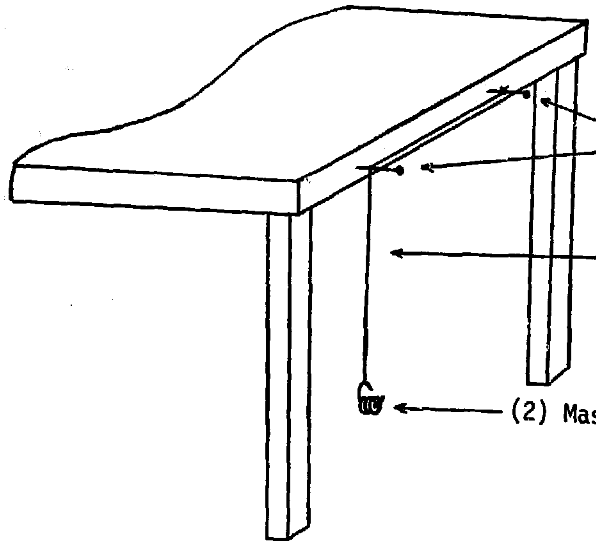
Place two fingers from the left hand over the pulse on the right wrist. The pulse beat can easily be detected.

c. Notes

(i) The pulse beat may be calibrated against that of other individuals and against other timing devices. Under normal conditions it remains surprisingly constant, but its rate varies according to the degree of exertion to which the individual is currently subjected.

(ii) It is useful to note that if the pulse in the neck, just below the angle of the jaw, is monitored with one hand, the other hand is left free for other functions.

B2. Simple Pendulum



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) String	1	String (A)	1 meter long
	1	Paper Clip (B)	--
(2) Mass	10	Washers (C)	--
(3) Support	2	Nails (D)	3 cm long

b. Construction

(1) String

Take the length of string (A), and attach a hook [made from the paper clip (B)] to one end.

(2) Mass

Suspend washers (C) from the hook to serve as a variable mass.

(3) Support

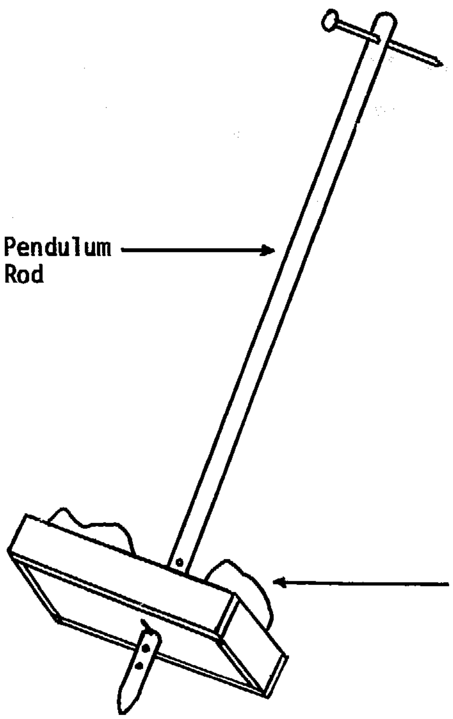
Drive two nails (D) into the side of a table, or into a wall, so that the nails are at the same height above the ground. Wrap the desired length of string two or three times around one nail, and fasten the spare length of string to the other nail. This should insure that

the string is pivoted rigidly
at the first nail.

c. Notes

(i) If the length of the pendulum, from the support to the center of gravity of of the mass, is adjusted to 25 cm (or more accurately to 24.8 cm) the pendulum will oscillate with a period of one second.

B3. Classroom Clock *



a. Materials Required

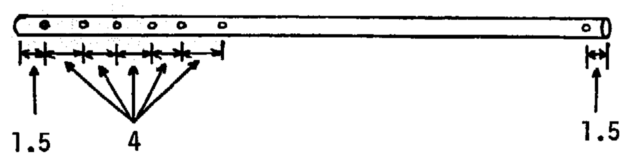
Components	Qu	Items Required	Dimensions
(1) Pendulum Rod	1	Broom Handle (A)	120 cm long, 2.5 cm diameter
	1	Metal Tube (B)	2.5 cm long, 1 cm external diameter; approximately 0.7 cm internal diameter
	1	Nail (C)	15 cm long, 0.5 cm diameter
(2) Mass	2	Wood (D)	22 cm x 6 cm x 0.5 cm
	2	Wood (E)	30 cm x 6 cm x 0.5 cm
	1	Wood (F)	31 cm x 22 cm x 0.5 cm
	1	Nail (G)	10 cm long, 0.5 cm diameter
	--	Bricks, Rocks, etc. (H)	--

*Adapted from Nuffield Foundation, Guide to Experiments I, Physics, (London: Longmans/Penguin, 1967), pp 79-81.

(3) Support	2	Tables (I)	--
	2	Stools (J)	--

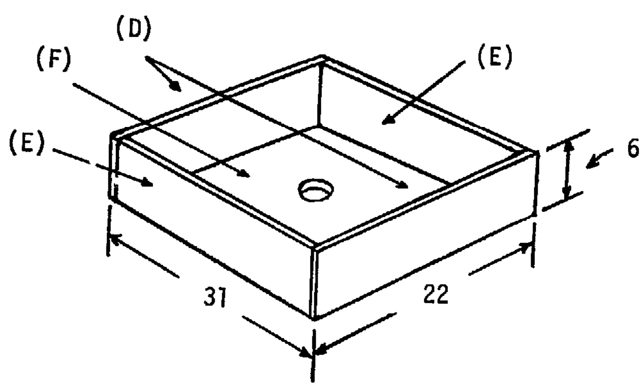
b. Construction

(1) Pendulum Rod



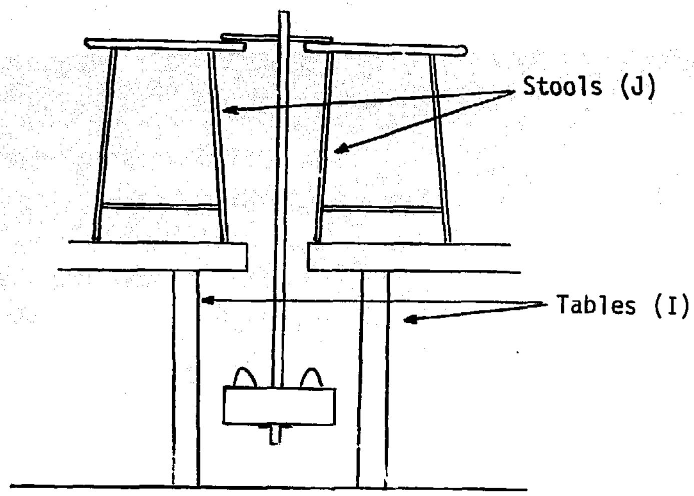
Make the pendulum rod out of the broom handle (A). Drill six holes (0.6 cm diameter) in one end of the rod at 4 cm intervals. Drill another hole (1 cm diameter) 1.5 cm from the other end of the rod. Line this with a short length of metal tubing (B) to reduce friction at the pivot, and insert a long nail (C) through the tube.

(2) Mass



Construct a wooden tray to hold the masses. Use one piece (F) for the base. Nail the four other pieces (D,E) to the base as shown. Drill a hole (2.7 cm diameter) in the middle of the tray base (F), and slide the tray onto the pendulum rod by way of this hole. Insert the strong nail (G) through one of the six holes in the end of the rod to hold the tray in position. The bricks or rocks (H) may be placed in the tray to serve as appropriate masses.

(3) Support



Place two tables (I) fairly close together, and sit the stools (J) on top of both tables, sufficiently close to one another so that the pendulum may be supported by means of its pivot nail resting between the tops of the stools. The nail (G) must be held firmly in position on top of the stools by hand, clamps, or any device which will hold it firmly.

c. Notes

(i) With the length (L) of the pendulum from pivot to tray bottom fixed at 103.5 cm the period (T) of the pendulum was noted to be two seconds.

Mass = 7,000 g

L (cm)	T (sec)
97.0	1.94
101.0	1.98
105.0	2.02
109.0	2.05
113.0	2.09
117.0	2.12

(ii) The initial displacement of the pendulum mass has negligible effect on the period. Keeping the length of the pendulum fixed at 105 cm and the mass constant at 7,000 g the following correlation of period (T) and initial displacement (D) was recorded.

D (cm)	T (sec)
5	1.99
10	2.01
15	2.00
20	2.00

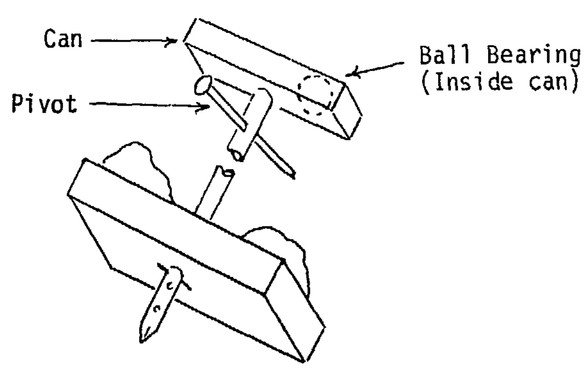
(iii) The period of the swing is virtually unaffected by variation of the mass. Hence, keeping the pendulum length constant at 105 cm, the mass (M) in the pendulum tray was varied by increasing the number of bricks. The following observations of the period (T) were recorded.

M (g)	T (sec)
1500	2.00
3250	2.00
5000	2.00
7000	2.01

(iv) The major effect of increasing the mass (M) of the bricks carried by the pendulum is to reduce the damping effect on the oscillations. With the length of the pendulum fixed at 105 cm, the pendulum mass was displaced a fixed distance (10 cm) and the number of oscillations (N) recorded as the displacement fell from 10 to 5 cm. The following results were obtained.

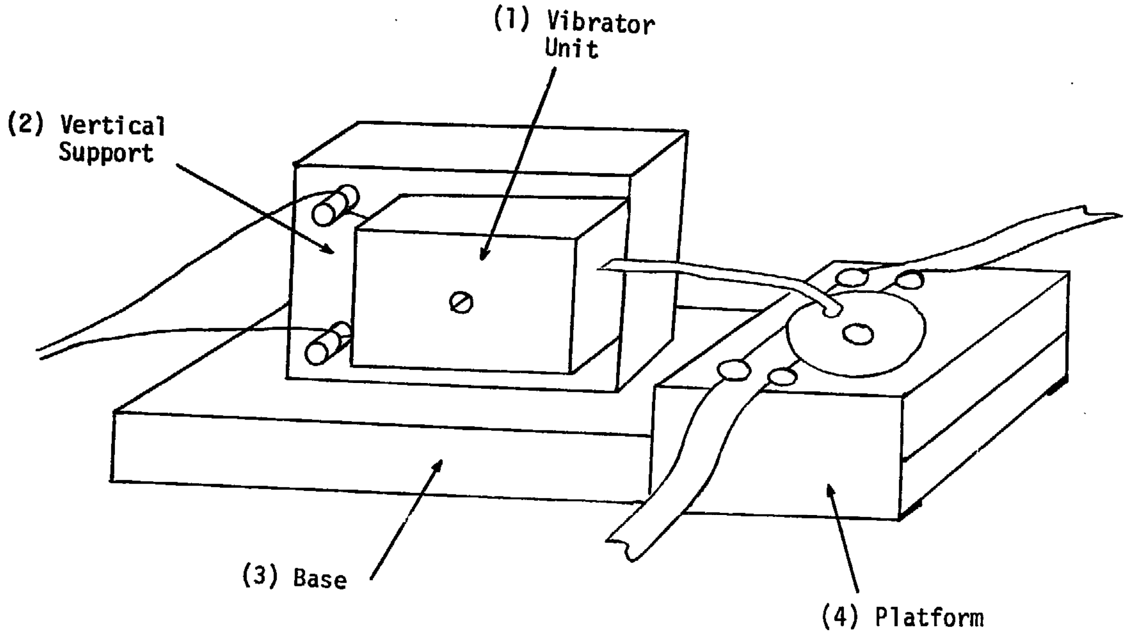
M (g)	N	Damping Effect
0	51.0	High
1500	95.5	Moderate
3250	97.8	Moderate
5000	98.2	Moderate
7000	131.6	Low

(v) If this timing device is to be used by a large class, it might be useful to modify it slightly to make the counting of oscillations possible without continuous visual observation. It is suggested that a metal container might be attached to the top of the pendulum rod, and a 2.5 cm ball bearing allowed to roll freely in the container, so that a click will occur twice per oscillation as the ball bearing hits the ends of the can.



C. SHORT INTERVAL TIMERS

C1. Ticker Tape Timer ©



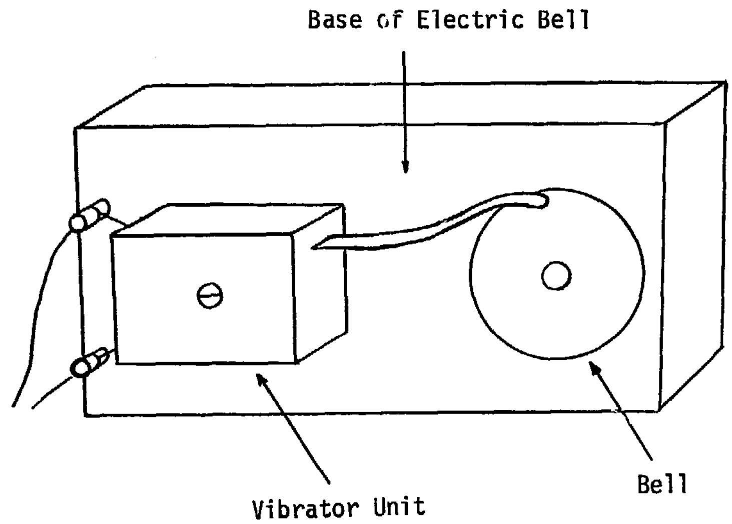
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Vibrator Unit	1	Household Electric Bell (A)	--
(2) Vertical Support	1	Wood (B)	7 cm x 5 cm x 2 cm
(3) Base	1	Wood (C)	16 cm x 6 cm x 2 cm
	2	Screws (D)	3 cm long
(4) Platform	1	Wood (E)	6 cm x 5 cm x 2 cm
	2	Aluminum Sheets (F)	6 cm x 5 cm x 0.05 cm
	1	Carbon Paper (G)	4 cm x 4 cm
	5	Thumbtacks (H)	--

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 12-14.

b. Construction

(1) Vibrator Unit

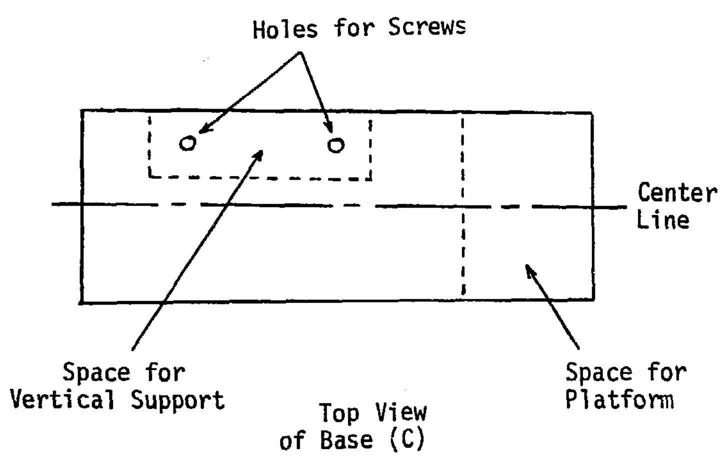


Take the household electric bell (A), and remove the vibrator unit. (The bell utilized in this instance was designed to operate normally at 10 volts.)

(2) Vertical Support

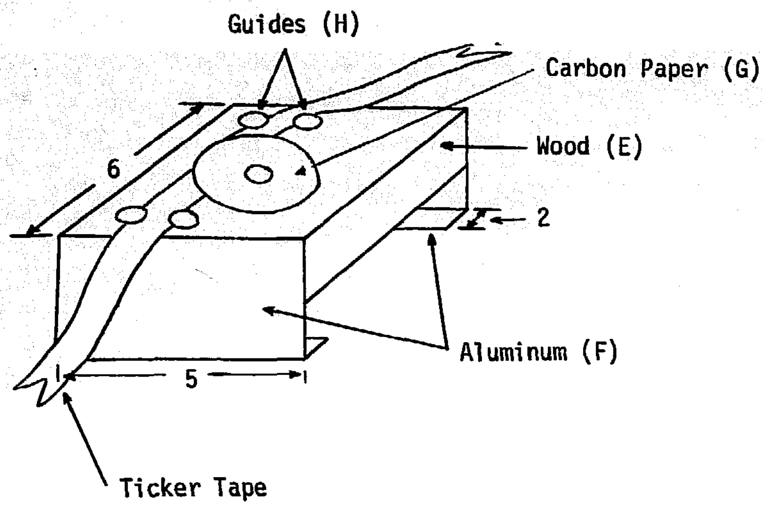
Use the piece of wood (B) to serve as the vertical support, and attach the vibrator unit to it with screws.

(3) Base



Use the wood piece (C) as the base. Place the vertical support on the base in such a position that the vibrator arm will be parallel to, and directly above, the line bisecting the length of the base. Mark in the position of the support, and then drill two appropriate holes in the base so as to facilitate the attachment of the support with the screws (D).

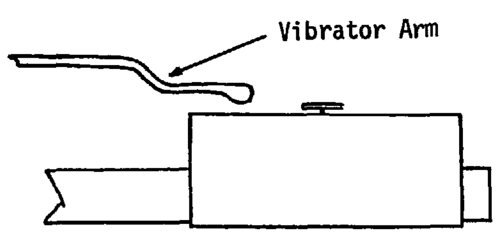
(4) Platform



Attach the aluminum sidepieces (F) to wood (E) with nails to make a platform. Then with the platform in position on the base, bend the sidepieces at the bottom to hold the platform firmly in contact with the base. (A loosely fitting platform will result in a poor track being recorded on the ticker tape.)

Cut a circular disc out of the carbon paper (G) and pierce the center so that it may pivot freely about a thumbtack (H) in the center of the platform.

Pin four more thumbtacks (H) in the platform to serve as guides for the ticker tape, which must pass under the carbon disc. There must be negligible friction between the guides and ticker tape.



Side View

Bend the vibrator arm downwards so that the endpiece is within 0.3 or 0.4 cm of the platform surface.

c. Notes

(i) Two dry cells in series will generally operate the timer, even though the bell is designed for operation on a 10 volt supply.

(ii) If ticker tape is difficult to obtain, cashiers' paper rolls (for cash registers) are generally available, and may be cut into strips of suitable width, so long as care is taken to obtain smooth straight edges.

(iii) If the ticker tape from the vibrating timer is attached to a moving object, the motion of the object will be recorded on the ticker tape. It is thus possible to determine the distance moved by the object during specific time intervals. This is the basis of a wide range of experiments to determine the relationship between force and motion.

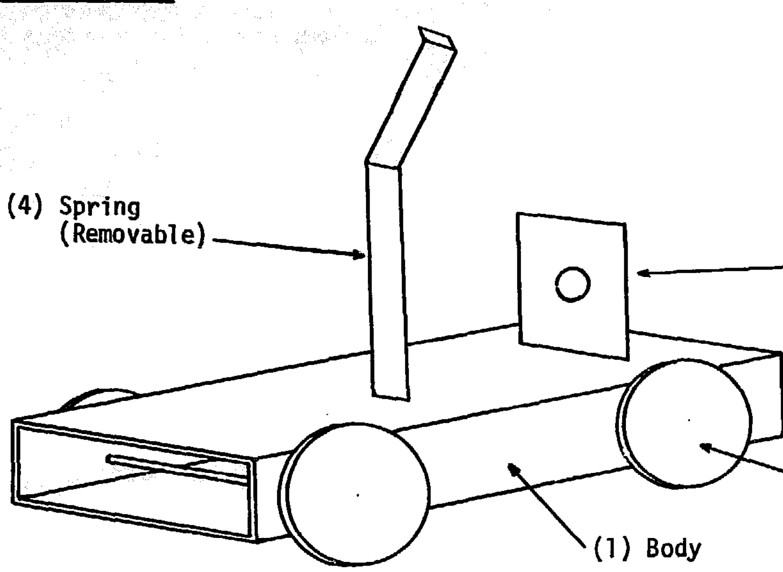
III. CARTS

A. FORCE AND MOTION CARTS

The carts described in this section are presented in increasing order of sophistication, ranging from the simplest cart which can only be used for qualitative observation to the more sophisticated carts which can be used for quantitative experimentation of the relationship between force, mass and acceleration.

A. FORCE AND MOTION CARTS

A1. Elementary Cart *



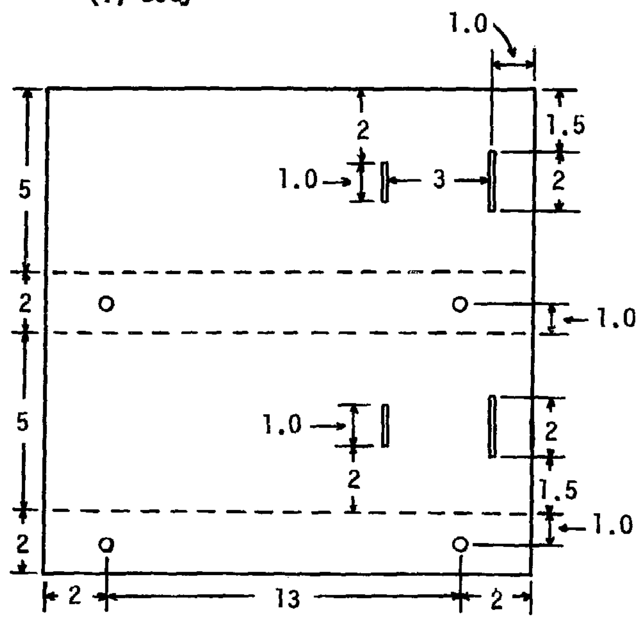
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Body	1	Cardboard Sheet (A)	15 cm x 14 cm
(2) Wheels	2	Wooden Spools (B)	Diameter of spool ends approximately 4 cm
	2	Coat Hanger Wire (C)	8 cm long, 0.2 cm diameter
	1	Drinking Straw (D)	--
(3) Balloon Support	1	Cardboard Sheet (E)	4 cm x 7 cm
	1	Balloon (F)	--
(4) Spring	1	Packing Case Band (G)	11 cm long, approximately 1.2 cm wide
	1	Washer (H)	Approximately 17 g

*Adapted from Nick Oddo and Edward Carini, Exploring Motion, An Exploring Science Book, (USA: Holt, Rinehart and Winston Inc., 1964), pp 24-27.

b. Construction

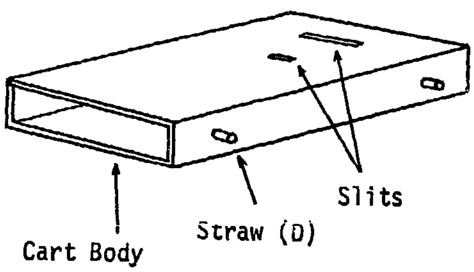
(1) Body

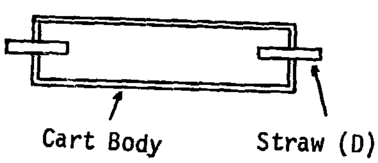


Cardboard (A)

Draw dotted lines on the piece of sturdy cardboard (A) and make four slits and four axle holes as illustrated in the diagram. Fold the cardboard along the dotted lines to make a box, fastening the free sides together with the help of adhesive tape.

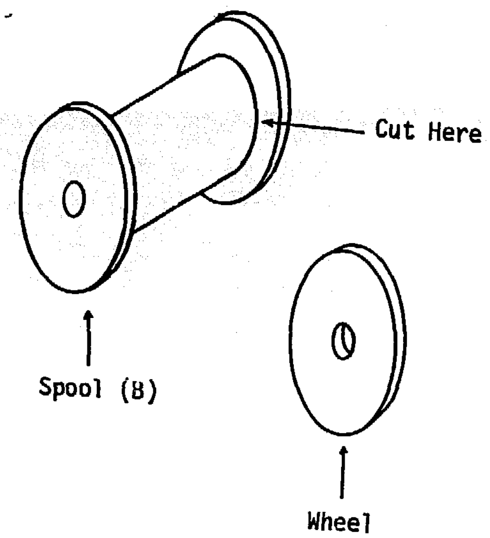
(2) Wheels



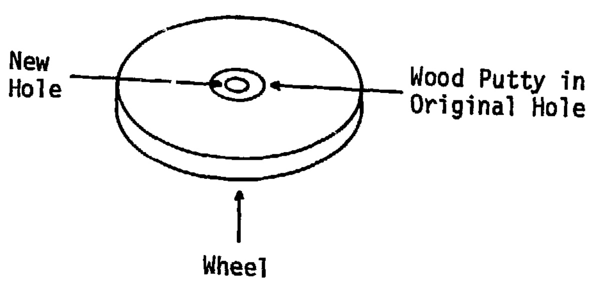


Cross Section

Cut four equal sections (each 1 cm long) from a standard drinking straw (D). Place each section into an axle hole in the body of the cart, and glue firmly in position. The straw sections act as bearings for the axles as well as spacers between the wheels and the body of the cart.



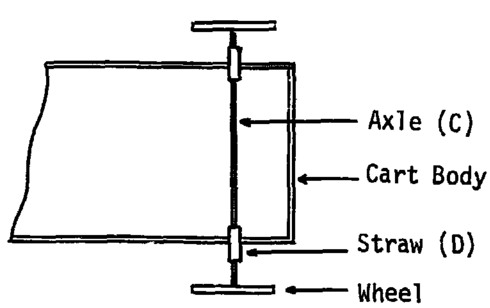
Cut the four wheels from the ends of the two wooden spools (B). Fill the spool holes (0.5 cm diameter) with wood putty and allow the putty to dry hard.



Cut two lengths of wire (C) from wire coat hangers to serve as axles for the cart.

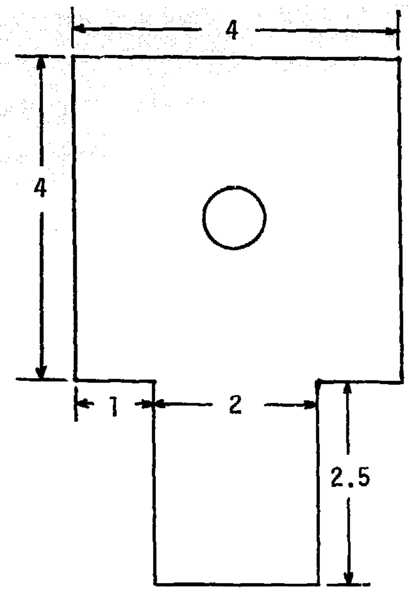
Drill holes, slightly less than 0.2 cm in diameter, through the exact center of each wheel, and put a little epoxy resin in the holes.

Tap the end of one axle into one of these holes, checking carefully to insure that the axle is at right angles (90°) to the wheel, thus avoiding subsequent wheel wobble.



Insert the axle through the body of the cart, and attach a second wheel by the same process. Repeat the procedure with the remaining two wheels and axle, thus providing the cart with front and rear wheels.

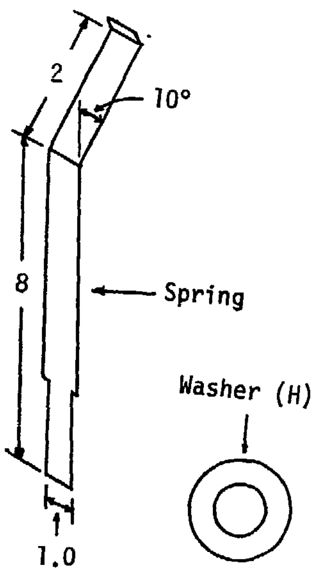
(3) Balloon Support



Cardboard (E)

Cut the strong cardboard (E) to a "T" shape as shown. Make a hole (diameter 1 cm) in the center of the top portion. Insert the support through the pair of slits closest to the end of the cart body. Use a rubber balloon (F) to provide acceleration for the cart [see Note (i)].

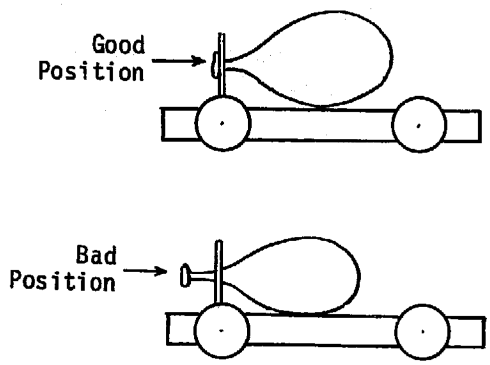
(4) Spring



Cut the packing case band (G) as indicated to make the spring. To facilitate the throwing of the washers (H) by the spring, bend the top end of the packing case band at an angle. Insert the spring through the remaining slits in the cart.

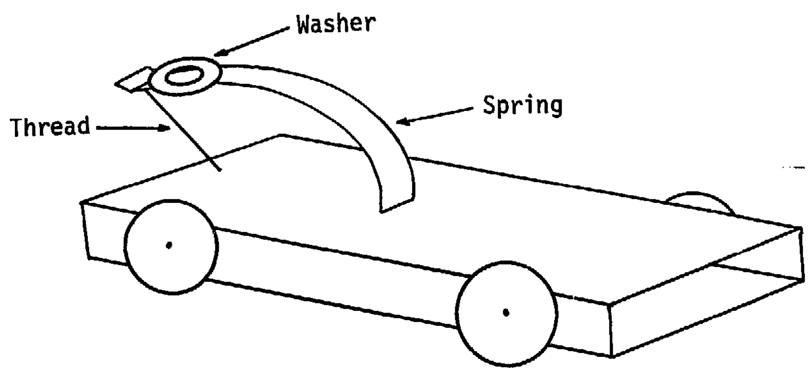
c. Notes

(i) Spherical balloons, as opposed to sausage-shaped ones, may be held in the balloon support (so long as the spring is removed), and are capable of accelerating the cart by the expulsion of air. The cart will be accelerated most efficiently if the open end of the balloon is held in such a way as to prevent it flopping from side to side with resultant dissipation of energy in all directions.



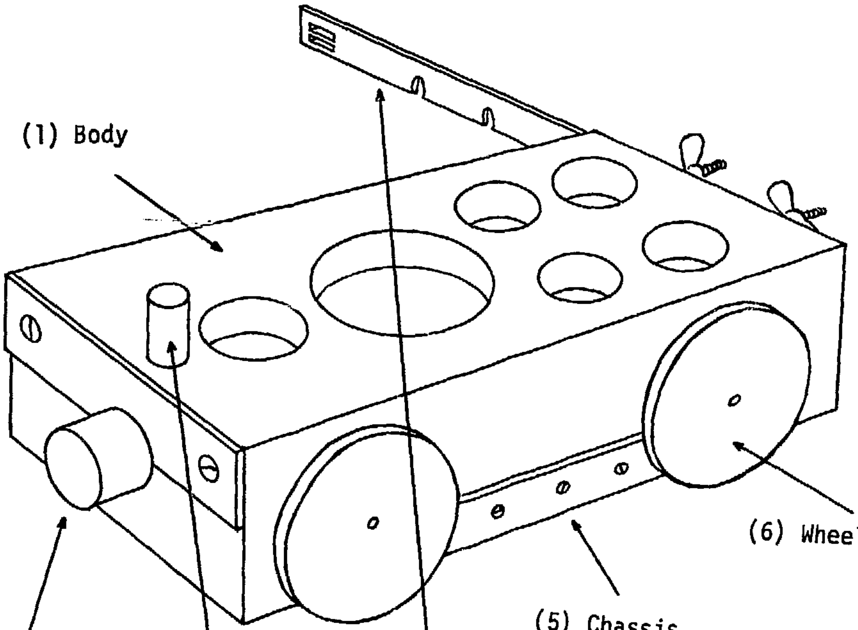
Not only does the cart motion illustrate action and reaction, but it also demonstrates accelerated motion due to a force. Once the balloon is deflated the acceleration ceases and the cart decelerates to a stop.

(ii) Take a length of strong thread (say 15 cm long), and tie the top end of the spring to the end of the cart in such a way that the top end of the spring is almost horizontal. Place a washer on the top end of the spring. If a burning



match is applied to the thread, the spring will be released and eject the washer forward, while the cart will be propelled backwards, thus offering another demonstration of action and reaction.

A2. Lightweight Cart©



a. Materials Required

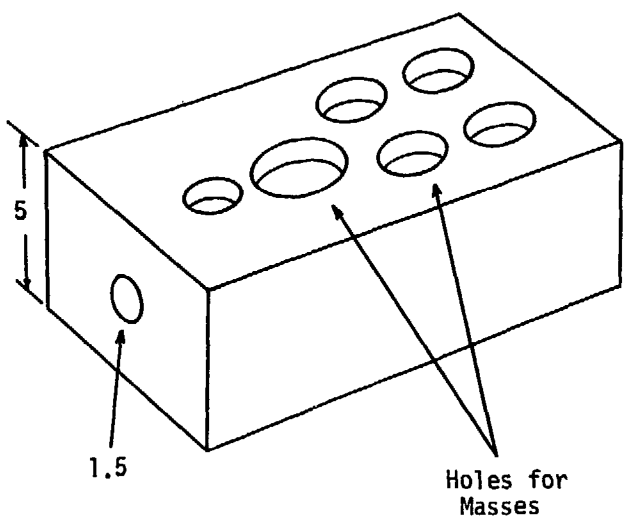
Components	Qu	Items Required	Dimensions
(1) Body	1	Wood (A)	15 cm x 6 cm x 5 cm
(2) Spring Device	1	Steel Wire (B)	80 cm long, 0.09 cm diameter
	1	Wood Dowel (C)	10 cm long, 1.2 cm diameter
	1	Rubber Stopper (D)	Approximately 2.5 cm diameter, and 1.5 cm long
	1	Screw (E)	1 cm long
(3) Spring Release System	1	Metal Plate (F)	6 cm x 1.5 cm x 0.05 cm

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 39-46.

	2	Screws (G)	1.5 cm long
	1	Wood Dowel (H)	3.5 cm long, 0.8 cm diameter
	1	Steel Wire (I)	#30, 3.5 cm long
(4) Ticker Tape Bracket	1	Aluminum Sheet (J)	15 cm x 1.2 cm x 0.05 cm
	2	Bolts (K)	0.2 cm diameter, 2 cm long
	2	Wing Nuts (L)	0.2 cm internal diameter
(5) Chassis	2	Packing Case Steel Bands (M)	Approximately 15 cm x 1.5 cm x 0.02 cm
(6) Wheel System	2	Wooden Spools (N)	Approximately 4 cm diameter
	2	Coat Hanger Wire (O)	10 cm long, 0.2 cm diameter
	1	Masking Tape (P)	1 cm wide
	--	Washers (Q)	--

b. Construction

(1) Body

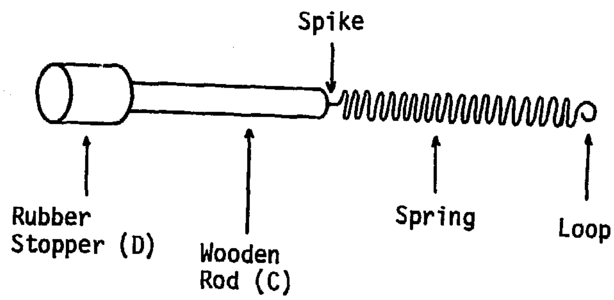


Bore a hole from the center of one end of wood (A) to the center of the other end, in order to accommodate a spring device. The diameter of the hole (1.5 cm) should be slightly larger than that of the spring (1.2 cm).

Bore holes into the top surface of the wood (A) to accommodate six masses (see I/C2), namely one 100 g mass (diameter 2.5 cm), four 200 g masses (diameter 2.5 cm) and one 500 g mass (diameter 4.0 cm). The holes should not be so deep as to cut into the horizontal hole for the spring.

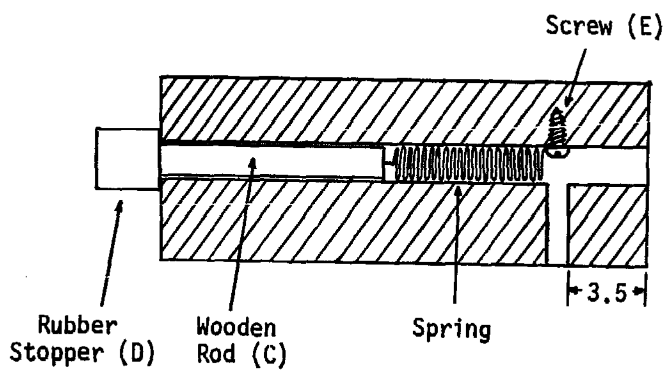
(2) Spring Device

Wind about 60 cm of the steel wire (B) into an open spring approximately 8.5 cm long,



1.2 cm in diameter, and with about 0.5 cm separation between each turn. (A method of winding the spring is described under I/C4). Straighten out one end of the spring into a spike and the other to a horizontal loop.

Attach the spring of one end of the wooden rod (C) by means of the spike and epoxy resin. Attach the rubber stopper (D) to the other end of the rod.

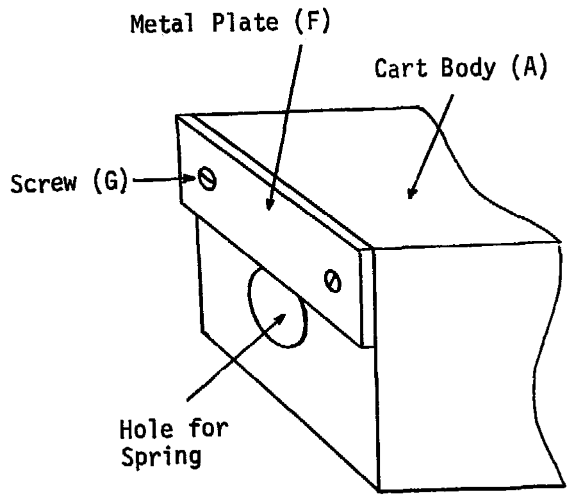


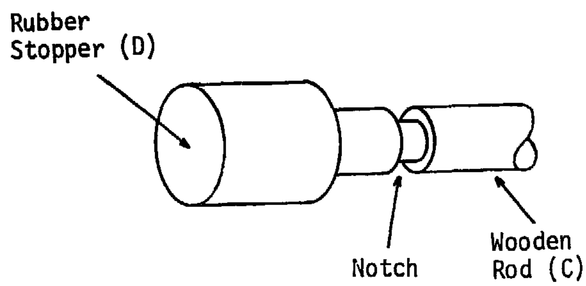
Cross Section
(Side view)

Bore a hole into the bottom of the cart body so that it meets the bore hole for the spring 3.5 cm from the end of the body. Then insert the screw (E) to anchor the loop end of the spring.

Ideally, two or three alternative springs of varying thickness and length should be made for trial purposes. The ultimate spring selected will be such that if two identical carts (one carrying three times its own weight) are placed end to end, and the spring device on one cart is then released, both carts will move apart a sufficient distance at uniform velocity to enable a measure of their initial separation velocities to be recorded.

(3) Spring Release System

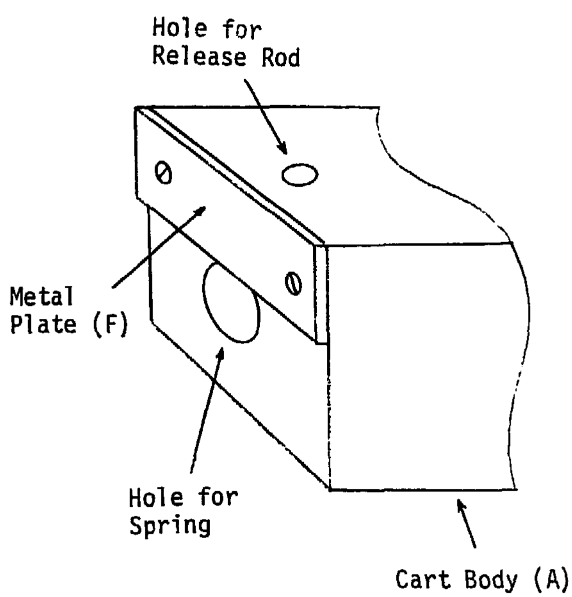




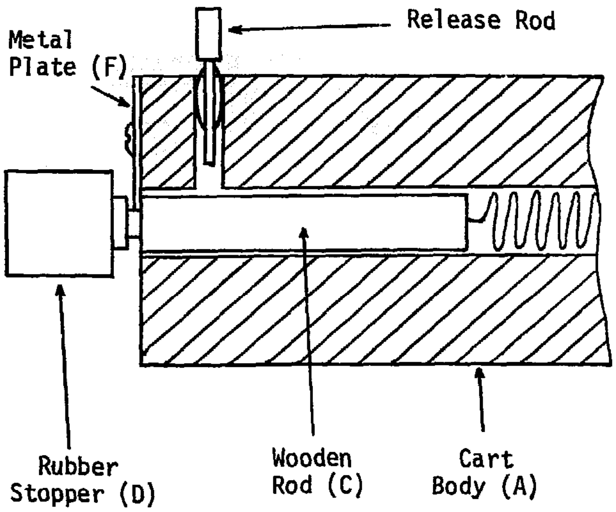
Fasten the metal plate (F) (brass, steel, etc.) onto the front of the cart with two screws (G) so as to just overlap the top of the hole for the spring.

File a small notch around the wooden rod (C) on the spring device, close to the stopper.

It is thus possible to compress the spring into the hole, and hold it in position by means of the notch and metal plate.

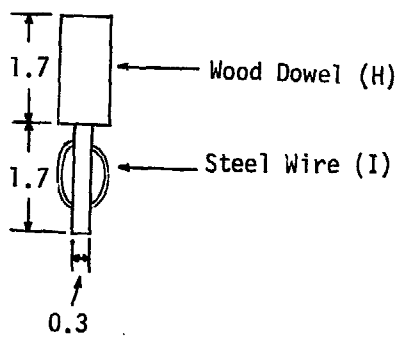


Bore a vertical hole (diameter 0.5 cm) into the top of the cart, near the front end, so that it meets the horizontal bore hole for the spring. The small wooden rod (H) (release rod) inserted into this hole, and pressed against the horizontal rod of the spring device itself, will release the spring from its state of compression. (The need to have the diameter of the spring bore hole slightly



Cross Section

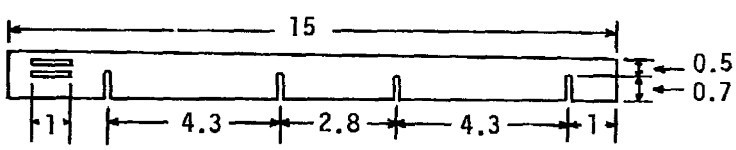
greater than that of the spring and attached rod should now be clear, for it is an essential requirement if the spring is to be released).



Release Rod

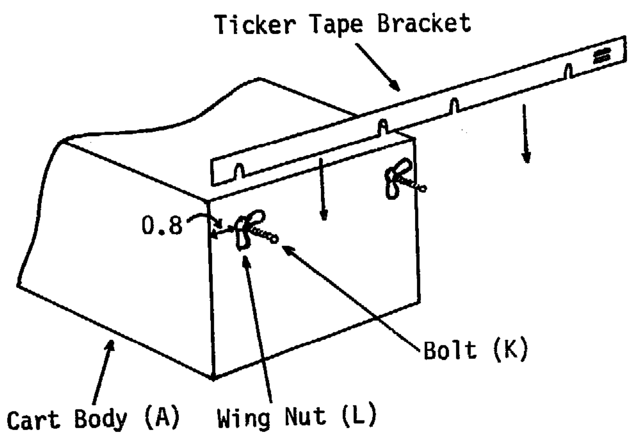
Cut the wood dowel (H) to the dimensions illustrated. The rod should be capable of moving freely in its bore hole, but at the same time it should not be so loose that it is easily lost. To prevent losing it, thread a thin piece of steel wire (I) through the rod so that it acts as a spring contact between the sides of the rod and the bore hole.

(4) Ticker Tape Bracket

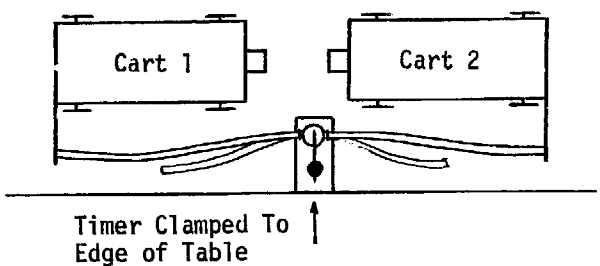


Sheet Metal (J)

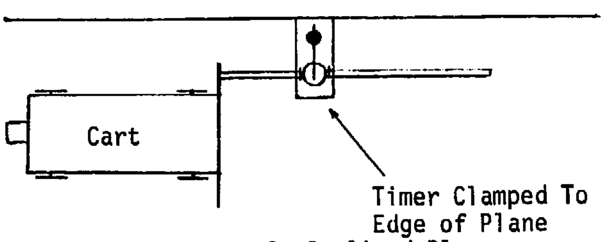
Cut the ticker tape bracket from the sheet of metal (J) (brass, aluminum) which should be reasonably rigid. Make slits (0.1 cm wide) near the end to take the ticker tape, and slots (0.35 cm wide) along the bottom to enable the bracket to be attached to the bolts (K) at the



rear of the cart. Wing nuts (L) should be used to fasten the bracket in position.



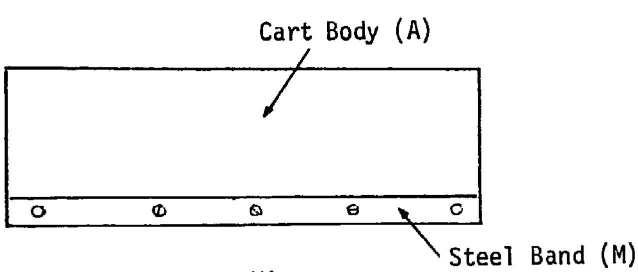
Mutual Repulsion



On Inclined Plane

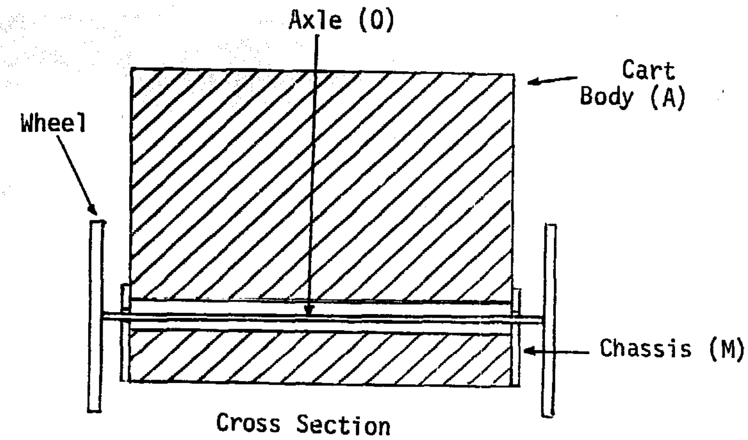
The purpose of the bracket is to insure that ticker tape attached to the cart is in line with the guides of the timer during any experiment, thus reducing friction. Two typical examples are illustrated when carts are mutually repulsed from one another, and when a single cart runs down an inclined plane.

(5) Chassis



Side View

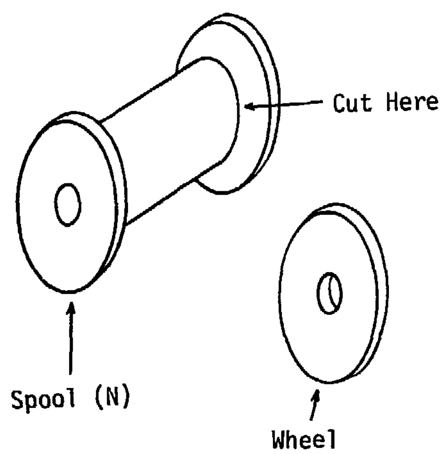
Drill two horizontal holes (0.5 cm in diameter) through the cart body to permit passage of the front and rear axles. Make these holes 1.0 cm from each edge of the cart body (A). Cut the chassis from metal packing case bands (M). Drill five holes along the length of the



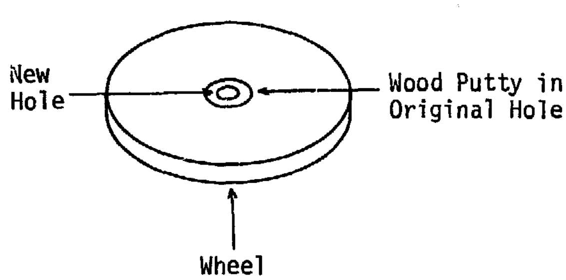
strip, two (diameter 0.3 cm) to coincide with the centers of the axle holes and three to enable the strip to be attached firmly to the body with screws.

The axles of the cart will in fact pivot in the chassis holes and not on the wooden holes through the cart, thus reducing friction.

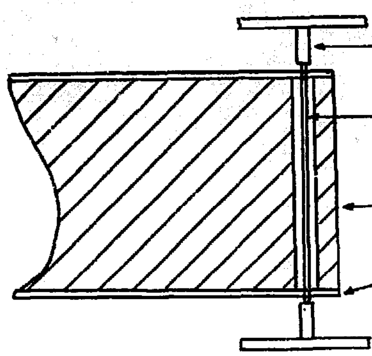
(6) Wheel System



Cut the four wheels from the ends of two wooden spools (N). Fill the spool holes with wood putty and allow the putty to dry hard.



Cut two lengths of wire (O) from wire coat hangers to serve as axles for the cart. Drill holes, slightly less than 0.2 cm in diameter, through the exact center of each wheel, and put a little epoxy resin in the holes.



Cross Section

Tap the end of one axle (O) into one of these holes, checking carefully to insure that the axle is at right angles to the wheel (thus avoiding subsequent wheel wobble).

Insert the axle through the body of the cart, and attach a second wheel by the same process. Repeat the procedure with the remaining two wheels and axle, thus providing the cart with front and rear wheels.

Make small spacers for all four wheels from masking tape (P), in each case wrapping it around the axle (next to the wheel) until it produces a cylindrical spacer 1 cm long and 0.5 cm in diameter.

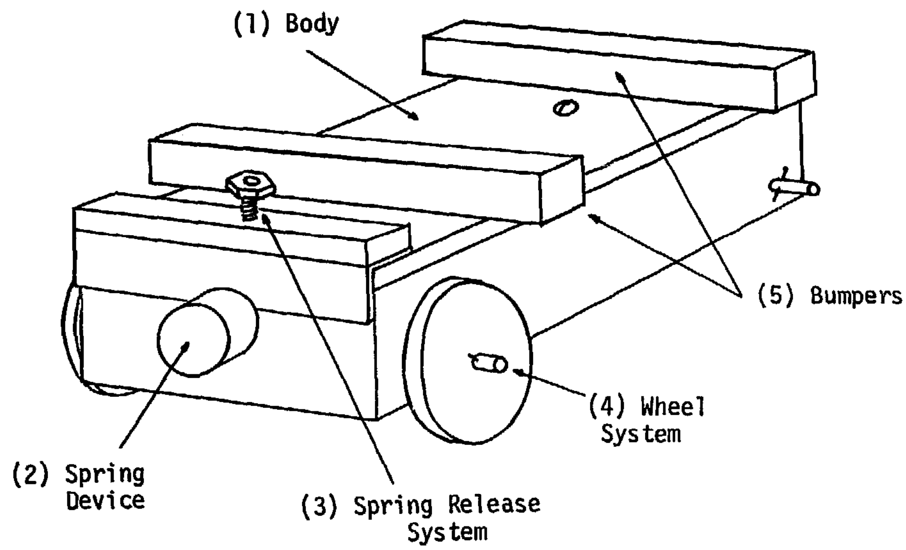
A little soap applied to each axle will serve as a lubricant between the axle and chassis contact points.

It is convenient to adjust the mass of the completed cart to the nearest 100 g. This may be done by shaving wood off the top or bottom surface of the body of the cart, or by adding washers to the body of the cart. In this case holes were drilled in the bottom of the cart, and washers (Q) fixed in the holes with screws. In this way the mass of the cart was adjusted to 400 g.

c. Notes

(i) This cart will inevitably be affected by friction more than a cart made with ball bearing wheels (III/A3). However, a full range of force and motion experiments may be performed with the cart if an inclined plane is used to compensate for friction affecting the cart. Simply adjust the inclination of the plane prior to any experiment so that the cart runs down the plane with constant velocity, the slope of the plane just compensating for the effect of friction.

A3. Heavyweight Cart

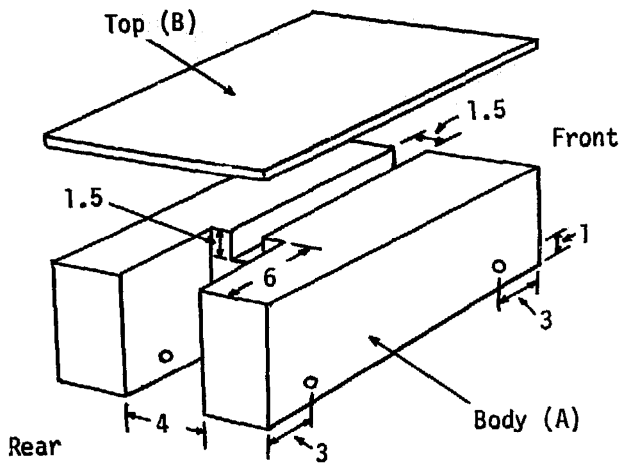


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Body	1	Wood (A)	30 cm x 8 cm x 4 cm
	1	Plywood (B)	30 cm x 8 cm x 0.5 cm
(2) Spring Device	1	Wooden Dowel (C)	16 cm long, 1.2 cm diameter
	1	Roll of Steel Wire (D)	0.09 cm diameter
	1	Rubber Stopper (E)	Approximately 2.5 cm diameter
	1	Screw (F)	4 cm long, 0.2 cm diameter
(3) Spring Release System	1	Aluminum Sheet (G)	8 cm x 3 cm x 0.05 cm
	1	Bolt (H)	3 cm long, 0.3 cm diameter
	2	Nuts (I)	0.3 cm internal diameter
	1	Wooden Strip (J)	8 cm x 2 cm x 0.5 cm
(4) Wheel System	3	Ball Bearing Wheels (K)	Approximately 5 cm diameter
	1	Wooden Dowel (L)	22 cm long, 0.5 cm diameter
	4	Nails (M)	Approximately 2 cm long
(5) Bumpers	2	Wood (N)	12 cm x 2 cm x 2 cm

b. Construction

(1) Body

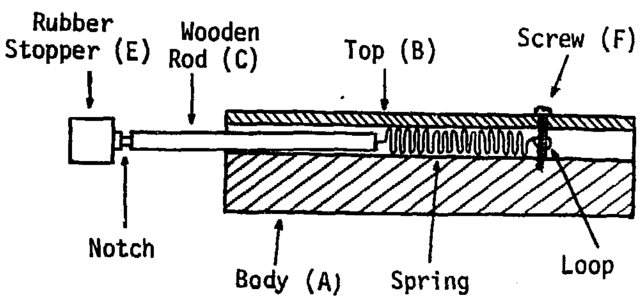


Cut the body of the cart from the piece of wood (A). Drill horizontal holes (diameter 0.5 cm) close to the front and rear of the cart to hold the axles of the wheel system.

Using a saw and chisel, cut a horizontal slot in the top surface of the cart to contain the spring device, and a vertical slot in the rear of the cart to accommodate the rear wheel.

Use the piece of plywood (B) to make a top plate for the cart, and nail it onto the main body.

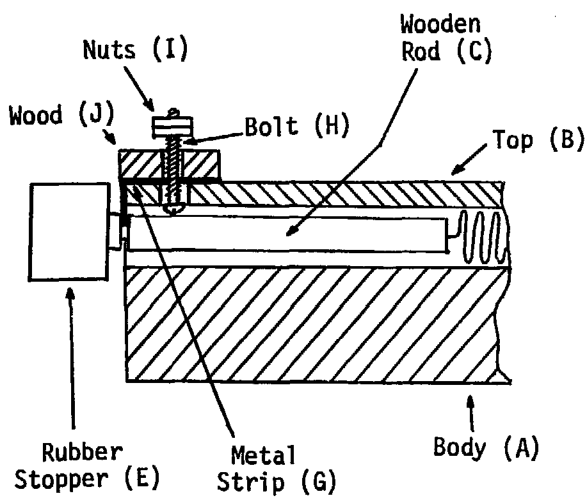
(2) Spring Device



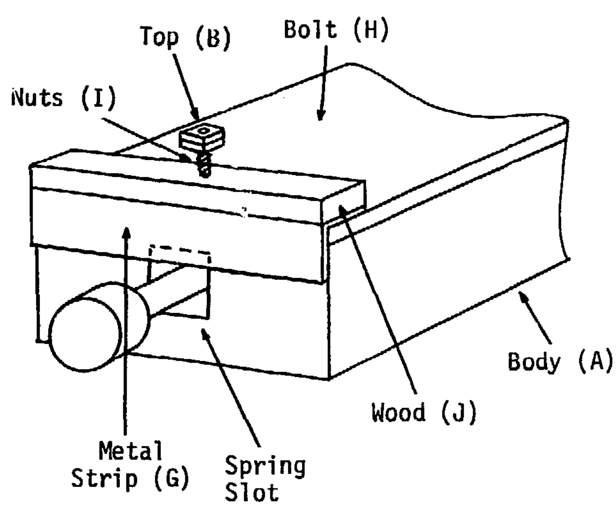
Cross Section

Make the spring device according to the instructions given for the previous cart (III/A2), but according to the dimensions indicated here. The spring, made from the steel wire (D), should be 1.2 cm in diameter and 16 cm long (excluding the spike and loop made on the end of the spring). Nail the rubber stopper (E) onto the end of the wooden rod (C), and make a notch (0.2 cm deep) around the rod about 0.5 cm from the end. Place the spring device in the appropriate slot in the cart, and anchor it in position by means of the screw (F) inserted through the top plate of the cart in such a way as to pass through the loop on the end of the spring.

(3) Spring Release System



Cross Section



Bend the sheet of aluminum (G) into an "L" shape (8 cm wide, 2 cm tall, with a base of 1 cm). Attach the sheet to the front of the cart so that the base of the sheet just overlaps the slot for the spring device. In this way the spring may be compressed and held in position by means of the metal sheet and the notch in the rod.

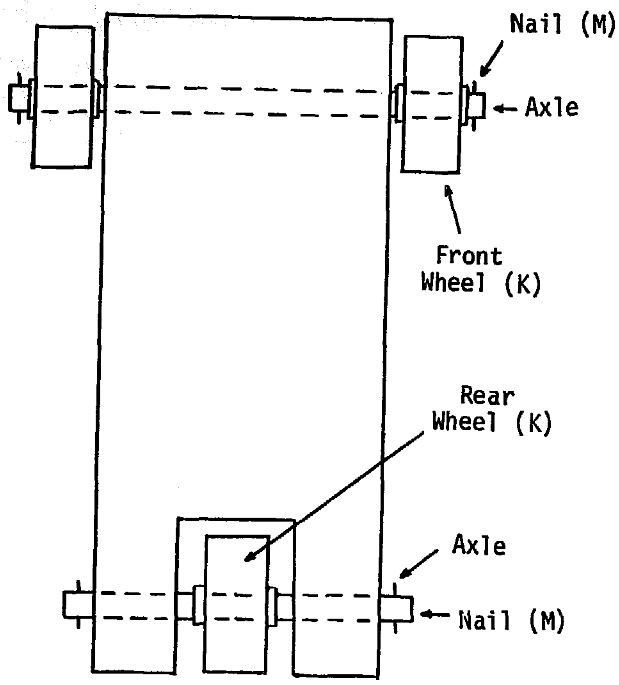
Use the bolt (H) and two appropriate nuts (I) to serve as a releasing device, and bore a hole through the metal sheet and top plate of the cart, 1 cm from the front, so as to expose the rod of the spring device.

The diameter of the hole should be large enough to admit the head of the selected bolt.

Drill a hole through the middle of the wood strip (J). The diameter of the hole should be just large enough to admit the bolt (H), but not the head of the bolt. Place the bolt through the strip with the bolt head beneath the strip, such that it sits in the newly drilled hole in the body of the cart. Nail the strip in position on the front of the cart, and add the two locking nuts (I) to the end of the bolt.

(4) Wheel System

Three ball bearing wheels (K) will have to be purchased (possibly imported) for this

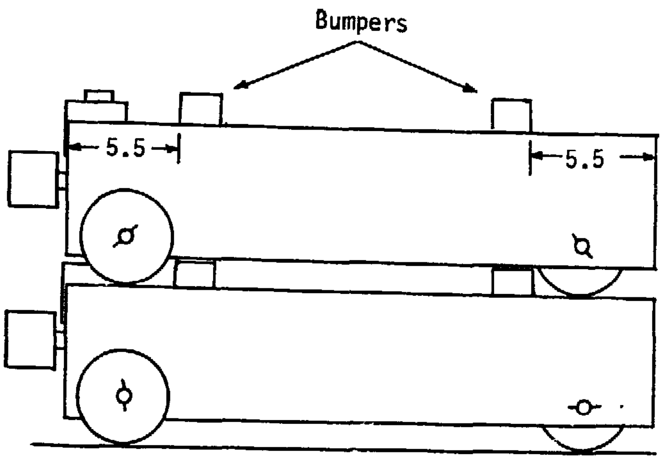


Top View

cart. Cut two axles from the wooden dowel (L). Make the front axle 13 cm, and rear 9 cm long (both 0.5 cm in diameter in this instance). The diameter of the dowel should be the same as the internal diameter of the ball bearing wheels, thus providing a tight fit.

Pass the axles through the axle holes in the cart and fit the wheels appropriately on the axles. Take the four small nails (M), and drill holes of the same diameter as the nails through the axle ends. Insert the nails through the holes, thus securing the axles and wheels in position.

(5) Bumpers



Side View

Use the two strips of wood (N) as bumpers. Nail them in position on top of the cart in such a way that they will hold a second cart (placed on top of the first) firmly in position.

c. Notes

(i) The final weight of the cart will be of the order of 1,000 g. With ball bearing wheels this will not produce too much friction, while it will result in the moving cart having high momentum, and the cart will be little affected by what friction does exist.

(ii) A whole range of experiments related to force and motion will be found in many laboratory books, for example The Physical Science Study Committee, Laboratory Guide, (USA: D. C. Heath and Company, 1965).

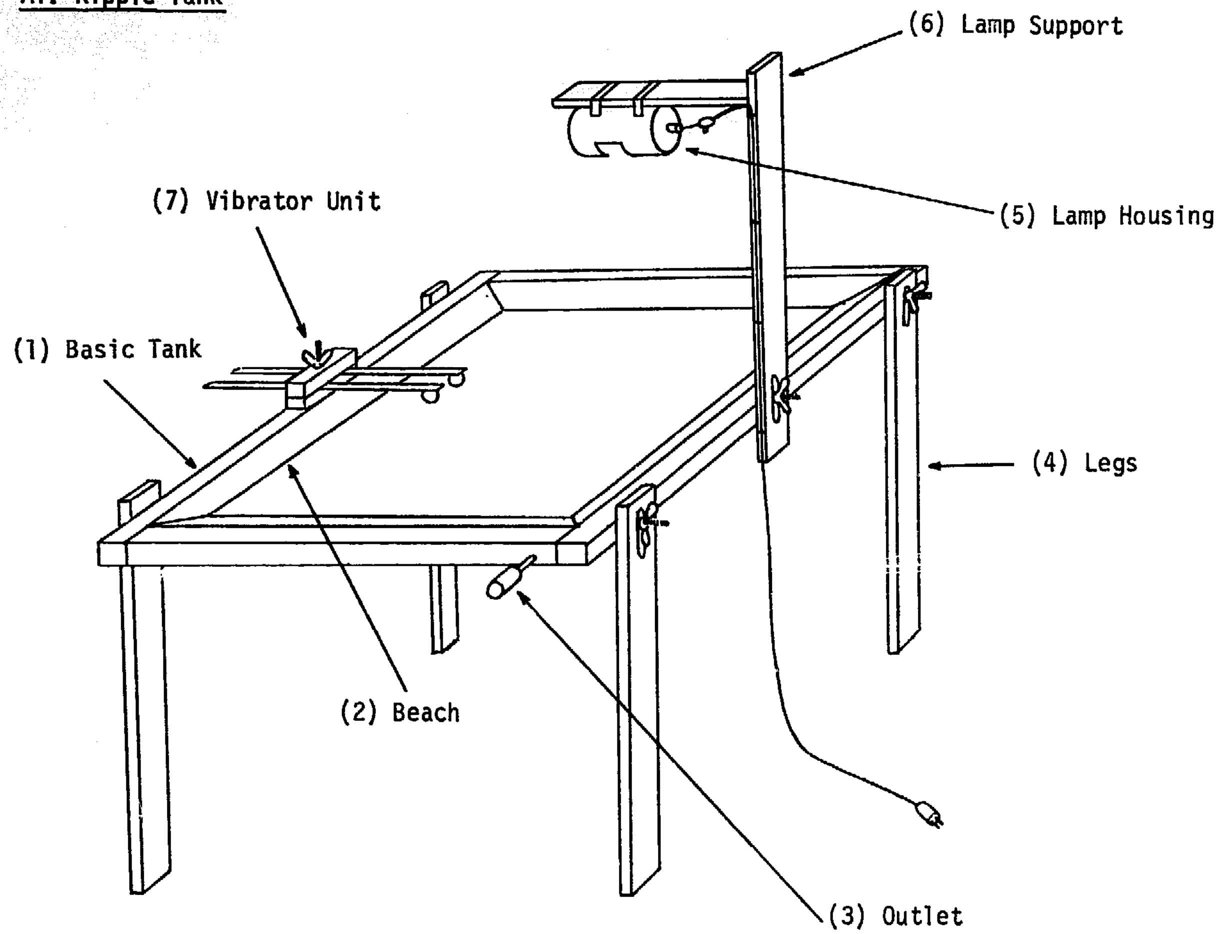
IV. WAVE MOTION APPARATUS

A. RIPPLE TANK APPARATUS

There are many ways of introducing wave motion to students, through observations of waves in water, heat radiation, acoustics, optics and electromagnetism. Each approach requires a different set of equipment. The materials here are limited to presenting wave motion through the observation of waves on water, and the equipment is thus limited to ripple tanks and accessories.

A. RIPPLE TANK APPARATUS

A1. Ripple Tank ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Basic Tank	2	Wood (A)	60 cm x 3.5 cm x 3.5 cm
	2	Wood (B)	57 cm x 3.5 cm x 3.5 cm
	1	Glass Plate (C)	57 cm x 57 cm x 0.3 cm
	1	Rubber Based Cement (D)	--

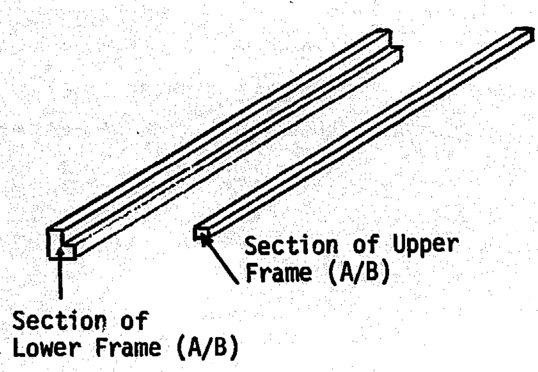
© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 82-91.

(2) Beach	4	Soft Wood (E)	56.5 cm x 6 cm x 2 cm
	4	Brass Discs (F)	0.05 cm thick, 3 cm diameter
(3) Outlet	1	Metal Tube (G)	5 cm long, 1 cm diameter
	1	Rubber Stopper (H)	2.5 cm diameter, 2.5 cm deep
(4) Legs	4	Wood (I)	60 cm x 3 cm x 2 cm
	4	Bolts (J)	3 cm long, 0.4 cm diameter
	4	Wing Nuts (K)	0.4 cm internal diameter
(5) Lamp Housing	1	Aluminum Sheet (L)	35 cm x 16 cm x 0.05 cm
	1	Plywood (M)	11 cm diameter, 0.4 cm thick
	1	Aluminum Sheet (N)	15 cm diameter, 0.05 cm thick
	1	Lamp (O)	100 watt, straight filament
	1	Electrical Socket (P)	Fits above lamp
(6) Lamp Support	1	Wood (Q)	65 cm x 3 cm x 2 cm
	1	Bolt (R)	4.5 cm long, 0.3 cm diameter
	1	Wing Nut (S)	0.3 cm internal diameter
	1	Wood (T)	48 cm x 2 cm x 1 cm
	1	Triangular Wood (U)	5 cm x 4 cm x 3 cm, and 1 cm thick
	1	Packing Case Steel Band (V)	7 cm x 0.5 cm x 0.02 cm
	2	Aluminum Strips (W)	1.5 cm x 0.6 cm x 0.02 cm
(7) Vibrator Unit	2	Packing Case Steel Bands (X)	30 cm x 1 cm x 0.05 cm
	2	Glass Marbles (Y)	1.5 cm diameter
	2	Wood (Z)	7 cm x 2 cm 2 1 cm
	1	Bolt (AA)	2.5 cm long, 0.4 cm diameter
	1	Wing Nut (BB)	0.4 cm internal diameter

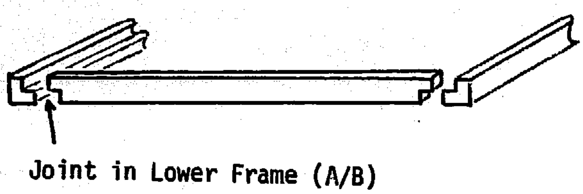
b. Construction

(1) Basic Tank

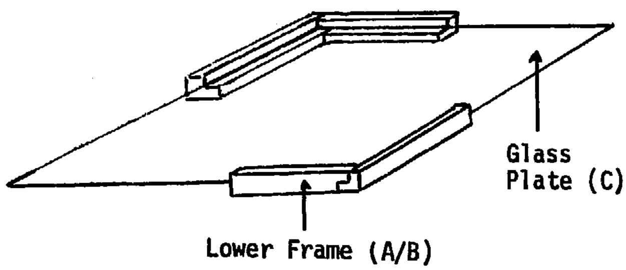
Out of each of the side wood strips (A and B) cut a single length approximately 2.0 cm x 2.0 cm. (A small circular



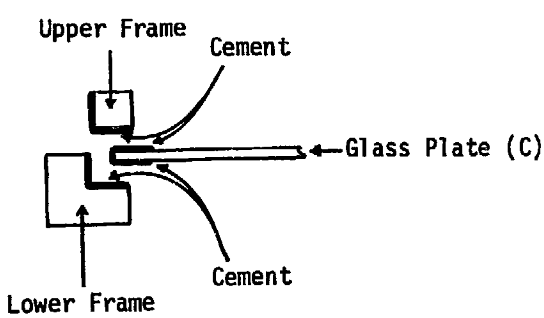
saw is useful in performing this task). You now have four large pieces of wood to make the lower frame, and four small pieces to make the upper frame.



The end pieces of the shorter lengths for the lower frame are cut (as illustrated) so that they may be firmly joined together with wood cement.

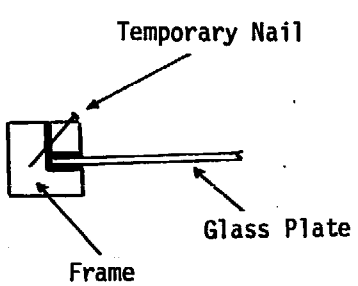


Set the glass plate (C) on the ledge of the lower frame. Cover the edges of the glass, and the inner edges of the lower and upper frame with a waterproof cement (D) as illustrated. An asphalt or rubber based cement is ideal. Set the glass on the ledge of the lower frame, and hold it in position by placing the upper frame on top of it.



Cross Section of Frame

The whole frame may be held together by clamps, or nails, tacked temporarily through the two frames, until the cement is dry.

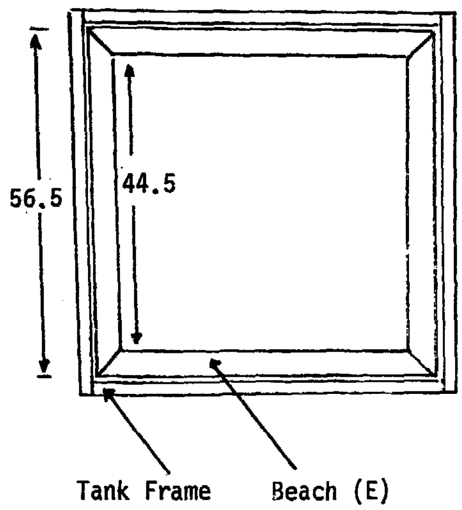


Cross Section of Frame

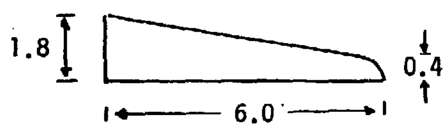
You now have a basic tank with an inner and outer frame insuring the tank is leak proof.

(2) Beach

The beach is any device which will cut out unwanted reflection from the sides of the tank. One of the most effective, and durable of beaches is made from soft pine wood (packing case material). Make the beach rather like a picture frame from the softwood (E) so that it sits on the glass surface of the tank, and fits snugly within the upper frame.

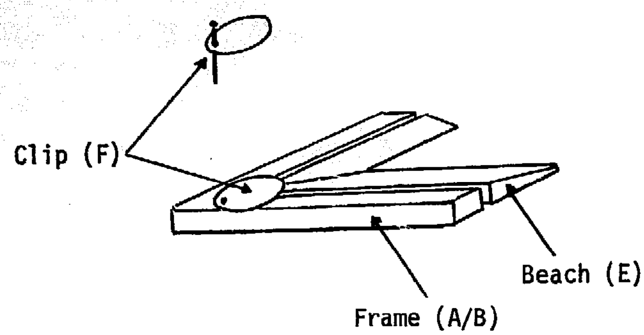


Plan of Frame and Beach

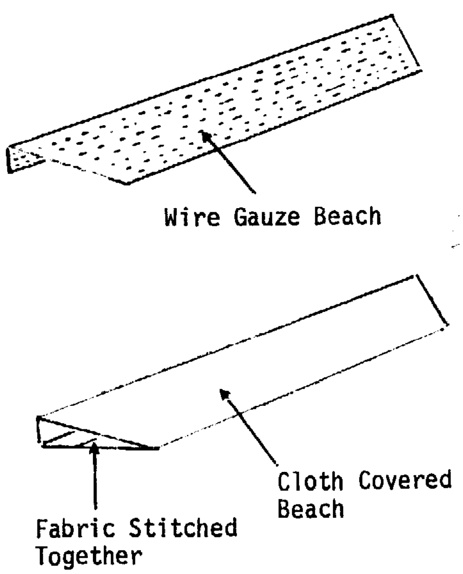


The most important aspect of the beach is the angle of the surface as it slopes downward from its outer to inner edge. The dimensions of a cross section to cope with water depths varying from 0.5 cm to 1.5 cm is illustrated.

Smooth the surface of the beach with fine sandpaper (leaving a smooth, but porous, surface), but do not varnish. Wetting the surface of the beach at the commencement of a series of experiments makes the damping of the waves most effective.

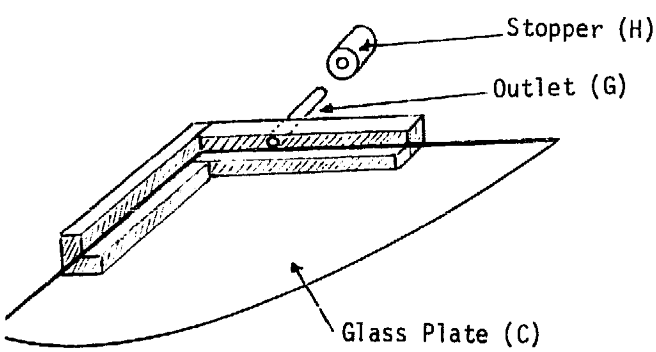


Drill a small hole (0.2 cm diameter) close to the edge of each of the brass discs (F). Attach each to a corner of the frame of the tank with a nail in such a way that the disc may be pivoted about the nail. In this way the discs may be rotated over the beach frame to prevent it from floating, or they may be rotated in the opposite direction to release the beach.



(Beaches may be made from many alternative materials. Fine wire gauze is frequently used for this purpose, but on its own is not as effective as the wooden beach. However, if the surface of the wire gauze is covered with cotton cloth an extremely good beach is created. The only problem is that the cloth must be replaced periodically.)

(3) Outlet

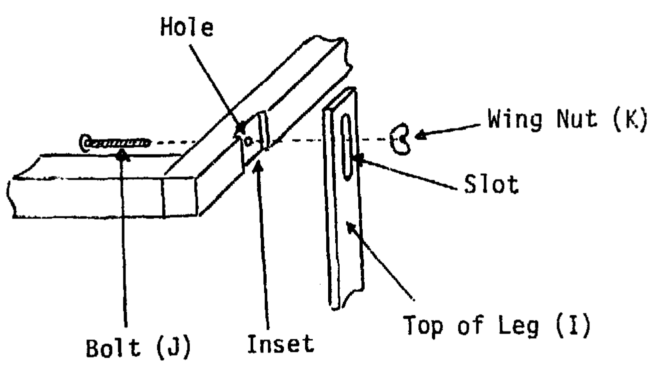


A water outlet is not absolutely essential, but it does make the draining of water from the ripple tank so much simpler, and prevents the spilling of water all over the floor.

Bore a horizontal hole (1 cm diameter) into the ripple tank frame, close to one of the tank's corners, so that drainage may be assisted by tilting the tank towards the corner. The bottom edge of the outlet hole should be at the same level as the top surface of the glass (or just a little below).

Seal the metal tube (G) into the horizontal hole with a waterproof cement. Bore a hole (0.9 cm diameter) partway into the rubber stopper (H) using an electric drill (not a cork borer). Fit the stopper on the tube, thus controlling the outflow of water.

(4) Legs

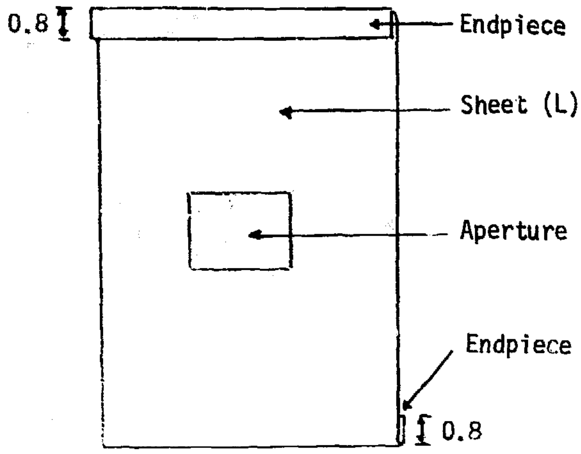


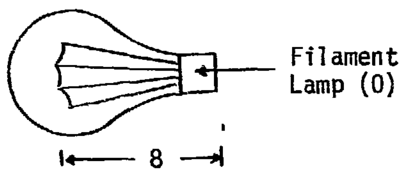
Drill and chisel a slot (2 cm x 0.5 cm) in the top of each of the four wood pieces (I) to make adjustment slots for the legs. Make four insets (0.3 cm deep) in the frame to hold the legs firmly in a vertical position. Then, drill a horizontal hole (0.4 cm diameter) through the lower part of the outer frame (that is beneath the level of the glass) at the middle of each inset. Attach each leg to the frame with a bolt (J) passed through the hole in the frame and the slot in the leg. Fasten the bolt and leg firmly in position with a wing nut (K).

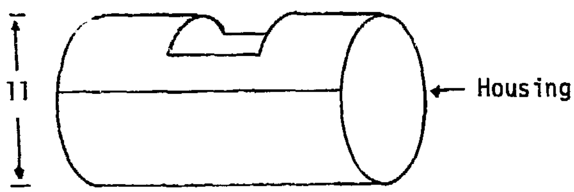
(5) Lamp Housing

The size of the lamp housing will be dependent on the size of the contained lamp. In this case the lamp (O) utilized was 8 cm from the socket to to filament. Ideally the filament should be a straight line, but a slightly bent filament such as that illustrated will serve the same purpose.

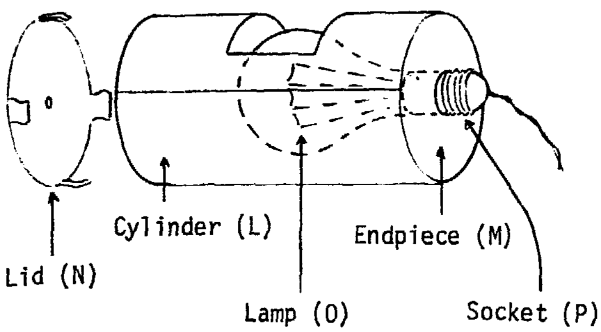
To make the housing for the above lamp take a sheet of aluminum (L) and cut an aperture (5 cm x 5 cm) from its center. Roll the sheet into a cylindrical shape, and hold it in position. by means of bent end pieces.

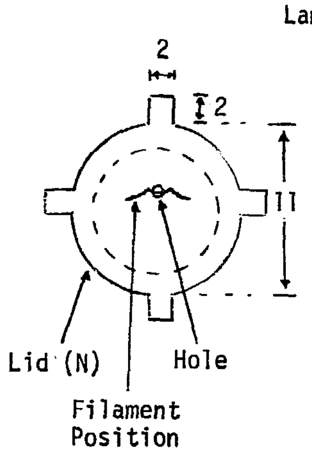


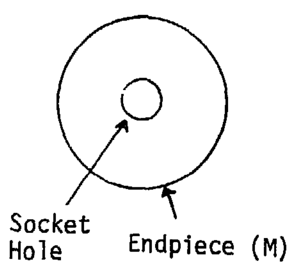




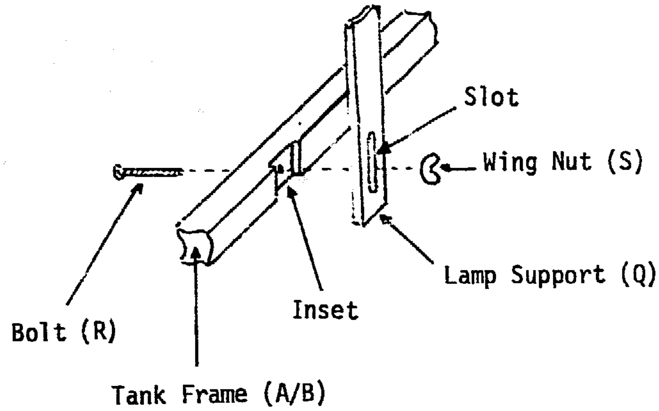
Attach the hardboard or plywood endpiece (M) to the base of the container with very small nails. Drill a central hole in the endpiece to facilitate the placement of the lamp (O) and electrical socket (P). Complete the housing by making a lid out of aluminum sheet (N). Drill a small hole (0.2 cm diameter) in the lid, such that it is in line with the filament.



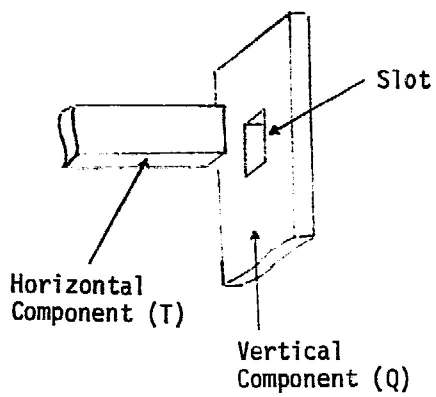




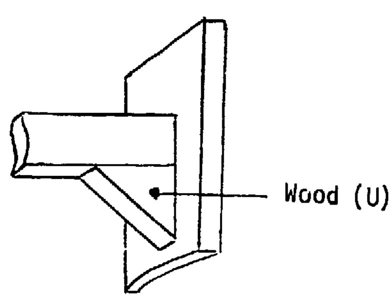
(6) Lamp Support

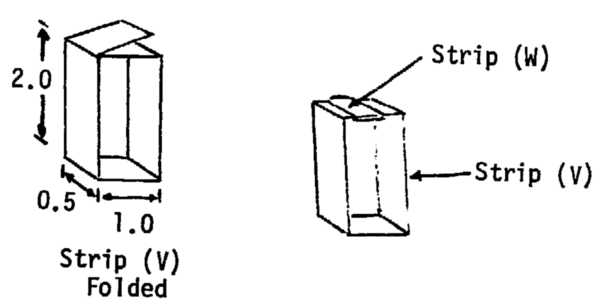


The vertical component of the lamp support is made, and attached to the ripple tank, in very much the same way as the legs. Drill and chisel a slot (7 cm x 0.5 cm) near to the bottom of end wood (Q) to permit adjustment. Attach the support to the ripple tank frame with bolt (R) passed through the lower part of the frame, and held in position by wing nut (S).

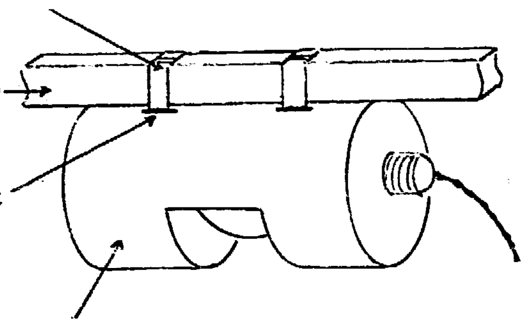


Cut a rectangular slot (2 cm x 1 cm) in the top of wood (Q) to take the horizontal component, wood (T). Fasten the two firmly together with wood cement. Glue a triangular piece of wood (U) between the two components to make a stronger junction.



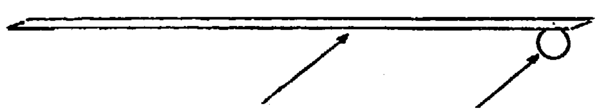


In order to attach the lamp housing to the horizontal components of the support make two brackets from steel strips (V) as illustrated. Cut four horizontal slots in the upper part of the lamp housing and

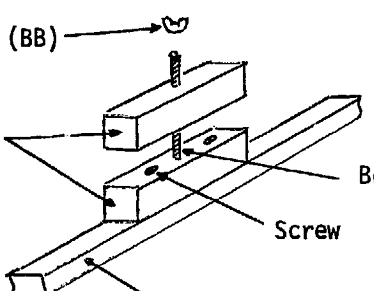


pass the steel strips through. Fasten the loose ends of the brackets together with folded pieces of aluminum (W). Then slide the brackets over the lamp support.

(7) Vibrator Unit



The steel strips (X), or stiff coat hanger wire, will serve as the arms of the vibrator. Attach a glass sphere (Y) to the end of each arm using epoxy resin.

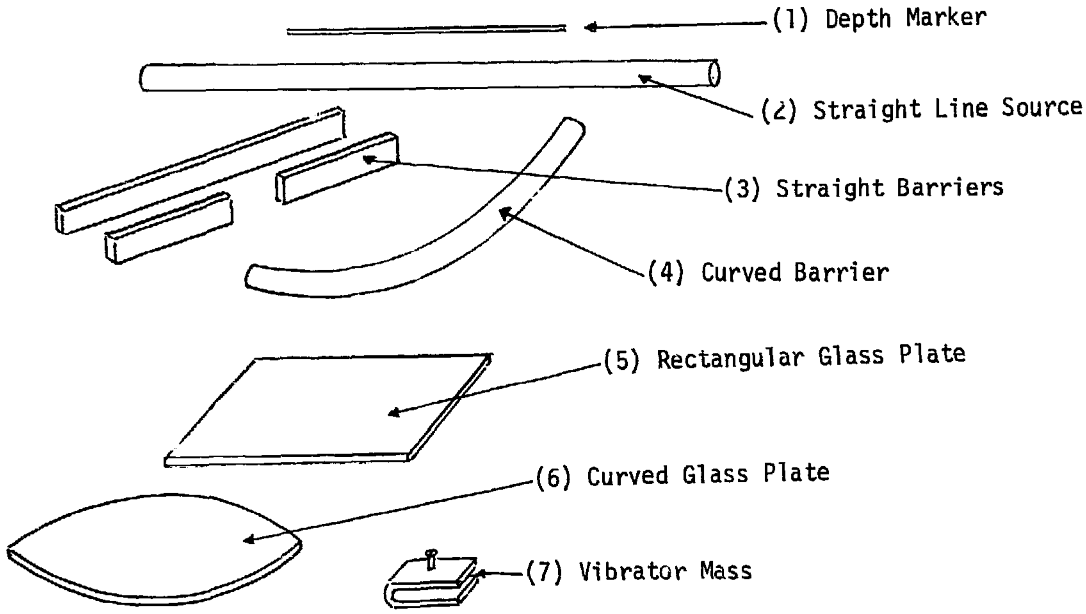


Make the vibrator clamp from two strips of wood (Z). Drill a hole (0.4 cm diameter) through the lower strip, and then attach the strip to the frame with two screws. Set the top strip on top of the first, and fasten it in position with the bolt (AA) and wing nut (BB). The vibrator arms may now be clamped firmly between the strips of the clamp, being held at the middle of the arms. This insures the maximum possible period of vibration.

c. Notes

(i) With the help of the Ripple Tank Accessories (IV/A2) it is possible to observe the phenomena of reflection, refraction, interference and diffraction in waves created in the Ripple Tank.

A2. Ripple Tank Accessories ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Depth Marker	1	Coat Hanger Wire (A)	10 cm long
(2) Straight Line Source	1	Wooden Dowel (B)	40 cm long, 2 cm diameter
	2	Nails (C)	15 cm long approximately
(3) Straight Barriers	1	Wood (D)	40 cm x 2.5 cm x 1 cm
	1	Wood (E)	15 cm x 2.5 cm x 1 cm
	2	Wood (F)	10 cm x 2.5 cm x 1 cm
	1	Wood (G)	5 cm x 2.5 cm x 1 cm
(4) Curved Barrier	1	Hose Pipe with Smooth Surface (H)	55 cm long, 2 cm diameter
(5) Rectangular Plate	2	Glass Sheets (I)	25 cm x 15 cm x 0.4 cm
(6) Curved Glass Plate	2	Glass Sheets (J)	25 cm x 15 cm x 0.4 cm

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 92-95.

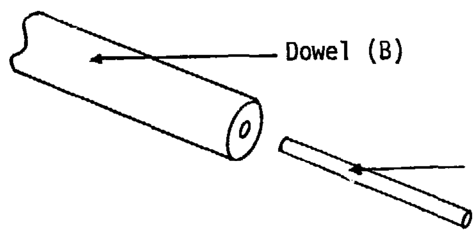
(7) Vibrator Mass	1	Iron Bar (K)	11 cm x 2 cm x 0.3 cm
	1	Bolt (L)	0.2 cm diameter, 1 cm long

b. Construction

(1) Depth Marker

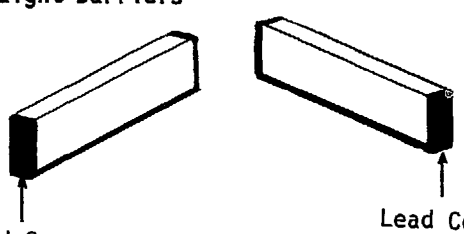
Mark off the end of wire (A) in half centimeter intervals (0-2 cm). The marker may then be used to determine the depth of the water at the four corners of the ripple tank, and makes the levelling of the tank simpler.

(2) Straight Line Source



Bore holes into both ends of the wooden dowel (B) and insert long nails (C) into the holes to prevent the rod from floating in the ripple tank.

(3) Straight Barriers



Nail thin strips of lead along the sides and base of the pieces of wood (D, E, F and G) to prevent them from floating in the ripple tank. The weighted pieces serve as suitable barriers.

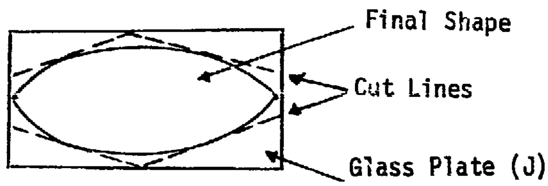
(4) Curved Barrier

A smooth surfaced hose pipe (H) serves as a suitable curved barrier. The pipe may be curved into any desired arc.

(5) Rectangular Plate

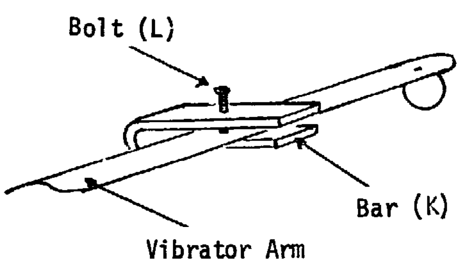
Take a sheet of glass (0.4 cm thick) and mark out two sections (each 25 cm x 15 cm x 0.4 cm) with a glass cutter. Break the glass along the marks by hand. The two newly produced sheets (I) may be set one on top of the other in water, thus creating a plate of thickness 0.8 cm.

(6) Curved Glass Plate



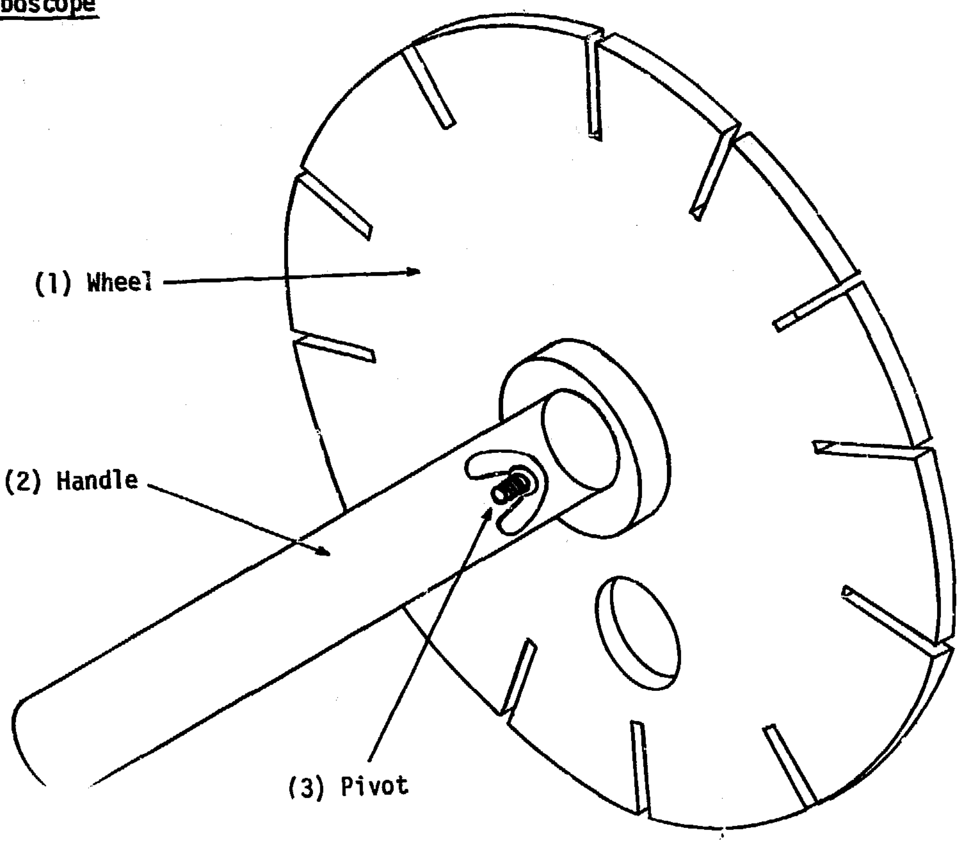
Scratch guidelines on the glass plates (J) in the shape of a parallelogram. Cut along the lines with a glass cutter, and break the glass along the lines. Grind down the shape to a curve, as indicated, with the help of a sandstone. The two plates may be used one on top of the other in the ripple tank, making a plate of thickness 0.8 cm.

(7) Vibrator Mass



The soft iron bar (K) should weigh approximately 50 g. Place the bar in a strong clamp, and use a hammer to bend it in half so that it becomes two parallel bars about 0.3 cm apart. Drill a hole (0.2 cm diameter) in the middle of the top bar, and make a thread (0.2 cm diameter) in the hole. Screw bolt (L) into the hole thus making it possible to clamp the bar onto the ripple tank's vibrator arm.

A3. Stroboscope ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Wheel	1	Hardboard (A)	25 cm diameter, 0.3 cm thick
(2) Handle	1	Wooden Dowel (B)	25 cm long, 2 cm diameter
(3) Pivot	1	Bolt (C)	4.5 cm long, 0.4 cm diameter
	1	Wing Nut (D)	0.4 cm internal diameter
	1	Nut (E)	0.4 cm internal diameter
	1	Wood (F)	3 cm diameter, 1.5 cm thick

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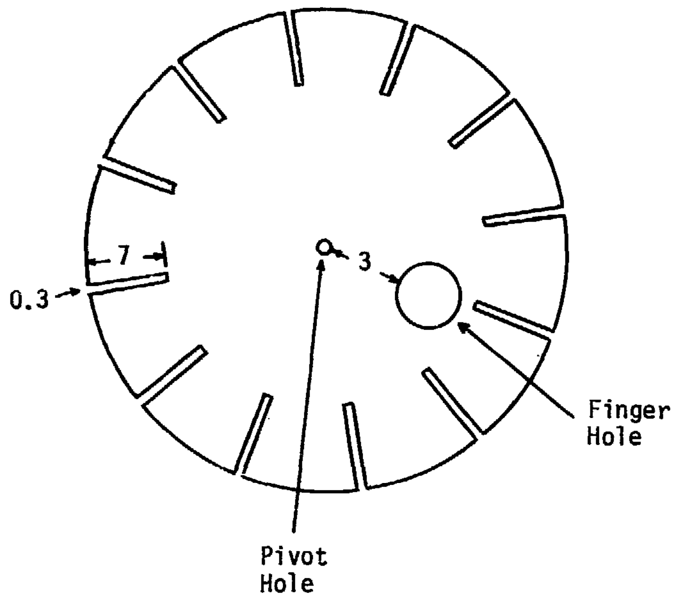
(1) Wheel

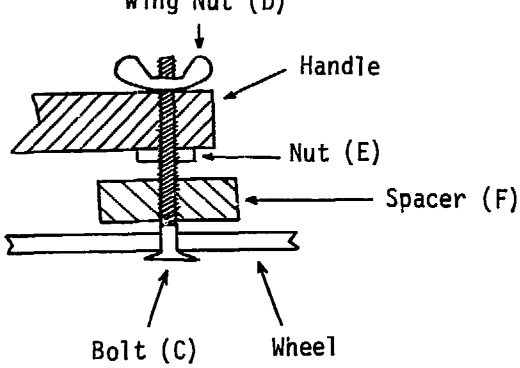


Cut the stroboscope wheel from the piece of hardboard (A). Make 12 equally spaced slits in the perimeter of the wheel. Drill a finger hole (2 cm diameter) at a distance of 3 cm from the center of the wheel, and a pivot hole (0.5 cm diameter) at the center of the wheel.

(2) Handle

The handle is simply a wooden dowel (B). Drill a hole (0.4 cm diameter) through one end of the nandle to take the pivot bolt (C).

(3) Pivot



Detail
(Cross-section)

Use the bolt (C) to serve as the pivot for the wheel. Insert this through the wheel, the spacer (F), a locking nut (E) and the handle (B). Use the locking nut (E) and the wing nut (D) to hold the handle in a fixed position on the pivot.

c. Notes

(i) If the components of a moving body repeatedly take up fixed positions at regular intervals (e.g., vibrating bodies, waves) it is possible to "stop" the motion by viewing it through the slits of the stroboscope, rotated at an appropriate speed.

V. THE MULTIPURPOSE SYRINGE

The purpose of this chapter is to illustrate some of the multiple uses to which a syringe may be applied. The syringe devices are therefore grouped according to the concepts they are intended to illustrate.

A. AIR PRESSURE APPARATUS

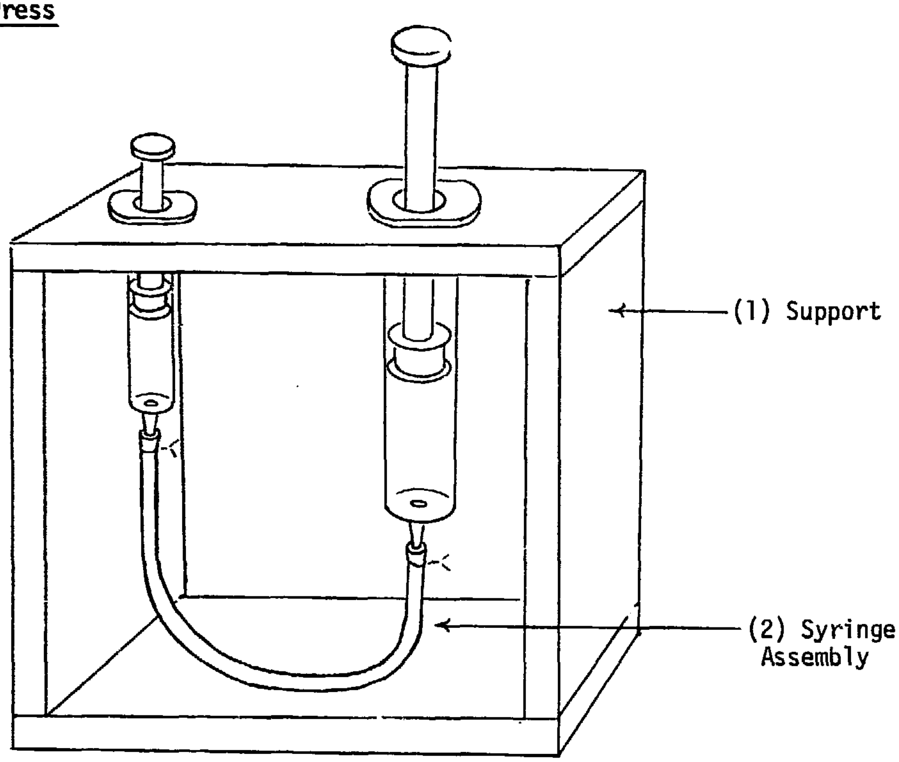
The devices in this section are all concerned with varying air pressure in the syringe.

B. SPECIFIC GRAVITY APPARATUS

The syringes in this section are used in one way or another to determine the specific gravity of solids and liquids.

A. AIR PRESSURE APPARATUS

A1. Hydraulic Press



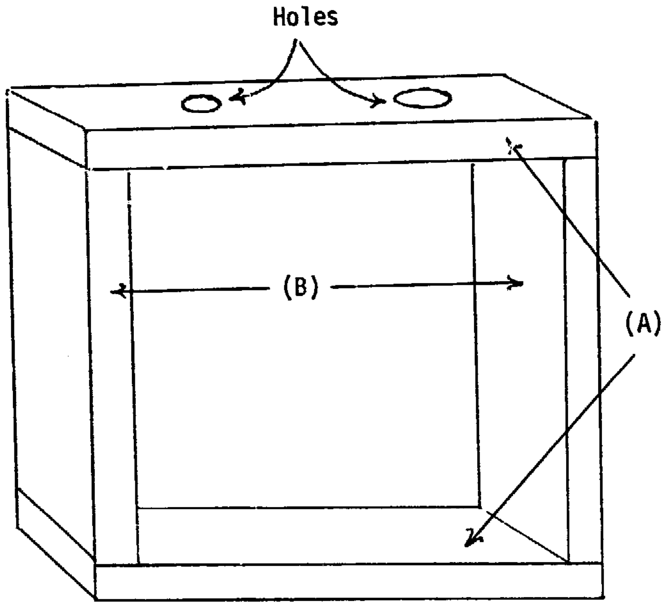
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support	2	Wood (A)	20 cm x 5 cm x 2 cm
	2	Wood (B)	17 cm x 5 cm x 2 cm
(2) Syringe Assembly	1	Plastic Disposable Syringe (C)	10 cc capacity
	1	Plastic Disposable Syringe (D)	60 cc capacity
	1	Rubber Tube (E)	20 cm long, 0.5 cm diameter
	2	Fine Wire (F)	5 cm long

b. Construction

(1) Support

Nail the two shorter pieces of wood (B) to the ends of one of the longer pieces (A) in upright positions. Before



nailing the last piece (A) into position across the top of the support, two holes must be drilled in it. These holes must be slightly larger in diameter than the barrels of the syringes used. Make these holes about 10 cm apart.

(2) Syringe Assembly

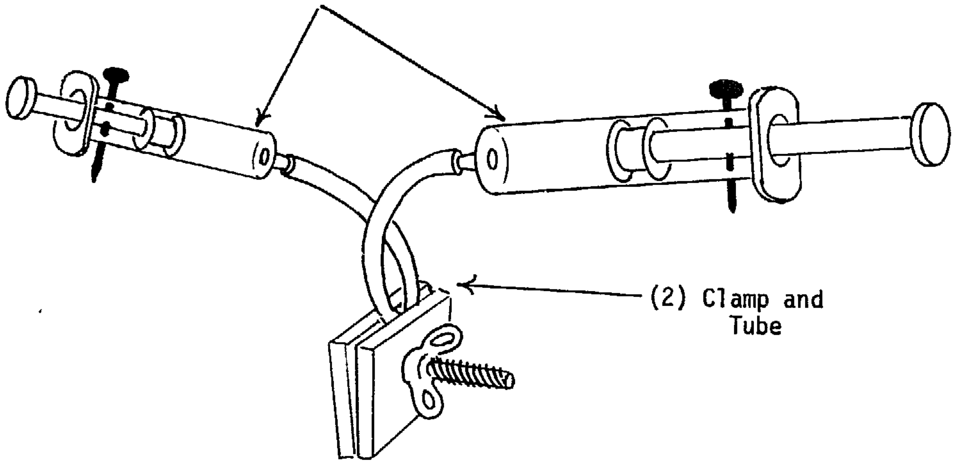
Attach one end of the rubber tube (E) to the nozzle of the larger syringe (D). Wrap one piece of wire (F) around this joint to seal it as tightly as possible. Withdraw the plunger of this syringe halfway to fill it with water through the end of the rubber tube. Try to eliminate as many of the air bubbles from the syringe as possible.

Holding the free end of the rubber tube so that no water can escape, run the end of the tubing through the hole in the support and put the large syringe into position. Put the barrel only of the small syringe (C) into position, and connect the end of the rubber tubing to the nozzle. Again, use the wire (F) to make the junction tight. Push the plunger of the large syringe down until the water rises in the small syringe and is about to run over. Insert the plunger of the small syringe now and push down, and a minimum of a air should be trapped in the system.

c. Notes

(i) The lifting power of the hydraulic press may be felt by exerting a gentle downward pressure on each syringe simultaneously with both hands. The load on the smaller syringe will lift the plunger of the larger syringe, even when the load on the latter is felt to be greater than that on the smaller syringe.

A2. Vacuum Apparatus

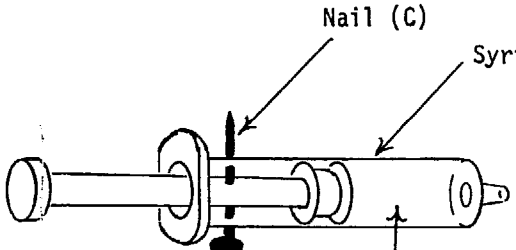


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Fixed Syringes	1	Plastic Disposable Syringe (A)	35 cc capacity
	1	Plastic Disposable Syringe (B)	10 cc capacity
	2	Nails (C)	4 cm long
(2) Clamp and Tube	1	Plastic Tube (D)	20 cm long, 0.5 cm diameter
	1	Screw Clamp (E)	CHEM/IV/A5

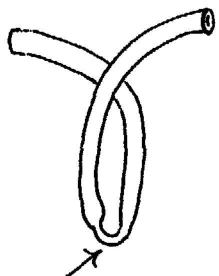
b. Construction

(1) Fixed Syringes



Use a drill of a slightly larger diameter than that of the nails (C) to carefully make holes through the barrel and plunger of the plastic syringe (A). When the nail (C) is inserted through these holes, the plunger should be held in a position such that the volume in the syringe is 25 cc. Similarly, prepare the second syringe (B) so that the volume is held at 5 cc capacity when the nail is in place.

(2) Clamp and Tube



Connect the two syringes with the length of plastic tube (D). Be certain the connections between the nozzles and tubing are tight. Also, the tubing must be flexible enough to allow the clamp to close it off completely while, at the same time, it should be elastic enough not to collapse as pressure in the system becomes lower. The clamp (E) will close off air flow through the tube most easily when the tube is doubled over against itself.

c. Notes

(i) To use this piece of equipment to create a vacuum in the larger syringe (A), first fix the volume of the air in the syringe (A) at 25 cc using the nail to hold the plunger in position. Connect the clamp and tubing to it. Depress the plunger in the smaller syringe (B) completely, then fasten the syringe to the tubing, and close the clamp. Now, open the clamp and withdraw the plunger in the smaller syringe. This will extract air from the larger syringe. Fix the plunger of the smaller syringe with the nail, and reclose the clamp. Remove the smaller syringe from the tubing.

The extraction procedure may be repeated five or six times in succession in order to produce very low pressures.

(ii) After one or more extractions, the reduced pressure in the large syringe may be determined by holding the syringe under water and removing the clamp from the tube. Water will rise in the syringe until the trapped air is once again at atmospheric pressure. Note the volume of the trapped air.

If

The volume of air finally trapped above water = V_2
The pressure of air finally trapped above water = P_2
(Where P_2 = atmospheric pressure)

And if

The volume of same mass of air prior to contraction = V_1
(Where V_1 = volume of syringe)
The pressure of same mass of air prior to contraction = P_1

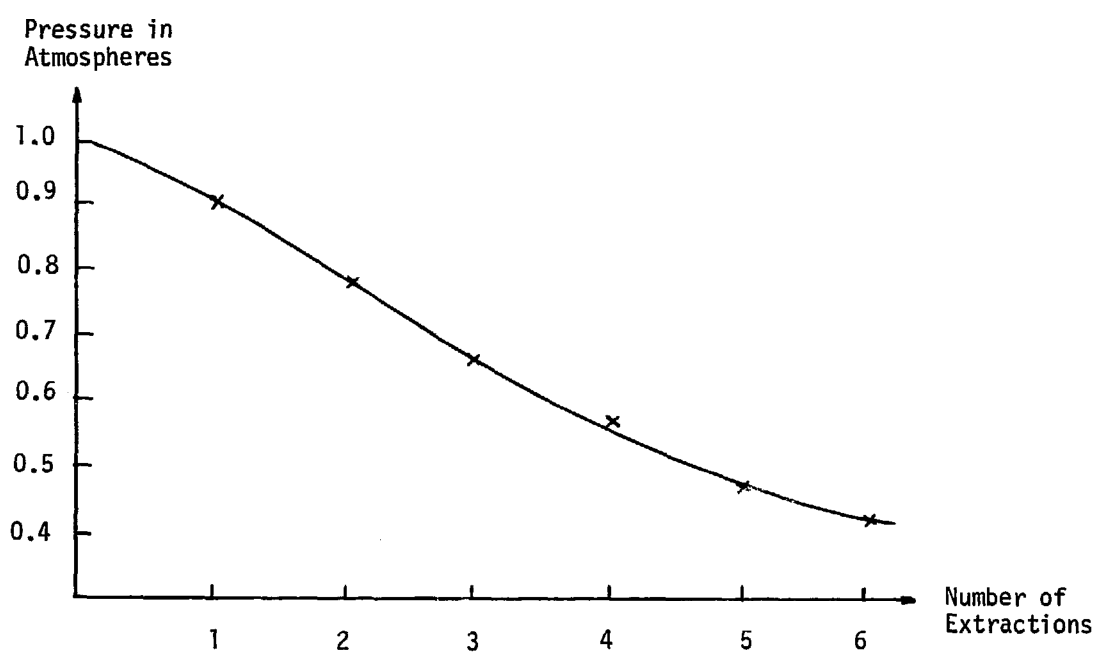
Then

The pressure of the vacuum created is given by

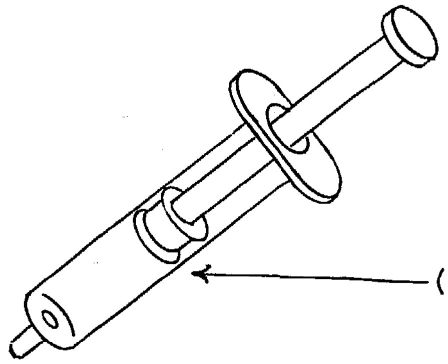
$$P_1 = \frac{P_2V_2}{V_1}$$

(iii) In a typical experiment (results indicated below) five extractions reduced the pressure in the large syringe to 0.5 atmosphere pressure.

No. of Extractions	V_2 cc	V_1 cc	P_1 Atmospheres
1	25	23	0.92
2	25	19.5	0.78
3	25	16.5	0.66
4	25	14.5	0.58
5	25	12.0	0.48
6	25	10.5	0.42



A3. Elasticity Device



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Size can be variable

b. Construction

(1) Syringe

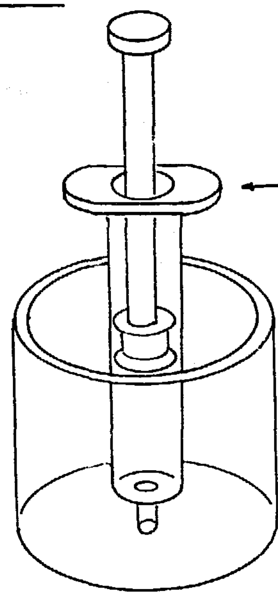
Place a finger over the air outlet to seal the air in the tube.

c. Notes

(i) With a sealed syringe, elasticity of air may be felt by pushing down or pulling out the plunger. In either case, if the syringe is airtight, the plunger will be pusned or pulled back to its original position by the air trapped in the syringe.

(ii) It is of interest to replace the air in the syringe by water in order to compare the elasticity of water with that of air.

A4. Gas Expansion Device ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe Unit	1	Plastic Disposable Syringe (A)	Size can be variable
	2	Beakers (B)	Approximately 250 ml

b. Construction

(1) Syringe Unit

Any size syringe (A) may be used, but one approximately 10 - 15 cc in capacity is convenient. Fill one beaker (B) with hot water and the other with cold water.

c. Notes

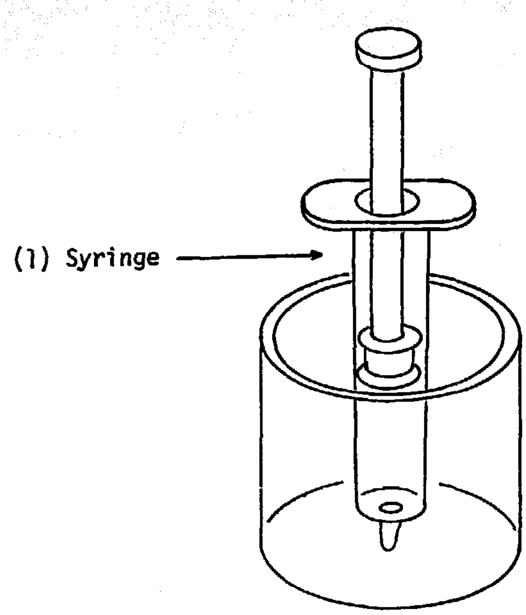
(i) After the syringe has been filled with suitable gas (e.g., air) it is placed in the cold water bath for several minutes. It is then removed, emptied of any water which may have entered through the open nozzle, adjusted to a volume of 5 or 10 cc, and placed in the hot water bath. As the gas expands, bubbles will leave the syringe. After the bubbling has ceased, remove the syringe and place

© From Andrew Farmer, "The Disposable Syringe: Additional Experiments," School Science Review, CLXXVIII (1970), pp 59-60.

it back in the cold water bath. As the gas contracts, water will enter the syringe, and the amount of water entering serves as a measure of the expansion of the gas. Quantitative data on gas expansion can be obtained by using the same gas and syringe, and varying the temperature of the hot water bath, or by using the same syringe and hot water bath and varying the gases.

B. SPECIFIC GRAVITY APPARATUS

B1. Volume Determinator



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	Size can be variable
	1	Beaker (B)	Approximately 250 ml

b. Construction

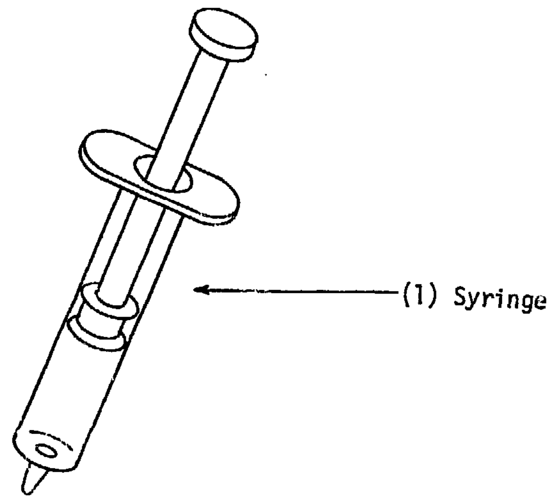
(1) Syringe

Choose a plastic, disposable syringe (A) with a barrel capacity large enough to hold the object whose volume is to be measured. Fill the beaker (B) about one half full of water.

c. Notes

(i) Use this apparatus by placing the object whose volume is to be measured into the syringe. Replace the plunger and depress it until it almost touches the object in the bottom of the syringe. Hold the syringe so that the end of it is under water in the beaker. Draw enough water into the syringe to cover the object by withdrawing the syringe plunger. Find the difference between the original syringe reading and the final syringe reading. This indicates the volume of water drawn into the syringe. Note the apparent volume of water in the syringe (that is the volume of the object and the water combined) and subtract from this the volume of water known to have been drawn into the syringe. The resultant value indicates the volume of the object.

B2. Specific Gravity Device



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Syringe	1	Plastic Disposable Syringe (A)	35 cc capacity

b. Construction

(1) Syringe

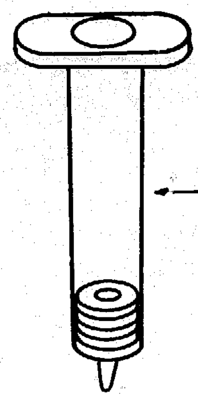
Use the syringe (A) with no modification except to remove the needle, as usual.

c. Notes

(i) To determine the specific gravity of a liquid, simply draw up 25 cc of the liquid, and find the mass of the liquid plus syringe. Subtract the mass of the empty syringe from this total to find the mass of the liquid. Divide the mass of the liquid by 25 to obtain the specific gravity.

(ii) If the liquid should leak from the syringe, simply seal the nozzle of the syringe with a nail. Remember to add the mass of the nail into the calculations.

B3. Hydrometer



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Weighted Syringe	1	Plastic Syringe Barrel (A)	35 cc capacity
	6-8	Metal Washers (B)	Slightly less wide than the barrel

b. Construction

(1) Weighted Syringe

Place enough washers (B) in the syringe barrel (A) to cause it to sink to the 25 cc mark when placed in water. Seal the nozzle by heating it until it melts shut.

c. Notes

(i) For use as a hydrometer, the syringe barrel must be calibrated. Use a graduated cylinder (CHEM/III/B2) to make the calibrations. Note the water volume in the cylinder before and after the syringe barrel is placed in it. The difference of these two values indicates the volume of water displaced by the syringe. By this means it is possible to indicate a displacement value for each reading on the syringe. The following table was created for the syringe under test.

Scale on Syringe	Volume of Water Displacement
cc	cc
20	27.2
21	28.6
22	29.2
23	30.4
24	31.5
25	33.0
26	34.5
27	36.1
28	37.5
29	38.4
30	39.6

Weigh the syringe (and its washers), and then place it in the liquid whose density is to be determined.

(ii)

If

V = The volume of liquid observed to be displaced

M - The mass of the syringe and washers

Then

M = The mass of liquid displaced

$M/_V$ = The density of the liquid displaced

VI. OPTICS APPARATUS

The apparatus in this section has been grouped according to the concepts, and are identified as follows:

A. GENERAL APPARATUS

This apparatus is for use in studying all aspects of optics whether this might be reflection and refraction, or interference and diffraction.

B. REFLECTION APPARATUS

This apparatus is sufficient for a simple study of reflection. The electroplated mirrors are preferable to brass mirrors described, although the latter will be found adequate for most purposes.

C. REFRACTION APPARATUS

Apparatus for the study of refraction using plastic prisms.

D. LENS APPARATUS

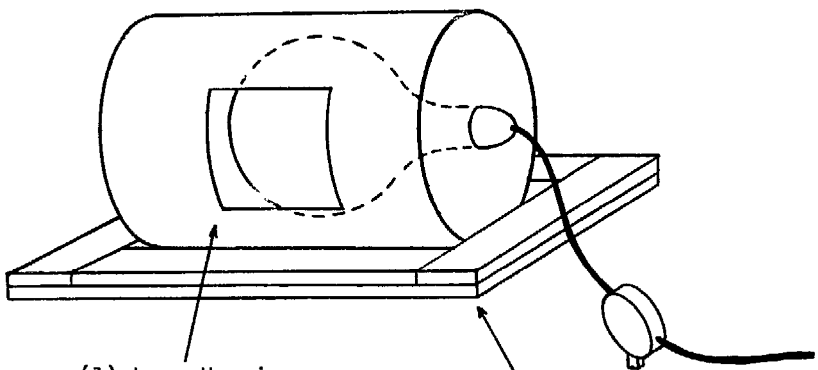
Apparatus to enable a study of the properties of lenses.

E. DIFFRACTION AND INTERFERENCE APPARATUS

A study of the basic phenomena of interference and diffraction is possible with this apparatus, using simple slits, holes and thin films.

A. GENERAL APPARATUS

A1. Light Source©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Lamp Housing	1	Ripple Tank, Lamp Housing (A)	IV/A1, Component (5)
(2) Base	1	Plywood (B)	21 cm x 11 cm x 0.5 cm
	2	Wood Strips (C)	16 cm x 2.5 cm x 1 cm
	2	Wood Strips (D)	11 cm x 2.5 cm x 1 cm

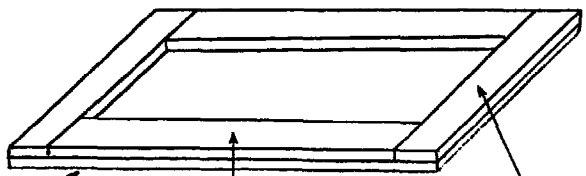
b. Construction

(1) Lamp Housing

This lamp housing (A) is precisely the same as that designed for the ripple tank (IV/A1). All that is added is a base.

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), p 98.

(2) Base

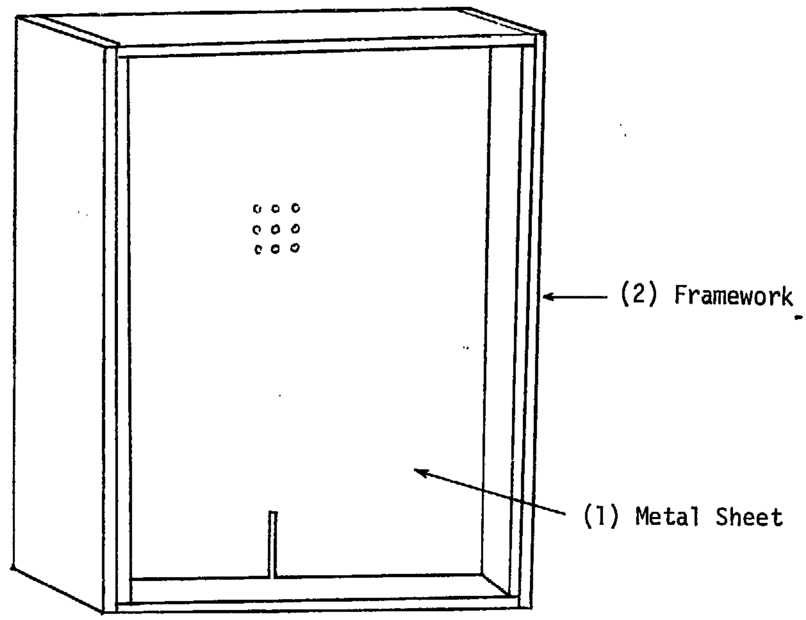


Make the base from the piece of plywood (B). Nail the two short pieces of wood (D) to the ends of the plywood (B) and nail the remaining wood strips (C) to the plywood, too. Make sure that they will hold the lamp housing firmly in position. Then nail it into position.

c. Notes

(i) This light source may be used in conjunction with the Slit/Aperture Combination (VI/A2) to investigate the behavior of rays of light transmitted from the source. The light source is designed for use with all the items included in this chapter, including the interference and diffraction apparatus. If the bulb used is bright (e.g., 100 watts), there will be no need to black out the laboratory.

A2. Slit/Aperture Combination

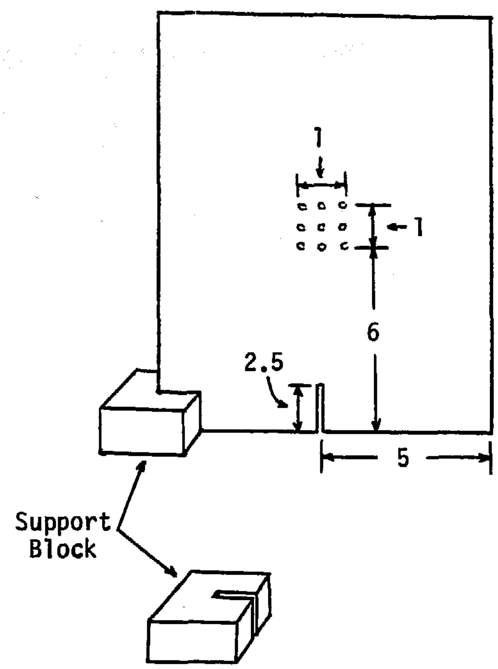


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Metal Sheet	1	Aluminum Sheet (A)	15 cm x 10 cm x 0.02 cm
(2) Framework	4	Wood Side Strips (B)	15 cm x 1 cm x 0.5 cm
	2	Wood Side Strips (C)	15 cm x 2 cm x 0.5 cm
	2	Wood Strips (D)	11 cm x 2 cm x 0.5 cm

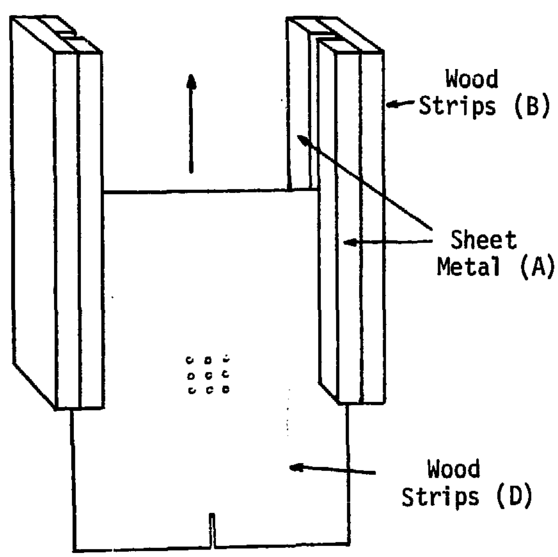
b. Constr ction

(1) Metal Sheet

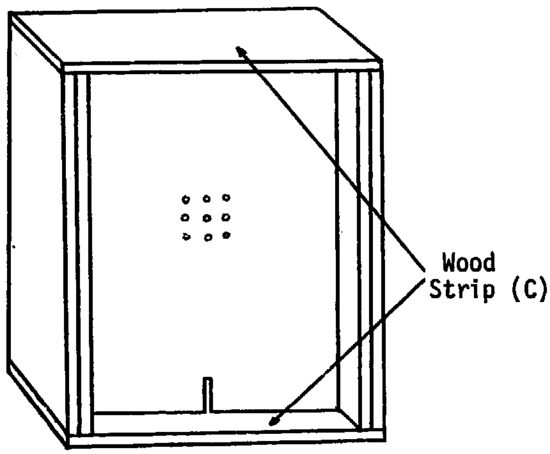


Cut the slit (0.1 cm width) and apertures (0.1 cm diameter) in any suitable thin sheeting (A) (metal, bakelite, cardboard) so long as the slit and apertures have clean cut edges. If the material used is relatively rigid, a small wooden block will provide adequate support. If the material tends to flex under its own weight, a framework, such as that indicated below, will be required for support.

(2) Framework



Nail or glue two wood strips (B) to a third strip (C), leaving about a 0.1 cm gap between them. Make an identical piece from the other two narrow strips (B) and the one remaining wide strip (C). Slide the metal sheet into position between the two pieces.



Nail the top and bottom pieces (D) to the two upright pieces to complete the framework. The thickness of the bottom strip (D) should not be much more than 0.5 cm, as there is a tendency for this strip to cut off a desirable portion of any light path.

c. Notes

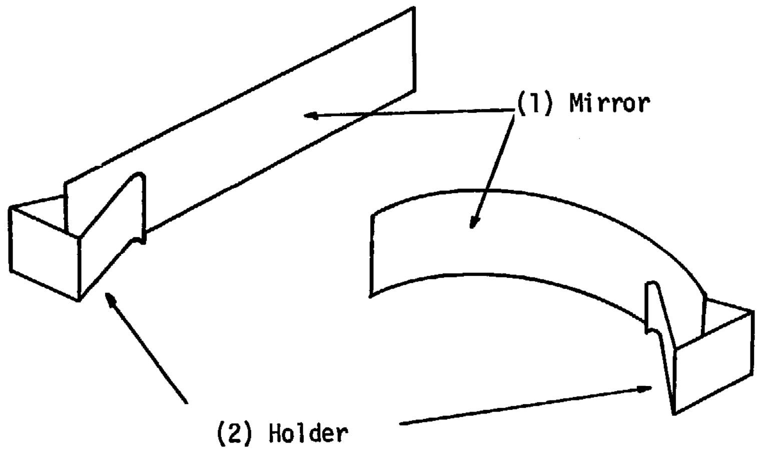
(i) The decision as to whether to use a frame will probably be one of economics. Thick metal sheets are much more expensive than thin ones, but the cost of labor involved in making a framework for a thin sheet may in some instances offset the difference between the two.

(ii) The slit is primarily intended for delineating light rays (from the Light Source, VI/A) which may be traced across a horizontal surface.

(iii) If the metal sheet is placed on its side the apertures will sit at an appropriate height in front of the Light Source (VI/A1), and may be used as objects for experiments with lenses.

B. REFLECTION APPARATUS

B1. Mirrors and Electroplating ©

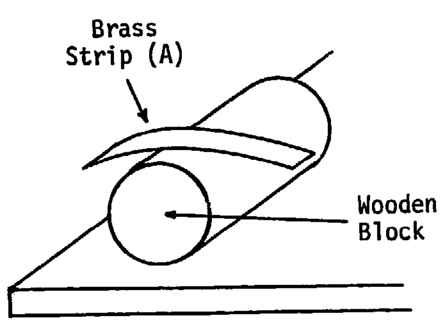


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Mirror	2	Brass Sheet (A)	10 cm x 2.5 cm x 0.1 cm
(2) Holder	2	Metal Strapping (B)	Approximately 6 cm x 2 cm x 0.02 cm
	2	Plastic Tape (C)	2 cm x 1 cm

b. Construction

(1) Mirror



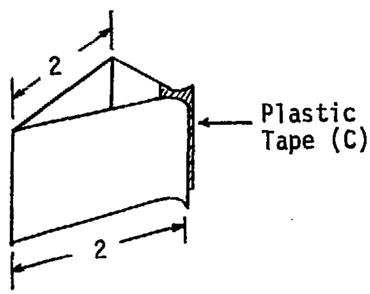
Cut the sheet of brass (A) on a metal guillotine (to be found in your nearest metalwork shop). If the metal sheet is cut with bench sheers some distortion is almost certain to result, thus lowering the quality of the mirror. If the mirror is to be curved, bend it over a smooth, curved, wooden block until the mirror becomes the arc of a circle of radius 8.5 cm.

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 101-103.

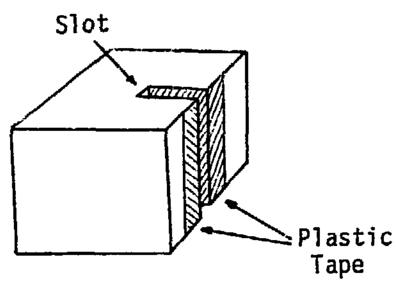
Polish the metal strips first with coarse carborundum paper, and then with successively finer and finer grades, taking care at each polishing to remove the deeper marks of the previous polishing.

Obtain a mirror finish by polishing the surface with a soft cloth and metal polish.

(2) Holder



Bend the piece of metal packing case band (B) into a triangular shape. Curve the endpieces and cover them with the plastic tape (C) to protect the mirror surface.



Alternatively, cut a slot (0.2 cm wide) in a wooden block (2 cm x 2 cm x 2 cm). Line the slot with plastic tape to prevent the wood from scratching the surface of the mirror to be held.

c. Notes

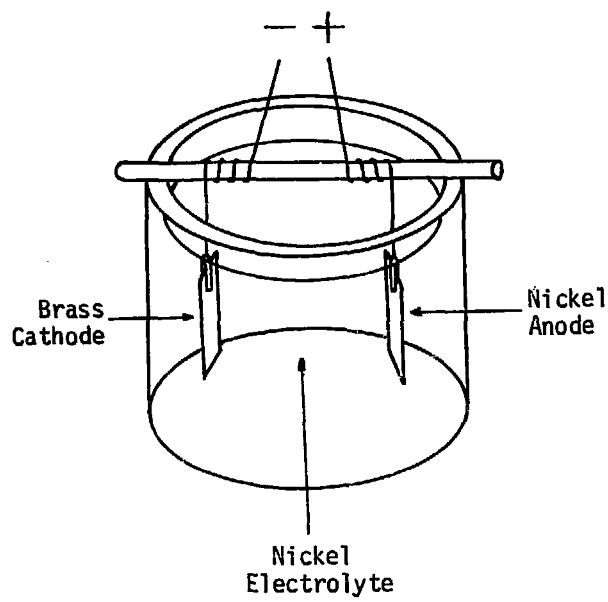
(i) Brass mirrors must be cleaned with metal polish before each usage. This process may be eliminated if the metal surface is electroplated. The procedure to be followed is described below:

Procure a plastic, or glass, container about 15 cm deep and 10 cm in diameter, and fill it with a nickel solution (e.g., Gleamax and Levelbrite).

Wash the polished brass mirror in caustic soda (soap) to remove grease and rinse with clean water. Grip the brass mirror in a crocodile clip, attached to an electrical lead, and suspend the brass mirror in the nickel solution. The mirror may be held in position by wrapping the electrical lead (by which it is suspended) around a wooden dowel bridging the container.

Suspend a nickel plate in a similar fashion from a second electrical lead. We now have an anode (nickel plate), a cathode (brass mirror) and an electrolyte (nickel solution).

Connect the anode to the positive terminal and the cathode to the negative terminal of a 6 volt battery, and pass a current through the nickel solution for 15 to 20 minutes. The quality of the final surface will depend primarily on the quality of the initial polished surface, prior to electroplating.

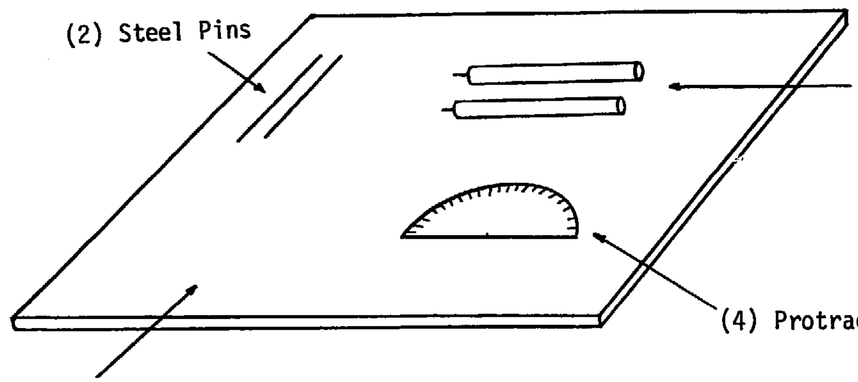


(ii) Mirrors may also be made by a very simple chemical process. Prepare three solutions as follows:

I.	40 ml	H_2O	II.	10 g	NaOH	III.	100 ml	Concentrated fructose solution (Glucose or any aldehyde may be used, although the reaction may be slower).
	60 ml	Concentrated NH_4OH		100 ml	H_2O			
	10 g	$AgNO_3$						

Just before using, mix equal volumes of solutions I and II. Then add the fructose solution to the new mixture in the ratio of 1:4. Silver will deposit on any glass surface in contact with the solution. If a microscope slide is placed in the solution, it will be coated on two sides. The external appearance will be dullish. Remove one such coating with a cloth. The glass-silver interface will be seen as an excellent mirror.

B2. Optical Board and Accessories



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Optical Board	1	Hardboard (A)	40 cm x 40 cm x 0.5 cm
(2) Steel Pins	2	Steel Rods (B)	7 cm long, 0.1 cm diameter
(3) Steel Pins with Sleeves	2	Steel Rods (C)	7 cm long, 0.1 cm diameter
	2	Pencils (D)	6.5 cm long
(4) Protractor	1	Aluminum Sheet (E)	10 cm x 5 cm x 0.05 cm

b. Construction

(1) Optical Board

This is simply a piece of hardboard (A) into which pins can be readily stuck. Normally a plain sheet of paper will be placed on top of the hardboard to facilitate the recording of experimental observations. The Refraction Model Apparatus (VI/C3) is such a piece of hardboard.

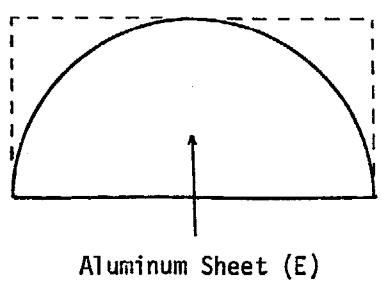
(2) Steel Pins

The steel rods (B and C) may be cut from cycle spokes or similar steel rods. Sharpen one end of each rod with the help of a file.

(3) Steel Pins with Sleeves

Remove the pencil lead from the pencils (D) with the help of a steel pin. Coat the steel pin (C) with epoxy resin, and slide it into the space originally occupied by the lead, so that, instead of the pencil lead, a steel pin protrudes from the end. Cover the sleeve with a white coat of paint.

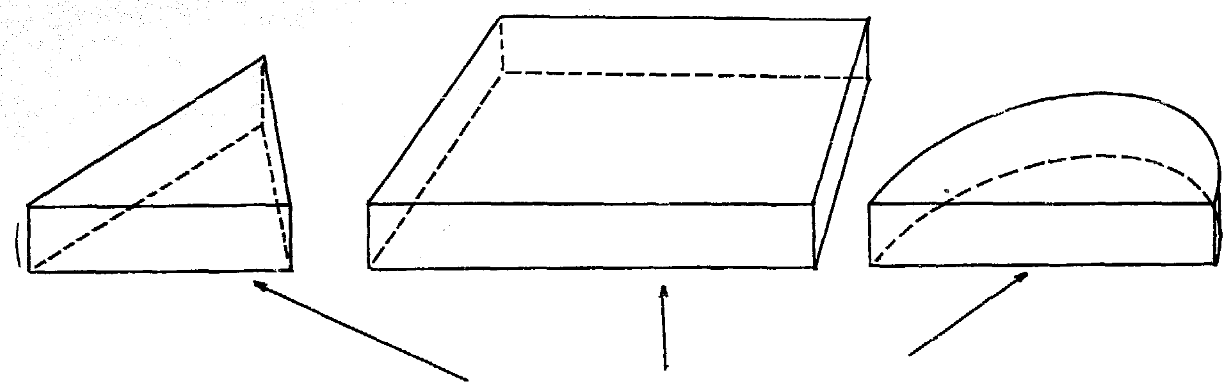
(4) Protractor



Make a protractor by cutting a semicircular piece of metal from the aluminum sheet (E). Mark as many angles around the periphery of the protractor as desired.

C. REFRACTION APPARATUS

C1. Optical Prisms and Lenses ©



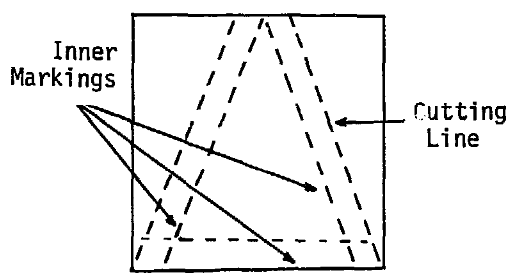
(1) Prisms

a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Prisms	1	Sheet of Acrylic (A)	16 cm x 10 cm x 2 cm

b. Construction

(1) Prisms



Triangular Prism

Take the sheet of acrylic (A) and mark out the shape of the desired prism with a sharp point. Draw a parallel set of lines about 0.5 cm outside the initial marking. The inner markings should outline a triangle (3 cm x 3 cm x 3 cm), a rectangle (8 cm x 5 cm) and a semicircle (9 cm diameter).

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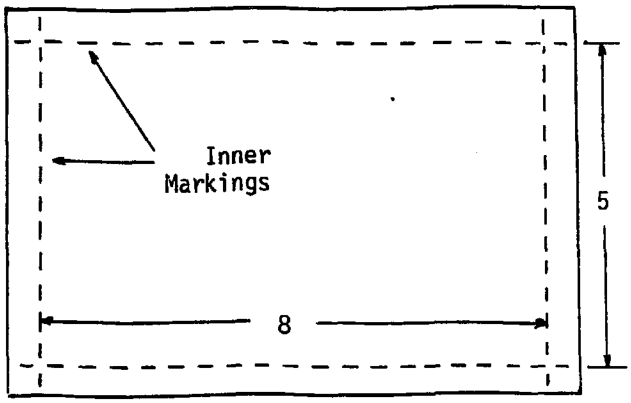
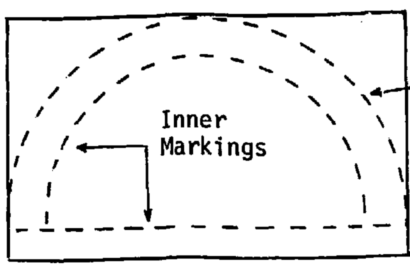
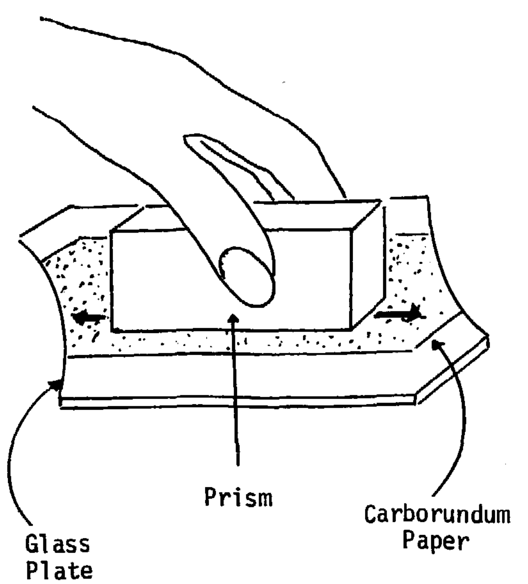


Rectangular Prism



Semicircular Prism



Using a fine-toothed saw, carefully cut the plastic down to the outer markings. The cut produced will have very jagged edges, the plastic showing a tendency to chip. This is normal, and should cause no concern.

The next step is to remove the rough edges from the prism, reducing its size to that of the inner markings. For this purpose place a coarse sheet of carborundum paper on top of a smooth surface (e.g., a strong glass sheet). Then smooth down the surfaces of the prism by rubbing them on the carborundum surface.

Repeat the process with successively finer and finer grades of carborundum paper, taking care at each rubbing to remove the deeper marks of the previous rubbing.

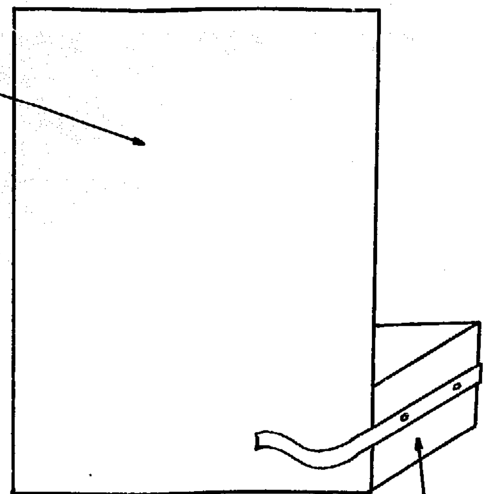
Finally, replace the carborundum paper by a sheet of plain paper. Drop a little metal polish on the paper, and repeat the rubbing process. The surface produced will be highly polished.

The rubbing and polishing process is repeated with all the surfaces except that surface which will normally be in contact with the table top during experimentation. This surface is smoothed with carborundum paper, but not metal polish, thus leaving the surface sufficiently rough to scatter light.

c. Notes

(i) Plastic is not as hard as glass, and is therefore more easily scratched and damaged. From time to time it is therefore necessary to repolish the surfaces with metal polish, as described above.

C2. Screen with Holder



a. Materials Required

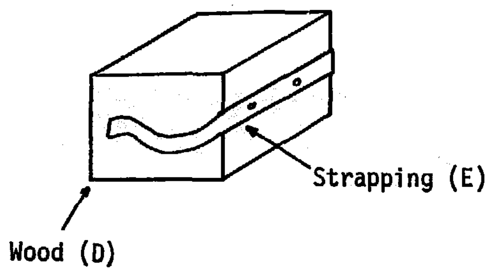
Components	Qu	Items Required	Dimensions
(1) Screen	1	Cardboard (A)	25 cm x 15 cm
	1	White Paper (B)	25 cm x 15 cm
	1	Black Paper (C)	25 cm x 15 cm
(2) Holder	1	Wood Block (D)	4 cm x 4 cm x 4 cm
	1	Steel Band (E)	Approximately 8 cm x 1 cm x 0.02 cm

b. Construction

(1) Screen

Make the screen from the stiff piece of cardboard (A). It is very convenient to have a front white surface and a rear black surface. This may be achieved by sticking appropriate sheets of paper (B,C) on the two surfaces.

(2) Holder

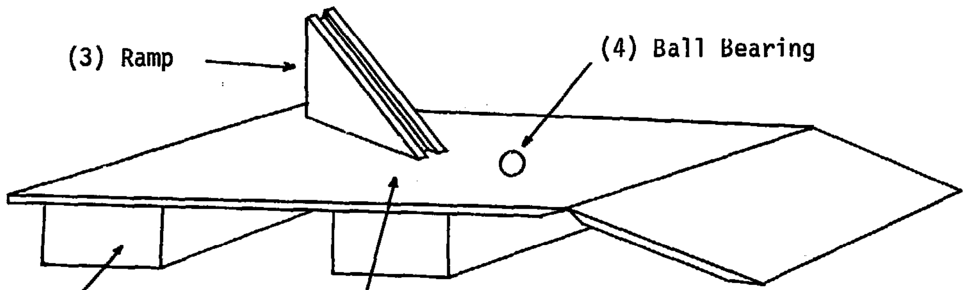


Bend a length of packing case steel (E) as shown and nail it to the side of the wooden block (D).

c. Notes

(i) The white surface of the screen is used for normal image formation, while the black surface is useful whenever the screen is used as a barrier to exclude light.

C3. Refraction Model Apparatus

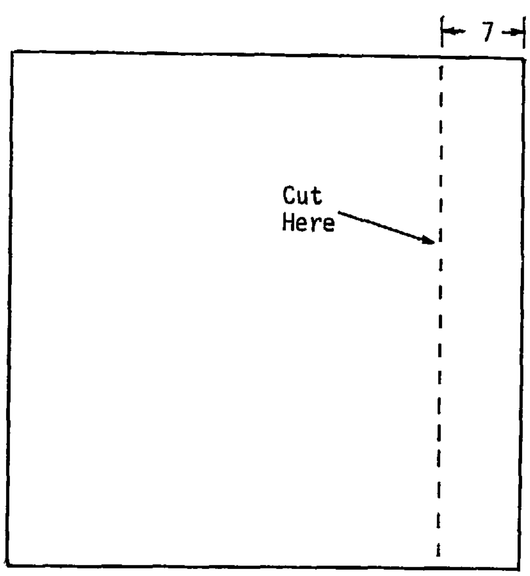


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Platform	1	Hardboard (A)	40 cm x 40 cm x 0.5 cm
	2	Hinges (B)	Approximately 2 cm long, sidepieces no more than 0.5 cm wide
(2) Supports	2	Wood (C)	30 cm x 4 cm x 2 cm
(3) Ramps	1	Wood (D)	12 cm x 5 cm x 2 cm
	1	Wood (E)	12 cm x 3 cm x 2 cm
(4) Ball Bearing	1	Ball Bearing (F)	2.5 cm diameter

b. Construction

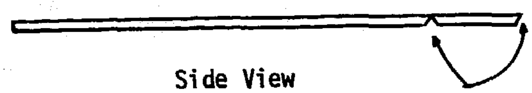
(1) Platform



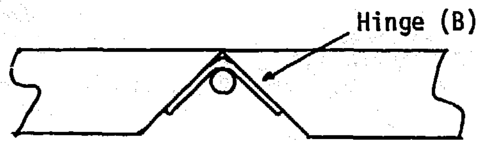
Hardboard (A)

Cut a 7 cm strip from one side of the plywood (A), and shape the newly cut edges back at an angle of 45° as illustrated. Reattach the 7 cm strip to the platform with very small hinges (B) avoiding the creation of a gap between the strip and main platform. Shape the free edge of the 7 cm strip to an angle of 45°. This shaping insures good contact between the strip and the table.

(Also see illustration on next page.)



Side View

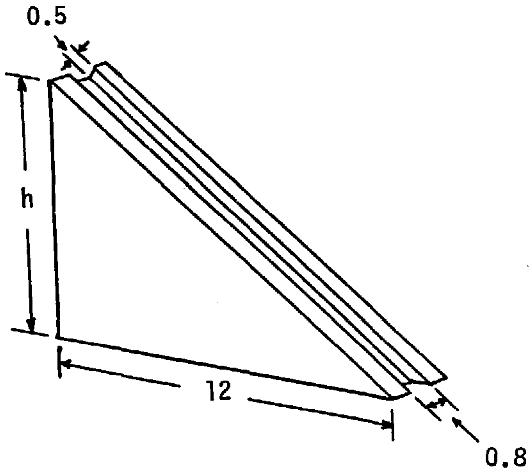


Detail

(2) Supports

Books, or blocks of wood (C), may be used to elevate the platform to different heights above the table top (e.g., 2 and 4 cm).

(3) Ramp



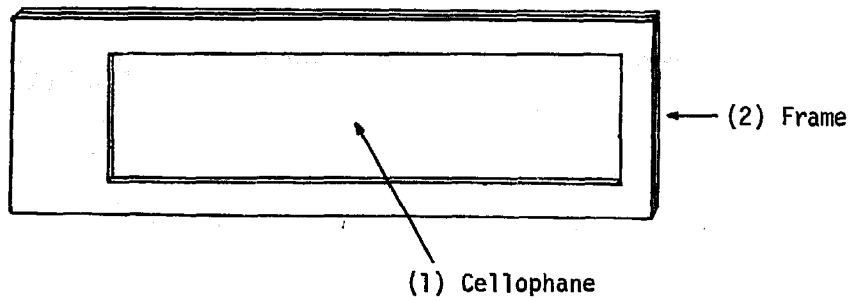
Cut two triangular shapes out of the pieces of wood (D,E). The height (h) of one triangular shape will be 5 cm and the other will be 3 cm, while both will have a base 12 cm long.

The groove is best cut with the help of a saw.

c. Notes

(i) This apparatus is used to demonstrate the refraction of light according to Newton's Corpuscular Theory. The ball bearing may be rolled down the small ramp, across the top platform and down the ramp, or alternatively down the large ramp, across the table top and up the ramp. In either case refraction occurs in crossing the ramp from one level (or medium) to another, and appropriate comparisons may be made with the transmission of light across a boundary (ramp) from one medium (level) to another.

C4. Filter

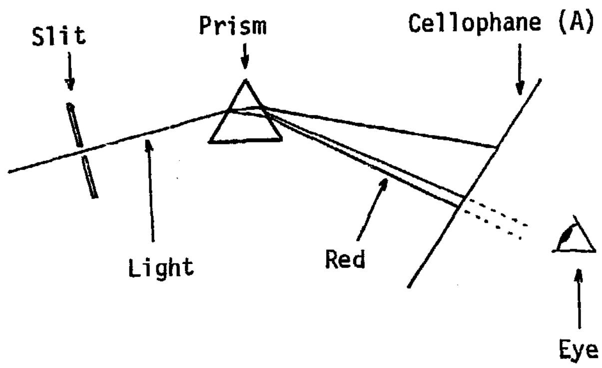


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cellophane	1	Red Cellophane (A)	10 cm x 3 cm
(2) Frame	2	Cardboard (B)	10 cm x 3 cm

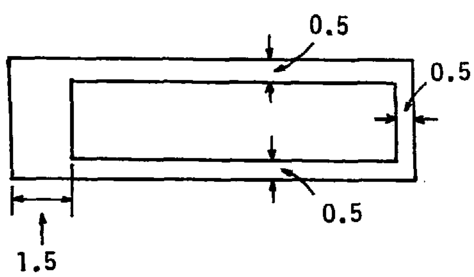
b. Construction

(1) Cellophane



Test different strips of red cellophane (A) for suitability by noting what parts of a spectrum can be seen through the cellophane. The cellophane cutting out almost all colors other than red will be most suitable.

(2) Frame



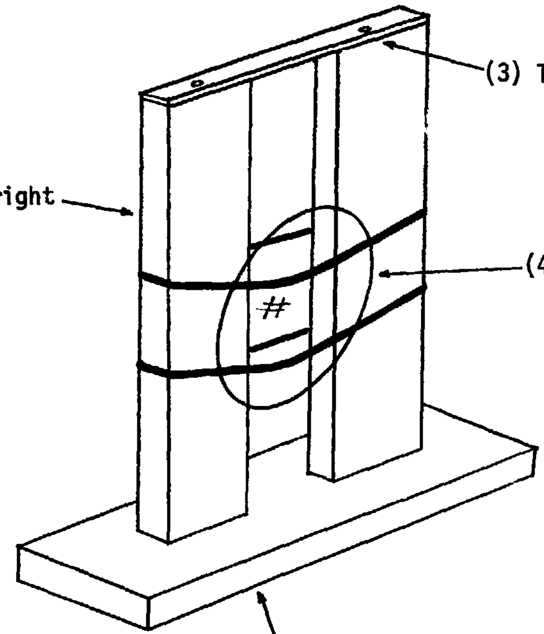
Cut the two pieces of cardboard (B) to the shape indicated, and stick (or clip) a suitable piece of red cellophane (A) between the two pieces.

c. Notes

(i) Filters are very useful not only in studying the way in which different colors of light superimpose one on the other, but also for the creation of monochromatic light. This is particularly important in studying interference and diffraction phenomena.

D. LENS APPARATUS

D1. Lens with Holder ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	10 cm x 5 cm x 1 cm
(2) Uprights	2	Wood Strips (B)	12 cm x 2 cm x 1 cm
	2	Screws (C)	1.5 cm long
(3) Top Plate	1	Metal Sheet (D)	7 cm x 1 cm x 0.1 cm
	2	Screws (E)	Approximately 0.7 cm long
(4) Lens	1	Magnifying Glass (F)	--

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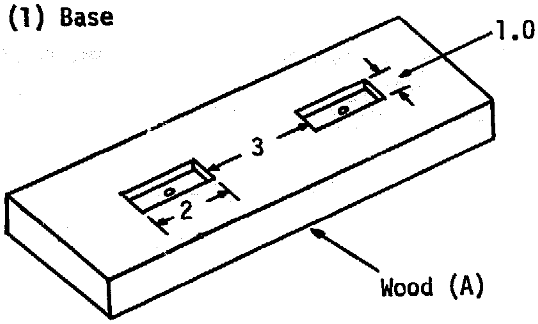
b. Construction

(1) Base



Make two insets (0.5 cm deep) in the wood (A) to take the two uprights (B). Drill a small hole (0.2 cm diameter) in the middle of each inset.

(2) Uprights

Set the uprights (B) in the base insets with wood cement, insuring a firm joint by screwing the very small screws (C) through the base into the upright.

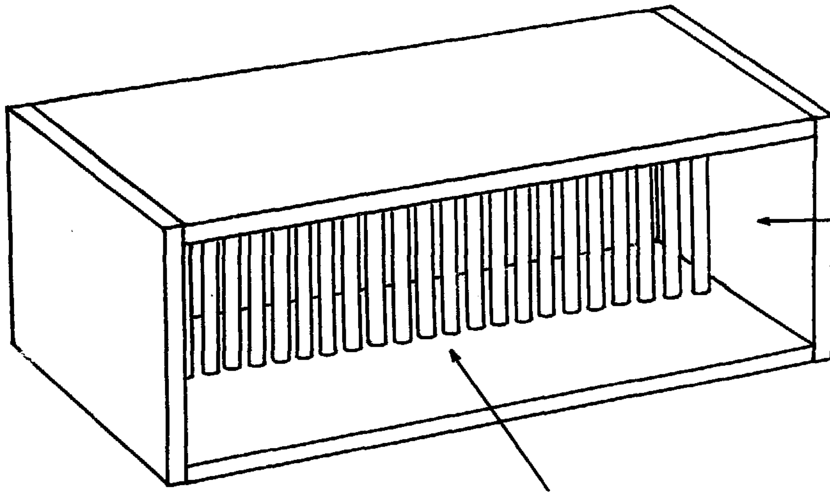
(3) Top Plate

Cut the top plate out of aluminum or brass (D). Drill a small hole (0.2 cm diameter) at a distance of 1 cm from each end. Attach the top plate to the uprights with very small screws (E).

(4) Lens

Purchase a suitable magnifying glass (F) locally. It may be held in any position on the upright by means of rubber bands.

D2. Multiple Slits

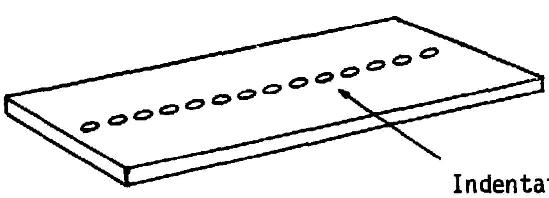


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Framework	2	Wood Strips (A)	10 cm x 2 cm x 0.5 cm
	2	Wood Strips (B)	4 cm x 2 cm x 0.5 cm
(2) Nails	1	Box of Nails (C)	0.2 cm diameter, more than 4 cm long

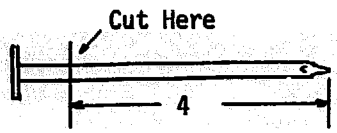
b. Construction

(1) Framework



Make regular indentations down the middle of the top and bottom strips (A) of the framework, the indentations being 0.4 cm apart. These indentations can easily be made with a hammer and nail. The remaining two pieces of wood (B) will serve as sidepieces for the framework. Do not complete construction of the framework until the nails (C) are in place.

(2) Nails



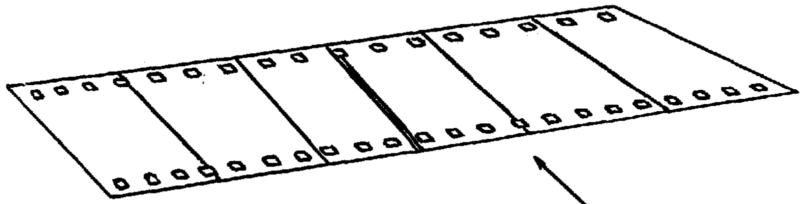
Take a handful of nails (C) and cut off the top ends to produce a uniform set of nails, each 4 cm long. Tap the nails into the bottom strip (A), positioning them in the indentations. Then press the upper strip (A) onto the upright nails, using the indentations on the upper strip for guidance in positioning the nails parallel to one another. Finally, attach the sidepieces (B) of the framework using very small nails or wood cement.

c. Notes

(i) The multiple slits are used primarily to break up beams of light into multiple pencils of light. Many alternative devices could be used for the same purpose, e.g., a hair comb supported by a wooden block.

E. DIFFRACTION AND INTERFERENCE APPARATUS

E1. Fixed Single and Double Slits

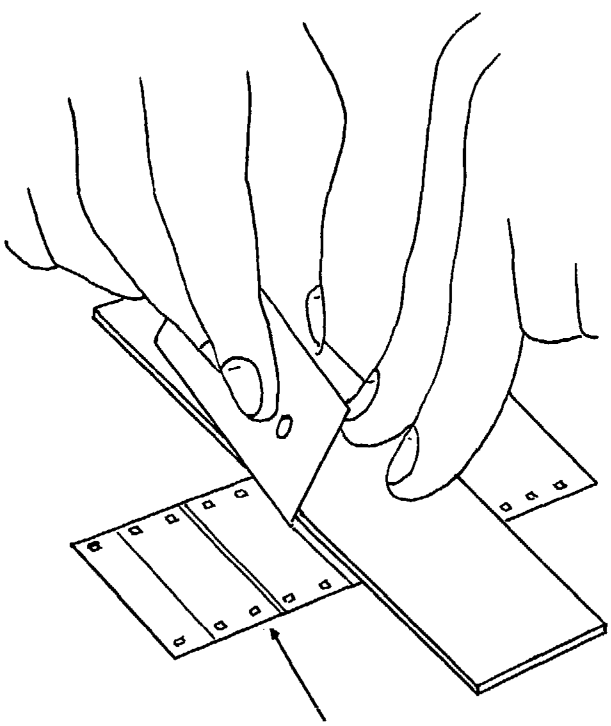


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Fixed Slits	1	Exposed Film (A)	Approximately 5 cm x 3.5 cm

b. Construction

(1) Fixed Slits



Take an exposed strip of film (A) (or a slide coated with colloidal graphite) and draw a straight line across it using a razor and a straight edge as a marker. The width of the slit may be increased, if desired, by drawing the razor over the same approximate line two or three times. Do not cut through the film.

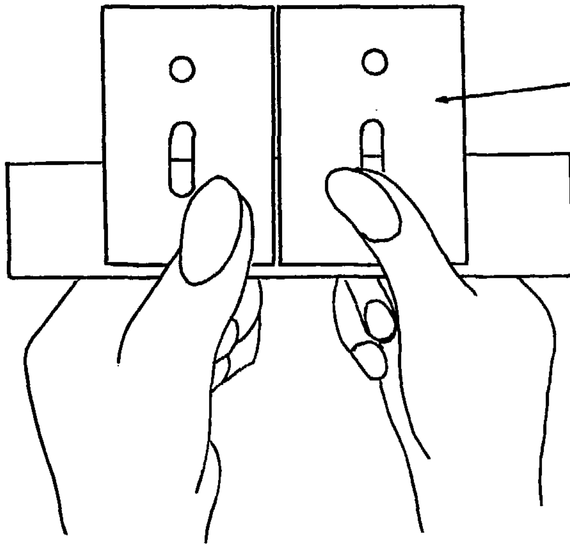
A double slit may be made in an almost identical way. Simply hold two razors face to face, and draw the line across the film with the two razor blades pressed closely together. The space between the slits may be increased, if desired, by holding the blades at an angle to the vertical as the double line is drawn against the straight edge.

c. Notes

(i) In making single or double slits it is well worthwhile repeating the procedure several times on different parts of the film, and then selecting the best slits after testing.

(ii) If the slits are held in a vertical position close to the eye, and if the vertical filament of the Light Source (VI/A1) at a distance of about three meters is viewed through the slits, interference and diffraction patterns will be observed even in daylight. The patterns are clarified by the use of the Filter (VI/C4) placed in front of the slits.

E2. Adjustable Single Slit



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Adjustable Slit	2	Razor Blades (A)	--
	1	Metal Strip (B)	Approximately 7 cm x 2 cm

b. Construction

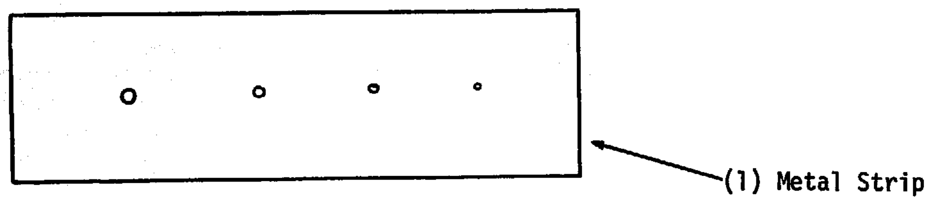
(1) Adjustable Slit

Hold the two razor blades (A) against the metal strip (B) so that the edges of the blades are almost touching and are parallel to one another.

c. Notes

(i) If the slit is held in a vertical position close to the eye, and the vertical filament of the Light Source (VI/A1) viewed at a distance of about three meters, a diffraction pattern may be observed in daylight conditions. The pattern is clarified by the use of the Filter (VI/C4) placed in front of the slit. The effect on the pattern of changing the slit width may readily be observed.

E3. Diffraction Holes



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Metal Strip	1	Metal Strip (A)	10 cm x 2.5 cm x 0.1 cm

b. Construction

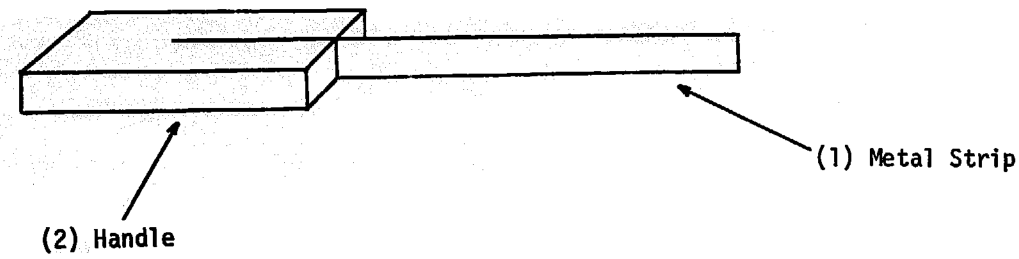
(1) Metal Strip

Drill four holes (diameters approximately 0.1, 0.08, 0.05, and 0.02 cm) in the metal strip (A) at regular intervals.

c. Notes

(i) Circular diffraction patterns may be studied with these holes and the Light Source (VI/A1) placed in such a position that the light filament is viewed through the small hole in the lid of the lamp housing, thus acting as a point source. If this point source is viewed at a distance of about three meters by looking through one of the diffraction holes, when the strip is held close to the eye, a diffraction pattern will be seen even in daylight conditions. The pattern will appear clearer if the Filter (VI/C4) is placed in front of the diffraction hole.

E4. Interference Strips



a. Materials Required

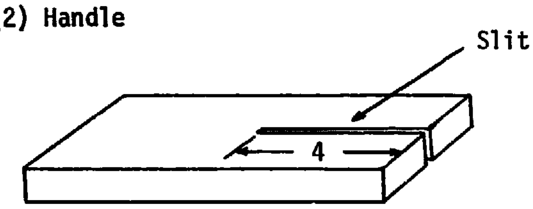
Components	Qu	Items Required	Dimensions
(1) Metal Strip	1	Metal Strip (Copper or Steel)	14 cm x 1 cm x 0.1 cm
(2) Handle	1	Wood	7 cm x 1 cm x 1 cm

b. Construction

(1) Metal Strip

The metal strip (A) may be of any desired metal. In this instance, two are specifically recommended, namely copper and steel (from packing case bands).

(2) Handle



The handle is made from the wood (B). Cut a slit down the middle of the handle with a saw. Cement the metal strip into this inset with epoxy resin.

c. Notes

(i) If the end of the metal strip is placed in a hot flame, interference bands will be produced on the strip.

VII. LABORATORY ACCESSORIES

Where a science room has an electric outlet teachers will wish to take advantage of the mains' supply. The apparatus described here considerably extends the usefulness of the electric outlet.

A. TRANSFORMERS

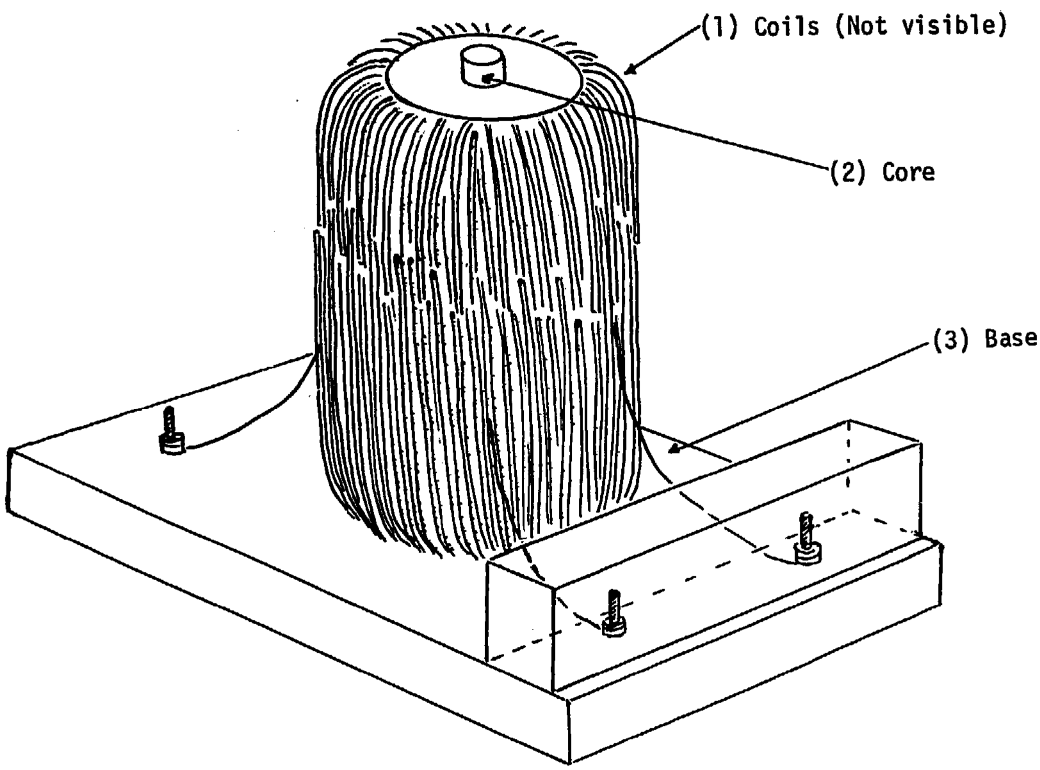
This section describes different types of transformers which may be used to produce low voltage AC outputs. The limitations of each transformer are carefully described in the notes.

B. RECTIFIERS

This section describes rectifiers, which may be used with the foregoing transformers, to produce low voltage DC current.

A. TRANSFORMERS

A1. Transformer, Iron Wire Core (6 volt output, 120 volt mains)



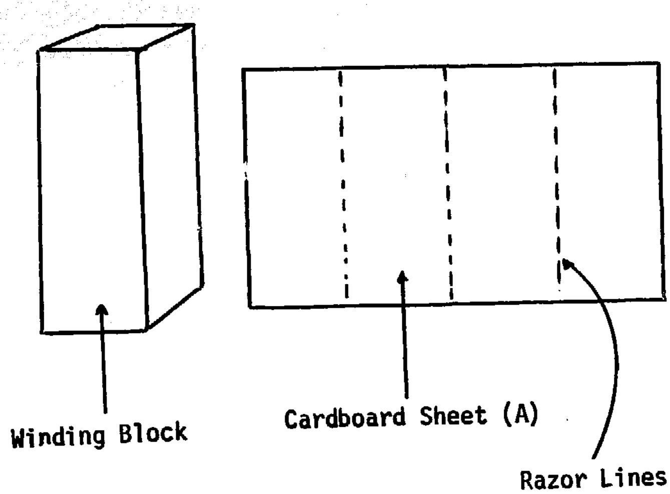
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Coils	1	Sheet of Cardboard (A)	12 cm x 7.5 cm
	1	Roll of Magnet Wire (B)	#24, 250 g
	1	Roll of Magnet Wire (C)	#20, 60 g
	1	Roll of Masking Tape (D)	--
(2) Core	1	Galvanized Wire (E)	#12, 30 meters
	--	Varnish (F)	--
	1	Bolt (G)	0.5 cm diameter, 14 cm long
	1	Nut (H)	0.5 cm internal diameter
	2	Washers (I)	4 cm external diameter
(3) Base	1	Wood (J)	20 cm x 15 cm x 1.5 cm
	1	Wood (K)	15 cm x 3 cm x 2 cm

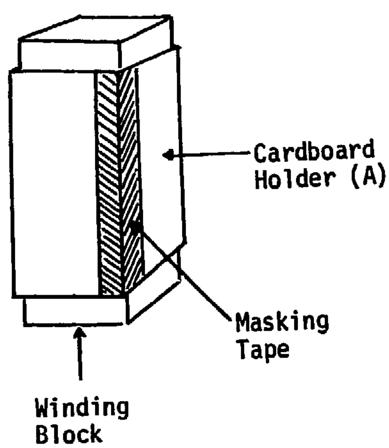
4	Bolts (L)	2.5 cm long, 0.3 cm diameter
8	Nuts (M)	0.3 cm internal diameter
--	Insulation Tape (N)	--

b. Construction

(1) Coils

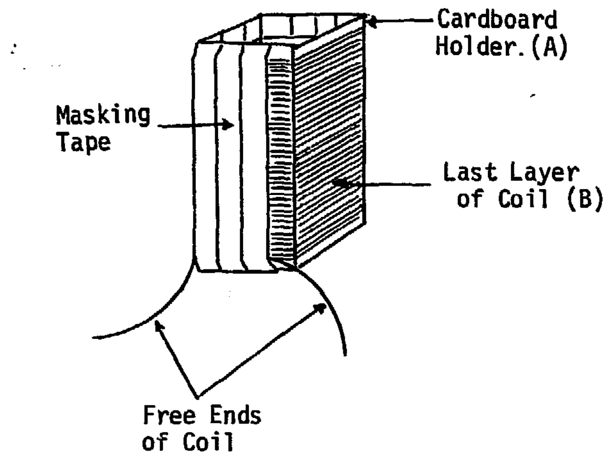


Cut a piece of wood (10 cm x 3 cm x 3 cm) to serve as a winding block for the primary and secondary coils. Take the sheet of cardboard (A) and use a razor blade to score parallel lines on it at 3 cm intervals so that it may readily be bent to the shape of the wooden block.

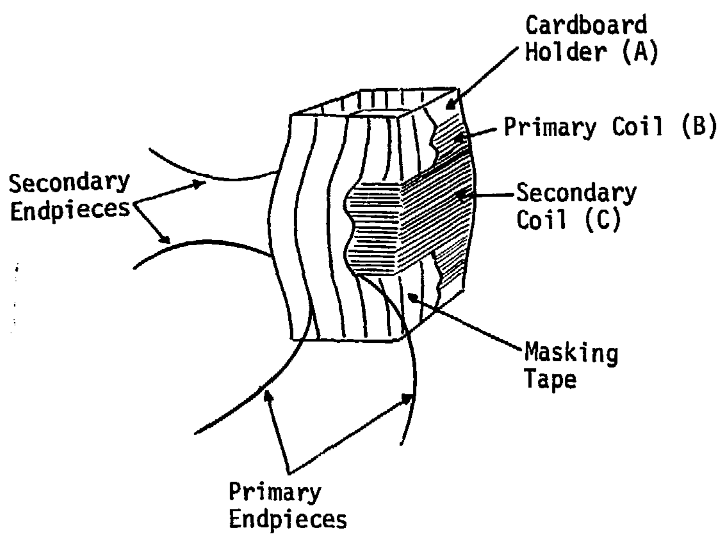


Wrap the cardboard around the block, fastening the two loose edges together with masking tape (D), thus producing a cardboard holder on which to wind the coils.

Wind 800 turns of #24 magnet wire (B), approximately 250 g, on to the cardboard holder to make the primary coil, leaving about 10 cm of wire free at



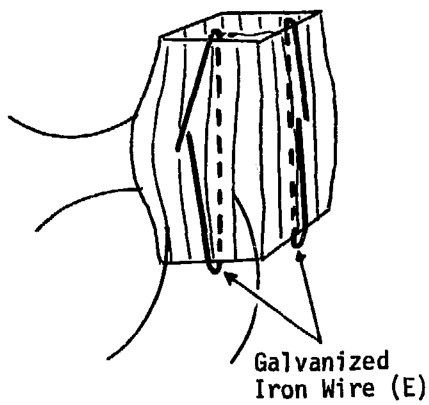
both ends. To do this a system of winding such as that described under IX/A2 should be adopted. (A variation is described in the notes below.) Wind the turns on to only the middle 6 cm or so of the cardboard holder. After winding each additional layer of turns, temporarily remove the cardboard holder (and turns) from the winding block, and cover the turns with masking tape. This not only holds the new layer of turns in position, but also insulates it from the next layer to be added.



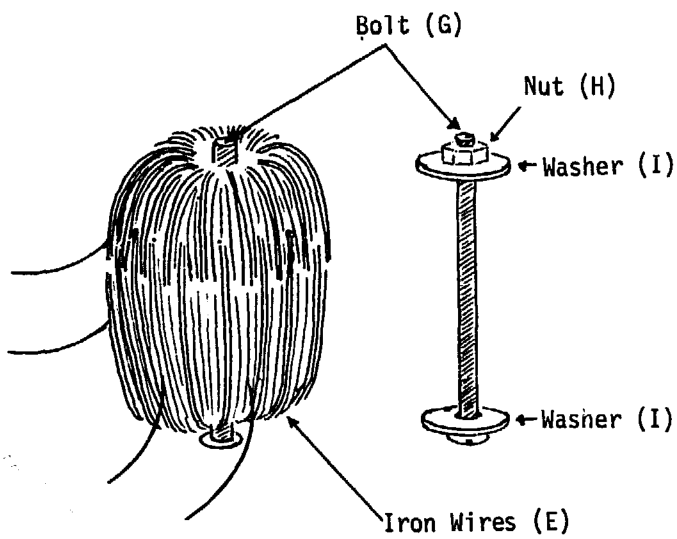
Next, take wire (C), and wind 40 turns, approximately 60 g, on top of the primary coil following the same procedures described for the primary coil, but in this case making each layer only about 3.5 cm long, instead of 6 cm. As before, insure that each layer of turns is insulated from the next with masking tape, and that some 10 cm of wire is left free at both ends of the coil. The newly added coil is appropriately labeled the secondary coil.

(2) Core

Cut the galvanized iron wire (E) into a series of 20 cm lengths. Dip these in varnish (F), and then lean them against a vertical surface to dry, in such a way that varnish is not removed from the wire in the process of drying. One to two days will be required for the varnish to dry.

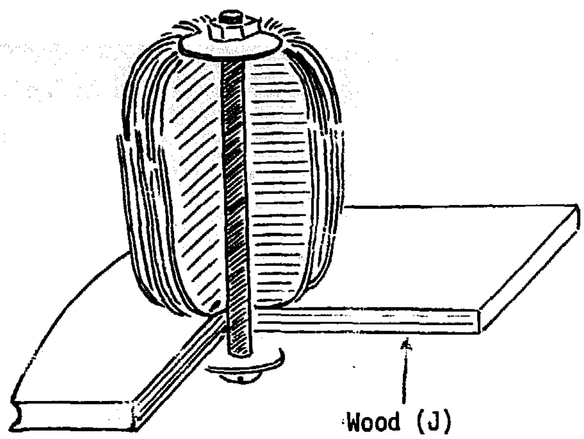


Take the dry wires one at a time, and bend them through, and around, the coil so that the wire ends just touch, or overlap, one another. If the wire is too long, cut the ends. Continue adding the iron wires to the coil in the same way, distributing the wires equally on each face of the coil, until the coil is almost full of iron wire. However, leave enough space to squeeze bolt (G) through the middle of the wire core.

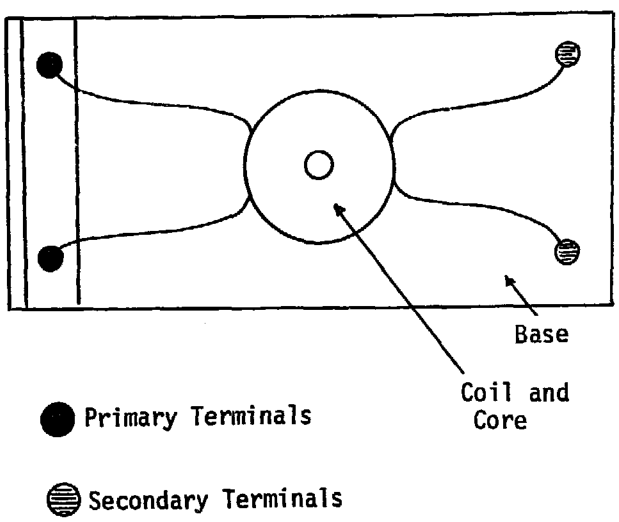


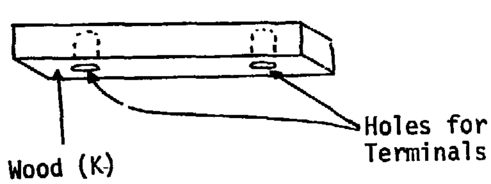
Slide bolt (G) through the middle of the iron wires. Washers (I) should be fitted on either end of the bolt, and the whole kept in position with a suitable nut (H).

(3) Base



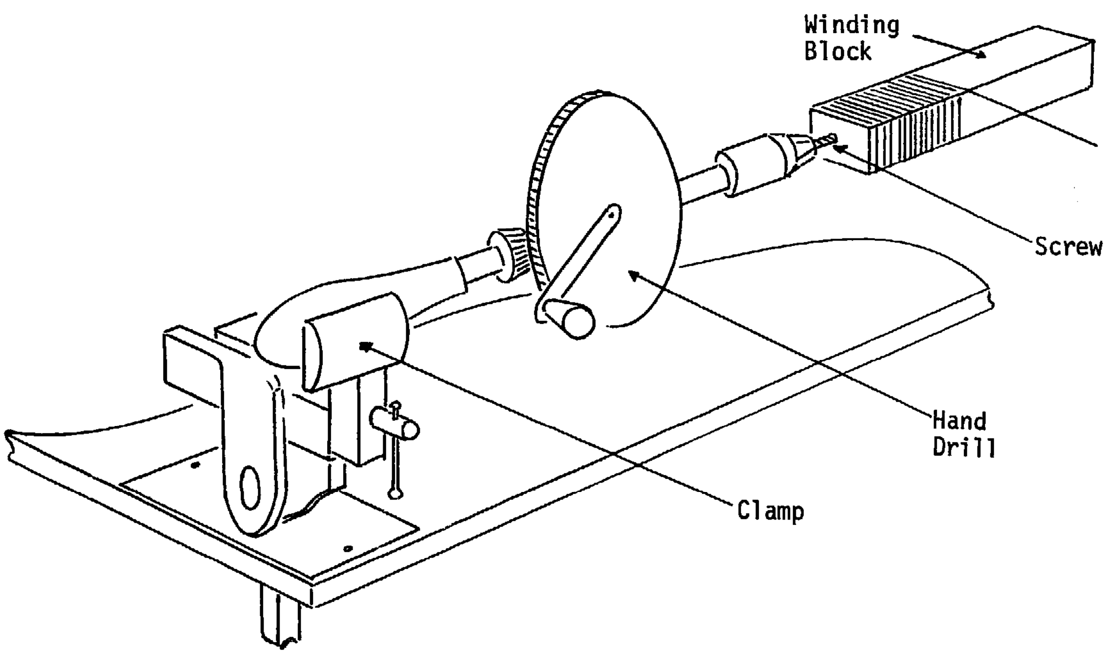
Make the base from wood (J). Drill a hole (diameter 0.5 cm) through the center, and attach the coil and core to the base with the help of the bolt (G) through the middle of the core. Make an inset in the bottom of the base to accommodate the bolt-head.





Use the bolts (L) and nuts (M) to make four terminals (as described under VIII/A2). Fit two at one end of the base to serve as secondary terminals, and attach the ends of the secondary coil to these, after cleaning the ends of the wire with sandpaper. Fit the other two terminals at the other end of the base to serve as the primary terminals. Attach the ends of the primary coil to the terminals after cleaning the ends of the wire with sandpaper. Remembering that the primary coil will be connected to the mains (120 volts) it is important to insure good insulation of all primary terminals and wires. Therefore, cover each of the wires from the primary coil to the relevant terminal with electrical insulation tape (N). In addition make a safety cover from wood (K). Simply cut holes (2 cm deep, 1 cm diameter) in the undersurface of the wood to accommodate the terminals, and set the wood on the base so that it covers the terminals.

c. Notes



(i) A convenient way of winding the coils is to use a hand drill and winding block. Clamp the hand drill horizontally above the bench surface, and hold a winding block horizontally in the drill chuck with the help of a screw fixed firmly in the end of the winding block. If a cardboard sleeve is fitted over the winding block, the wire may be wound on the sleeve, and the latter subsequently removed complete with newly wound coil.

(ii) The transformer made and tested here actually had 800 turns on the primary and 43 turns on the secondary. The voltage output was noted to be 6.6 volts when the current load was at a minimum, and that it fell to 5.5 volts as the load increased to 4 amps. At the same time the efficiency of the transformer increased from 32% at 6.6 volts to 45% at 5.5 volts.

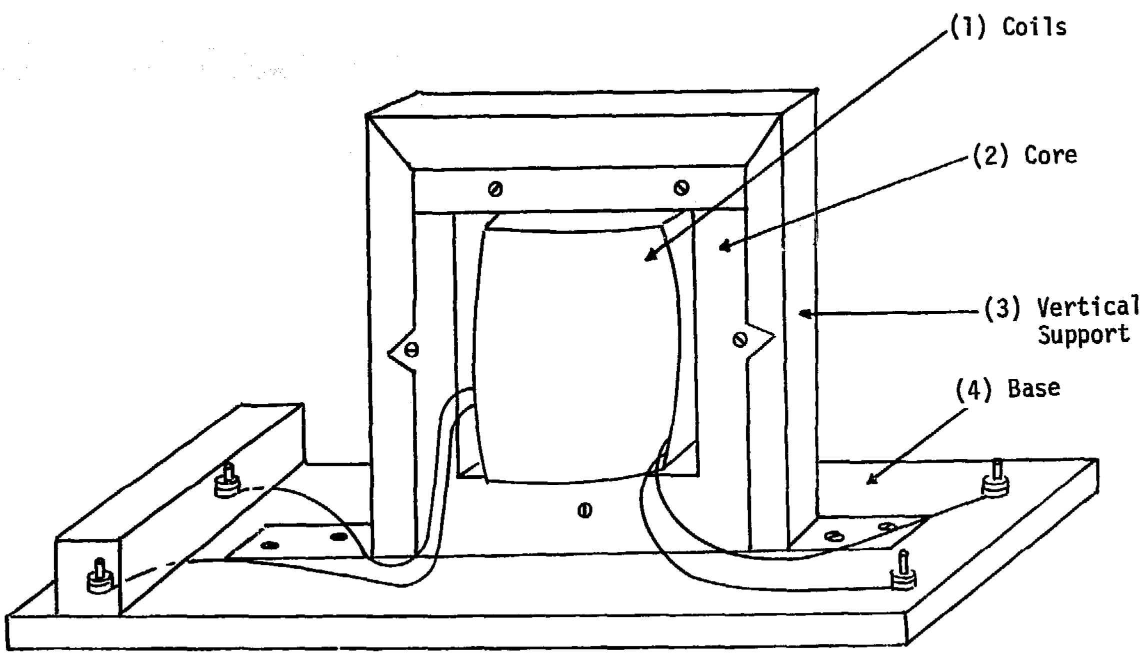
(iii) Tested under a continuous load of 4 amps, the temperature of the core rose to 69°C over a period of 50 minutes, at which point the load was cut off to prevent serious overheating of the core. The data, indicated below, suggested that this transformer could be used continuously under a load of 3 amps, but with a load of 4 amps it should not be used for periods exceeding 30 minutes at any given time.

Room Temperature	Output Voltage	Output Amperage	Running Time	Core Temperature
°C	Volts	Amps	Minutes	°C
24	5.5	4	0	24
			20	50
			40	64
			50	68
			Testing stopped after 50 min	

Under the smaller load of 2.8 amps the core heated up more slowly, stabilizing at 62°C.

Room Temperature	Output Voltage	Output Amperage	Running Time	Core Temperature
°C	Volts	Amps	Minutes	°C
24	6.0	2.8	0	24
			20	46
			40	56
			60	62

A2. Transformer, Sheet Iron Core (12 volt output, 120 volt mains)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Coils	1	Sheet of Cardboard (A)	12 cm x 7.5 cm
	1	Roll of Magnet Wire (B)	#24, 250 g
	1	Roll of Magnet Wire (C)	#20, 100 g
	1	Roll of Masking Tape (D)	--
(2) Core	60	Galvanized Iron Sheets (E) (more sheets required if thinner sheeting is used)	13 cm x 10 cm x 0.05 cm
	5	Bolts (F)	0.3 cm diameter, 3.5 cm long
	5	Nuts (G)	0.3 cm internal diameter
	--	Varnish (H)	--
(3) Vertical Support	1	Galvanized Iron or Aluminum Sheet (I)	47.5 x 5 x 0.02 cm
(4) Base	1	Wood (J)	30 cm x 15 cm x 1.5 cm
	1	Wood (K)	15 cm x 3 cm x 2 cm
	4	Bolts (L)	2.5 cm long, 0.3 cm diameter
	8	Nuts (M)	0.3 cm internal diameter

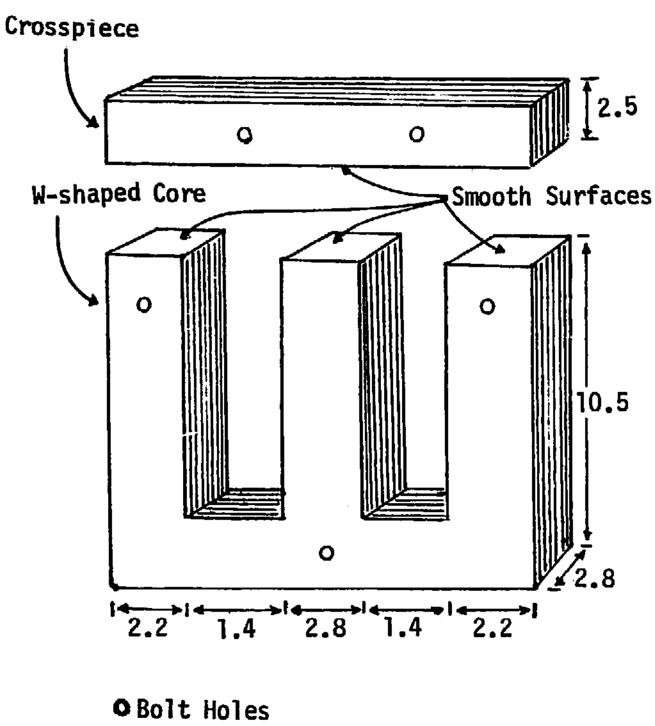
-- Insulation Tape (N) --

b. Construction

(1) Coils

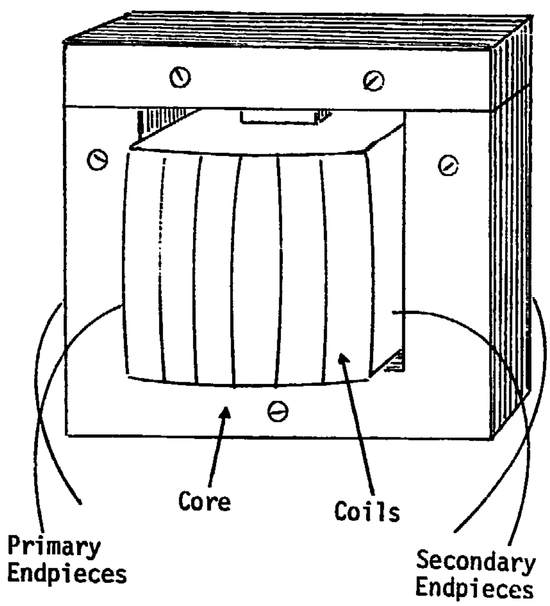
Follow the instructions given with the foregoing transformer (VII/A1) for the construction of the coils. Make a form, on which to wind the coils, from the cardboard sheet (A), and wind 800 turns of magnet wire (B) on to the form to make the primary coil. Then wind 80 turns (not 40) of magnet wire (C) on to the coil to make the secondary coil.

(2) Core



Stack the sheets of galvanized iron (E) one on top of the other, until they make a pile 2.8 cm thick. This will require 55, or more, sheets, dependent on the thickness of each. Then cut each sheet as illustrated to form a W-shaped core piece and a rectangular crosspiece.

Stack the newly cut plates back on top of each other, and drill five bolt holes (diameter 0.4 cm) through the plates. A drill press is preferred for this purpose, but it is possible to hand drill each plate separately. Use nuts (G) and bolts (F) to



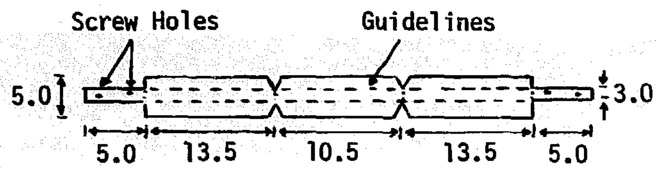
fasten the plates of the crosspiece and core together.

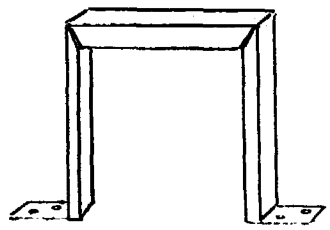
Take a file to smooth off the rough edges of the newly made core. It is important that the finished surfaces should insure good contact between the top of the W-shaped core and the crosspiece.

Now take the plates apart, paint varnish (H) on each in turn, reassembling the plates while still wet. The varnish acts as an insulator, which reduces eddy currents, and hence heating effects, within the core. The core may take one or two days to dry.

Assemble the coils on the W-shaped core, using paper or wood wedges if necessary to insure the coil is held firmly on the central upright of the core.

(3) Vertical Support

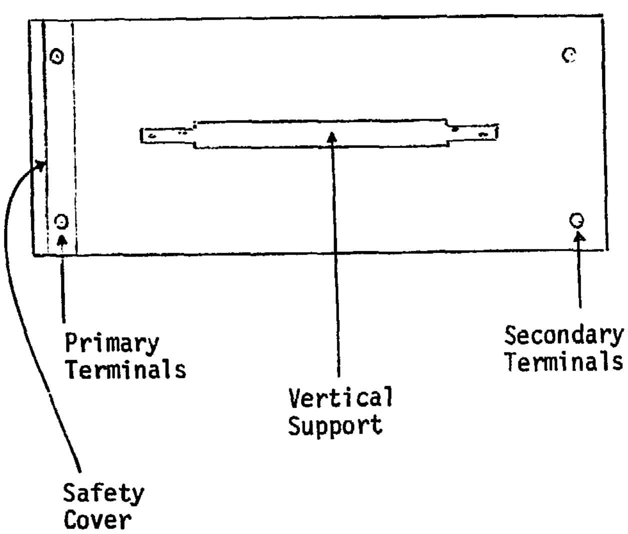




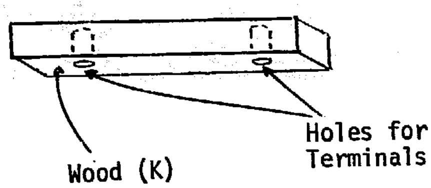
Use galvanized iron or aluminum sheeting (I) to make the vertical support. Cut it to the dimensions indicated, and bend it into the shape of a bridge. Drill two holes (diameter 0.3 cm) in either foot of the bridge so that the support may subsequently be attached to a base with screws.

(4) Base

Make a base for the transformer out of wood (J). Fit the vertical support snugly over the core and coils, and attach the support to the middle of the base with screws.



Use bolts (L) and nuts (M) to make four terminals [as described under VIII/A2, Component (4)]. Fit two at one end of the base to serve as secondary terminals, and attach the ends of the secondary coil to these after cleaning the ends of the wire with sandpaper. Fit the other two terminals at the other end of the base to serve as the primary terminals. Attach the ends of the primary coil to the terminals after cleaning the ends of the wire with sandpaper. Remembering that the primary coil will be connected to the mains (120 volts),it is important to insure good insulation of all



primary terminals and wires. Therefore, cover each of the wires from the primary coil to the relevant terminal with electrical insulation tape (N).

In addition, make a safety cover for the primary terminals from wood (K). Simply cut holes (2 cm deep, 1 cm diameter) in the undersurface to accommodate the terminals, and set the wood on the base so that it covers the terminals.

c. Notes

(i) The voltage output of the secondary coil of the transformer will be at a maximum when the current load is at a minimum. In this case it was noted that the output voltage fell from 12 volts at 1 amp to 11 volts at 4 amps. At the same time the efficiency of the transformer increased from 47% at 12 volts to 62% at 11 volts.

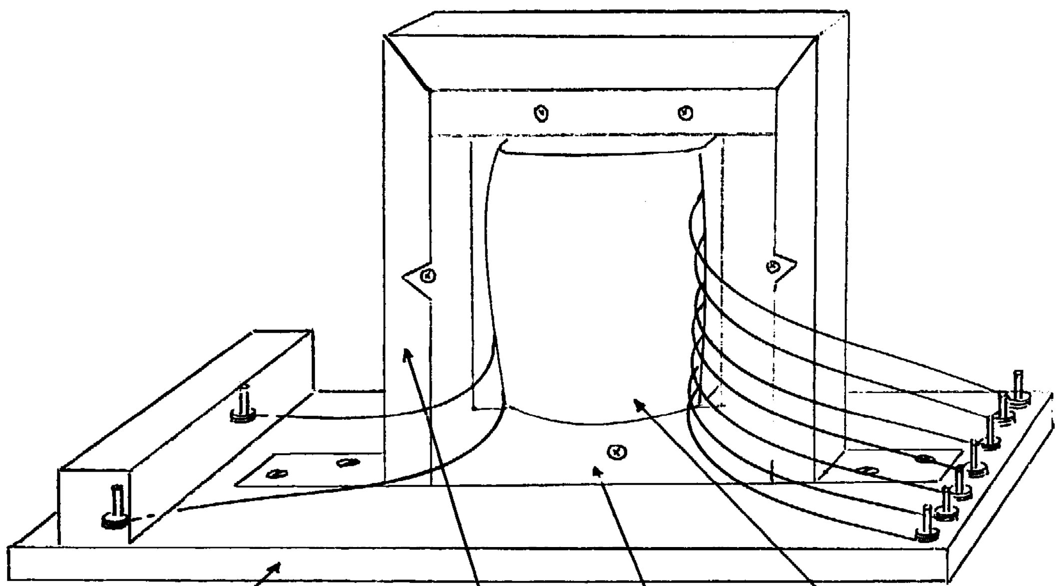
(ii) Tested over a period of 90 minutes under a continuous load of 4 amps, the temperature of the core remained well within acceptable limits. The following data indicates the degree of heating somewhat more explicitly.

Room Temperature	Output Voltage	Output Amperage	Running Time	Core Temperature
°C	Volts	Amps	Minutes	°C
24	10.8	4	0	24
			20	52
			40	56
			60	59
			90	59

Under smaller loads the core heats up more slowly, but observations tended to suggest that the ultimate equilibrium temperature achieved (59°C) was the same as with the heavier load. (See table on next page.)

Room Temperature	Output Voltage	Output Amperage	Running Time	Core Temperature
°C	Volts	Amps	Minutes	°C
24	11	3	0	24
			20	44
			40	52
			60	59

A3. Transformer, Variable Output (120 volt mains)



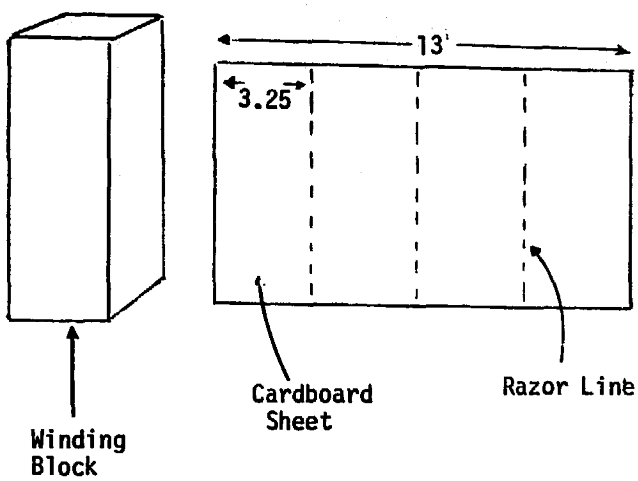
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Coils	1	Cardboard Sheet (A)	13.0 cm x 11.5 cm
	1	Roll of Magnet Wire (B)	#24, 250 g
	1	Roll of Magnet Wire (C)	#20, 250 g
	1	Masking Tape (D)	--
(2) Core	60	Galvanized Iron Sheets (E) (more sheets required if thinner sheeting is used)	17 cm x 10 cm x 0.05 cm
	5	Bolts (F)	0.3 cm diameter, 3.5 cm long
	5	Nuts (G)	0.3 cm internal diameter
	1	Can of Varnish (H)	--
(3) Vertical Support	1	Galvanized Iron or Aluminum Sheet	55.5 cm x 5 cm x 0.02 cm
(4) Base	1	Wood (J)	30 cm x 20 cm x 1.5 cm
	1	Wood (K)	20 cm x 3 cm x 2 cm

9	Bolts (L)	2.5 cm long, 0.3 cm diameter
18	Nuts (M)	0.3 cm internal diameter
1	Roll of Insulation Tape (N)	--

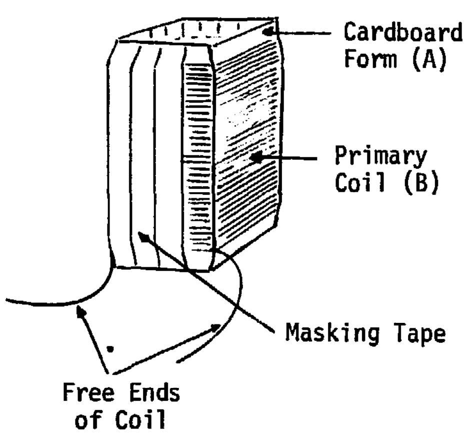
b. Construction

(1) Coils



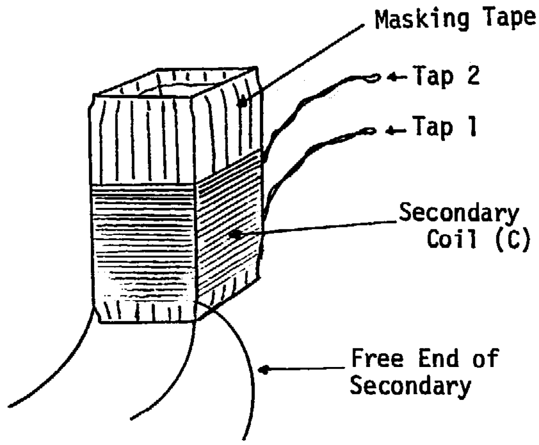
Cut a piece of wood (14 cm x 3.2 cm x 3.2 cm) to serve as a winding block for the primary and secondary coils. Take the thin sheet of cardboard (A) and use a razor blade to score parallel lines on it at intervals of 3.25 cm, so that the cardboard may readily be bent around the wooden block.

Wrap the cardboard sheet around the block, fastening the loose edges together with masking tape (D), thus producing a cardboard form on which to wind the primary and secondary coils.



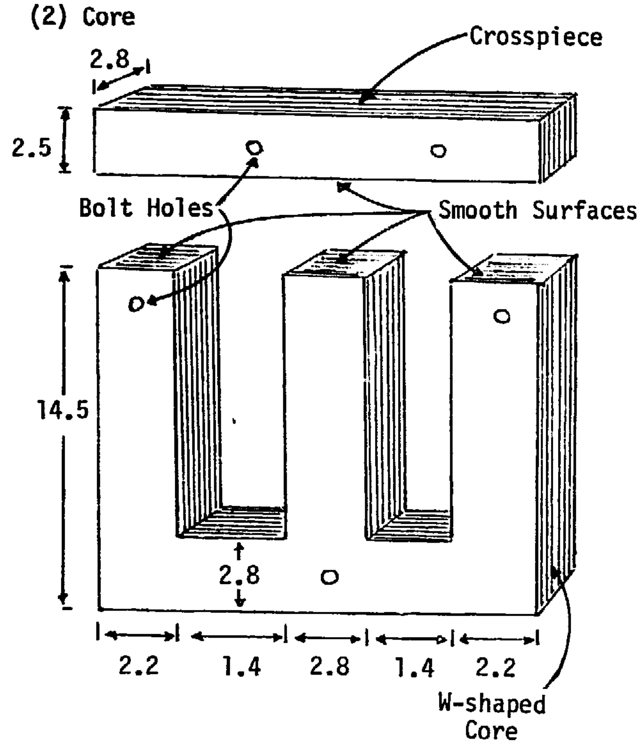
To make the primary coil, wind 720 turns (approximately 250 g) of magnet wire (B), onto the cardboard form. Each layer of turns will be 10 cm long. Place masking tape between each layer. The actual method of winding is described under VII/A1.

To make the secondary coil, wind 180 turns (approximately 250 g) of magnet wire (C) on top of the primary coil in the usual way (leaving a free end about 20 cm long at the start). However,



halt after every 30 turns to make a tap. (The latter is made by taking the next 40 cm of wire, folding it to make a double strand, and twisting it around itself.) Then continue for another 30 turns before making a further tap, again with a 40 cm length of wire. It is very important to make the taps at the corners of the secondary coil, otherwise they will interfere with the placement of the coil on the core. Each layer of turns should be covered in the usual way with masking tape to insulate it from the next layer. In all, there should be taps after 30, 60, 90, 120 and 150 turns, and a free end (20 cm long) after 180 turns.

(2) Core



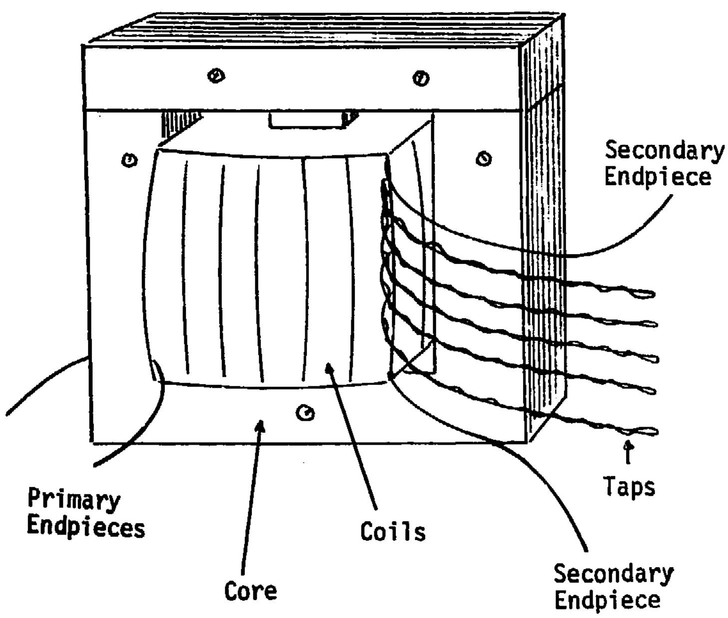
Stack the galvanized iron sheets (E) on top of the other until the pile is 2.8 cm thick. This will require 55, or more, plates, dependent on the thickness of the sheet. Then cut each of the sheets as illustrated to form a W-shaped plate and a rectangular crosspiece.

Stack the newly cut plates back on top of each other, and drill 5 bolt holes (diameter 0.4 cm) through the plates. A drill press is preferred for this purpose, but it is possible to hand drill each plate separately. Use nuts (G) and bolts (F) to fasten the plates of the crosspiece and core together.

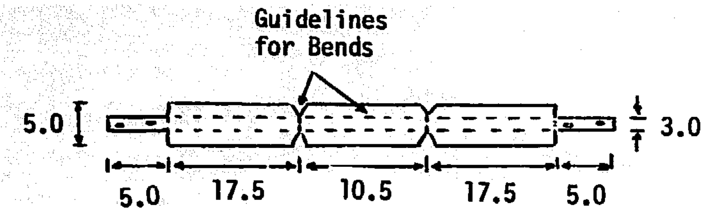
Take a file to smooth off the rough edges of the newly made core. It is important that the finished surfaces should insure good contact between the top of the W-shaped core and the crosspiece.

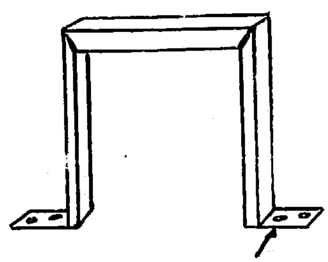
Now take the plates apart, and cover each in turn with varnish (H), reassembling the plates while still wet. The varnish acts as an insulator, which reduces eddy currents, and hence heating effects, within the core. The core may take one or two days to dry.

Assemble the coils on the W-shaped core, using paper or wood wedges if necessary to insure the coil is held firmly on the central upright of the core.

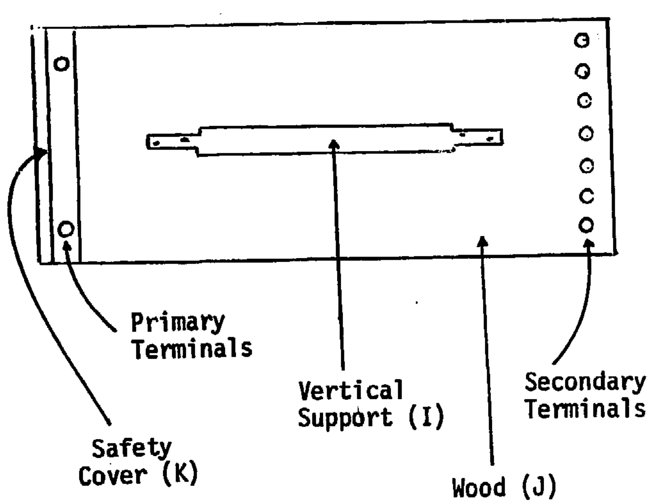


(3) Vertical Support

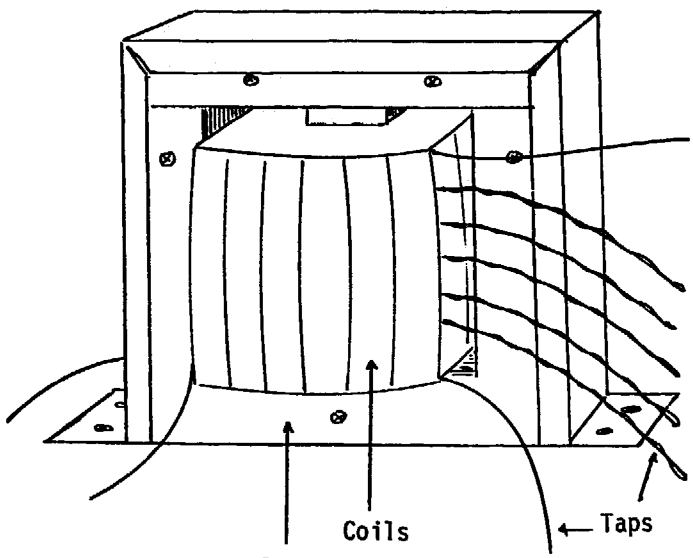




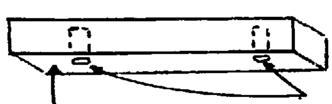
Use galvanized iron or aluminum sheeting (I) to make the vertical support. Cut it to the dimensions indicated, and bend it to the shape of a bridge. Drill two holes (diameter 0.3 cm) in either foot of the bridge so that the support may subsequently be attached to a base with screws.



Make a base for the transformer out of wood (J). Fit the vertical support snugly over the core and coils, and attach the support to the middle of the base with screws.



Use bolts (L) and nuts (M) to make nine terminals [as described under VII/A2, Component (4)]. Fit seven at one end of the base to serve as secondary terminals, and attach the ends of the secondary coil and the taps to these after cleaning the ends of the wire and taps with sandpaper. Cover the wires with insulation tape (N) or tubing to prevent any possibility of a short. Fit the other two terminals at the other end of the base to serve as the primary terminals. Attach the ends of the primary coil to the terminals after cleaning the ends of the wire with sandpaper. Remembering that the primary coil will be connected to the mains (120 volts),it is important to insure good insulation of all primary terminals and wires. Therefore, cover each of the wires from the primary coil to the relevant terminal with electrical insulation tape.



In addition, make a safety cover for the primary terminals from wood (K). Simply cut holes (2 cm deep, 1 cm diameter) in the undersurface to accommodate the terminals, and set the wood on the base so that it covers the terminals.

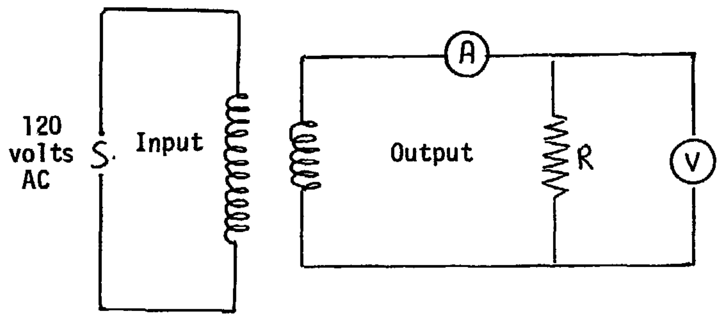
c. Notes

(i) Do not expect the output voltages to be exactly 5, 10, 15 volts and so on. With the apparatus produced and tested here the output voltages, observed by combining any one tap with the coil endpiece, were 4.5, 10.0, 15.0, 21.0, 26.3 and

31.0 volts when the primary voltage was 121 volts.

(ii) The transformer was tested using the 10, 20 and 30 volt outputs. As expected, it was noted that the transformer operated more efficiently at the higher voltages.

The voltage output from any given pair of terminals was observed to fall as the current output increased. Actual results are tabulated below.



Output Taps = 30 volts

Input	Output				
*Power Watts	I Amps	V Volts	R Ohms	*Power Watts	Efficiency %
46	1.00	28.4	28.4	28.40	62
52	1.25	28.0	22.4	35.00	67
59	1.50	27.5	18.3	41.25	70
68	1.75	27.0	15.4	47.25	69
75	2.00	26.5	13.2	53.00	71
82	2.25	26.0	11.5	58.50	71
90	2.50	25.5	10.2	63.75	71
97	2.75	25.0	9.1	68.75	71
105	3.00	24.0	8.0	72.00	69

* Power was measured directly with wattmeters.

Output Taps = 20 volts

Input	Output				
*Power Watts	I Amps	V Volts	R Ohms	*Power Watts	Efficiency %
33	0.75	19.5	26.0	14.6	44
38	1.00	19.2	19.2	19.2	50
43	1.25	19.0	15.2	23.7	55
48	1.50	18.5	12.3	27.7	58
52	1.75	18.3	10.4	32.0	61
56	2.00	18.0	9.0	36.0	64
61	2.25	17.7	7.9	39.8	65
66	2.50	17.5	7.0	43.7	66
71	2.75	17.0	6.2	46.7	66
76	3.00	16.5	5.5	49.5	65

Output Taps = 10 volts

Input	Output				
*Power Watts	I Amps	V Volts	R Ohms	*Power Watts	Efficiency %
22	0.50	9.0	18.0	4.5	20
24	0.75	8.8	11.7	6.6	27
26	1.00	8.7	8.7	8.7	33
29	1.25	8.6	6.9	10.7	37
31	1.50	8.4	5.6	12.6	41
34	1.75	8.3	4.7	14.5	43
36	2.00	8.1	4.0	16.2	45
38	2.25	8.0	3.5	18.0	47
40	2.50	7.8	3.1	19.5	49
43	2.75	7.7	2.8	21.2	49
45	3.00	7.6	2.5	22.8	51

* Power was measured directly with wattmeters.

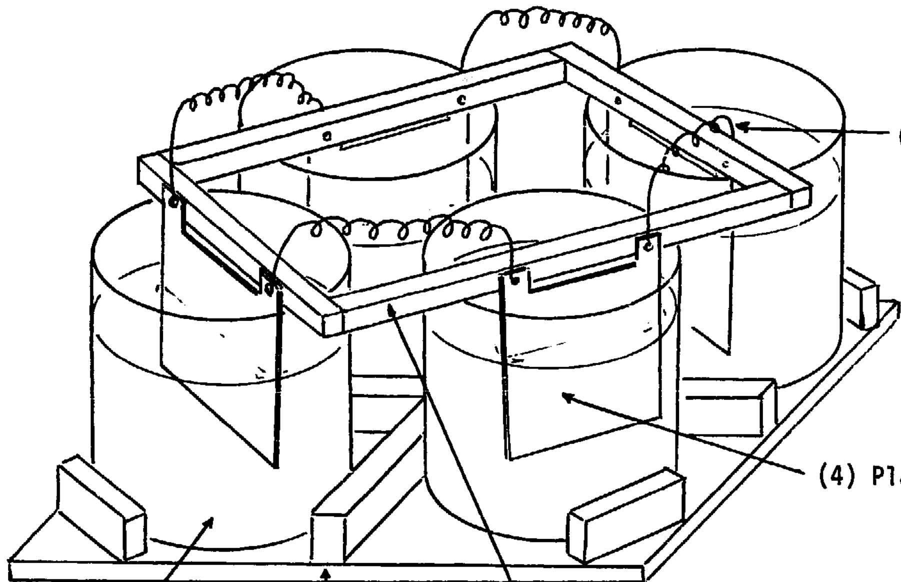
(iii) Some heating of the transformer was noted, but this appeared to be within acceptable limits. Hence, when a current of 3 amps was drawn from the maximum voltage taps (30 volts) the temperature of the transformer core did not rise beyond 60° Centigrade.

Output Taps = 30 volts
Output = 3 amps at 24 volts
Room Temperature = 24°C

Running Time (Minutes)	Core Temperature (Degrees Centigrade)
0	27° C
5	38° C
10	48° C
15	49° C
20	51° C
25	53° C
40	56° C
50	58° C
60	59° C

B. RECTIFIERS

B1. Sodium Bicarbonate Rectifier (2 Plate)



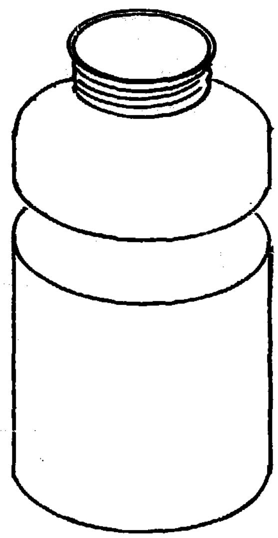
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Cell Containers	4	Glass Jars (A)	Approximately 300 ml, 10 cm diameter
(2) Base	1	Plywood Sheet (B)	22 cm x 22 cm x 0.5 cm
	1	Wood Strip (C)	22 cm x 2 cm x 2 cm
	2	Wood Strips (D)	10 cm x 2 cm x 2 cm
	4	Wood (E)	2 cm x 2 cm x 1 cm
(3) Plates Support	2	Wood (F)	15 cm x 1.5 cm x 1.5 cm
	2	Wood (G)	12 cm x 1.5 cm x 1.5 cm
(4) Plates	4	Lead Sheets (H)	6.5 cm x 5.0 cm x 0.02 cm
	4	Aluminum Sheets (I)	6.5 cm x 5.0 cm x 0.02 cm
	8	Bolts (J)	0.3 cm diameter, 2.5 cm long
	8	Nuts (K)	0.3 cm internal diameter

	16	Washers (L)	0.3 cm internal diameter, approximately
	4	Filter Papers (M)	5.5 cm x 5.5 cm
	1	Saturated Solution of Sodium Bicarbonate (N)	1 liter
(5) Wiring	1	Roll of Magnet Wire (O)	#24

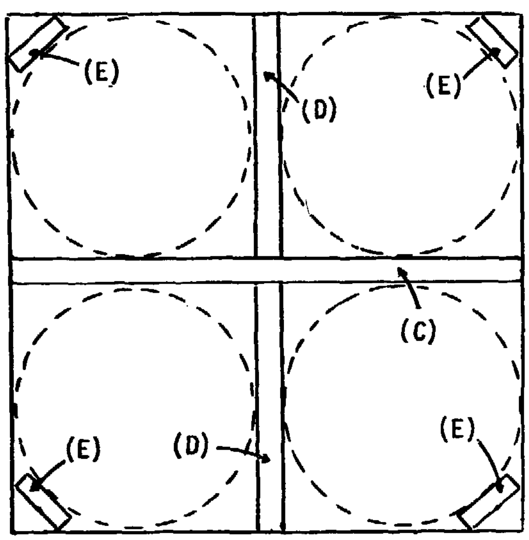
c. Construction

(1) Cell Containers



To make a cell container, take jar (A), and use a hot nichrome wire (CHEM/I/F2) to cut the top off the jar some 6 cm above the base. Repeat the process with three more jars.

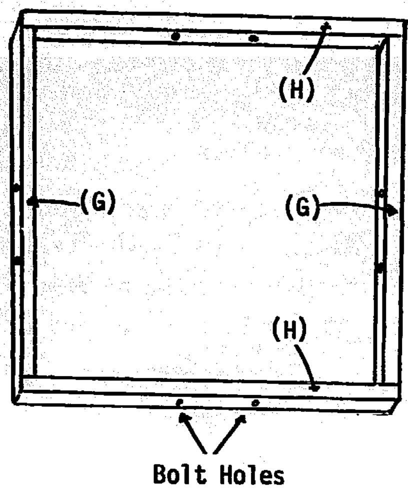
(2) Base



Plywood Base (B)

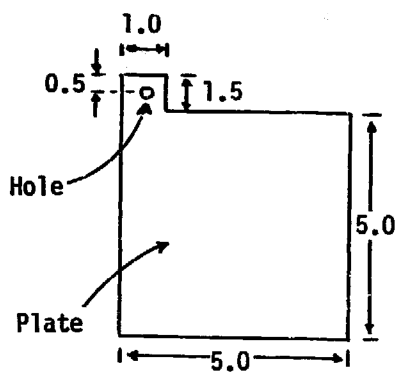
Nail wood strips (C,D) to the top of the plywood sheet (B) so as to divide it into four equal portions. Nail the wood strips (E) at the corners of the plywood in such a way that the four cell containers, placed in the appropriate quarters, will be held in position on the plywood base.

(3) Plates Support

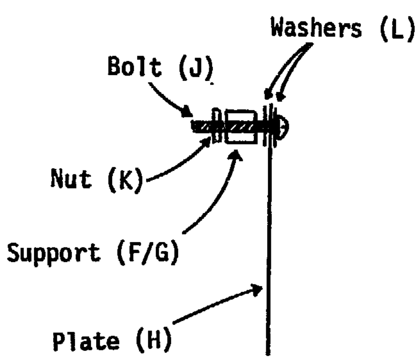


Use wood Strips (F) and (G) to make the frame of the plate support. Drill two bolt holes (0.3 cm diameter) in each side of the support, such that the holes in any one side are 4 cm apart, and are equidistant from the center of the side.

(4) Plates

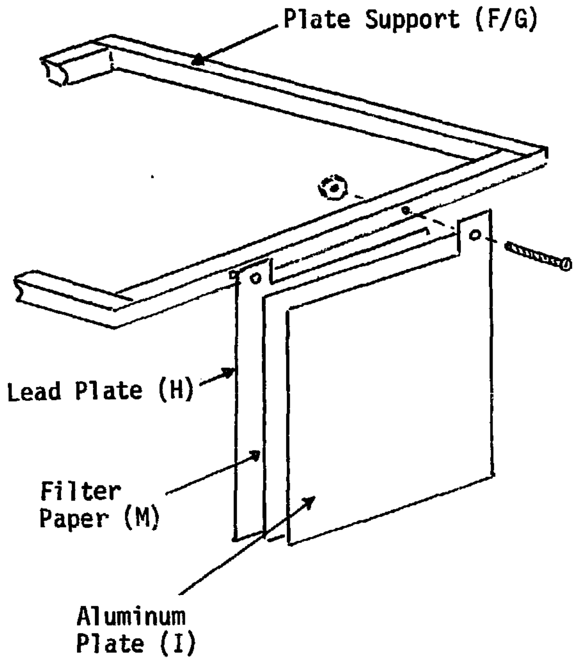


Cut a plate out of lead sheeting (H) and another out of aluminum sheeting (I) to the dimensions shown. Drill a hole (0.3 cm diameter) in the projecting portion of each plate.



Attach the lead plate to the plate support with the help of bolt (J), nut (K) and washers (L) placed either side of the plate.

Attach the aluminum plate to the plate support in the same way, but so that the aluminum plate lies on top of the lead plate. Place the sheet of filter paper (M) between the two plates, thus insulating one from the other.

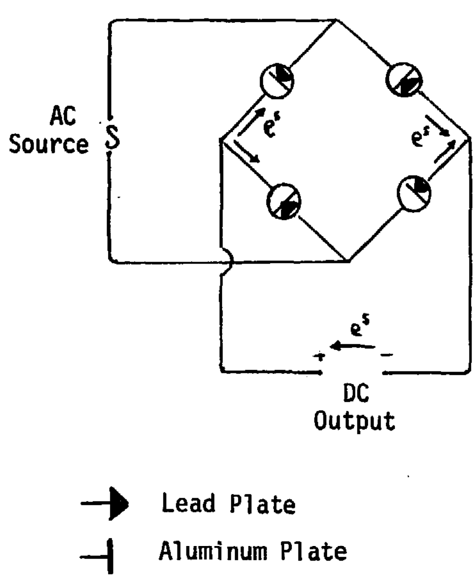


Cut three more lead plates and three more aluminum plates, and make identical plate pairs (insulated with filter paper) for the three remaining sides of the plate support.

Rest the plate support on the four cut jars, such that one pair of plates is suspended in each jar.

Almost fill each jar with a saturated solution of sodium bicarbonate (N), that is baking soda, and add a little extra sodium bicarbonate to each cell to insure that the solution remains saturated during use.

(5) Wiring

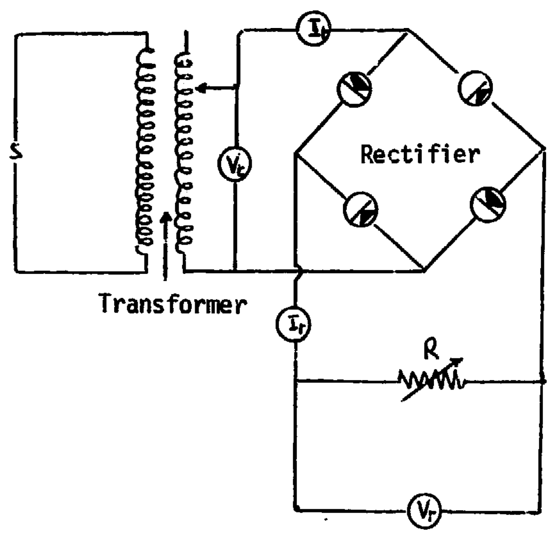


Use copper wire (O) to connect the plates of the four cells together, as indicated in the diagram. The cells have the simple property of permitting electrons to flow only in one direction, from aluminum to lead, and when connected as indicated to an AC source a rectified output is obtained. The type of output obatined with AC sources of 12 volts and 25 volts is indicated in the notes.

c. Notes

(i) The AC voltage supply may be taken from the transformer already described (VII/A3). A series of tests were conducted on the rectifier produced here, after it had been running for one hour. The results are tabulated below.

(ii) With a variable resistance (R) connected across the DC output it will be noted that the output voltage (V_r) fell off as the resistance decreased. [A very small proportion of the fall in voltage may be attributed to the drop in voltage (V_t) from the transformer.]



AC Supply = 15 volt taps

Load	Transformer Output			Rectifier Output			Efficiency
R Ohms	V_t Volts	I_t Amps	W_t Watts	V_r Volts	I_r Amps	W_r Watts	%
820	15.7	0.10	1.57	8.2	0.01	0.08	5.2
800	15.6	0.11	1.71	8.0	0.01	0.08	4.7
390	15.6	0.15	2.34	7.8	0.02	0.16	6.7
172	15.5	0.20	3.10	6.9	0.04	0.28	8.9
98	15.5	0.21	3.26	5.9	0.06	0.35	10.8
84	15.4	0.25	3.86	5.9	0.07	0.41	10.7
70	15.3	0.30	4.59	5.6	0.08	0.45	9.8
60	15.3	0.30	4.59	5.4	0.09	0.49	10.6
52	15.3	0.30	4.59	5.2	0.10	0.52	11.3
42	15.2	0.30	4.56	5.0	0.12	0.60	13.2
31	15.1	0.35	5.28	4.6	0.15	0.69	13.1
21	15.1	0.45	6.80	4.2	0.20	0.84	12.3
11	15.0	0.61	9.15	3.4	0.31	1.05	11.5
9	14.9	0.75	11.18	3.2	0.37	1.18	10.6
6	14.8	0.95	14.06	2.8	0.45	1.26	8.9
5	14.5	1.05	15.23	2.6	0.50	1.30	8.5
3	14.0	1.35	18.90	1.9	0.68	1.29	6.8

AC Supply = 25 volt taps

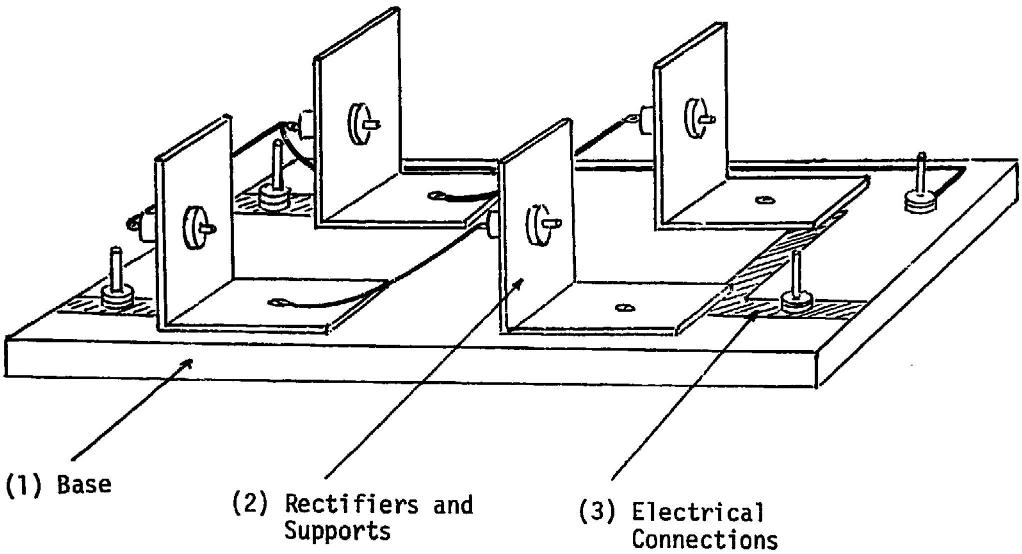
Load	Transformer Output			Rectifier Output			Efficiency
R Ohms	V_t Volts	I_t Amps	W_t Watts	V_r Volts	I_r Amps	W_r Watts	%
1,850	25.9	0.48	12.43	18.5	0.01	0.18	1.5
910	25.9	0.48	12.43	18.2	0.02	0.36	2.9
583	25.9	0.50	12.95	17.5	0.03	0.53	4.1
435	25.9	0.50	12.95	17.4	0.04	0.70	5.4
275	25.8	0.55	14.19	16.5	0.06	0.99	7.0
200	25.8	0.60	15.48	16.0	0.08	1.28	8.3
97	25.2	0.70	17.64	14.5	0.15	1.45	8.2
89	25.1	0.75	18.82	14.2	0.16	2.27	12.1
78	25.1	0.78	19.58	14.0	0.18	2.52	12.9
69	25.0	0.80	20.00	13.8	0.20	2.76	13.8
61	25.0	0.85	21.25	13.5	0.22	2.97	14.0
50	24.8	0.95	23.56	13.0	0.26	3.38	14.4
39	24.5	1.05	25.73	12.5	0.32	5.00	19.4
30	24.0	1.22	29.28	12.0	0.40	4.80	16.4
20	23.5	1.52	35.72	11.0	0.55	6.05	16.9
10	22.2	2.15	47.73	9.0	0.88	7.82	16.4

(iii) The current output of the rectifier was very low, but was noted to increase when the voltage from the transformer was increased. Thus with a resistance of 10 ohms in the external circuit the DC current produced was 0.34 or 0.88 amps according to whether the rectifier was connected to the 15 or 25 volt taps on the transformers.

(iv) The rectifier was extremely inefficient in its use of power. The maximum efficiency on the 15 volt taps was noted to be 13% and on the 25 volt taps to be 19%.

(v) It was noted that not only did the output voltage (V_r) from the rectifier decrease with increasing resistance (R), but that there was also some variation of the voltage (V_r) at a fixed resistance (R) with the passage of time. These factors suggest that although the apparatus is capable of producing a DC current, the latter is not suitable for quantitative (as opposed to qualitative) experimentation.

B2. Silicon Rectifier



a. Materials Required

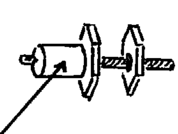
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	15 cm x 10 cm x 2 cm
(2) Rectifiers and Supports	4	Silicon Rectifier Diodes (B)	1N1341
	4	Brass Bars (C)	7 cm x 2 cm x 0.3 cm
(3) Electrical Connections	2	Brass Strips (D)	5 cm x 1 cm x 0.5 cm
	1	Brass Strip (E)	5 cm x 3 cm x 0.5 cm
	4	Bolts (F)	0.3 cm diameter, 3.5 cm long
	8	Nuts (G)	0.3 cm internal diameter
	1	Copper Wire (H)	#20, 40 cm long

b. Construction

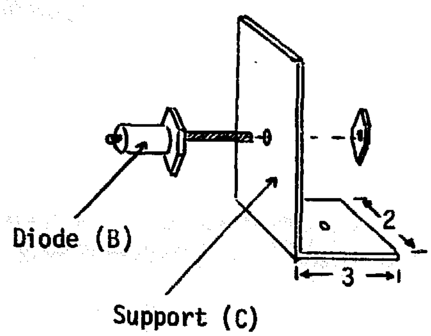
(1) Base

Use wood (A) as the base.

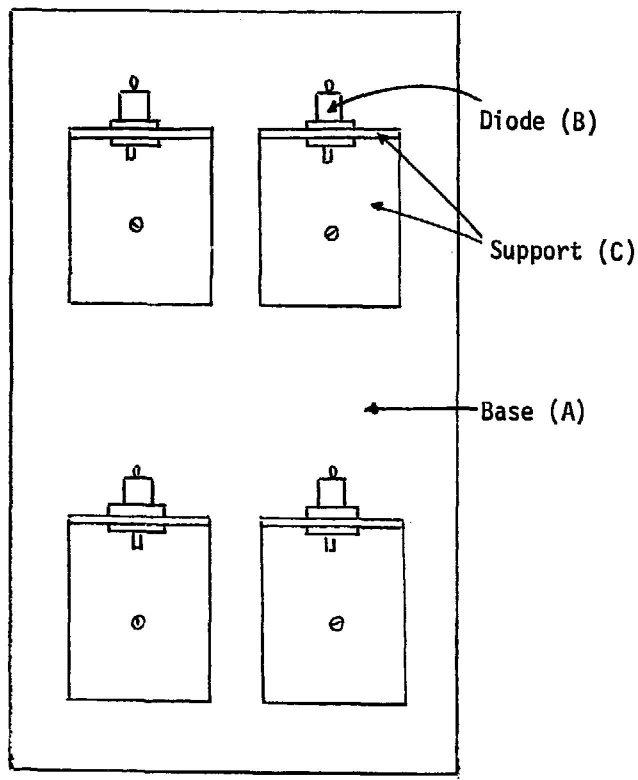
(2) Rectifiers and Supports



Purchase four silicon rectifier diodes (B) from a radio shop or electrical supply house. Ask for a rectifier identified as a 1N1341. This will be capable of handling a peak reverse

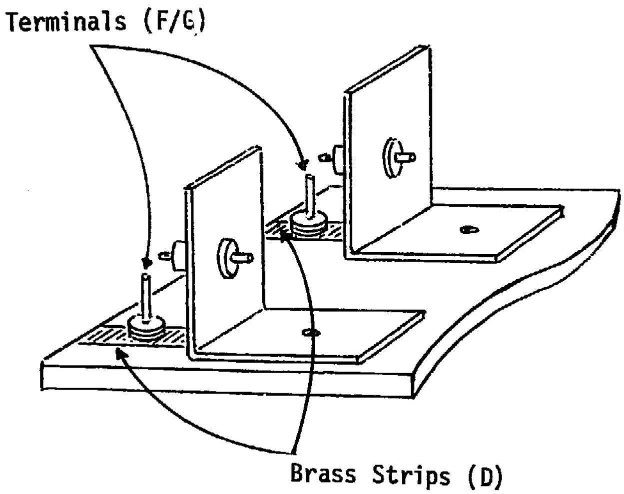


voltage of 50 volts, a continuous forward current of 6 amps and a maximum surge of 30 amps.

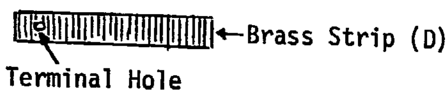


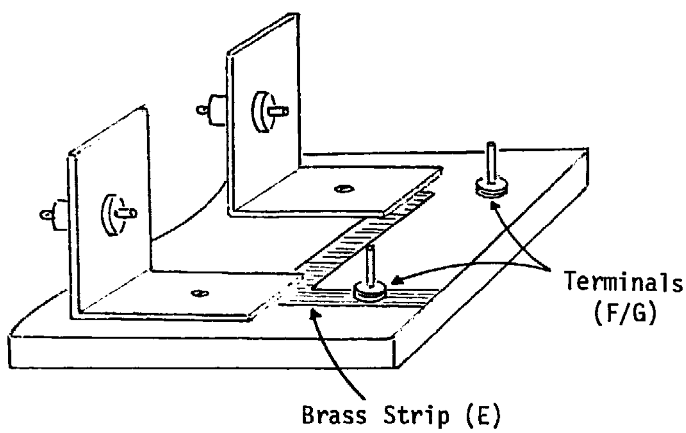
Take a brass bar (C) and bend it at right angles, 4 cm from one end, to form an L-shaped support. Drill a hole (0.5 cm diameter) in the middle of the long upright of the support and a hole (0.3 cm diameter) in the base of the support. Screw one of the rectifier diodes in the upright portion of the support. Attach the three remaining diodes (B) to three identical supports (C) in the same way. Attach the four supports to the base (A). It should be noted that the supports also act as heat sinks, removing heat that is generated within the diodes. It is for this reason that the support is made from a thick metal bar.

(3) Electrical Connections

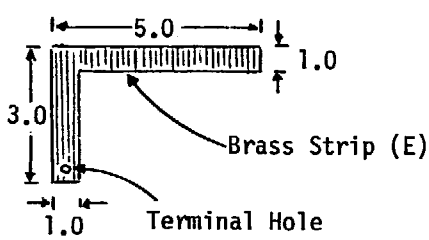


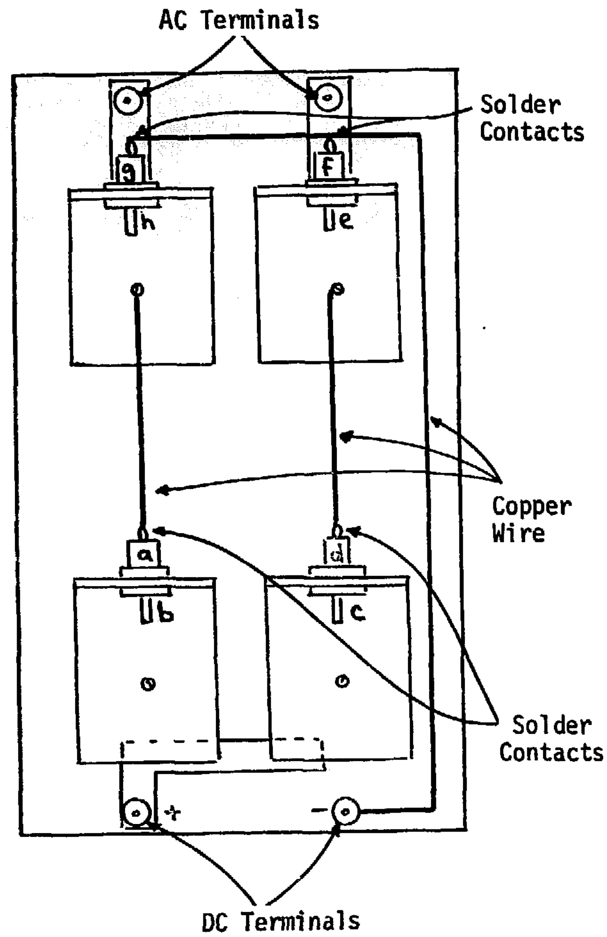
Take the two brass strips (D) and drill a hole (0.3 cm diameter) close to the end of each. Insert the strips under the supports (C) at one end of the base as indicated. Use bolts (F) and nuts (G) to make four terminals (F/G) as described under VIII/A2, Component (4). Fit two of the terminals on the base so that each is connected to a brass strip by means of the appropriate hole.





Cut an L-shaped strip out of brass sheet (E). Drill a hole (0.3 cm diameter) in the end of the shorter arm, and fit the longer arm beneath the two remaining supports so that they are connected electrically. Fit the two remaining terminals (F/G) to the end of the base, so that one is connected to the L-shaped strip.

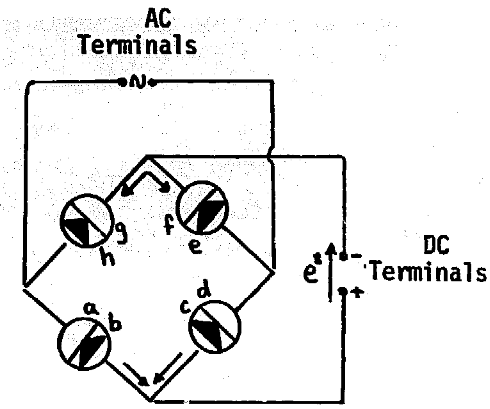




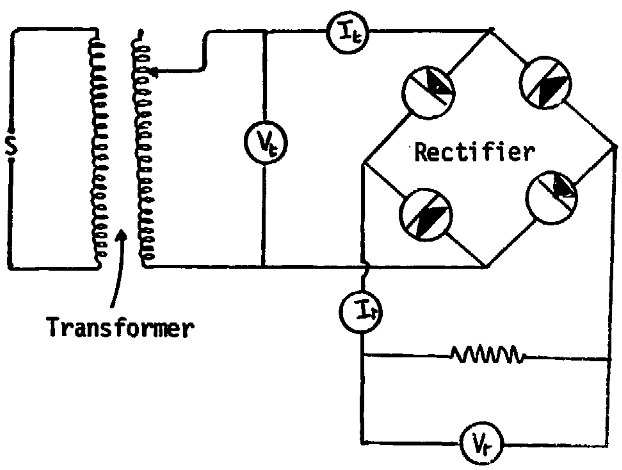
Take the copper wire (H) and connect the silicon diodes as illustrated. It will be necessary to solder the wire on to the ends of the diodes, and particular care should be taken to avoid overheating, since this can destroy the diodes.

c. Notes

(i) The rectifier produced is represented diagrammatically here. The reader should compare this with the previous diagram, noting the equivalent components marked by letters of the alphabet.



(ii) With a variable resistance R connected across the DC output it will be noted that the output voltage (V_r) falls off as the resistance decreases, even when the transformer is continuously monitored to keep the voltage (V_t) constant. This pattern of behavior is the same as for the Sodium Bicarbonate Rectifier (VII/B1). However, it will be noted that the efficiency of the Silicon Rectifier varies from 60% to 70% and the rectified current is as great as 3 amps at 5.5 volts. In this respect the Silicon Rectifier is a considerable improvement over the Sodium Bicarbonate Rectifier.



AC Supply = 10 volt taps

Load	Transformer Output			Rectifier Output			Efficiency
R Ohms	V_t Volts	I_t Amps	W_t Watts	V_r Volts	I_r Amps	W_r Watts	%
110	10.2	0.08	0.82	7.7	0.07	0.6	70.4
96	10.2	0.09	0.92	7.7	0.08	0.6	67.4
86	10.2	0.10	1.02	7.7	0.09	0.7	67.9
77	10.2	0.11	1.12	7.7	0.10	0.8	68.7
63	10.2	0.13	1.33	7.6	0.12	0.9	68.6
54	10.1	0.16	1.62	7.6	0.14	1.1	67.9
42	10.1	0.20	2.02	7.6	0.18	1.4	67.7
31	10.1	0.26	2.63	7.5	0.24	1.8	68.4
21	10.0	0.39	3.90	7.4	0.35	2.6	66.7
11	9.9	0.77	7.62	7.2	0.68	4.9	64.2
9	9.8	0.90	8.82	7.0	0.80	5.6	63.5
8	9.8	1.00	9.80	7.0	0.86	6.0	61.2
7	9.7	1.15	11.20	7.0	1.00	7.0	62.5
5	9.6	1.42	13.60	6.8	1.25	8.5	62.3
4	9.4	1.68	15.80	6.6	1.50	9.9	62.6
3	9.3	1.95	18.10	6.4	1.75	11.2	61.9
2	8.7	3.05	26.50	5.8	2.75	15.9	60.2
1	8.6	3.35	28.80	5.6	3.00	16.8	58.3

AC Supply = Held constant at 10 volts.

Load	Transformer Output			Rectifier Output			Efficiency
R Ohms	V_t Volts	I_t Amps	W_t Watts	V_r Volts	I_r Amps	W_r Watts	%
128	10.0	0.06	0.60	7.7	0.06	0.46	76.7
95	10.0	0.08	0.80	7.6	0.08	0.60	75.0
63	10.0	0.13	1.30	7.6	0.12	0.91	70.0
38	10.0	0.22	2.20	7.6	0.20	1.52	69.1
25	10.0	0.32	3.20	7.6	0.30	2.28	7.13
19	10.0	0.43	4.30	7.5	0.40	3.00	69.8
15	10.0	0.55	5.50	7.5	0.50	3.75	68.2
12	10.0	0.66	6.60	7.5	0.60	4.50	68.2
9	10.0	0.89	8.90	7.4	0.80	5.92	66.5
7	10.0	1.07	10.70	7.4	1.02	7.55	70.6
6	10.0	1.32	13.20	7.3	1.25	9.13	69.2
5	10.0	1.61	16.10	7.3	1.51	11.02	68.4
4	10.0	1.88	18.80	7.2	1.75	12.60	67.0
3	10.0	2.41	24.10	7.2	2.25	16.20	67.2
2	10.0	3.27	32.70	7.1	3.00	21.30	65.1

(iii) The output voltage (V_r) remains extremely steady with the passage of time, making this a much more suitable rectifier for quantitative experimentation than the Sodium Bicarbonate Rectifier.

AC Supply = 10 volt taps

Time	Transformer Output		Rectifier Output	
t Minutes	V_t Volts	I_t Amps	V_r Volts	I_r Amps
1	9.5	1.62	6.6	1.50
2	9.5	1.62	6.6	1.49
3	9.6	1.63	6.6	1.50
4	9.6	1.62	6.6	1.50
5	9.7	1.63	6.6	1.51
10	9.7	1.63	6.6	1.51
15	9.7	1.63	6.6	1.51
20	9.7	1.63	6.6	1.51
25	9.7	1.63	6.6	1.51
30	9.8	1.65	6.6	1.51

VIII. CIRCUIT APPARATUS

A. CELLS

This section contains cells and simple batteries which may serve as suitable sources of electrical energy for typical classroom experiments.

B. CIRCUIT COMPONENTS

The apparatus described here is limited to such typical components as switches and bulb holders.

C. RESISTORS

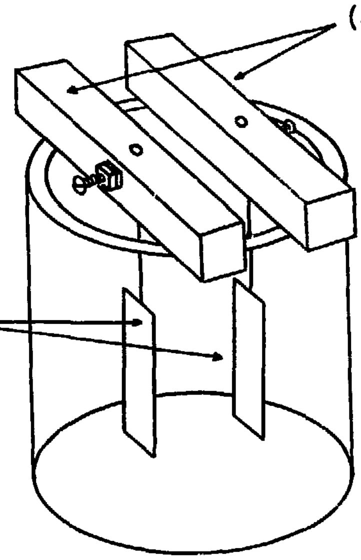
Fixed and variable resistors for typical classroom experiments are described in this section.

D. DYNAMO/MOTORS

This section contains two motors which may also be used as dynamos. The first is a very simple device which is capable of generating only a very minute current, whereas the second is a much more substantial item which generates sufficient current to light a bulb.

A. CELLS

A1. Chemical Cell ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Container	1	Plastic Container (A)	Approximately 8 cm diameter, 8 cm deep
(2) Plates	1	Zinc Sheet (B)	5 cm x 2 cm x 0.05 cm
	1	Copper Sheet (C)	5 cm x 2 cm x 0.05 cm
	1	Steel Sheet (D)	5 cm x 2 cm x 0.05 cm
	1	Carbon Rod (E)	Extracted from dry cell
	4	Brass Wire (F)	2.5 cm long, 0.1 cm diameter
(3) Holders	2	Wood Holders (G)	10 cm x 1 cm x 1 cm
	1	Bolt (H)	0.3 cm diameter, 1.5 cm long
	2	Nuts (I)	0.3 cm internal diameter

c. Construction

(1) Container

Use a plastic or glass jar (A) as the electrolyte container. (A wide variety of electrolytes

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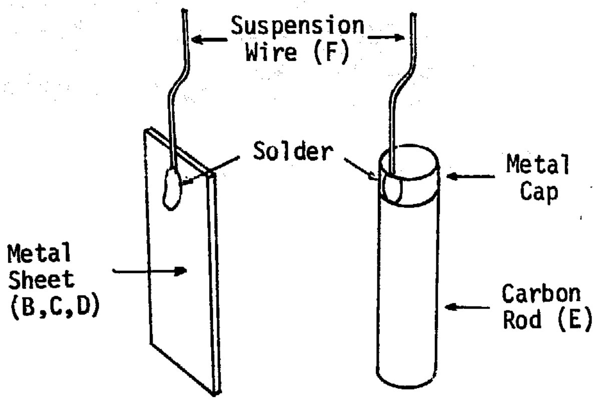
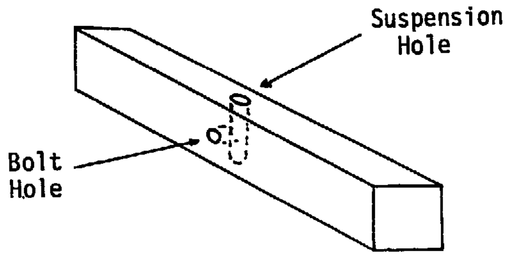
may be used, including commonly available vinegar and household salt solutions.)

(2) Plates

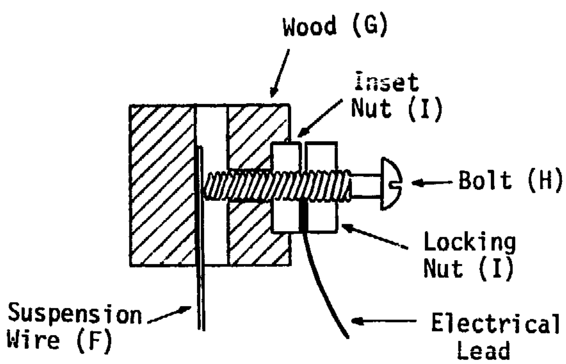


Solder a brass suspension wire (F) on to each of the metal sheets (B, C and D). Also solder a similar suspension wire (F) to the metal cap on a carbon rod (E) extracted from a dry cell.

(3) Holders



In each wood holder (G), drill a vertical suspension hole (0.2 cm diameter) and a horizontal bolt hole (0.3 cm diameter) to meet the vertical hole.



Cross Section

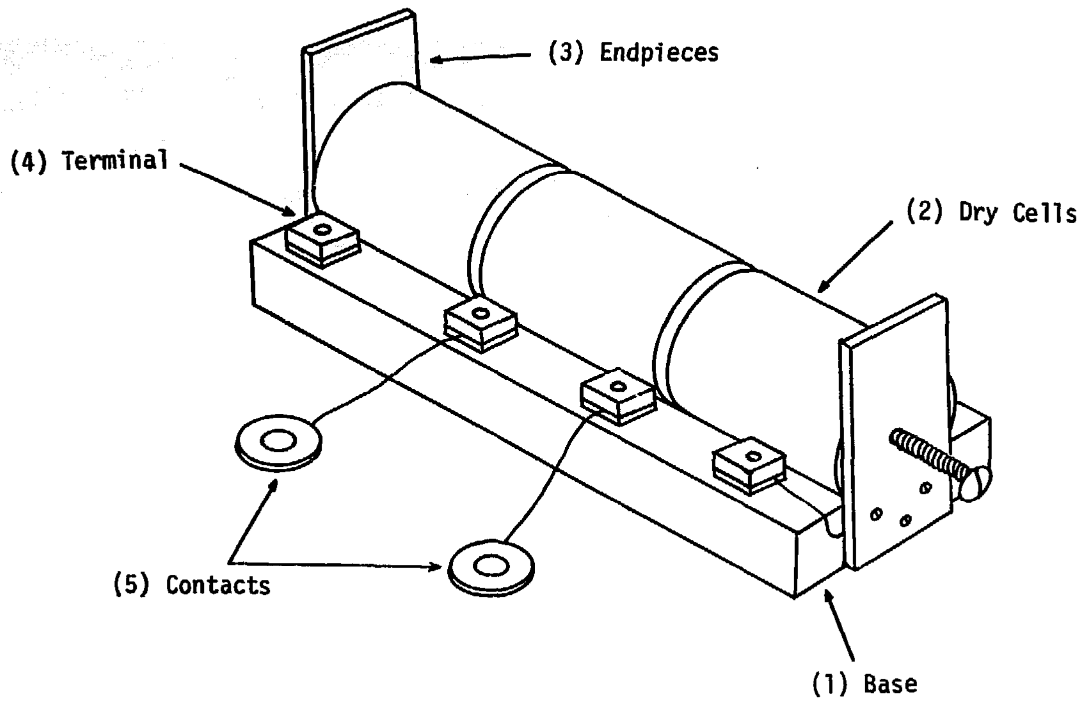
Inset one of the nuts (I) over the bolt hole with a sharp tap of the hammer. (A little epoxy resin will hold the nut permanently in position.) Thread the second nut (I) on to the bolt (H) to serve as a locking nut, and then screw the bolt into the bolt hole. Insert a suspension wire in the vertical hole, and clamp it in position by tightening the bolt.

Electrical leads may be fastened under the locking nuts on the holders, and the cell connected into an electrical circuit.

c. Notes

(i) Any of the two plates in combination with one of the electrolytes mentioned above will produce an electric current. The latter may be detected by means of a simple galvanometer (e.g., X/B1). It is recommended that students compare the magnitudes of currents that can be produced by the various plate and electrolyte combinations.

A2. Dry Cell Holder with Cells ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	18.5 cm x 5.5 cm x 2 cm
(2) Cells	3	Dry Cells (B)	1.5 volts each
(3) Endpieces	2	Brass Sheets (C)	4.0 cm x 1.5 cm x 0.3 cm
	6	Screws (D)	Approximately 0.8 cm long
	1	Bolt (E)	0.4 cm diameter, 2 cm long
	1	Nut (F)	0.4 cm internal diameter
(4) Terminals	4	Brass Bolts (G)	0.3 cm diameter, 2.5 cm long
	8	Nuts (H)	0.3 cm internal diameter
	4	Magnet Wire (I)	#22, 15 cm long

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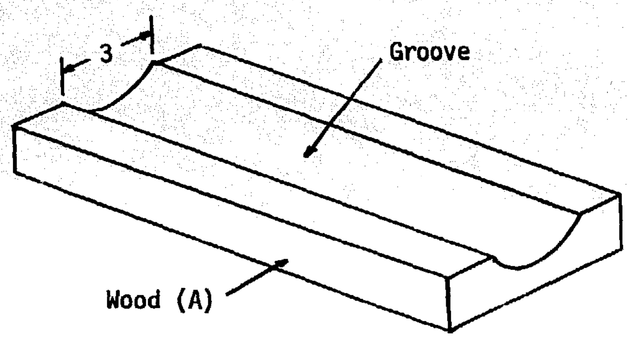
(5) Contact Plates | 2 | Circular Brass Sheets (J) | 1.5 cm diameter, 0.05 cm thick

<u>b. Construction</u>

(1) Base

Cut the base out of the soft wood (A), and use a curved chisel to make a long groove (about 0.5 cm deep) in the surface to hold the dry cells in position.

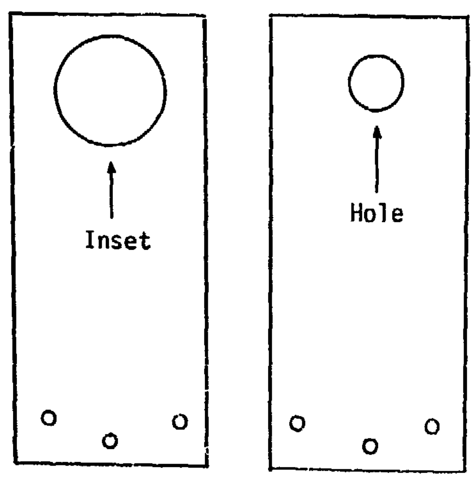


(2) Cells

Place three dry cells (B) in series in the groove of the base. The groove should be from 1 to 1.5 cm longer than the three cells placed end to end, thus allowing room for the placing of contacts between the cells, and for adjustment of the screw in one of the end-pieces.

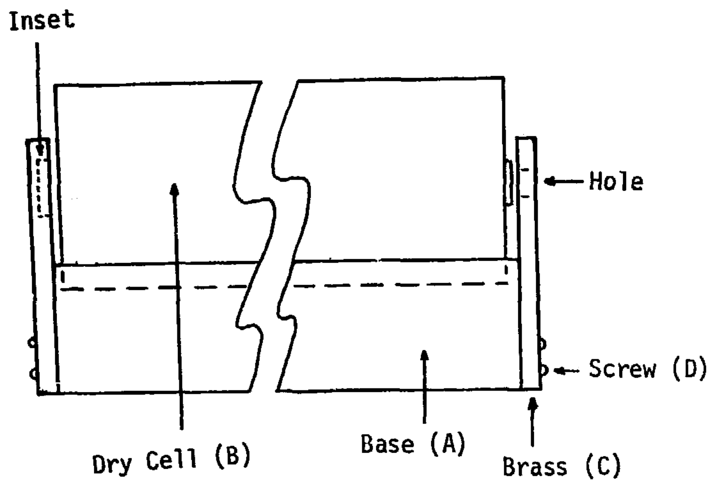
(3) Endpieces

Use the brass sheets (C) for endpieces. Drill three small holes (0.2 cm diameter) at the base of each endpiece to facilitate attachment to the base with the screws (D). Place the dry cells on the base to determine the height of the mid-point of the dry cells, and then drill an inset (0.9 cm diameter, 0.15 cm deep) at this height in one endpiece, and a hole (0.4 cm diameter) at the same height through the other endpiece. Thread the newly drilled hole to take the

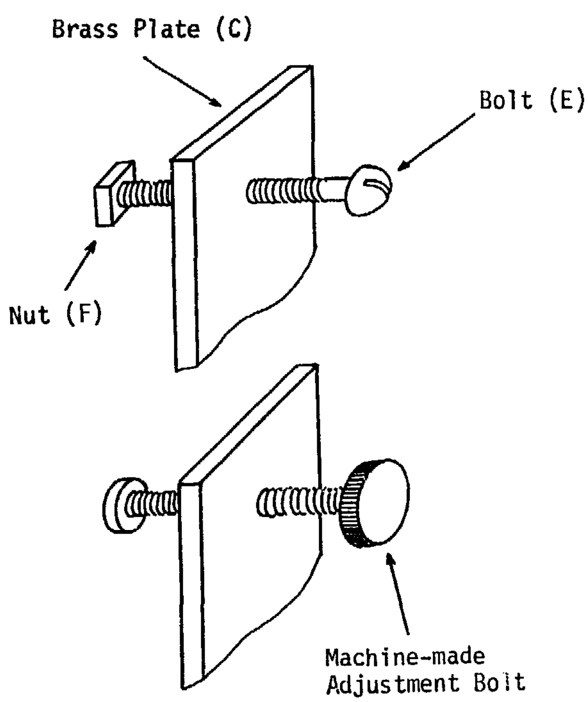


Brass Plates (C)

adjustment bolt (E).

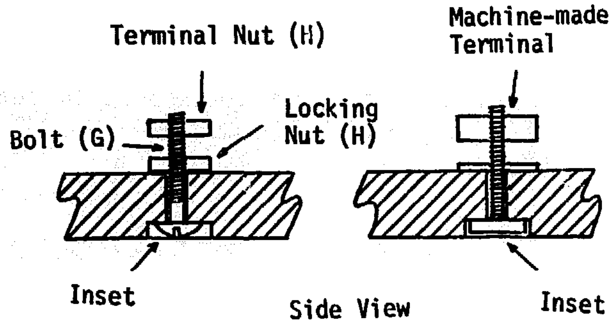


Side View



The latter bolt may have to be adjusted with the help of a coin, or some such device. A much more convenient adjustment bolt could be made by a technician, or anyone familiar with a metal lathe, cutting the head and bolt from a single piece of brass. The base in either case would be made from a separate nut (F), firmly attached to the bolt by damaging the threads at the end.

(4) Terminals

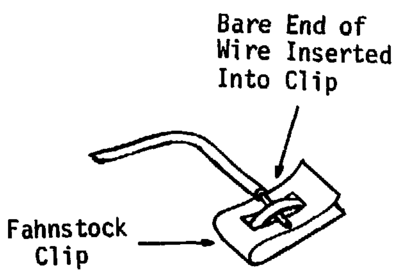


Side View

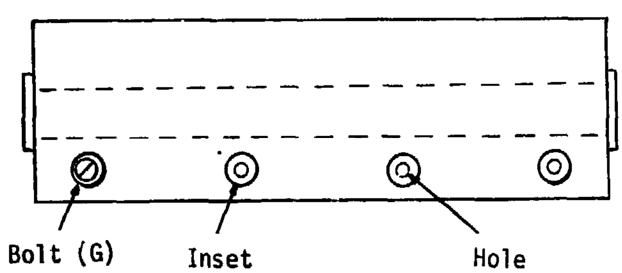
(Cross-section)

Make four terminals from the brass bolts (G) and nuts (H). Two nuts are required for each terminal, one to serve as a locking nut and one as a terminal nut.

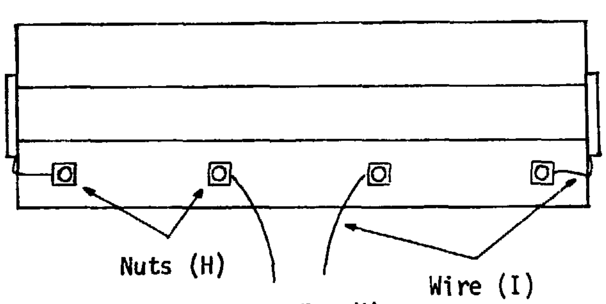
Somewhat better nuts, which are more easily adjusted with the fingers, may be made with a metal lathe. The terminal nut should be 0.5 cm thick, while the locking nut should be much thinner (0.2 cm). The diameter of both should be 1.0 cm.



In some localities it is cheaper to purchase terminals on the local market. Check the availability of such items as Fahnstock clips which can replace the above.



Base, Bottom View

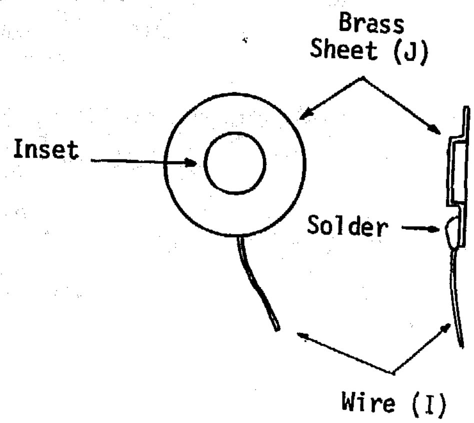


Base, Top View

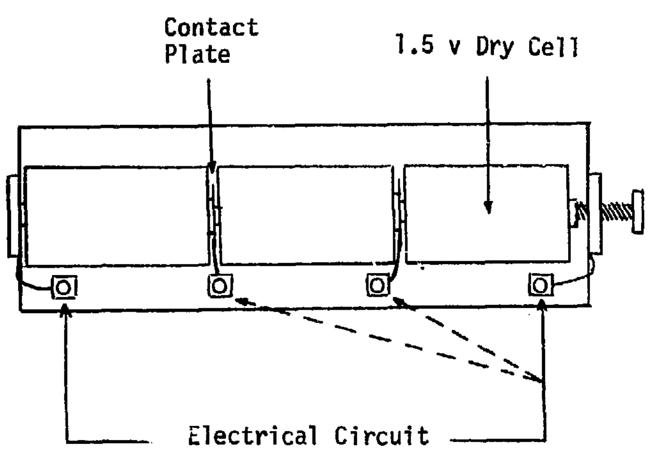
Make four insets (0.2 cm deep) at equal intervals underneath the front side of the base to take the boltheads of the terminals. Insert the four bolts (G) from below, through holes drilled through the base, and attach the locking nuts (H) and terminal nuts (H).

Use copper wire (I) to attach the end terminals to the end-pieces, fastening the bare ends of the wire beneath the terminal locking nuts and brass endpieces. Similarly attach a length of copper wire (I) (15 cm long) to each of the middle terminals.

(5) Contact Plates

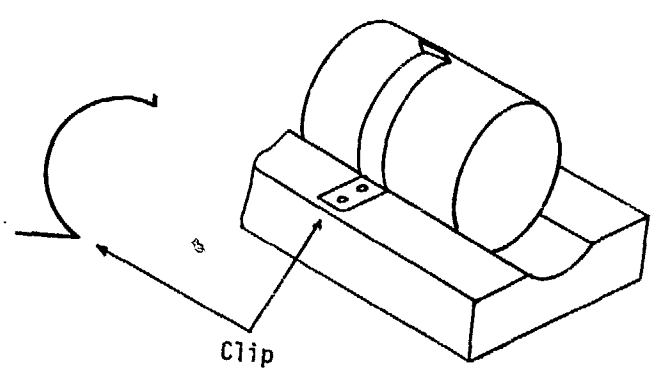


Use a nail head, or punch, to make a central inset (1 cm diameter, 0.2 cm deep) in the two brass sheets (J). Solder the two plates to the bare ends of the wire (I) attached to the two middle terminals. The contact plates are placed between the first and second, and second and third cells, thus enabling the apparatus to provide an external circuit with 1.5, 3.0 or 4.5 volts according to the terminals connected to the circuit.



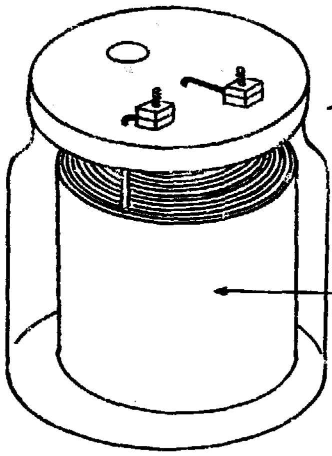
c. Notes

(i) So long as the adjustment bolt is not tightened too tightly, the cells will remain firmly in the base groove. However, should any problem occur (e.g., due to bad alignment of the adjustment screw) the cells could be held more firmly in place by means of clips made from packing case bands.



(ii) The dry cell holder serves as a variable source of potential providing from 1.5 to 4.5 volts, according to the terminals connected into the circuit.

A3. Simple Battery *



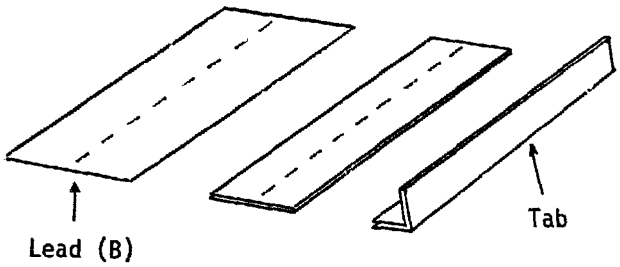
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Plates	2	Lead Sheets (A)	80 cm x 7.5 cm x 0.01 cm
	2	Lead Sheets (B)	15 cm x 6 cm x 0.01 cm
	2	Thick Blotting Paper (C)	85 cm x 10 cm
	2	Rubber Bands (D)	--
(2) Container	1	Jar (E)	Capacity 1 liter, approximately
	1	Plywood Lid (F)	10 cm diameter, 0.5 cm thick
	2	Terminals (G)	VIII/A2, Component (4)
	1	Sulphuric Acid (H) (Concentrated)	200 ml

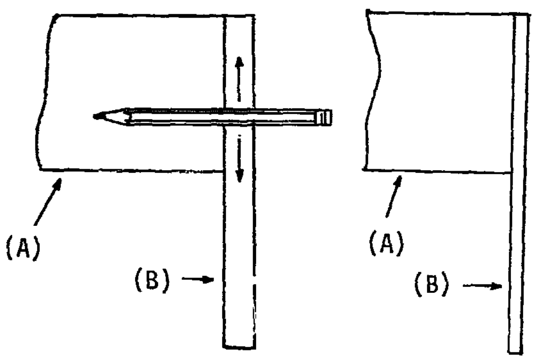
*Adapted from Intermediate Science Curriculum Study, Probing the Physical World, Volume 1, Experimental Edition, (Tallahassee, Florida: Florida State University, 1967), pp 1-4.

b. Construction

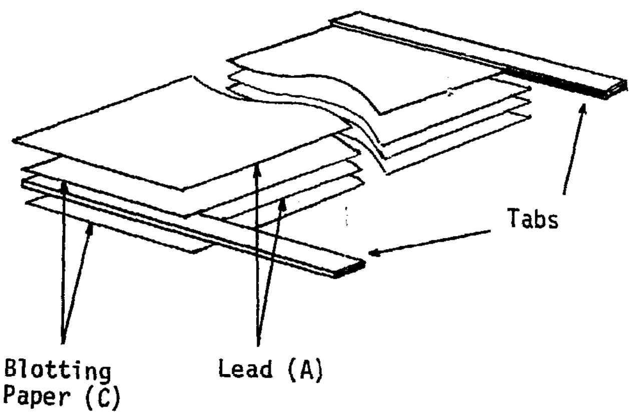
(1) Plates



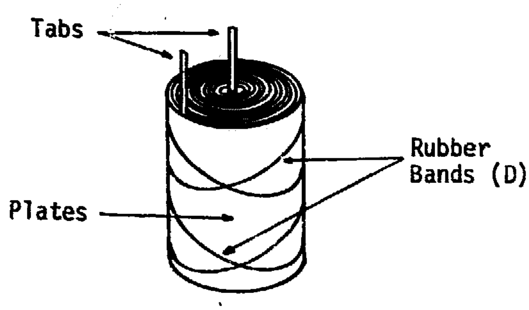
Fold one of the small lead sheets (B) down the middle. Repeat the process again, but this time leave the fold open. You now have a tab for attachment to one of the lead plates.



Fit the end of one of the large lead sheets (A) into one of the tabs (B), and fold the tab firmly down over the sheet using a pencil to flatten the tab down. With the lead sheet fully inserted into the tab, fold the tab once more, and smooth it again. You now have one lead plate complete with tab. Now make a second lead plate complete with tab in an identical manner, using the remaining lead sheets (A and B).

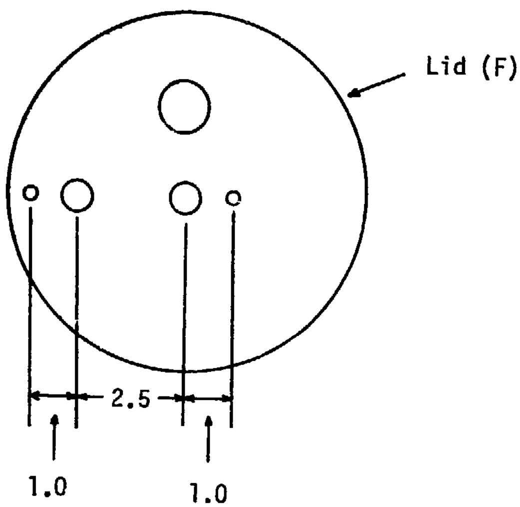


Make a plate "sandwich" by placing the blotting paper (C), lead plate, blotting paper (C), lead plate one on top of the other. The tabs should be at opposite ends of the sandwich, but emerging from the same side.

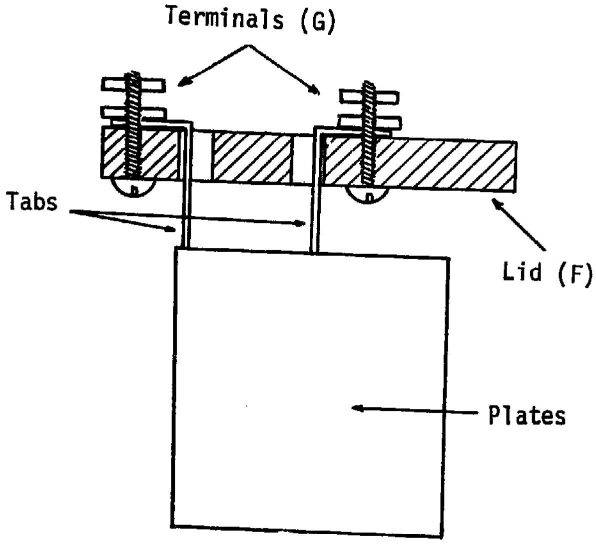


Roll the "sandwich" up into a tight cylinder. One tab will protrude from the center and one from the edge. Hold the plates in the form of a cylinder by wrapping the rubber bands (D) around the cylinder.

(2) Container



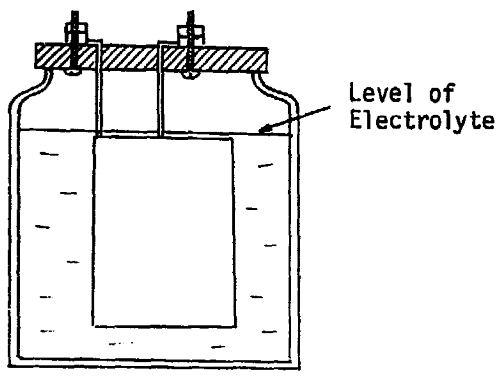
Obtain a one liter jar (E), and use the plywood lid (F) to cover the open end of the jar. Bore two holes (0.5 cm diameter) through the lid to accommodate the tabs, one hole being at the center of the lid and the other 2.5 cm away from the first hole. Drill two more holes (0.3 cm diameter), one on either side of the first two holes to accommodate the terminals. Drill a fifth hole (1 cm diameter) anywhere else in the lid to permit addition of the electrolyte.



Cross Section

Push the plate tabs through the two larger holes in the lid (the center tab through the center hole), and fold the top 1.5 cm of each tab over at right angles so that each overlaps the adjacent small hole in the lid. Fit two terminals (G) into the small holes in the lid, and lock a tab under each terminal. Make one liter of electrolyte in a separate container. This may be dilute sulphuric acid or solium sulphate. Sulphuric acid is the better electrolyte, but from a student point of view it can be dangerous if it is not handled carefully. Many will prefer to use sodium sulphate for this reason.

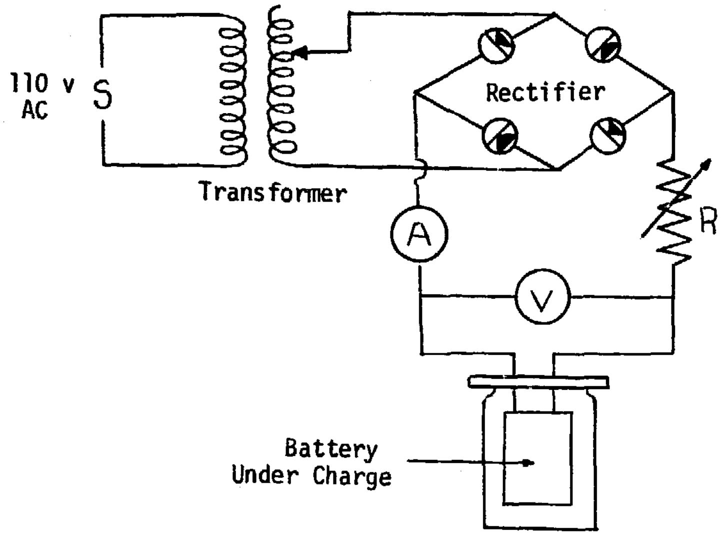
To make the sulphuric acid electrolyte pour 813 ml of water into a container. Then add 187 ml of concentrated sulphuric acid (H) to the water in very small quantities, letting the acid run down the sides of the container into the water. Much heat will be caused by the interaction. Stir the electrolyte, and allow it to cool before adding more concentrated acid. Before pouring the electrolyte into the battery it must be completely cool. (If a sodium sulphate electrolyte is preferred add 1.0 liter of water to 114 g of solid sodium sulphate and stir.)



Pour the electrolyte carefully through the appropriate hole in the lid until it just covers the plates. The battery is now ready for charging and use.

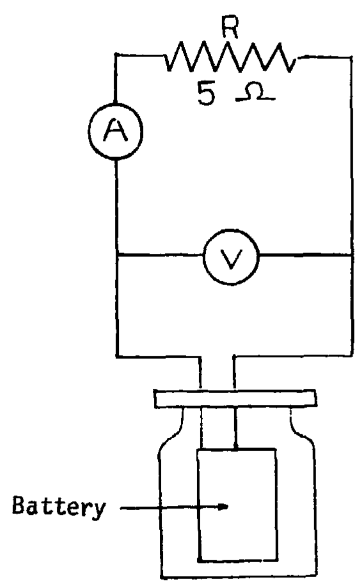
c. Notes

(i) To charge the battery a DC current of one amp at approximately 2.5 to 3.0 volts is required. This is best obtained with the help of a transformer (VII/A3) and rectifier (VII/B2). Connect the rectifier to the 10 volt taps on the transformer, and connect the battery across the rectifier as illustrated. A variable resistor (VIII/C2) should be connected into the circuit to control the current, and an ammeter and voltmeter connected as indicated to monitor the circuit.



Charge the battery for 30 minutes keeping the current steady at one amp by adjusting the variable resistance. (The voltage will not remain constant throughout the charge.)

(ii) Some idea of the strength of the battery may be obtained by discharging it through a five ohm resistor, and noting the current generated over a period of time, and the voltage of the battery output. The results of one such discharge are given below (for the battery with sulphuric acid electrolyte).



t Minutes	V Volts	I Amps
1	1.00	0.40
2	0.40	0.20
3	0.20	0.10
4	0.19	0.04
5	0.19	0.04

The voltage and current output fall off rapidly with time, indicating that the battery in its present state is not suitable for quantitative experimentation.

(iii) A good, strong battery may be produced simply by recharging the battery and discharging it several times over. This process is more successful if the direction of the current is changed for each recharge. The battery tested above was charged four more times (each time with reversed polarity) and discharged for five minutes through the five ohm resistor after each charge. After each discharge the battery terminals were shorted to remove any remaining charge. The results of the fifth discharge show that the battery, after repeated charging and discharging, is capable of maintaining a steady current output at a steady voltage, and as such is suitable for quantitative experimentation.

t Minutes	V Volts	I Amps
1	1.9	0.39
2	1.9	0.39
3	1.9	0.39
4	1.9	0.39
5	1.8	0.35

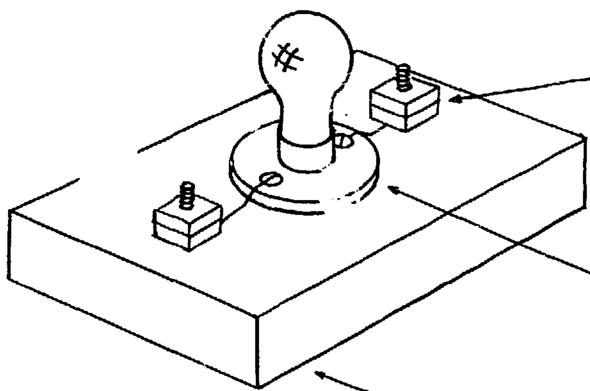
(iv) Some idea of the strength of the battery is obtained by comparing the discharge of a small dry cell (through a five ohm resistor) with the above observations. The results indicate that the dry cell is not as steady a source of current and voltage as the battery after successive recharging, but that it is much steadier than the battery after only one charge.

t Minutes	V Volts	I Amps
1	1.39	0.25
2	1.37	0.25
3	1.36	0.24
4	1.35	0.24
5	1.35	0.24

(v) Somewhat similar results are obtained if the battery is filled with sodium sulphate electrolyte and tested in the same way.

B. CIRCUIT COMPONENTS

B1. Bulb Holder with Bulb



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	7 cm x 3 cm x 1 cm
(2) Bulb Holder	1	Bulb Holder (B)	To hold flashlight bulbs
	1	Bulb (C)	1.1, 2.5, or 6.2 volts
(3) Terminals	2	Brass Bolts (D)	0.3 cm diameter, 2.5 cm long
	4	Nuts (E)	0.3 cm internal diameter
	2	Magnet Wire (F)	4 cm long

b. Construction

(1) Base

Use the wood (A) to serve as the base of the bulb holder.

(2) Bulb Holder

Obtain a bulb holder (B) (porcelain or metal) from the local market, and screw it onto the base. The holder should take a variety of local bulbs (C) (e.g., 1.1 volts, 2.5 volts and 6.2 volts).

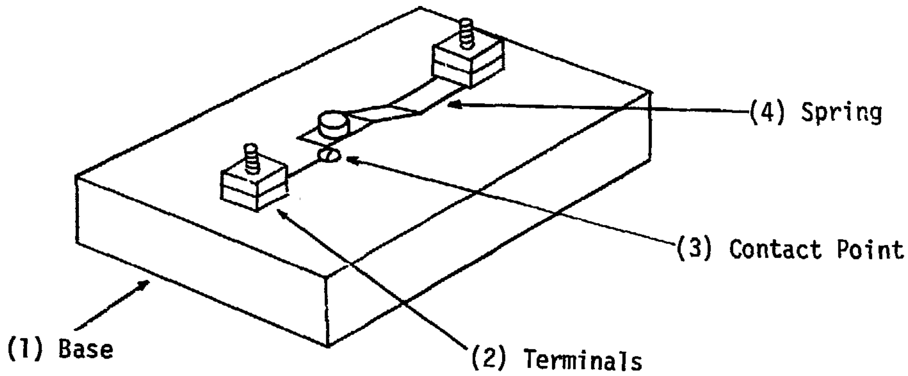
(3) Terminals

Make the terminals from the nuts (E) and bolts (D) as described in item VIII/A2, Component (4). Use the magnet wire (F) to connect the bulb and terminals, not forgetting to clean the ends of the wire.

c. Notes

(i) Bulbs may be used not only to investigate electrical phenomena in simple circuits, but also tc serve as suitable resistances.

B2. Switch ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	7 cm x 3 cm x 1 cm
(2) Terminals	2	Brass Bolts (B)	0.3 cm diameter, 2.5 cm long
	4	Nuts (C)	0.3 cm internal diameter
(3) Contact Point	1	Brass Screw (D)	0.8 cm long
	1	Magnet Wire (E)	#22, 3 cm long
(4) Spring	1	Brass Sheet (F)	5 cm x 1 cm x 0.1 cm
	1	Wooden Dowel (G)	1 cm diameter, 0.5 cm long

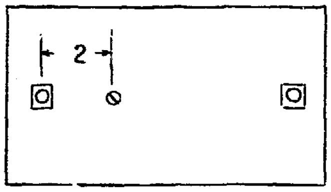
b. Construction

(1) Base — Use the wood (A) to serve as the base of the switch.

(2) Terminals — Make the terminals from the nuts (C) and bolts (B) as described in item VIII/A2, Component (4).

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 129-130.

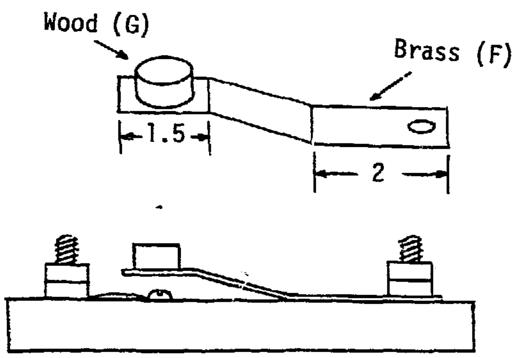
(3) Contact Point



Top View

Screw the brass screw (D) into the wood (2 cm from one terminal) and connect it to the terminal by means of the short length of copper wire (E).

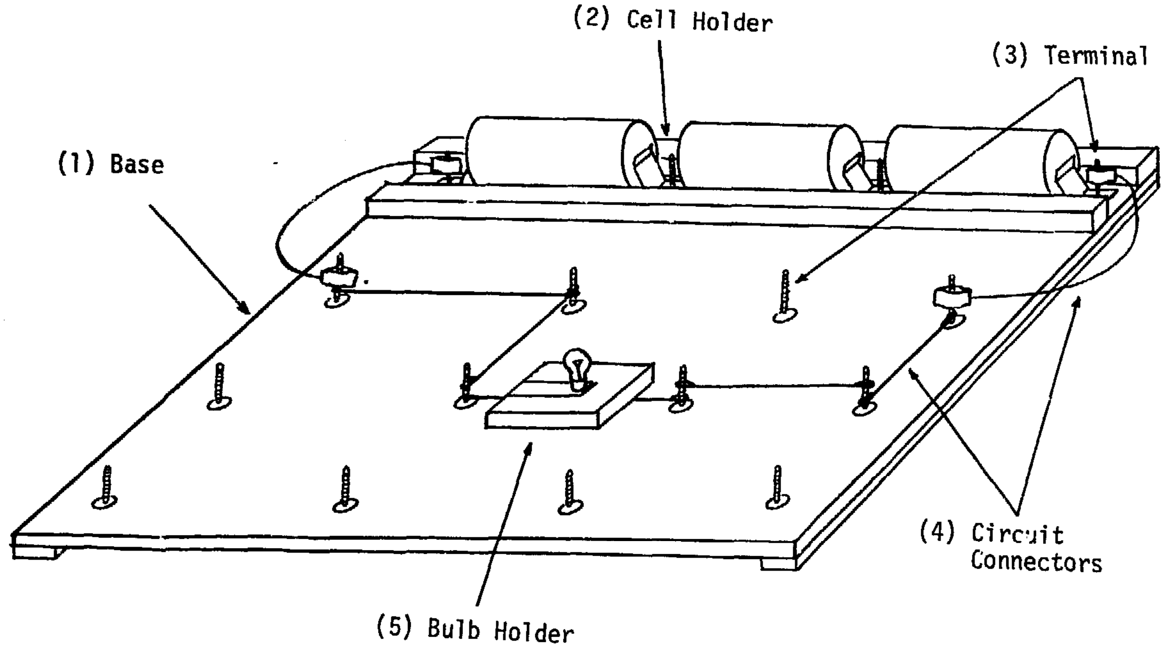
(4) Spring



Side View

Make the spring out of the piece of brass sheeting (F). Drill a small hole (0.3 cm diameter) in one end of the spring so that the terminal bolt will pass through it, and hold the spring in position by fastening the terminal locking nut. Cut the wooden head (G) and attach it to the free end of the spring with epoxy resin.

B3. Circuit Board



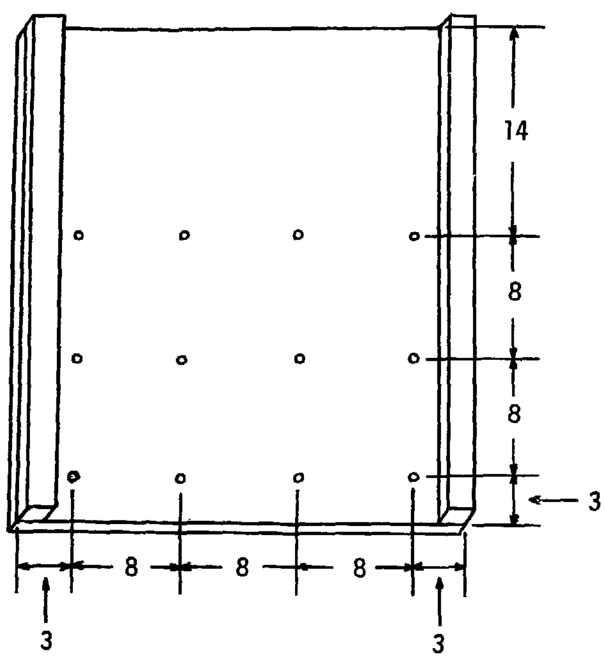
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Plywood (A)	33 cm x 30 cm x 0.6 cm
	2	Wood (B)	33 cm x 2 cm x 0.5 cm
(2) Cell Holder	2	Wood (C)	30 cm x 2 cm x 2 cm
	3	Dry Cells (D)	1.5 volts each
	2	Metal Strips (E)	4 cm x 2 cm x 0.02 cm
	2	Metal Strips (F)	6 cm x 2 cm x 0.02 cm
	4	Bolts (G)	0.3 cm diameter, 4 cm long
	4	Nuts (H)	0.3 cm internal diameter
	8	Washers (I)	Approximately 1.2 cm external diameter
(3) Terminals	12	Bolts (J)	0.3 cm diameter, 4 cm long
	12	Nuts (K)	0.3 cm internal diameter
	24	Washers (L)	Approximately 1.2 cm external diameter
(4) Circuit Connectors	12	Coat Hanger Wire (M)	10 cm long
	10	Metal Strips (N)	6 cm x 1.5 cm x 0.02 cm

	5	Copper Wires (O)	#18, 25 cm long
(5) Bulb Holders	3	Wood (P)	5 cm x 3 cm x 2 cm
	3	Coat Hanger Wires (Q)	6 cm long
	3	Eye Screws (R)	Approximately 3 cm long
	6	Screws (S)	1 cm long, approximately
	3	Washers (T)	--
	3	Metal Sheets (U)	3 cm x 2 cm x 0.02 cm
	--	Assorted Flashlight Bulbs (V)	--

b. Construction

(1) Base

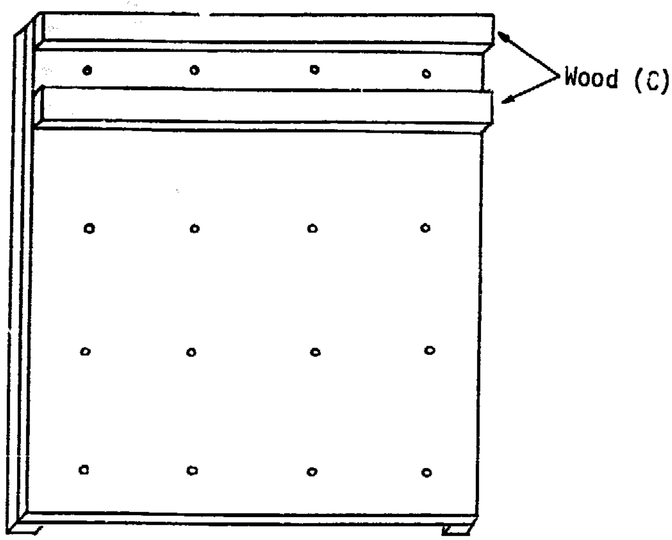


Botton View

Drill 12 holes (diameter 0.3 cm) through the plywood (A) in the positions indicated. If a piece of scrap wood is placed beneath the plywood during drilling the bottom edges of the hole will not splinter so readily.

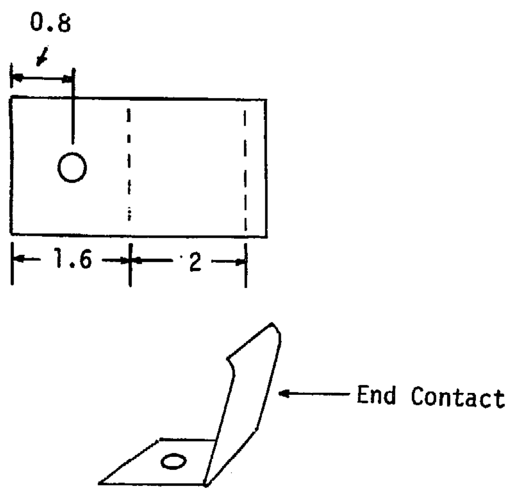
Glue the two strips of wood (B) along the bottom edges of the base, at right angles to the grain of the wood, so that bending or warping of the base is prevented.

(2) Cell Holder

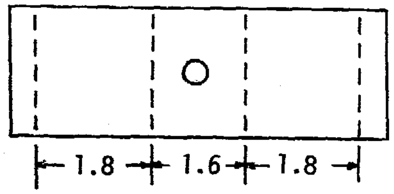


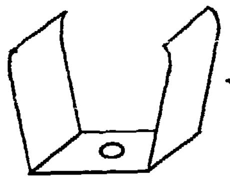
Use two pieces of wood (C) to serve as the cell holder strips. Using nails and glue attach one strip to the end of the base which has not yet been drilled with holes. Place the second strip parallel to, and about 3 cm away from, the first strip. Adjust the separation between the two strips so that they will hold three dry cells (D) snugly in position. Then glue and nail the second strip firmly in position.

Drill four holes (diameter 0.3 cm) between the two strips as illustrated.

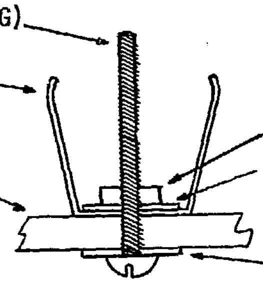


The two strips of flexible metal (E) may be cut from a tin can (or similar source). Drill a hole (0.3 cm diameter) in the end of each sheet, and then bend the sheet into the shape of an end contact, as indicated. Use sandpaper to remove any coating which might interfere with good electrical contact.



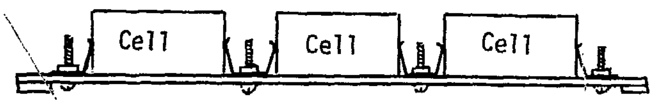


Two more metal strips (F) may be cut from the same source as before. Drill a hole (0.3 cm diameter) at the mid-point of each strip, and then bend each, as indicated, into the shape of a center contact. Use sand-paper to remove any coating which might interfere with good electrical contact.



Side View
(Cross-section)

Mount the contacts in position on the circuit board base, in each instance using a bolt (G), a nut (H) and two washers (I). The purpose of the washers is to hold the bolts (which also serve as terminals) rigidly in a vertical position.

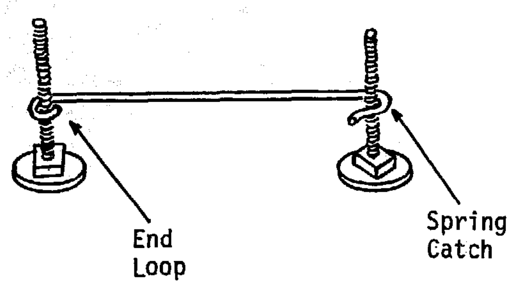


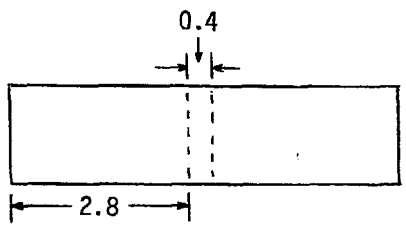
Side View

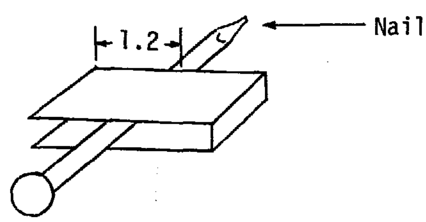
(3) Terminals

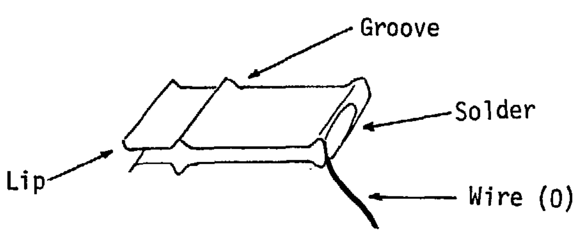
Fit 12 terminals in the remaining holes in the base. Each terminal is made in the same way as described above, each consisting of a bolt (J), a nut (K) and two washers (L).

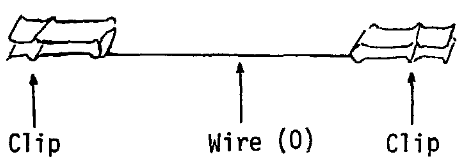
(4) Circuit Connectors







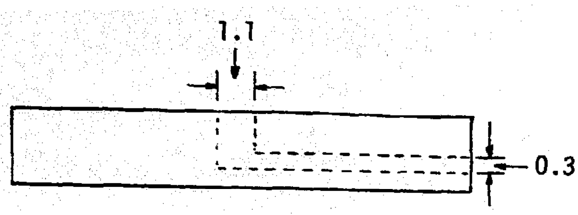




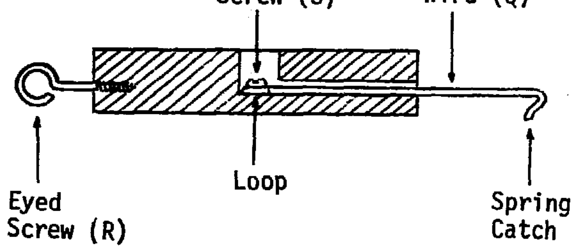
Remove any paint or coating from the wires (M) with sandpaper. Bend one end of each wire into a loop, and slip this onto one of the terminals. Bend the free end of the wire around an adjacent terminal so as to form a spring catch. Make a small lip on the end of the catch, thus permitting the catch to be readily attached to, or released from, an adjoining terminal.

The ten strips of metal (N) may be cut from a tin can or similar source (brass sheet, etc.). Clean the surfaces with sandpaper. Bend each sheet into a "U" shape in which the sides are 0.4 cm apart. Then place a nail (0.2 cm diameter) between the sides of the "U" sheet, and squeeze the sheet on either side of the nail with pliers to form a small groove. Make small lips on the open ends of the "U" sheet to permit easy attachment to the terminal posts. Finally, attach each end of each copper wire (O) to one of the newly created clips with the help of solder. You should now have twelve coat hanger wire connections and five copper wire connections for completing circuits.

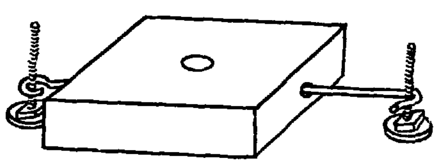
(5) Bulb Holders



Side View



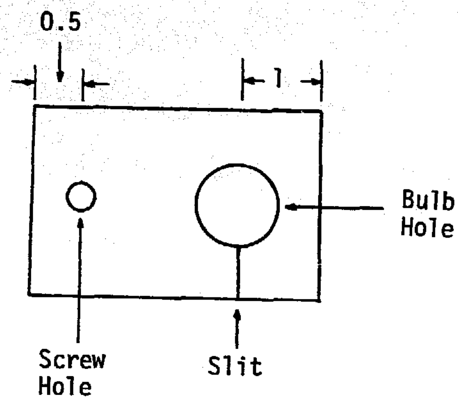
Cross Section

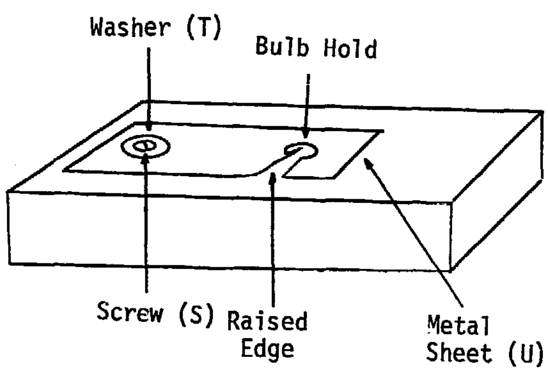


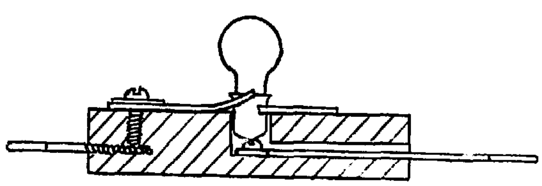
Drill a vertical hole (1.0 cm diameter, 1 cm deep) into the middle of the top surface of the wood (P). Drill a horizontal hole (0.3 cm diameter) into the middle of one end of the block, so as to meet the first hole.

Clean the surface of the wire (Q) with sandpaper. Insert one end of the wire fully into the horizontal hole, and using a pair of dog-nosed pliers (inserted through the vertical hole) bend a loop into the inserted end of the wire. Insert a small screw (S) through the loop to attach the wire permanently within the block.

Fit an eye screw (R) into the middle of the other end of the block, and finally make a spring catch in the free end of the coat hanger wire (Q) (in just the same way as for the circuit connectors) so that the holder may be readily connected between adjacent terminals on the circuit board.







Cross Section

The flexible sheet of metal (U) may be cut from a tin can, or similar source (thin brass sheet). Drill a bulb hole (diameter 0.9 cm) and screw hole (diameter 0.3 cm) in the sheet as indicated. Make a cut in the sheet between one outer edge and the bulb hole. If one side of the slit is raised slightly higher than the other, the hole will serve as a screw socket for a bulb (V). Use a small screw (S) and washer (T) to attach the metal sheet to the top of the block so that the bulb hole in the sheet sits over the hole in the block.

The screw (S) should also be centered on the block so that it makes contact with the threads of the eye screw (R). (If this adjustment is found difficult, contact between the two screws may be made by soldering a short length of copper wire from one screw to the other.)

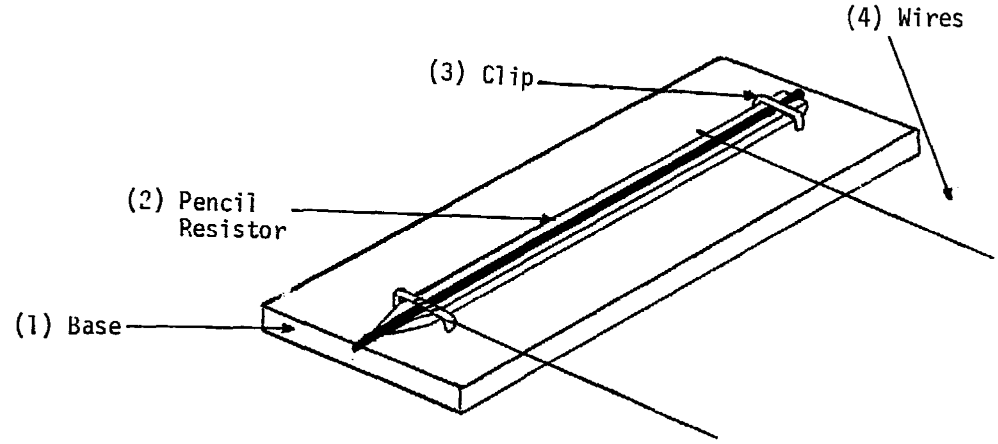
Three identical bulb holders should be made, each with a selection of bulbs (V) (e.g., 1.1 volts, 2.5 volts, 6.2 volts).

c. Notes

(i) The Circuit Board is a very convenient way of setting up electrical circuits. A typical series of experiments using such a circuit board will be found in Nuffield Foundation, Nuffield Physics, Guide to Experiments 2, (London: Longmans/ Penguin Books, 1967), pp 16-63.

C. RESISTORS

C1. Variable Resistor (Carbon)



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	20 cm x 3 cm x 1 cm
(2) Pencil	1	Pencil (B)	20 cm long, approximately
(3) Clips	2	"U" Tacks (C)	--
(4) Wires	2	Copper Wires (Cotton or Plastic Covered) (D)	#22, 30 cm long

b. Construction

(1) Base

Use wood (A) as the base.

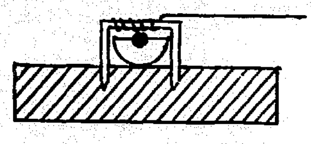
(2) Pencil Resistor

Split a soft lead pencil in half so that the lead (B) protrudes along its axis. It is important that the lead should not be broken or cracked by this process.

(3) Clips

Take two U-shaped tacks (C), normally used for securing electrical leads, and secure the pencil (B) to the base (A). One of the clips should be left relatively loose.

(4) Wires

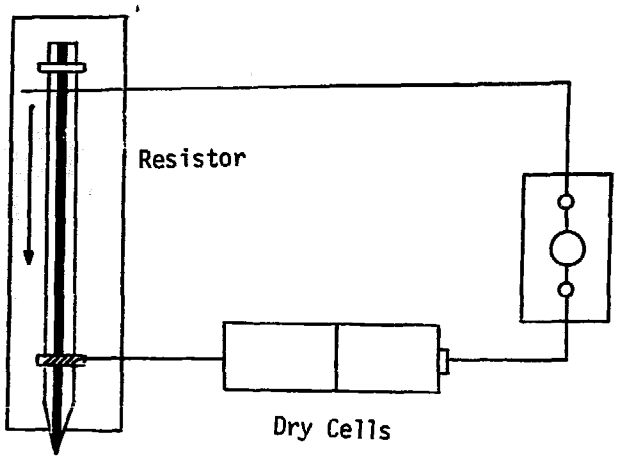


Cross Section

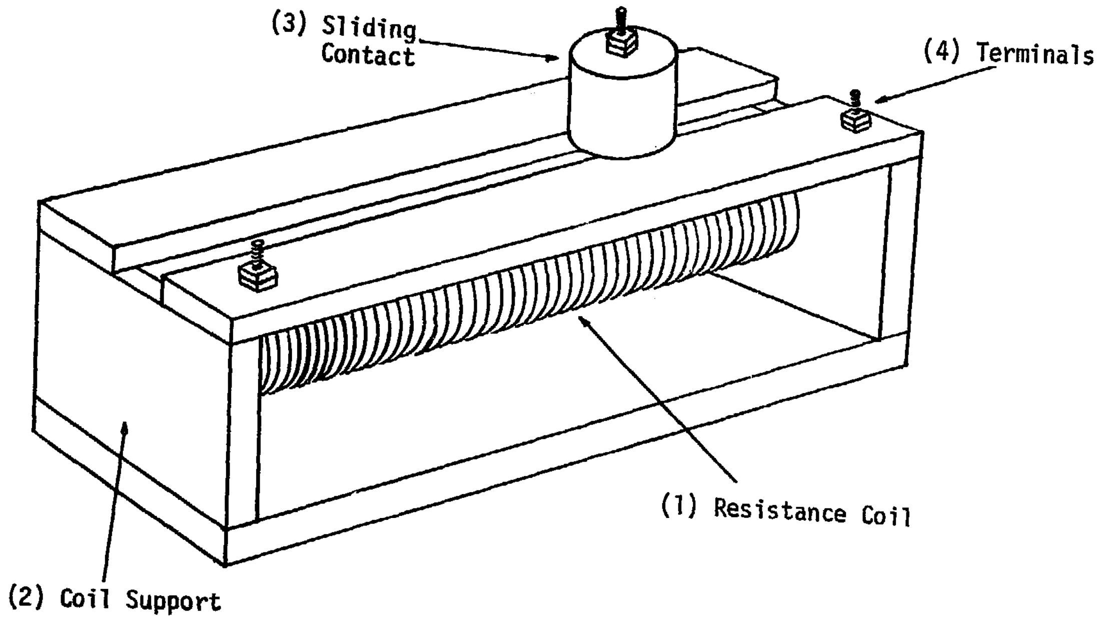
Take the bare end of a length of copper wire (D), and wrap it around the loose clip, so that when the latter is tapped securely into position the copper wire makes good contact with the pencil lead.

c. Notes

(i) If the resistor is connected into a circuit in series with two dry cells (1.5 volts each) and a flash-light bulb (approximately 1.5 volts), it will be found that increasing the length of pencil lead included in the circuit will diminish the brightness of the bulb, the full length of lead (approximately 20 cm of #2B lead) almost extinguishing the light altogether.



C2. Variable Resistor (Nichrome)



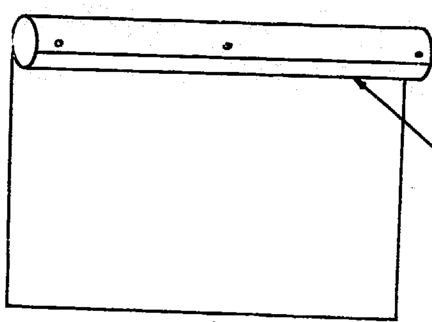
a. Materials Required

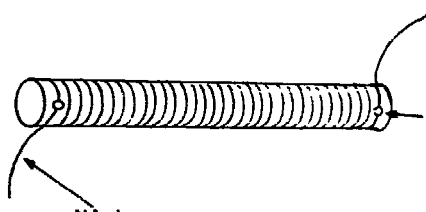
Components	Qu	Items Required	Dimensions
(1) Resistance Coil	1	Wooden Dowel (A)	26 cm long, 2.5 cm diameter
	1	Asbestos Paper (B)	40 cm x 26 cm
	1	Nichrome Wire (C)	#20, 450 cm long
(2) Coil Support	1	Wood (D)	30 cm x 7.5 cm x 2 cm
	2	Wood (E)	8 cm x 7.5 cm x 2 cm
	2	Plywood (F)	30 cm x 3 cm x 0.7 cm
(3) Sliding Contact	1	Wood Dowel (G)	3 cm diameter, 3 cm long
	1	Wood Dowel (H)	3 cm diameter, 1 cm long
	1	Brass Strip (I)	13 cm x 1 cm x 0.02 cm
	1	Bolt (J)	0.3 cm diameter, 6 cm long
	3	Nuts (K)	0.3 cm internal diameter
	--	Washers (L)	1.2 cm external diameter

(4) Terminals	2	Bolts (M)	0.3 cm diameter, 2.5 cm long
	4	Nuts (N)	0.3 cm internal diameter

b. Construction

(1) Resistance Coil





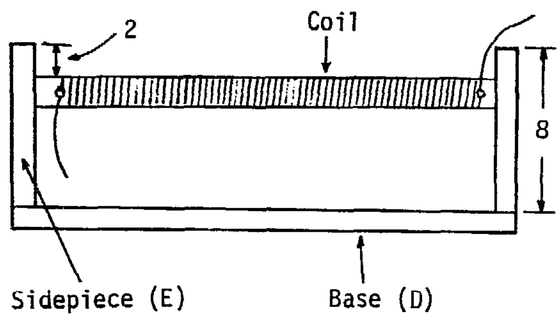
The dimensions of the apparatus depend very much on the resistance required. In this case a 25 ohm resistor, capable of carrying a current of up to 3 amps was required, and it was decided that this could be achieved by using some 400 cm of #20 nichrome wire which had a resistance of approximately 1 ohm per 16 cm length. This determined the dimensions of the coil and the resulting item of equipment.

Attach the asbestos paper (B) to the wooden dowel (A), as indicated, with two or three short nails, and then wrap the paper closely around the dowel. There should be enough paper to make about five layers. Attach the loose end of the asbestos paper to the dowel with two or three more short nails.

Attach the nichrome wire (C) to one end of the dowel by means of a nail, leaving about 7 cm of wire as a free end. Wrap the wire firmly around the dowel to make a coil with a regular 0.5 cm between turns. Do not allow the wire to touch any of the nail heads in the dowel, thus avoiding a "short" between adjacent turns. On reaching the end of the dowel, attach the wire once more to the dowel with a short nail. Cut off any unnecessary wire, leaving about 7 cm as a free end.

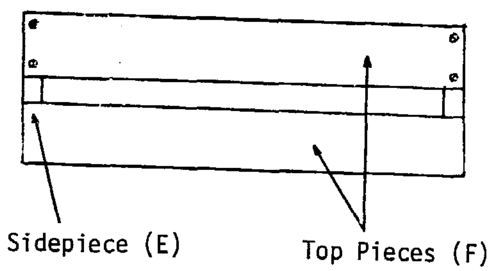
(2) Coil Support

Make a support for the resistance coil from wood (D) for the base and wood (E) for the two sidepieces. Nail the resistance coil between the sidepieces (E) such that it is 2 cm from the top of, and on the median bisecting, each sidepiece.



Side View

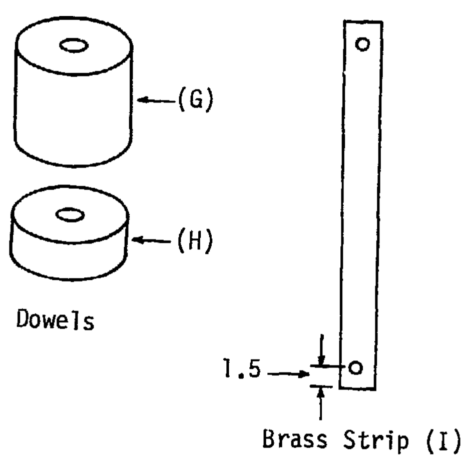
Set the two pieces of plywood (F) in position on top of the support as indicated, but only screw one piece in position for the moment.

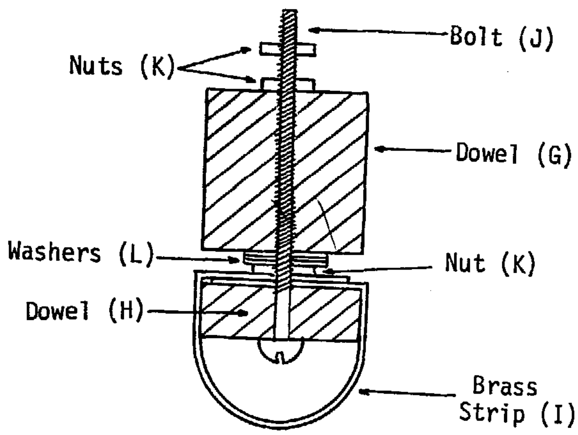


Top View

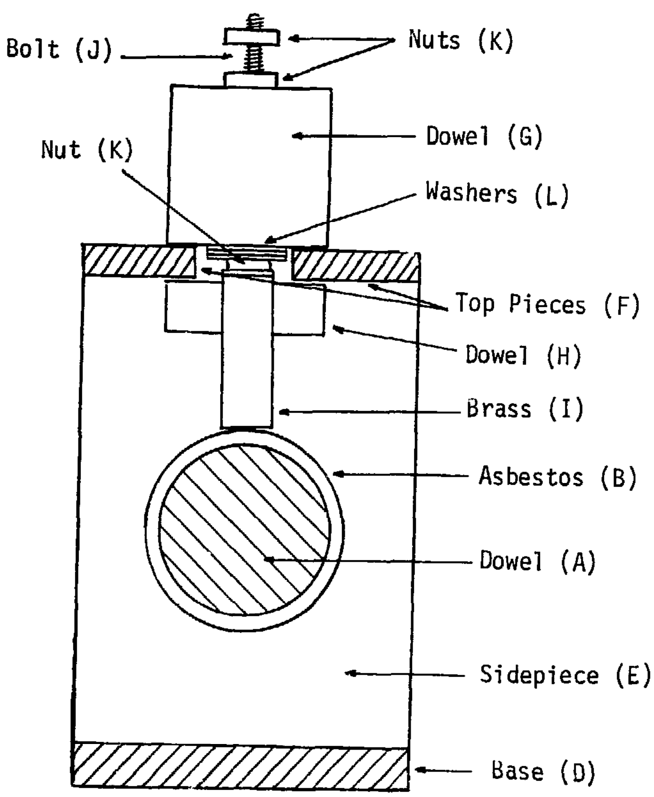
(3) Sliding Contact

Bore a hole (diameter 0.3 cm) along the axis of each dowel (G,H). Similarly, drill a hole (0.3 cm diameter) at a distance of 1.5 cm from either end of the brass strip (I).





Side View
(Cross-section)



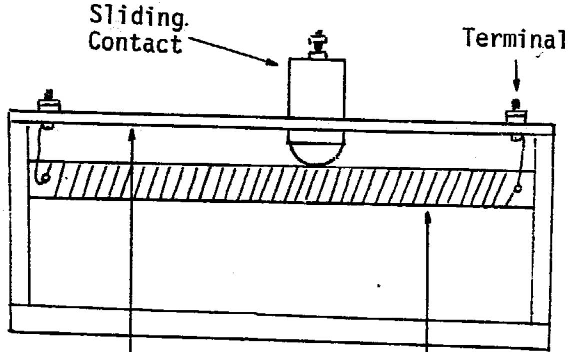
End View
(Cross-section)

Bend the brass strip (I) into a semicircular shape around the smaller dowel. Insert the bolt (J) through the lower dowel (H) and the end holes in the brass strip (I). Lock the strip in position with a nut (K), and then add washers (L) (no more than 1.2 cm in diameter) to create a spacer between the two dowels of 0.8 cm depth. Slide the larger dowel (G) onto the bolt, and fix it in position with a locking nut (K). Add another nut (K) to serve as a terminal.

Place the sliding contact above the resistance coil so that the fixed top piece of the support fits into the space between the dowels of the sliding contact. Take the second top piece (F) already cut, and set it in position on top of the support so that it holds the sliding contact in position in contact with the resistance coil. Screw the top piece in position on top of the endpieces. If necessary, adjust the position of the resistance coil to insure not only that there is good electrical contact between the sliding contact and the resistance coil, but also that the contact slides smoothly along the length of the coil.

(4) Terminals

Use the nuts (N) and bolts (M) to make two terminals [see VIII/A2, Component (4)], one at either end of the support top piece, and fasten the free ends of the resistance coil to these terminals.



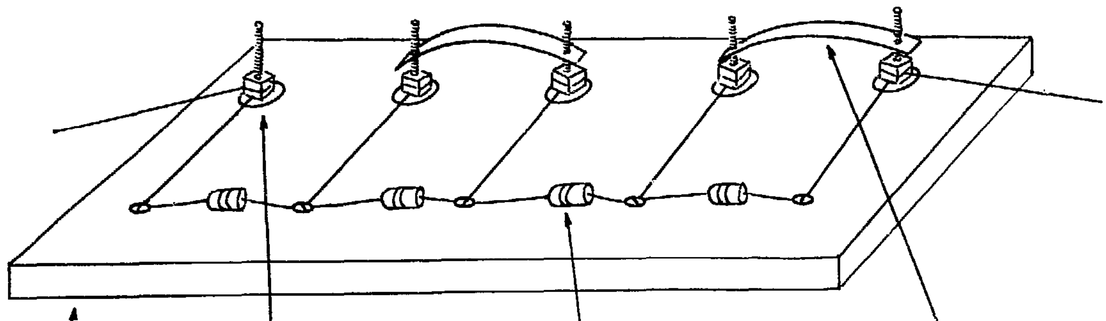
Side View

c. Notes

(i) If the resistor is connected into a circuit by means of the two fixed terminals, a fixed resistance of 25 ohms is added to the circuit. If the terminals used are one fixed terminal and the terminal on the sliding contact, then the resistance added to the circuit may be varied from 25 ohms to almost zero.

(ii) A current passing through the coil will tend to heat it up. A 2-amp current makes the coil fairly hot, and a 3-amp current makes it very hot, but the heating does not affect the performance of the resistor.

C3. Decade Resistor



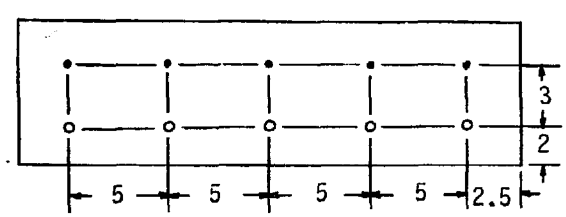
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	25 cm x 7 cm x 2 cm
(2) Terminals	5	Bolts (B)	0.4 cm diameter, 5 cm long
	10	Nuts (C)	0.4 cm internal diameter
	20	Washers (D)	--
(3) Resistors	1	Resistor (E)	10 ohms, 2.5 watts
	1	Resistor (F)	20 ohms, 1.5 watts
	2	Resistors (G)	30 ohms, 1.0 watt
	1	Copper Wire (H)	#24, 30 cm long
	5	Screws (I)	1.5 cm long
(4) Connectors	4	Brass Strips (J)	7.5 cm x 1.5 cm x 0.05 cm

b. Construction

(1) Base

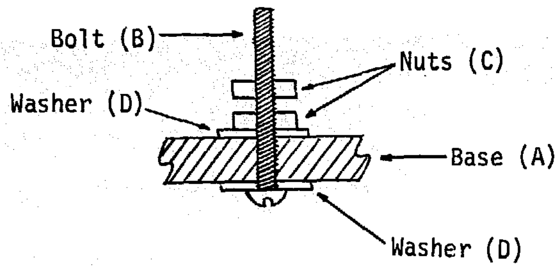
Use wood (A) for the base. Mark on the top surface the position of the terminals and screws as indicated.



• Terminal Positions

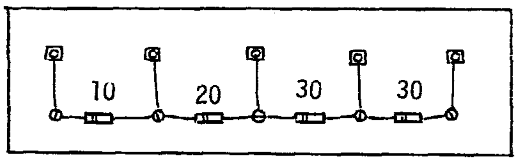
o Screw Positions

(2) Terminals



Drill holes (0.4 cm diameter) in the base (A) in the terminal positions, making sure that the holes are at right angles to the plane of the base. Use a bolt (B), two nuts (C), and two washers (D) to make each terminal.

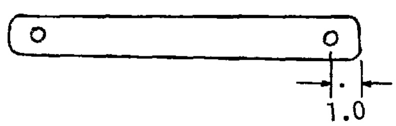
(3) Resistors

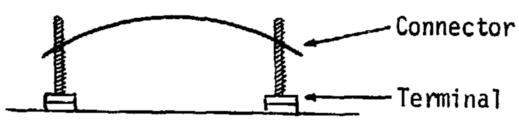


Top View

Insert five screws (I) into the base in the positions indicated. Connect each screw to the nearest terminal with a short length of copper wire (H). Connect radio resistors (E, F, G) (see notes) of 10, 20, 30 and 30 ohms between successive pairs of screws (see notes).

(4) Con[illegible]s



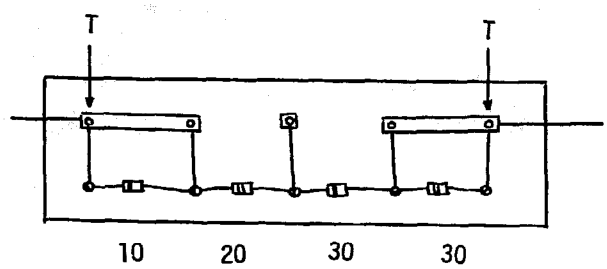


Side View

Make four connectors from the brass sheeting (J). Drill a hole (0.7 cm diameter) at a distance of 1.0 cm from each end. Squeezed gently into the shape of an arc, it should be possible to set the connector across two terminals, thus shorting one of the resistors out of the circuit.

c. Notes

(i) The resistance between the main terminals (T) may be any multiple of 10 ohms from 0 to 90, according to the way in which the connectors are placed across the terminals. In the case illustrated the resistance would be 50 ohms.



(ii) If the decade resistor is designed for use with a voltage supply of no more than 5 volts then the 10, 20, and 30 ohm resistors purchased should have ratings of 2.5, 1.5 and 1.0 watts respectively.

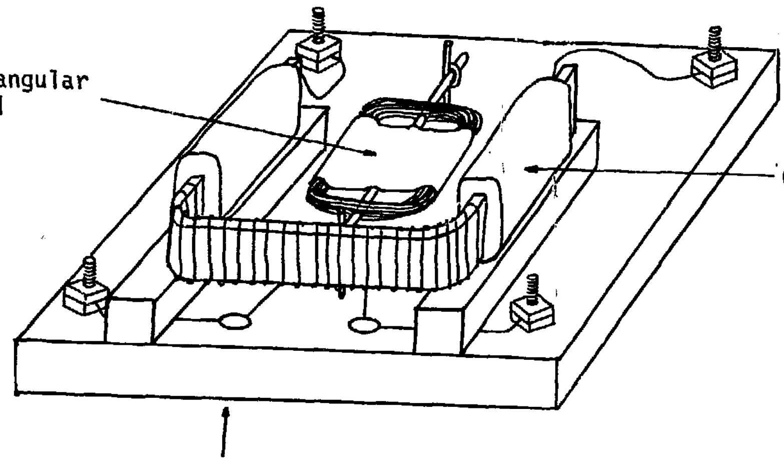
R Ohms	V Volts	I Amps	W Watts
10	5	0.50	2.50
20	5	0.25	1.25
30	5	0.17	0.83

Alternatively, if all the resistors purchased were rated at 1 watt, then the voltage placed across the 10, 20 and 30 ohm resistors should never exceed 3.0, 4.5 and 5.5 volts respectively.

R Ohms	W Watts	V = W.R Volts
10	1.0	3.2
20	1.0	4.5
30	1.0	5.5
40	1.0	6.3
50	1.0	7.1
60	1.0	7.6
70	1.0	8.4
80	1.0	8.9
90	1.0	9.5

D. DYNAMO/MOTORS

D1. Simple Motor

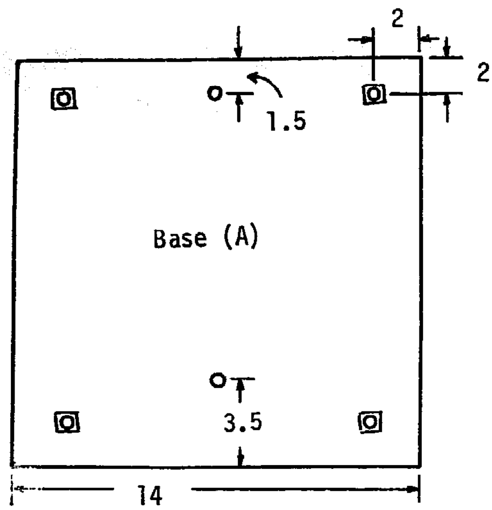


a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	14 cm x 13 cm x 1.5 cm
	4	Bolts (B)	0.3 cm diameter, 3.0 cm long
	8	Nuts (C)	0.3 cm internal diameter
	2	Coat Hanger Wire (D)	7 cm long, 0.2 cm diameter
(2) Rectangular Coil	1	Roll of Magnet Wire (E)	#26
	1	Coat Hanger Wire (F)	10 cm long, 0.2 cm diameter
	1	Insulating Tape (G)	--
	1	Masking Tape (H)	--
	2	Magnet Wire (I)	#26, 10 cm long
	4	Thumbtacks (J)	--
(3) Electromagnet	1	Soft Iron Bar (K)	17.5 cm x 2.0 cm x 0.3 cm
	1	Roll of Magnet Wire (L)	#26, approximately 100 g
	1	Masking Tape (M)	--
	2	Wood Strips (N)	8 cm x 1.5 cm x 1.0 cm

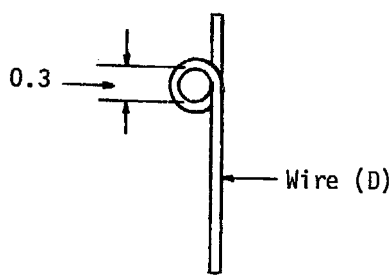
b. Construction

(1) Base



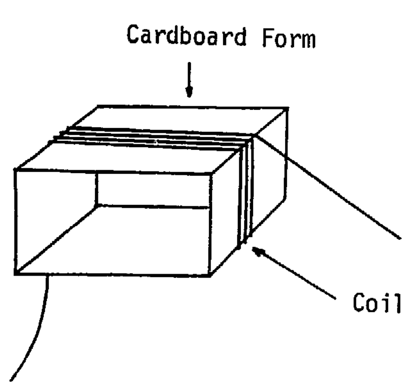
Top View

Use wood (A) as the base. Use the four bolts (B) and eight nuts (C) to make four terminals [see VIII/A2, Component (4)]. Attach a terminal at each corner of the base, making sure to inset the boltheads into the bottom of the base. Drill two holes (0.2 cm diameter, 1.0 cm deep) into the base to hold the vertical supports.

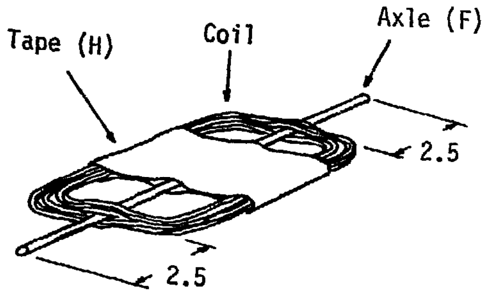


Make two vertical supports for the coil by twisting the coat hanger wire (D) into the shape indicated. Set the supports vertically upright in the newly drilled holes in the base.

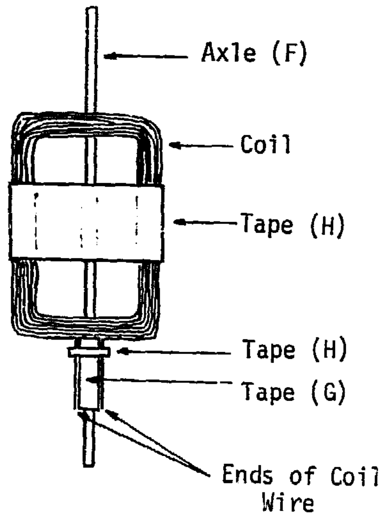
(2) Rectangular Coil



Wind 30 turns of magnet wire (E) around a cardboard form in order to make a coil of internal size 3.5 cm x 1.5 cm. Leave 10 cm of wire free at either end of the coil.

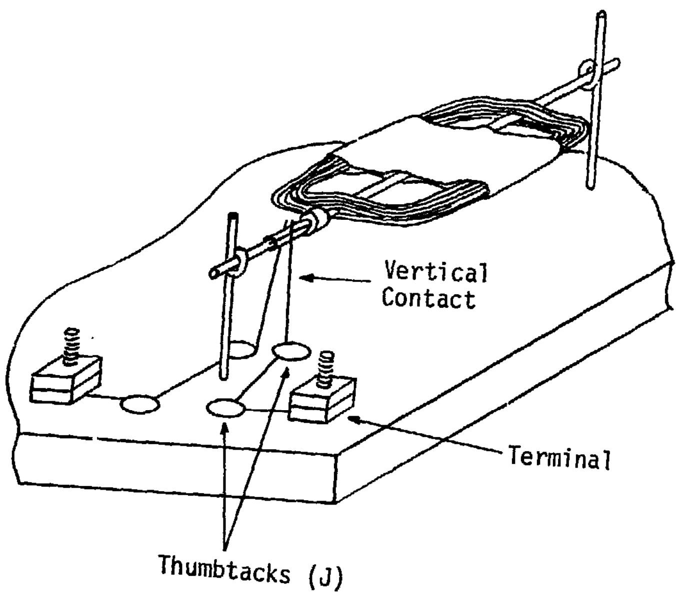


Take the length of straight coat hanger wire (F) and thread it through the middle of the coil to serve as the axle. Wrap the masking tape (H) around the coil and axle to hold the coil firmly in position.



Wrap a length of insulating tape (G) around the axle, adjacent and external to the coil, to create a region of insulation, 1.5 cm long, on the axle (F).

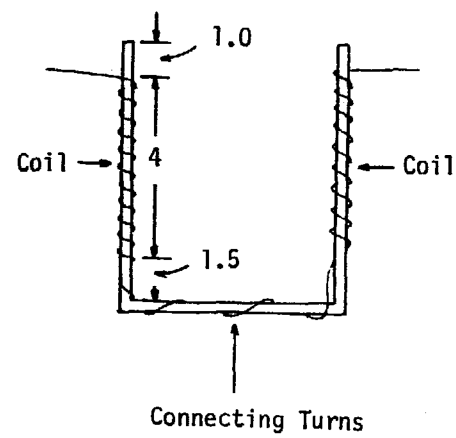
Adjust the ends of the coil wire so that they lie parallel to this insulated portion of the axle, and on either side of it. Cut the parallel wires so that they do not protrude beyond the insulation. Clean the enamel off the wire with sandpaper.



Fasten a thin piece of masking tape (H) around the ends of the coil wire and axle, thus keeping the ends of the coil wire in position. Fit the coil axle into the coil supports on the base. Take the two lengths of copper wire (I), and remove the varnish from the ends. Make one end of each wire into a vertical contact which just touches one of the wire ends from the coil. Hold each wire in position on the base with thumbtacks (J), and attach the free end of the wire to one of the front terminals as indicated.

(3) Electromagnet

A simple horseshoe magnet, with poles about 4 cm apart, will serve the purpose well. However, if a suitable horseshoe magnet is not available, an electromagnet may readily be made as follows.



Take a soft iron bar (K), and bend it into a horseshoe shape with parallel sides 4.5 cm apart. Take about 100 g of #26 magnet wire (L), and wind a coil on each side of the U-shaped bar. Each coil should be about 4 cm long, and should contain ten layers of wire. The coils should be connected in series to one another, simply by continuing the windings in the same direction around the bar from one coil to the other in a series of widely spaced connecting turns. Cover the final layer of turns with masking tape (M) to hold the coils in position. Connect the free ends of the coils to the rear terminals on the base.

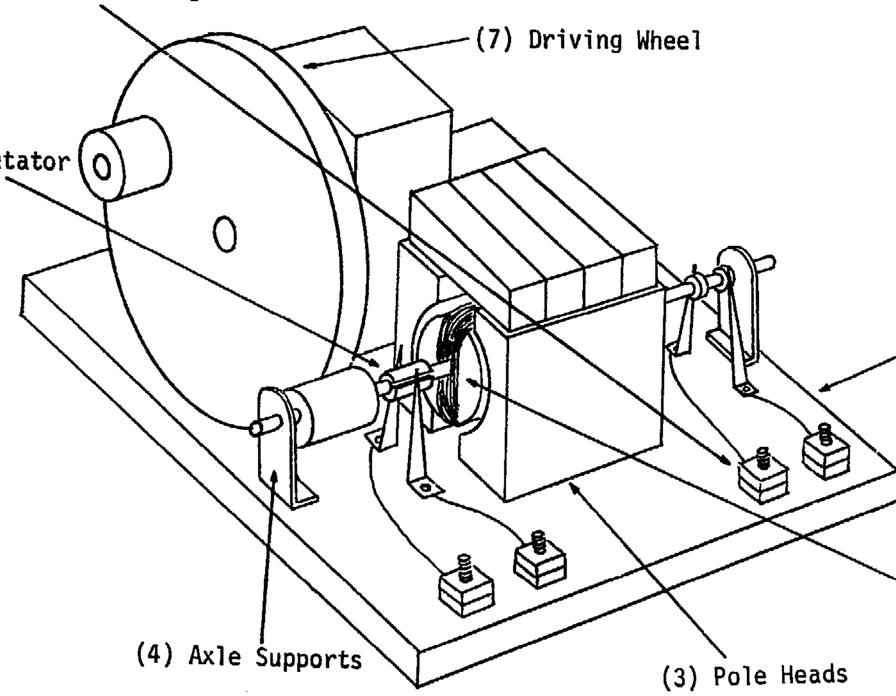
Place two wood strips (N) beneath the electromagnet such that the magnetic poles are either side of, and at the same height as, the middle of the rectangular coil.

c. Notes

(i) With a current of 1 amp through the electromagnet and about 0.7 amp through the rectangular coil, the latter will rotate quite rapidly, thus behaving as a motor. The current required may be readily provided by dry cells.

(ii) With a current of 1 amp through the electromagnet it is possible to generate a current in the rectangular coil by rotating it as rapidly as possible. However, the current generated is extremely small (of the order 0.1 milliamps).

D2. Dynamo/Motor ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	20 cm x 15 cm x 2 cm
(2) Armature	1	Nail (B)	0.7 cm diameter, 15 cm long
	1	Box of Nails (C)	4 cm long
	1	Epoxy Resin (D)	--
	1	Roll of Magnet Wire (E)	#26
(3) Pole Heads	1	Box of Nails (F)	4 cm long
	1	Epoxy Resin (G)	--
	4	High Quality Steel (or Alnico) Bars (H)	7 cm x 1 cm x 1 cm

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 61-73

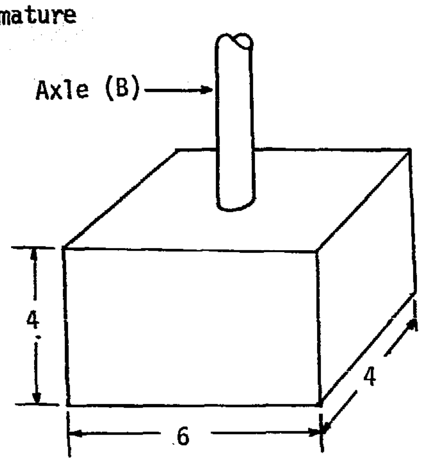
(4) Axle Supports	2	Brass Sheets (I)	5.5 cm x 2.0 cm x 0.2 cm
	1	Masking Tape (J)	--
(5) Commutators	1	Brass Tube (K)	1 cm long, 1 cm external diameter, 0.8 cm internal diameter
	1	Epoxy Resin (L)	--
	2	Brass Sheets (M)	5.0 cm x 1.0 cm x 0.1 cm
	1	Brass Tube (N)	1 cm long, 1 cm external diameter, 0.8 cm internal diameter
	2	Brass Sheets (O)	5.0 cm x 1.0 cm x 0.1 cm
	1	Magnet Wire (P)	#26, 15 cm long
(6) Terminals and Electric Wiring	4	Bolts (Q)	0.3 cm diameter, 3.5 cm long
	8	Nuts (R)	0.3 cm internal diameter
	1	Magnet Wire (S)	#26, 40 cm long
(7) Driving Wheel System	1	Wooden Spool (T)	2.5 cm long, 3 cm diameter
	1	Rubber Strip (U)	9.5 cm x 2.5 cm
	1	Wood (V)	12 cm x 5 cm x 4 cm
	1	Wood Disc (W)	15 cm diameter, 1.5 cm thick
	1	Nail (Y)	0.7 cm diameter, 6 cm long
	1	Wooden Spool (Z)	2.5 cm long, 2.5 cm diameter
	1	Screw (AA)	4 cm long
	4	Washers (BB)	0.8 cm internal diameter diameter, approximately

b. Construction

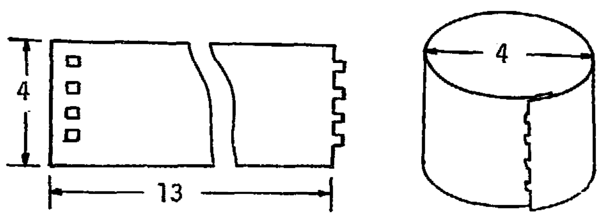
(1) Base

Use the wood (A) as the base.

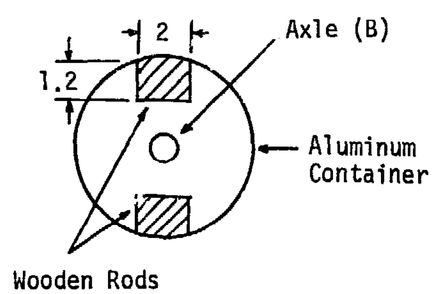
(2) Armature



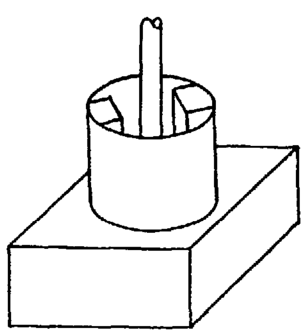
Take a wooden block, and drill a vertical hole (0.8 cm diameter) through its center so that it can support steel axle (B). The latter may be a very long nail with the head removed.



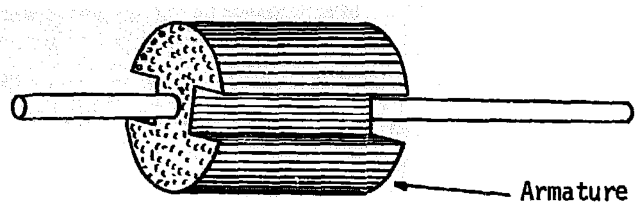
Take a sheet of aluminum (13 cm x 4 cm) and with the help of an appropriate series of end projections and holes make it into a cylindrical container (4 cm tall, 4 cm diameter).



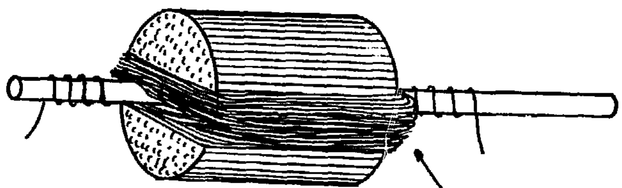
Top View



Place the container on the wooden block so that it encircles the axle. Take two wooden rods (4 cm x 2 cm x 1.2 cm) and stand these against opposite walls of the container. Now fill the remaining space in the container with the nails (C) (or similar soft iron material) packed closely side by side and parallel to the axle.

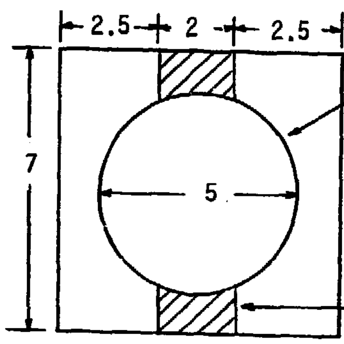


Cover the ends of the nails (not the wood) at both ends of the container with epoxy resin (D), so that when it dries the nails are welded together into a solid soft iron core, penetrated along its axis by the steel axle (B) protruding 4 cm at one end and 7 cm at the other. Remove the aluminum container and the wooden rods. You now have the core of your armature.



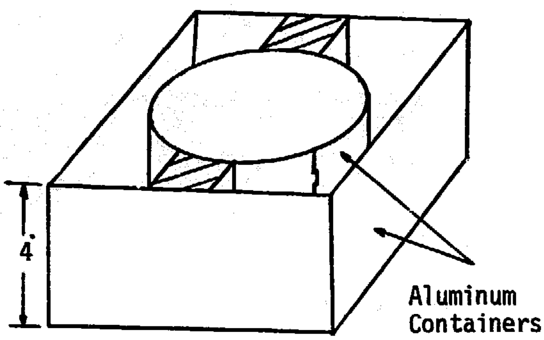
Wind as much magnet wire (E) as possible into a coil around the core, making sure that you have about 10 cm of both ends left free on completion of the coil. Temporarily twist the loose ends around the long end of the axle. The resistance of the coil will be approximately 5 ohms.

(3) Pole Heads

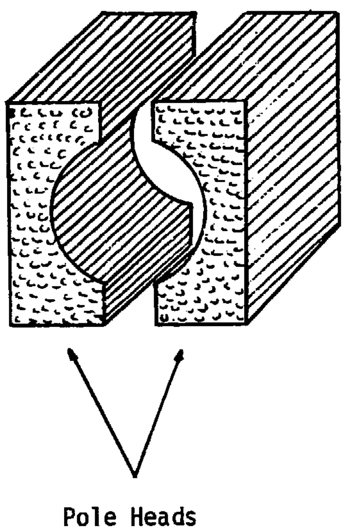


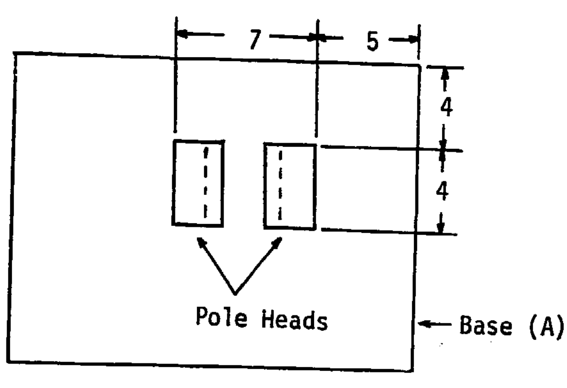
Top View

The pole heads are made in very much the same way as the armature core. Two open ended aluminum containers are required this time, one cylindrical (5 cm diameter, 4 cm long) and one a rectangular cube (7 cm x 7 cm x 4 cm). The cylindrical one is placed inside the rectangular one, and the two held apart by two wooden rods (2 cm x 1 cm x 4 cm). Just as when making the armature core, pack the space between the two containers with the nails (F) packed parallel to the axis of the cylindrical



container. Cover the nail ends at both extremities of the containers and the wooden rods. You will now have two pole heads.

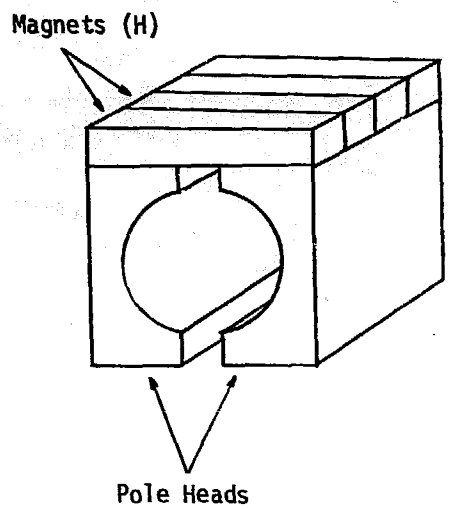




Top View

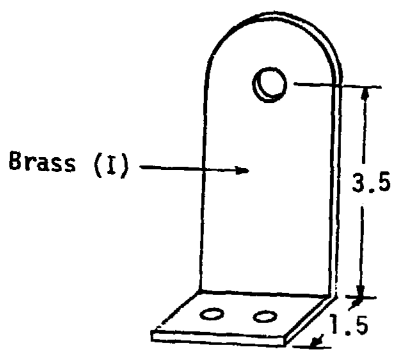
Place the pole heads on the base in the positions illustrated, and attach them firmly to the base with the help of epoxy resin.

Complete the system with four very strong magnets laid parallel to one another (North Pole touching North Pole) across the gap between



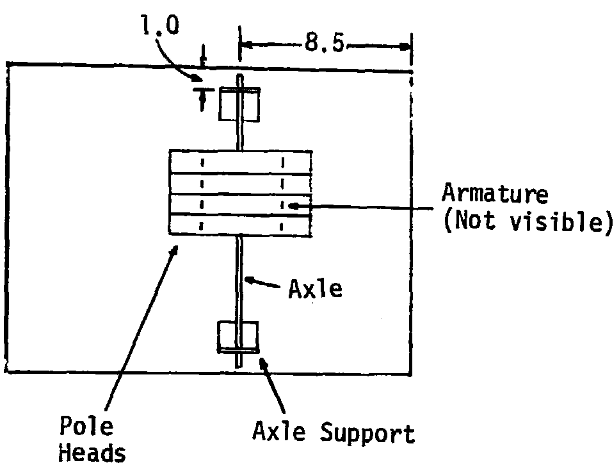
the pole heads. The magnet may be purchased, or made (as described under IX/A1 from the steel bars (H).

(4) Axle Supporters

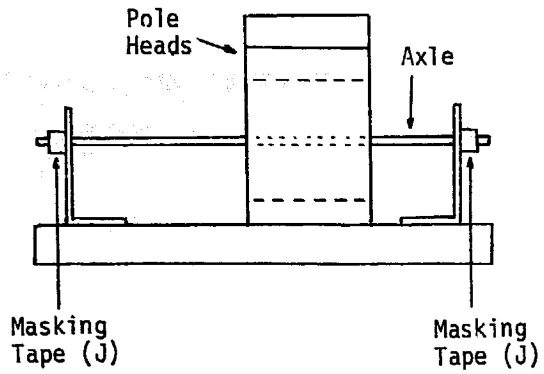


Make two axle supports out of the two brass sheets (I), drilling one hole (0.8 cm diameter) in the upright portion to take the axle, and two holes (0.3 cm diameter) in the base portion to take two screws.

Slide the supports on to either side of the axle (B), and attach them firmly to the base of the apparatus in the position shown.



Top View



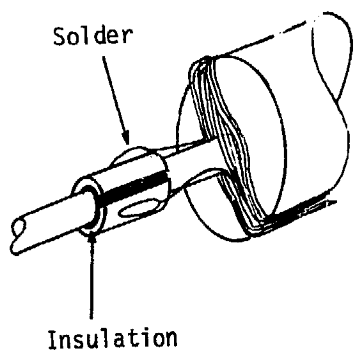
Side View

The axle may be held firmly in position by winding masking tape (J) (not scotch tape) around the axle next to, and just outside, the supports. Do this as a last step in constructing this item, however.

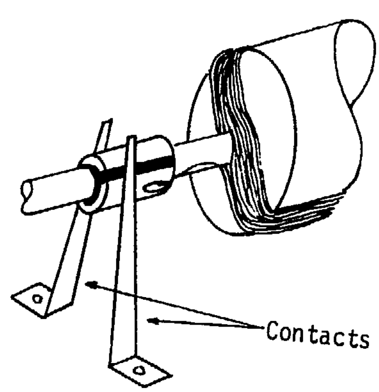
(5) Commutators

To make the DC commutator, take a piece of brass tubing (K), and cut it to make two halves.

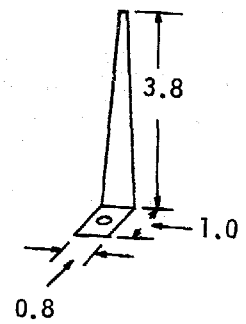
Take some epoxy resin (L), which is a good insulator, and coat all the inner surfaces of the two halves with resin about 0.1 cm thick.



Rotate the armature coil until it is in a vertical plane, and then attach the two split halves to the axle so that the split between the halves is in a horizontal plane. If the epoxy resin is thick enough, it will not only attach the split halves firmly to the axle, but will also insulate the two halves from one another, and from the axle itself.

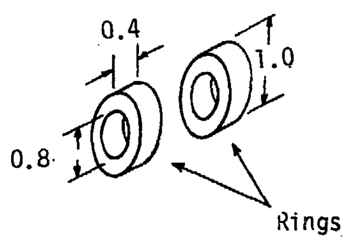


Take the two loose wires from the armature coil and, after cleaning the ends with sandpaper, solder one to one split half and the other to the other split half.

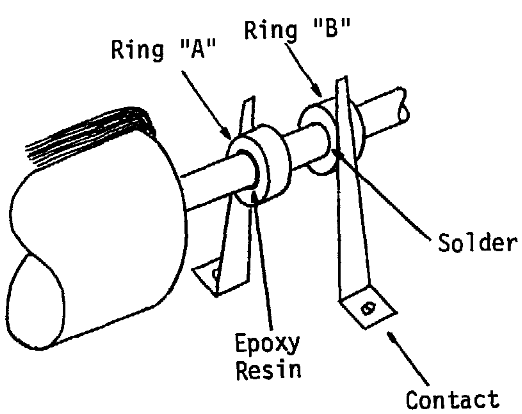


Cut two identical contacts out of the thin brass sheets (M) as shown. Attach these to the base of the apparatus with screws, so that they are in spring contact with opposite sides of the split halves.

The DC commutator is now complete.

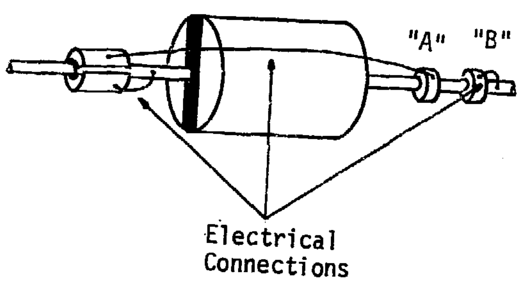


To make the AC commutator, cut two identical rings from the brass tubing (N).



Temporarily remove the axle support and slide the two rings onto the axle. Coat a length of axle (0.5 cm long) with epoxy resin about 0.1 cm thick and slide ring "A" into position over this. The epoxy resin should be such as to insulate the ring from the axle as well as to hold it firmly in position.

Ring "B" is soldered to the axle about 0.5 cm from ring A. Solder insures good electrical contact between the ring and axle. Two contacts, identical to those described above, should be cut from brass (O), and attached to the base so that each is in spring contact with one of the rings.

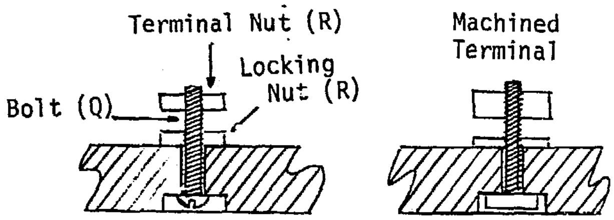


Connect ring "B" electrically to one of the split halves by soldering a very short length of magnet wire (P) from ring "B" to the axle and another piece from one split half to the axle. Don't forget to clean the ends of the magnet wire with sandpaper prior to soldering.

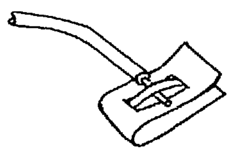
Connect ring "A" electrically to the other split half by soldering a length of magnet wire (P) from one to the other.

The AC commutator is now complete.

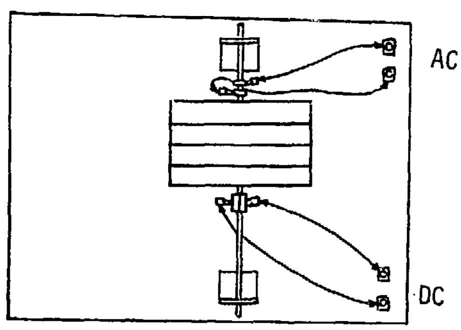
(6) Terminals and Electric Wiring



Side View
(Cross-section)



Fahnstock Clip



Top view

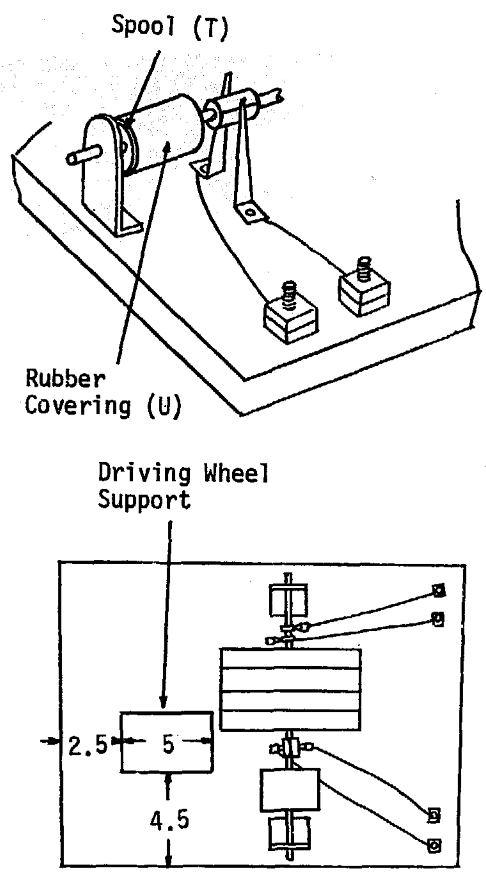
Drill four holes through the base to take four terminals, two to serve as an AC outlet and two as a DC outlet.

Make each terminal as described under VIII/A2, Component (4). Each terminal requires a bolt (Q), and two nuts (R).

It is of course very nice to have fairly large nuts which can be easily adjusted with the fingers. Such nuts are probably best made on a metal lathe. The nuts might both be 1 cm in diameter, with the thickness of the terminal nut being 0.5 cm and that of the locking nut 0.2 cm.

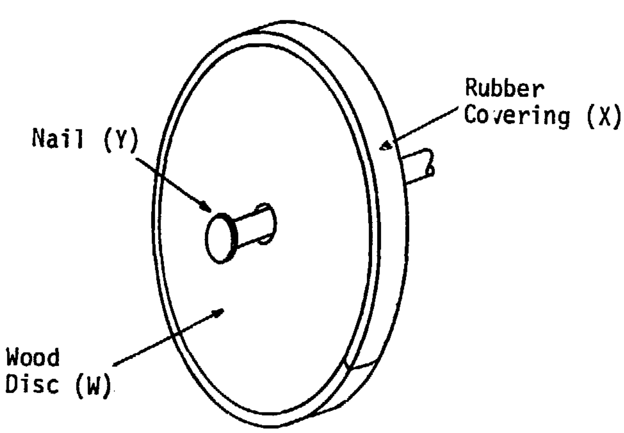
In some localities it is cheaper to purchase terminals on the local market. Check the availability of such items as Fahnstock clips which can replace the above. Take some magnet wire (S), clean the ends with sandpaper, and then connect the terminals to the contacts as illustrated, fastening the wire beneath the locking nut on the terminal.

(7) Driving Wheel System

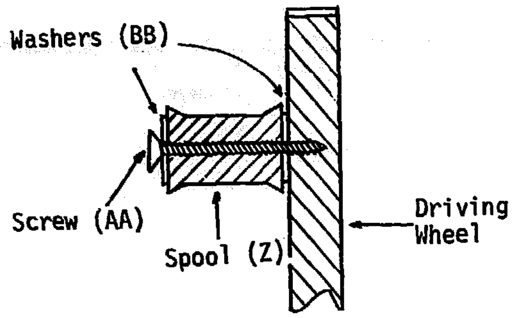


Top View

Take the wooden spool (T) and fill the central hole with wood putty. When the latter is perfectly dry, drill a new hole (0.7 cm diameter) along its axis so that it will just fit on the armature axle. A rubber strip (U) may be cut from an old car inner tube. Nail it around the perimeter of the spool. Temporarily remove the appropriate axle support, and attach the spool firmly to the axle with epoxy resin. Use wood (V) as a support for the driving wheel, locating it on the base in the position shown. Cut a slight inset (0.2 cm) into the base to hold the bottom of the support (V) firmly, and put some wood cement in the inset. Fasten the support firmly in position with the help of two wood screws passing through the base of the apparatus.



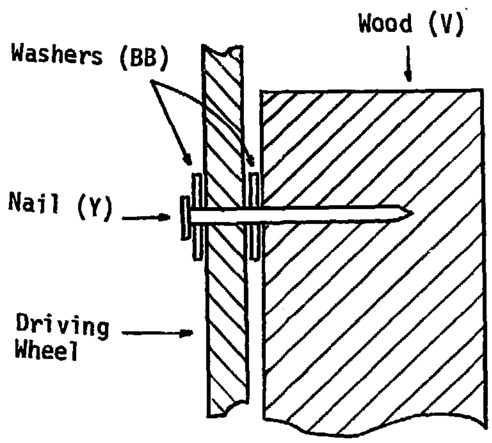
Use the wooden disc (W) to serve as the driving wheel. The rubber strip (X), cut from an old car inner tube, should be nailed around the perimeter of the disc. Drill a hole (0.8 cm diameter) through the center of the disc, and pass a nail (Y) through it to serve as a pivot.



Side View
(Cross-section)

Drill a hole along the axis of the spool (Z) so that the spool fits loosely on the screw (AA), but cannot slip over the screw-head. Screw the spool onto the driving wheel about 4 cm from the perimeter. Put washers (BB) either side of the spool to permit it freedom of motion. You now have a handle for the driving wheel.

Washers (BB) should be similarly placed on the pivot, either side of the driving wheel.



Side View
(Cross-section)

Finally, hold the driving wheel tight against the axle spool, and use the pivot (Y) to mark the best position to locate it permanently in the support. This will be at a height of approximately 10 cm on the support. Drill a horizontal hole (diameter 0.7 cm) into the support, and fix the pivot firmly in the hole with epoxy resin.

Your dynamo/motor is now ready for operation.

c. Notes

(i) The Dynamo/Motor was tested out with two Nuffield horseshoe magnets (Nuffield Physics Item 50/2) across the pole heads; these appear to produce a fairly standard field, whereas locally produced ones vary considerably in strength, depending on the quality of steel or alnico used. The driving wheel was turned at as rapid, but constant, a speed as possible, and was noted to be turned at

4.5 to 5.0 revolutions per second on the average. Under these conditions the following observations were made:

The dynamo was found to produce up to 1.1 volts DC and 1.2 volts AC on open circuit.

Connected in series with a small bulb (1.1 volts, 5 ohms) the dynamo produced a DC current of 0.11 amp at 0.25 volts, and an AC current of 0.13 amp at 0.5 volts. On both occasions the bulb was noted to flicker faintly.

(ii) With the driving wheel disconnected, it was noted that a voltage of 1.4 volts, producing 0.2 amp, was capable of driving the motor.

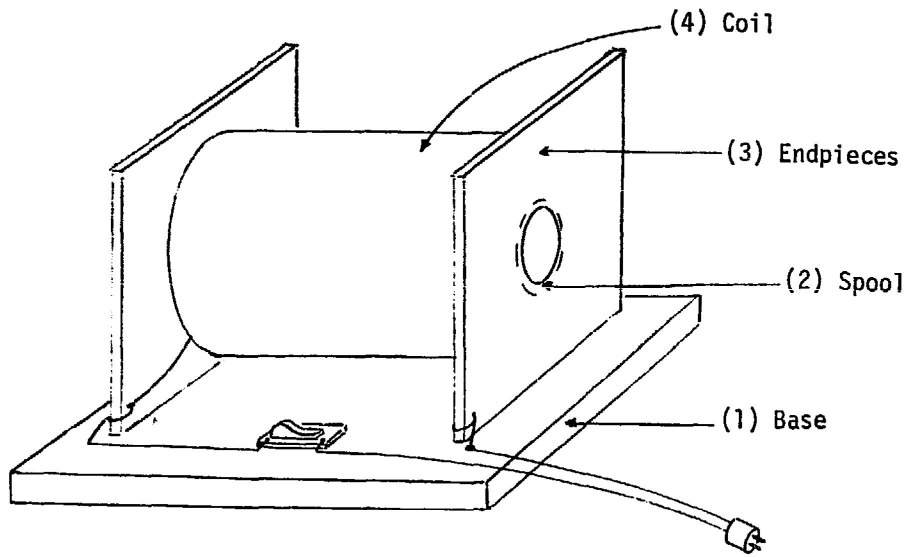
IX. ELECTROMAGNETISM APPARATUS

A. ELECTROMAGNETISM APPARATUS

The apparatus in this group is primarily concerned with the creation of magnetic fields in various forms.

A. ELECTROMAGNETISM APPARATUS

A1. Magnetizing Coil and Magnets ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	15 cm x 15 cm x 2 cm
(2) Spool	1	Wooden Dowel (B)	3 cm diameter, 8 cm long
(3) Endpieces	2	Wooden Strips (C)	8 cm x 8 cm x 0.5 cm
(4) Coil	1	Roll of Magnet Wire (D)	#22, 1 kg
	1	Switch (E)	220 volts
	1	Double Electrical Cord (F)	#20, 200 cm long
	1	Two Pin Plug	220 volts
	1	Insulating Tape (H)	--

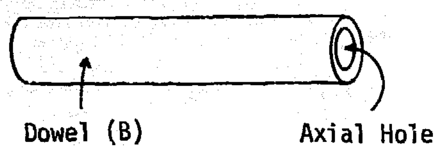
© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 138-142.

b. Construction

(1) Base

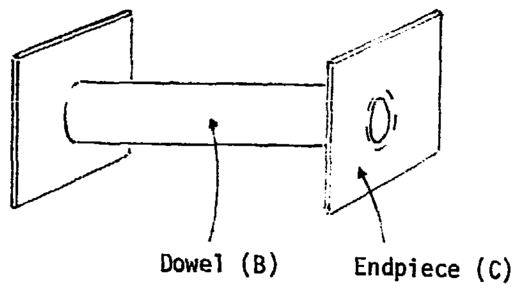
Use wood (A) as the base.

(2) Spool



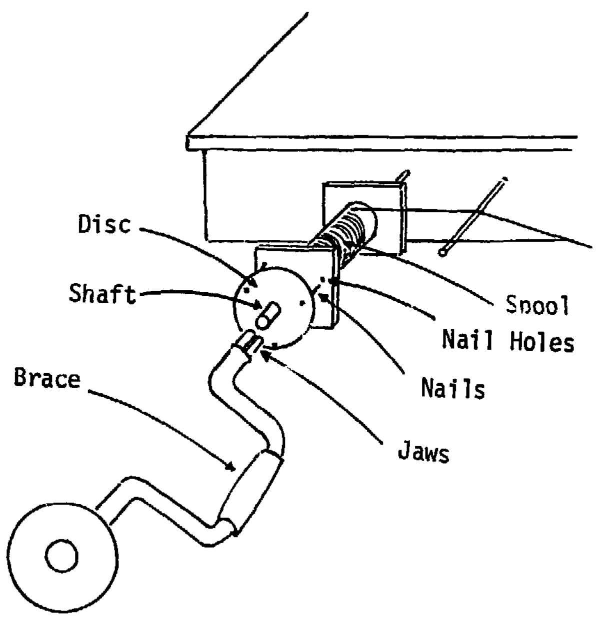
Drill a hole (2 cm diameter) along the axis of the wooden dowel (B) to make an appropriate spool.

(3) Endpieces



Drill a hole (2 cm diameter) in the middle of each wood strip (C) and attach the strips to either end of the spool with wood cement.

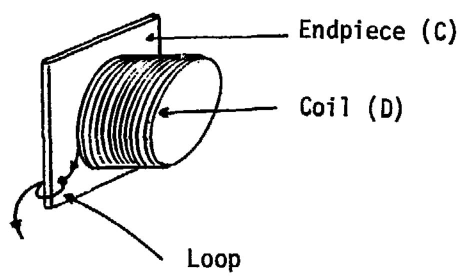
(4) Coil



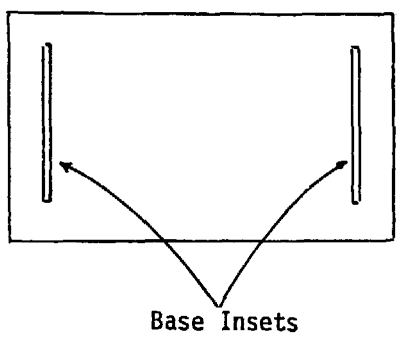
Wind all of magnet wire (D) on to the spool taking care to leave about 25 cm of free wire at either end of the coil for appropriate connections. The winding of the coil may be facilitated by the use of a brace as follows.

Hammer two large nails (15 cm long) into the side of a bench so that they protrude horizontally some 50 cm apart. Place the spool to be wound on one of the nails. Fasten the first turn of magnet wire around the spool in such a way that it will not slip on turning the spool. Then get your partner to hold the wire taut over the second nail so that it may be wound under tension.

Attach a short shaft (2 cm long, 1 cm diameter) to the center of a circular disc (7 cm diameter, 0.5 cm thick) by means of a screw. Hammer three nails through the perimeter of the disc and drill three corresponding holes in the endpiece of the spool to take the protruding nails. Clamp the jaws of the brace firmly on to the shaft. Lock the disc and spool together by means of the disc nails, and then begin to wind the coil by turning the brace.

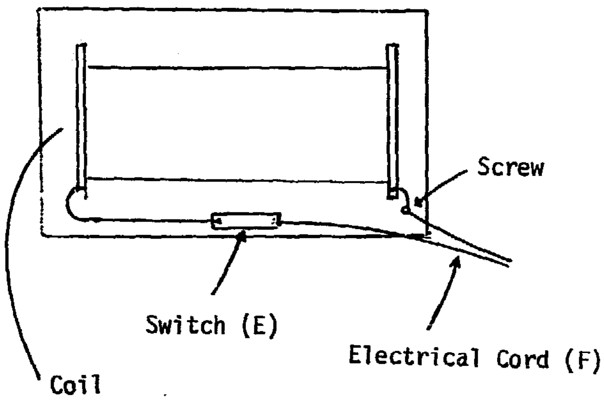


Drill a small hole in each endpiece and loop the wire ends through these holes to prevent unwinding of the coil.



Make two insets (8 cm long, 0.5 cm wide, 0.2 cm deep) in appropriate positions on the base to hold the endpieces. Fix the endpieces firmly in the insets with wood cement.

Attach switch (E) to the base, and connect one of the loose wires from the coil to the switch. Insert a screw into the base as indicated, and attach the other wire from the coil.to the newly inserted screw. Take



the double electrical cord (F) with two pin plug (G) attached, and connect one wire to the screw, and the other wire to the switch.

Since the coil and wires will carry a high voltage (220 volts), it is important that all wiring should be covered with insulating tape (H). Cover the coil, the wire and the screw with the tape.

c. Notes

(i) To magnetize an item, place a suitable steel specimen in the center of the coil. Switch the current quickly on and off. The specimen will be magnetized on removal from the coil.

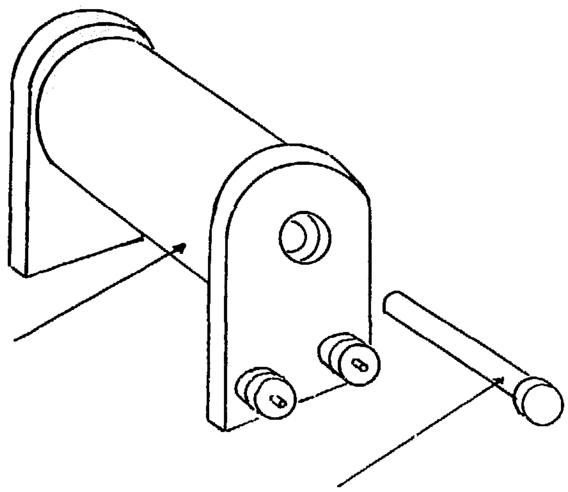
Ticonal is an ideal alloy for making magnets, but is rarely available on local markets. High quality tool steel is a good second best, and is generally found in good quality tools (chisels, screwdrivers, drill bits, etc.), as well as domestic items such as razor blades and sewing needles.

Unfortunately, the "high grade steel" sold on many local markets tends to to be of poor quality, and does not retain magnetism well. However, if the steel is heated to red heat in any oxy-actylene flame, and then quenched in cold water, it tends to be hardened, and hold magnetism somewhat better. (It should be noted that "steel rods" used in construction work for reinforcing concrete are made of soft iron, and cannot be permanently magnetized.

This magnetizing coil is designed for use with a 220 volt mains supply, and is capable of producing extremely strong magnets. It would also work with a 110 volt supply, but the magnetism induced in a given specimen would be weaker than with a 220 volt supply. The magnetizing coil should never be switched on and left on, as it would overheat and burn out. It is designed for usage over very short periods of time (2 or 3 seconds only).

To demagnetize a specimen, place the magnet inside the coil and hold its end very firmly. Switch on the current, and remove the specimen from the coil maintaining a firm grip on it. The current is not switched off until the specimen is completely out of the coil.

A2. Multipurpose Coil with Cores



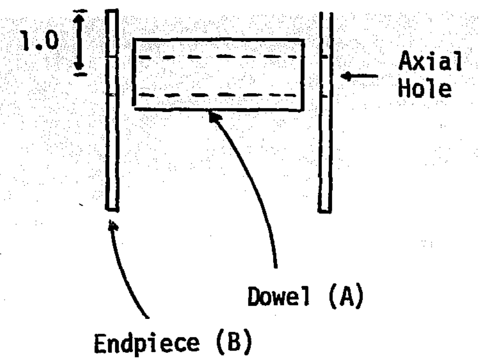
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Coil	1	Dowel (A)	1.2 cm diameter, 3 cm long
	2	Wood Strips (B)	3 cm x 2 cm x 0.5 cm
	1	Roll of Magnet Wire (C)	#22
	1	Masking Tape (D)	--
	2	Brass Bolts (E)	0.3 cm diameter, 1.5 cm long
	4	Nuts (F)	0.3 cm internal diameter
(2) Core	1	Bolt (G)	0.4 cm diameter, 4.5 cm long
	1	Soft Iron Plate (H)	3 cm x 2 cm x 0.3 cm

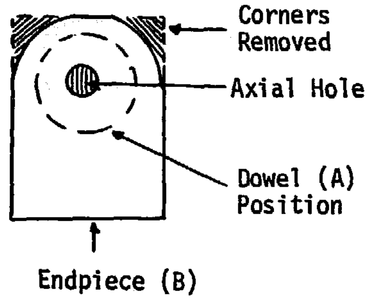
b. Construction

(1) Coil

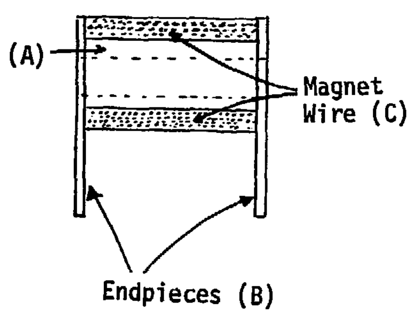
The size of the coil is not critical, but it does affect the spacing and size of components used on the Magnetic Field Apparatus (IX/A4) and Moving Coil Galvanometer (X/C2).



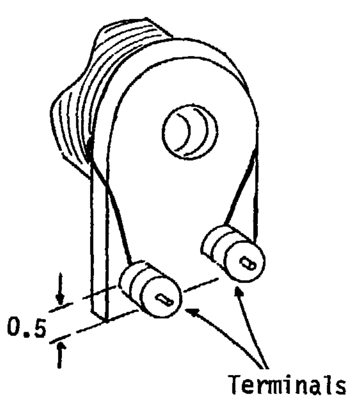
Drill a hole (0.6 cm diameter) along the axis of the dowel (A).



Drill similar holes in the two wood strips (B), at a distance of 1.0 cm from the ends, so that when the strips are attached to either end of the wooden dowel (A) they serve as endpieces with a common axial hole. Cut off the top corners of the end-pieces, and smooth them down with sandpaper.



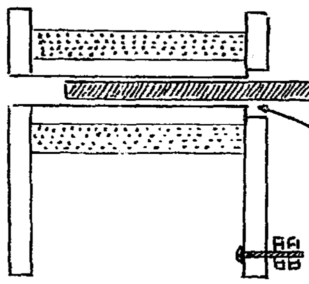
Wind ten layers of magnet wire (C) on to the dowel, leaving about 10 cm of wire free at either end of the coil. Cover the final layer of wire with masking tape (D) to hold the coil in position.



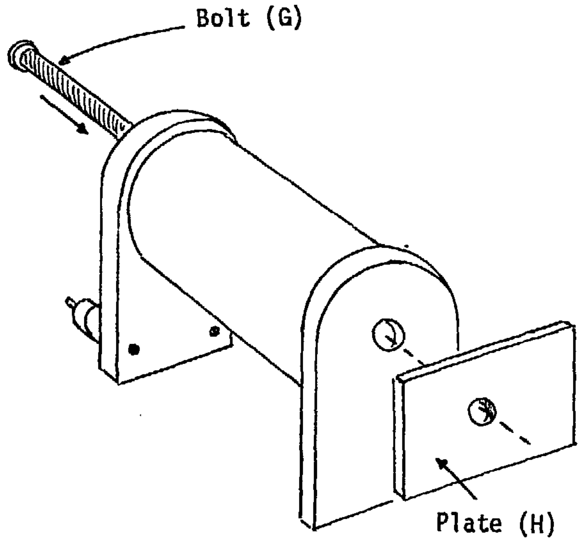
Use bolts (E) and nuts (F) to make two terminals as described under VIII/A2, Component (4), and attach them to one endpiece as indicated.

Clean the ends of the two wires from the coil, and fasten them under the locking nuts of the respective terminals. Make sure that it is possible to see the way in which the wire from each terminal begins to wind around the coil, for this makes it possible to determine the direction of the current around the coil, and hence the direction of the magnetic field produced.

(2) Core



Drill an inset (0.4 cm deep, 1.0 cm diameter) over the hole in the endpiece which contains the terminals. Insert bolt (G) so that the bolthead sits snugly in the inset.

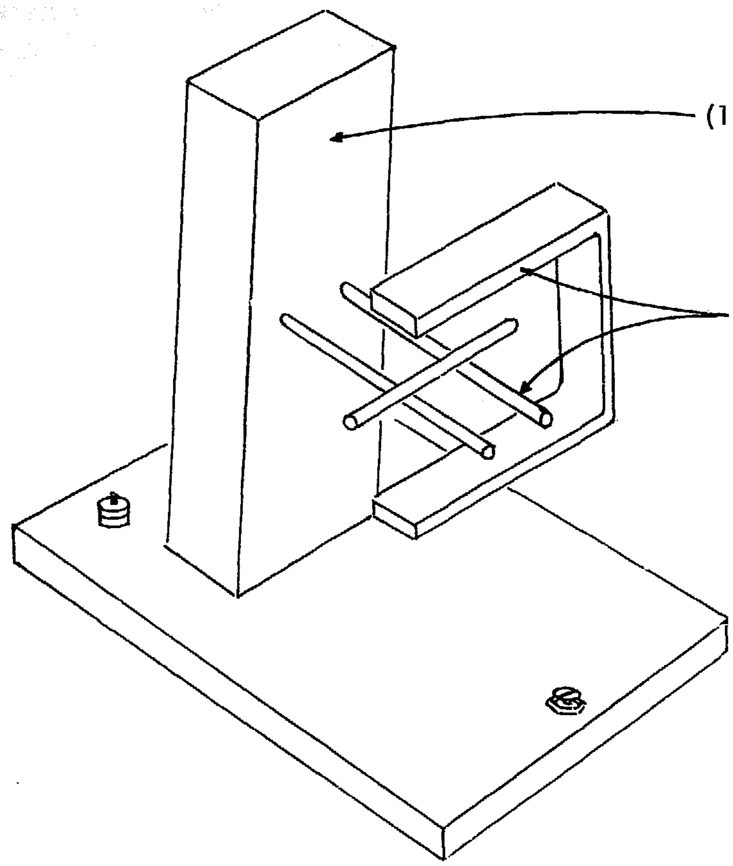


Drill a hole (0.4 cm diameter) through the center of the iron plate (H). Make a thread (0.4 cm diameter) in the hole, and attach the iron plate to the bolt (G) by means of the threaded hole.

c. Notes

(i) The multipurpose coil may be used in a wide range of experiments to produce magnetic fields. It may also be used in instruments [e.g., the Magnetic Field Apparatus (IX/A4) and the Moving Coil Galvanometer (X/C2)] where a fixed magnetic field is required.

A3. Magnetic Field Apparatus ©



a. Materials Required

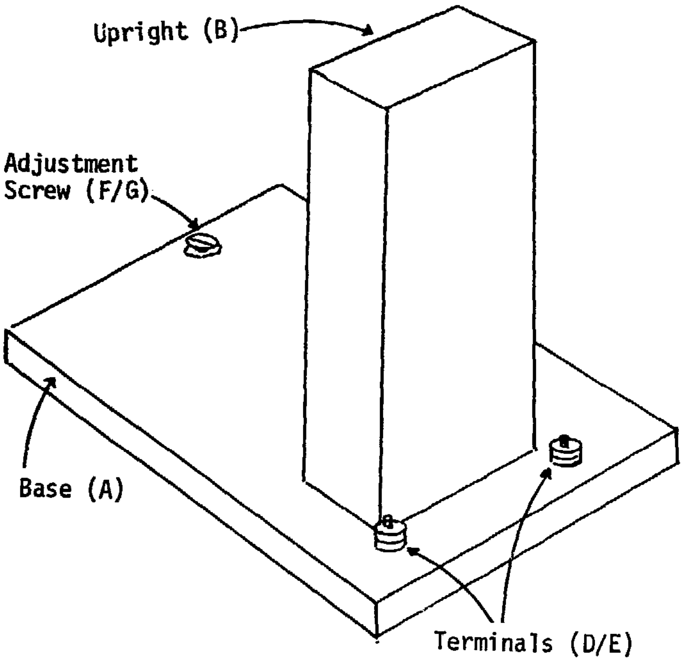
Components	Qu	Items Required	Dimensions
(1) Support	1	Wood (A)	10 cm x 7 cm x 1 cm
	1	Wood (B)	10 cm x 4 cm x 2 cm
	2	Wood Screws (C)	2 cm long
	2	Brass Bolts (D)	0.3 cm diameter, 2 cm long
	4	Nuts (E)	0.3 cm internal diameter
	1	Bolt (F)	0.2 cm diameter, 2 cm long
	1	Nut (G)	0.2 cm internal diameter
	2	Thumbtacks (H)	--

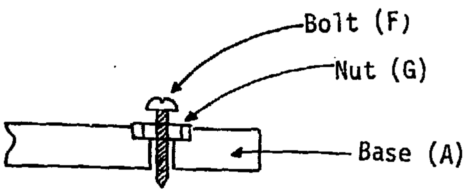
© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 146-148.

(2) Field System	2	Brass Rods (I)	0.4 cm diameter, 5 cm long
	2	Nuts (J)	0.3 cm internal diameter
	2	Magnet Wires (K)	#22, 8 cm long
	1	Aluminum Rod (L)	0.3 cm diameter, 4 cm long
	1	Horseshoe Magnet (M)	--

b. Construction

(1) Support





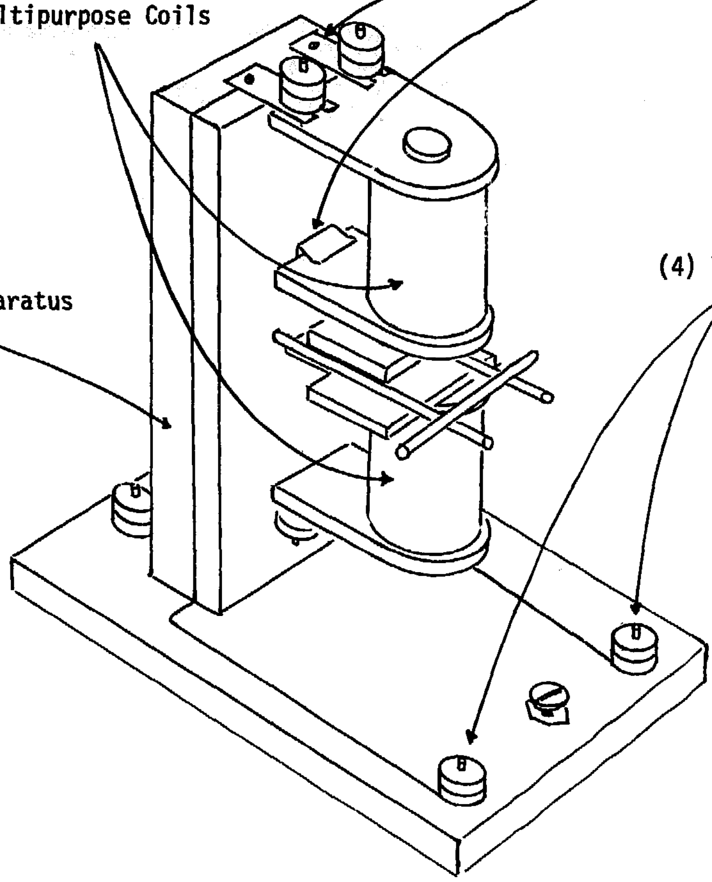
Use wood (A) as the base.

Attach wood (B) vertically to the base with two wood screws (C) passed through the base (4 cm from one end). Use wood cement to insure a firm joint between the upright and base.

Use the bolts (D) and nuts (E) to make two terminals, as described under VIII/A2, Component (4), and attach these to the base (A) just behind the upright (B).

Drill a hole (0.3 cm diameter) through the base to take bolt (F). Inset nut (G) over the hole by striking it into position with a hammer. Thread the bolt through the nut thus producing an adjustment screw for levelling the base. At opposite corners on the other side of the base, insert two thumbtacks (H) beneath the base, so that the latter sits on three points, the adjustment screw and two thumbtacks.

A4. Magnetic Field Apparatus with Multipurpose Coils ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Basic Apparatus	1	Magnetic Field Apparatus (A)	IX/A3, No magnet required
(2) Multipurpose Coils	2	Multipurpose Coils with Cores (B)	IX/A2
(3) Coil Holders	2	Brass Sheets (C)	2 cm x 2 cm x 0.02 cm
	4	Screws (D)	Approximately 0.6 cm long
	4	Brass Sheets (E)	3 cm x 0.8 cm x 0.05 cm

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 149-152.

	4	Screws (F)	Approximately 0.6 cm long
(4) Terminals	2	Brass Bolts (G)	0.3 cm diameter, 2 cm long
	4	Nuts (H)	0.3 cm internal diameter
	1	Magnet Wire (I)	#24

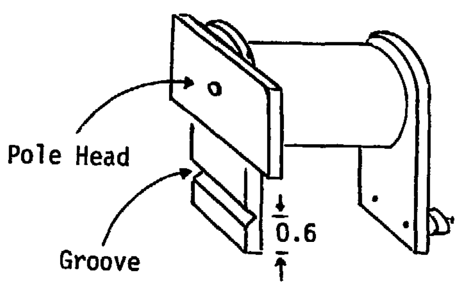
b. Construction

(1) Basic Apparatus

Make the Magnetic Field Apparatus (A) as described under IX/A3. A horseshoe magnet is not required, and the magnetic field is produced by means of the additional components described below.

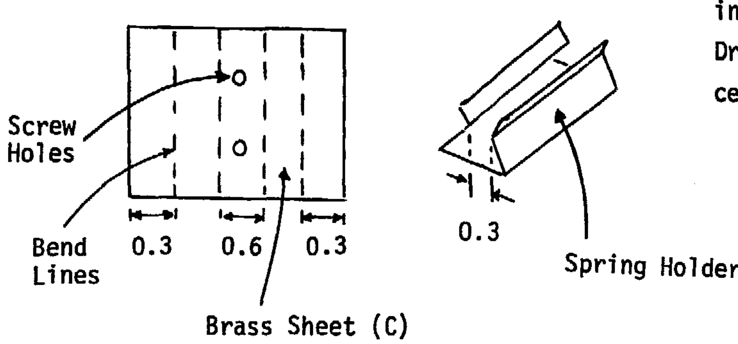
(2) Multipurpose Coils

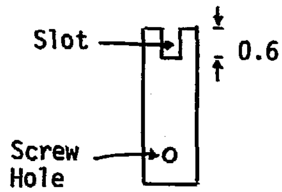
Make two Multipurpose Coils (B), complete with pole heads, as described under IX/A2. Cut a horizontal groove in the front endpiece of each (just beneath the pole heads) to insure a good grip for the coil holders.



(3) Coil Holders

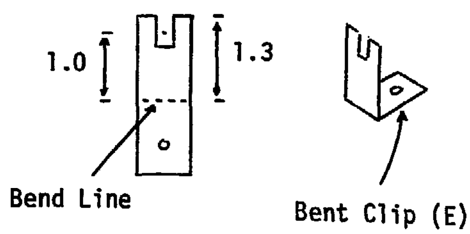
Bend the two brass sheets (C) into spring holders as indicated. Drill two screw holes in the center portion.





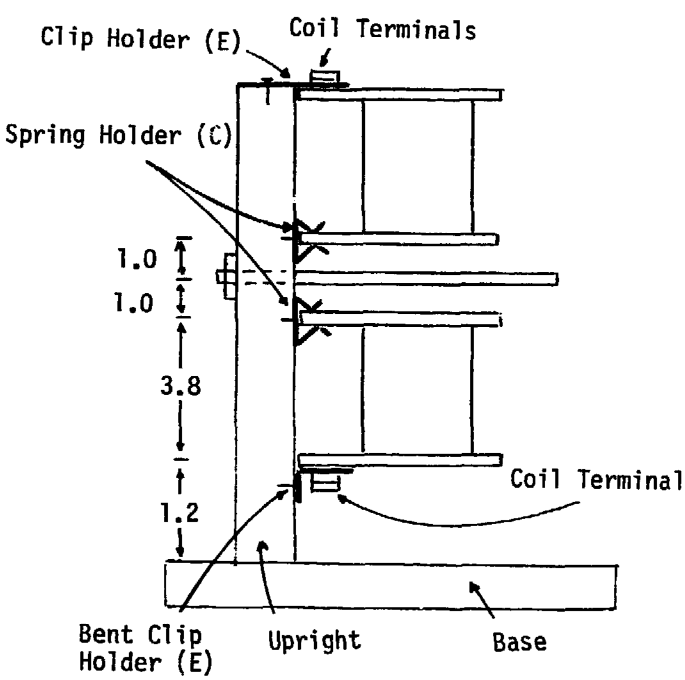
Clip Holder (E)

Cut a slot (0.7 cm x 0.3 cm) in the end of each of the brass sheets (E) and drill a screw hole in the other end, thus producing four clip holders.



Bend two of the holders at right angles to make L-shaped clips as follows.

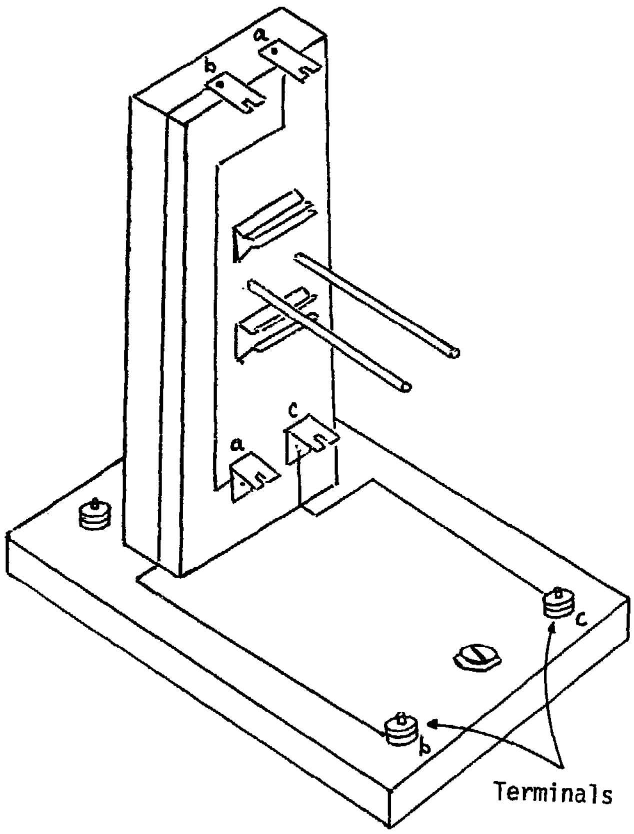
Measure the distance from the center of the coil terminal to the upright. Let's say this is 1 cm. Then the clips must be bent at right angles at 1.3 cm from the slotted end. Fit the slotted end of each clip holder under the locking nut of a terminal on the lower coil, and use screws (F) to attach the clips to the upright.



Use screws (D) to attach the spring holders horizontally to the upright of the apparatus, 1 cm above, and 1 cm below, the horizontal rods. Clip the multipurpose coils temporarily in the spring holders, and mark out the positions of the free endpieces of the coils.

Cut the top off the upright, so that it is level with the top of the upper coil. Take two clips, and fasten the slotted end of each under the locking nut of a terminal on the top end of the coil. Then holding the coil close to the upright, attach the

(4) Terminals



clips to it with small screws (F).

Use bolts (G) and nuts (H) to make two terminals, as described under VIII/A2, Component (4). Attach them to the front of the base. Finally connect the terminals and coil holders by magnet wire (I) so that electrical connections exist between points a to a, b to b, and c to c (see diagram), thus insuring that current will flow through the multipurpose coils in the same direction once the terminals at the front of the base are connected into a circuit.

c. Notes

(i) The apparatus may be used to study the relationship between the force exerted on a current carrying conductor and the magnetic field surrounding the conductor. For this purpose a suitable magnetic field may be created by connecting two dry cells (1.5 volts each) and a torch bulb in series with the multipurpose coils. A strong current may be passed through the lightweight roller by momentarily connecting three dry cells in series with the terminals leading to the horizontal rods. Under such conditions the roller will be propelled along the rods.

X. GALVANOMETERS

A. ELEMENTARY GALVANOMETERS

These are extremely simple instruments which illustrate the elementary principles of galvanometry. They may be used as simple measuring devices, but are not designed for accuracy of measurement.

B. FUNCTIONAL TANGENT GALVANOMETERS

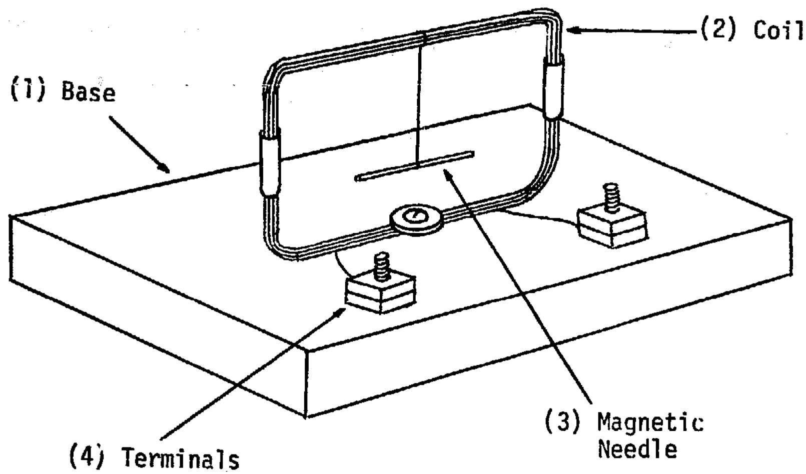
These instruments are probably the most suitable for general use in the school laboratory. They are simple to make and more durable than moving coil galvanometers. In addition, they are surprisingly sensitive, and with the help of shunts may be used for a multiple range of measurements.

C. FUNCTIONAL MOVING COIL GALVANOMETERS

These instruments are quite sensitive, and with the help of shunts may be used for a multiple range of measurements.

A. ELEMENTARY GALVANOMETERS

A1. Elementary Tangent Galvanometer



a. Materials Required

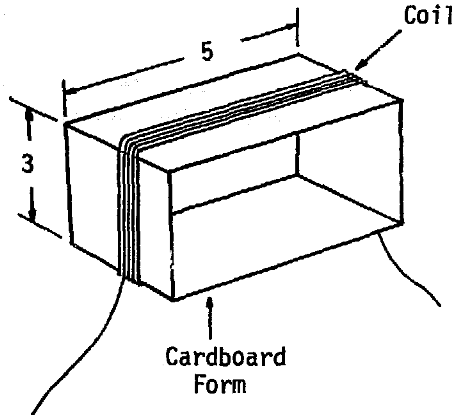
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	7 cm x 7 cm x 1 cm
(2) Coil	1	Magnet Wire (B)	#26, 400 cm long
	--	Masking Tape (C)	--
	1	Screw (D)	1 cm long
	1	Washer (E)	--
(3) Magnetic Needle	1	Needle (F)	0.1 cm diameter
	1	Cotton Thread (G)	5 cm long
(4) Terminals	2	Bolts (H)	0.3 cm diameter, 2.5 cm long
	4	Nuts (I)	0.3 cm internal diameter

b. Construction

(1) Base

Make the base out of wood (A).

(2) Coil



Wind 20 turns of the magnet wire (B) around a cardboard form to make a rectangular coil (5 cm x 3 cm), leaving about 5 cm of free wire at either end of the coil.

Remove the coil from the form, and wrap sufficient masking tape (C) around the coil to insure that it maintains its shape. Then separate the windings slightly on the bottom side of the coil, mount the coil on the base with the help of a washer (E) and a screw (D) passed through the separated windings.

(3) Magnetic Needle

Magnetize a needle (F) with the help of a magnetizing coil (IX/A1). Cut off about 4 cm of the needle, and suspend it horizontally at the middle of the coil by means of a cotton thread (G) attached to the top of the coil.

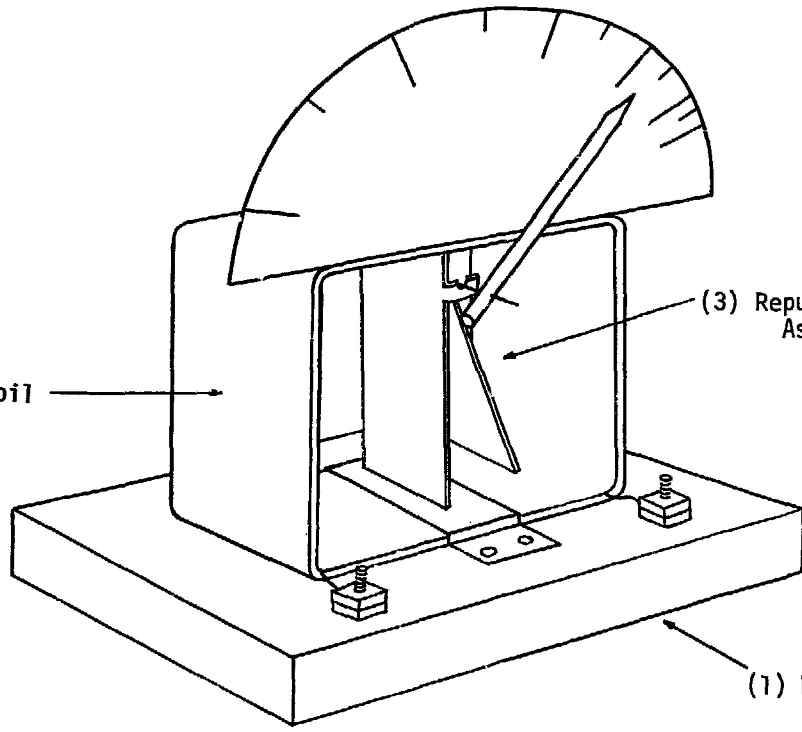
(4) Terminals

Use the bolts (H) and nuts (I) to make two terminals in the base as described under item VIII/A2, Component (4). Clean the ends of the coil wire with sandpaper, and fasten the wires to the terminals.

c. Notes

(i) Prior to using this apparatus it should be set so that the needle is suspended in the plane of the coil. A current passed through the coil will cause the needle to be deflected away from the plane of the coil, the deflection depending on the magnitude of the current carried by the coil. The apparatus simply illustrates the principle of the tangent galvanometer, and is too crude for specific measurements.

A2. Repulsion Type Galvanometer



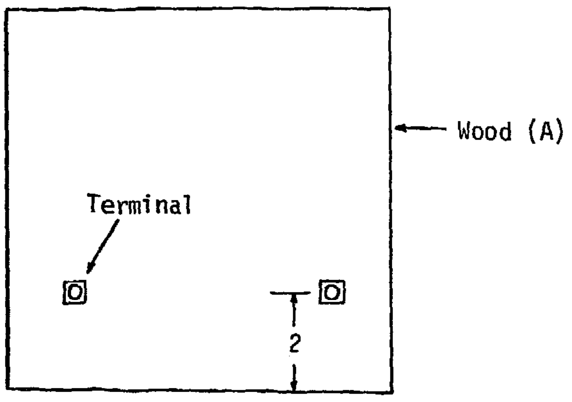
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	10 cm x 10 cm x 1 cm
	2	Bolts (B)	0.3 cm diameter, 2.5 cm long
	4	Nuts (C)	0.3 cm internal diameter
(2) Coil	1	Cardboard Sheet (D)	20 cm x 3.5 cm
	--	Masking Tape (E)	--
	1	Roll of Magnet Wire (F)	#26, (diameter 0.05 cm), 30 meters long
	1	Aluminum Sheet (G)	7 cm x 4 cm x 0.02 cm
	4	Screws (H)	1 cm long
(3) Repulsion Vane Assembly	1	Galvanized Iron Sheet (I)	7 cm x 3.5 cm x 0.02 cm
	1	Galvanized Iron Sheet (J)	4.3 cm x 2.5 cm x 0.02 cm
	1	Needle (K)	8 cm long, 0.1 cm diameter
	--	Masking Tape (L)	--

1	Soda Straw (M)	--
1	Cardboard Sheet (N)	12 cm x 12 cm

b. Construction

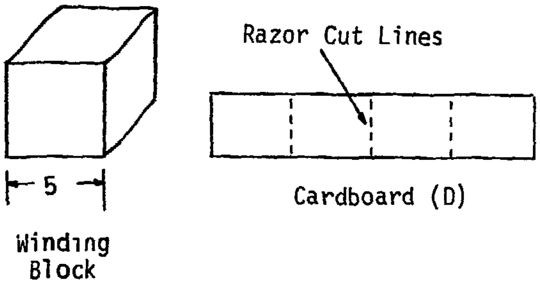
(1) Base



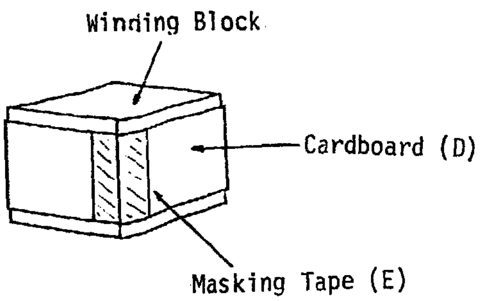
Top View

Make two terminals from bolts (B) and nuts (C) [as described under VIII/A2, Component (4)] and attach them at about 2 cm from the edge of the wood (A). The boltheads of the terminals should be countersunk into the base, so that the latter sits flat on any horizontal surface.

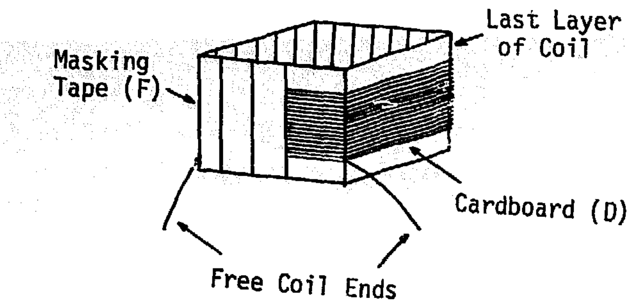
(2) Coil



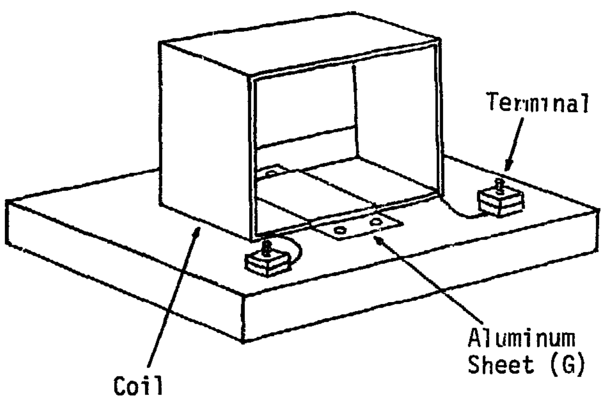
Cut a piece of wood (5 cm x 5 cm x 5 cm) to serve as a winding block for the coil. Use a razor blade to score parallel lines on the cardboard (D) at 5 cm intervals so that it may be readily bent into the shape of the wooden block.



Wrap the cardboard loosely around the block fastening the two loose edges together with masking tape (E).

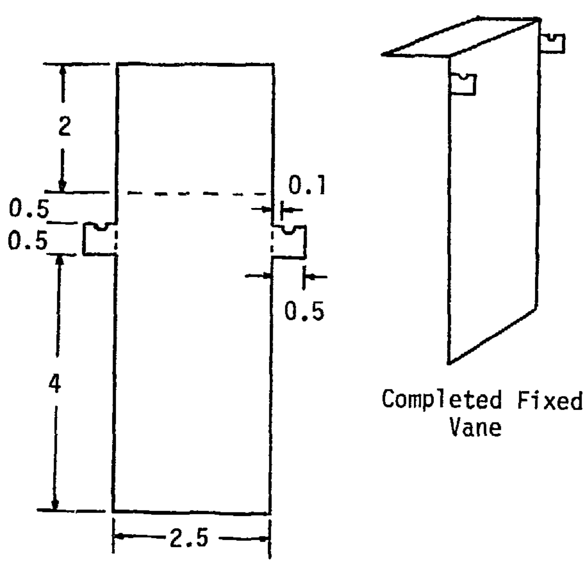


Wind approximately 150 turns of the magnet wire (F) onto the cardboard form. This will take three layers of turns. After winding the turns, remove the cardboard holder (and turns) from the winding block, and cover the turns with masking tape (E) to hold the wire in position. Make sure that about 10 cm of wire is free at both ends of the coil.

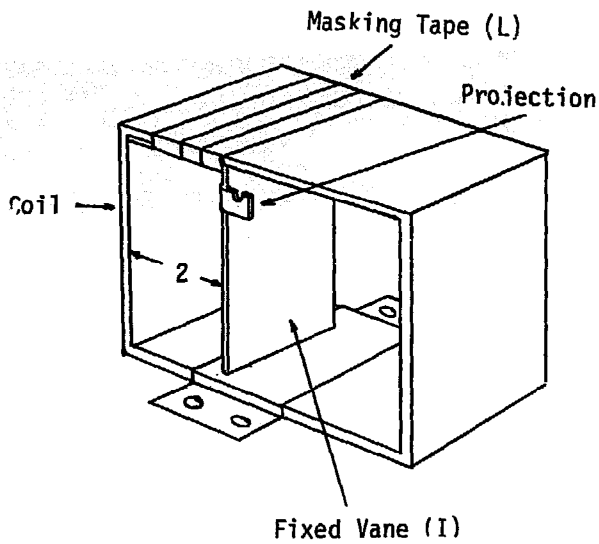


Drill two holes (diameter 0.2 cm) at either end of the aluminum sheet (G). Set the coil in a vertical plane on the base, and strap it in position with the help of the aluminum sheet (G) and four screws (H). Bare the ends of the wire, and attach them to the terminals on the base.

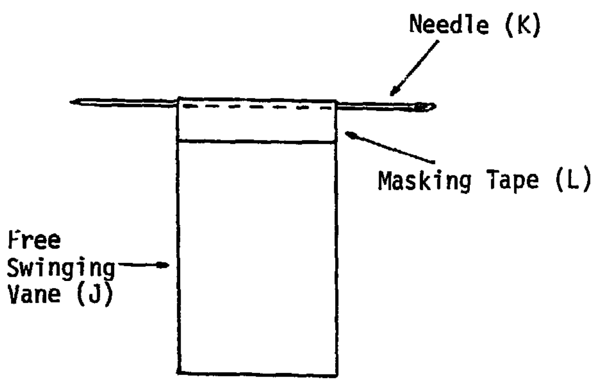
(3) Repulsion Vane Assembly



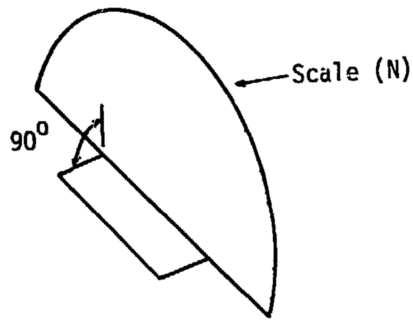
Two vanes are required, one fixed and one free swinging. The fixed vane may be cut from a sheet of galvanized iron (I) according to the dimensions indicated. The cut sheet resembles a vertical cross. Drill a hole (0.2 cm diameter) in the top edge of each of the horizontal portions of the cross (see illustration). Then bend the sheet at right angles along the lines indicated.



The completed vane may then be fixed vertically in position within the coil by wrapping masking tape (L) around the top of the coil, covering the horizontal portion of the fixed vane in the process.

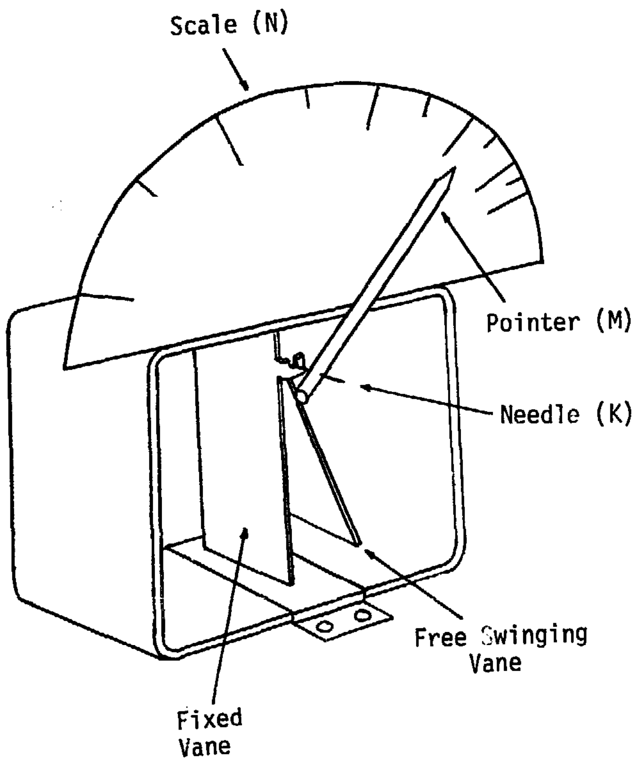


The free swinging vane is made from the other sheet of galvanized iron (J) and suspended from the middle of the needle (K) by wrapping a piece of masking tape (L) over the end of the vane. Suspend the vane from the projections on the fixed vane.



Back View

Make a pointer from the straw (M), and pivot it on the needle (K) at about 2 cm from the end of the straw. Make the scale from the cardboard (N), bending the bottom of the scale at right angles to form a horizontal flap. Use masking tape to attach the flap (and hence the scale) to the top of the coil.



c. Notes

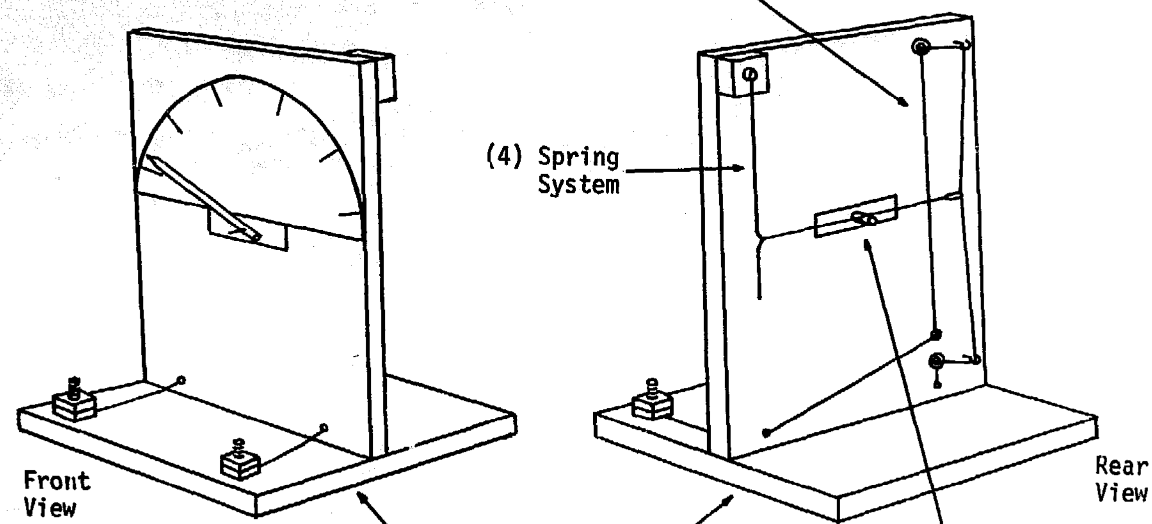
(i) The galvanometer may be calibrated by placing it in series with an ammeter (0 - 5 amps), a voltage supply (dry cells, battery, etc.) and a variable resistance.

(ii) The resulting scale will be nonuniform, the separation of points on the scale increasing with increasing amperage. The range of the scale for this particular design will be approximately 0 to 3 amps (DC).

(iii) The galvanometer will measure both DC and AC current equally well, since the repulsion of the vanes is independent of the direction of the current in the coil.

(iv) The resistance of the galvanometer is approximately 2.5 ohms. The current existing in a circuit will therefore be affected in general by the addition of the galvanometer to the circuit.

A3. Hot Wire Ammeter



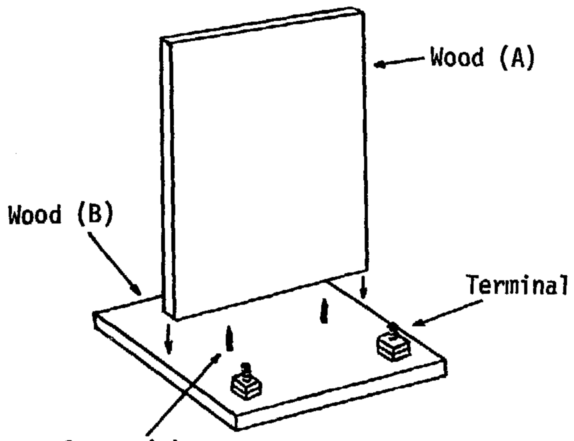
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Support	1	Wood (A)	20 cm x 12 cm x 2 cm
	1	Wood (B)	12 cm x 12 cm x 2 cm
	2	Screws (C)	3 cm long
	2	Bolts (D)	0.3 cm diameter, 3.5 cm long
	4	Nuts (E)	0.3 cm internal diameter
(2) Pulley System	2	Aluminum Sheets (F)	5 cm x 2 cm x 0.05 cm
	4	Screws (G)	1 cm long
	1	Needle (H)	5 cm long, 0.1 cm diameter
	1	Wooden Dowel (I)	0.5 cm diameter, 1 cm long
	1	Soda Straw (J)	--
	1	Cardboard Sheet (K)	12 cm x 6 cm
(3) Wiring	2	Eye Screws (L)	--
	3	Wood Screws (M)	1.5 cm long
	2	Washers (N)	--
	1	Nichrome Wire (O)	#30, 22 cm long, 0.02 cm diameter

	1	Copper Wire (P)	#24, 50 cm long
(4) Spring System	1	Wood (Q)	2 cm x 2 cm x 1 cm
	1	Steel Wire (R)	#16, diameter 0.12 cm, length 12 cm
	1	Screw (S)	1 cm long
	1	Thread (T)	10 cm long
	1	Paper Clip (U)	Approximately 1 cm long

b. Construction

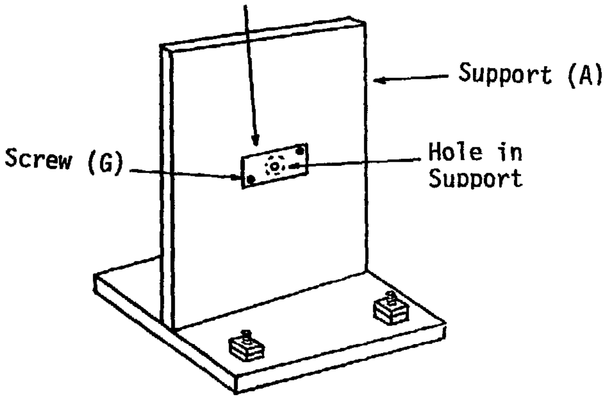
(1) Support



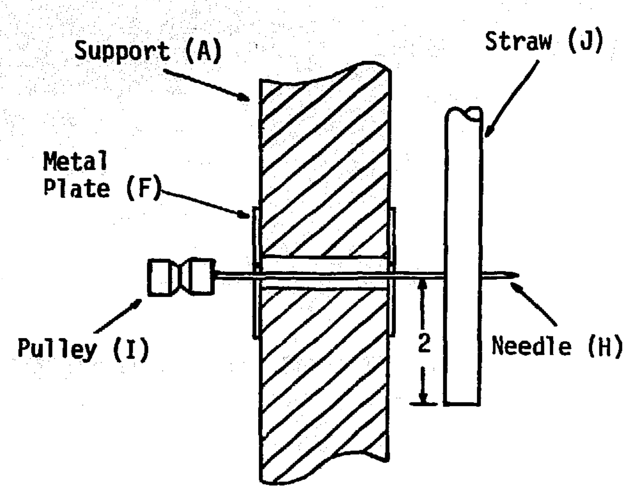
Attach the vertical component (A) to the middle of the base (B) with the help of screws (C) and wood cement.

Use the bolts (D) and nuts (E) to make two terminals [as described under VIII/A2, Component (4)] and attach these to the front of the base. The boltheads of the terminals should be countersunk into the bottom of the base (B) so that the latter sits flat on any horizontal surface.

(2) Pulley System



Drill a hole (diameter 0.5 cm) through the exact middle of the vertical component (A) of the support. Drill a hole (diameter 0.2 cm) through the center of each of the aluminum plates (F) to serve as pivot holes for the pointer. Drill two holes (diameter 0.2 cm) in diagonally opposite corners of each plate, so that the latter may be screwed onto either side of the support over the centrally drilled hole. The holes in the plates should be at the same height on both sides of



Cross Section

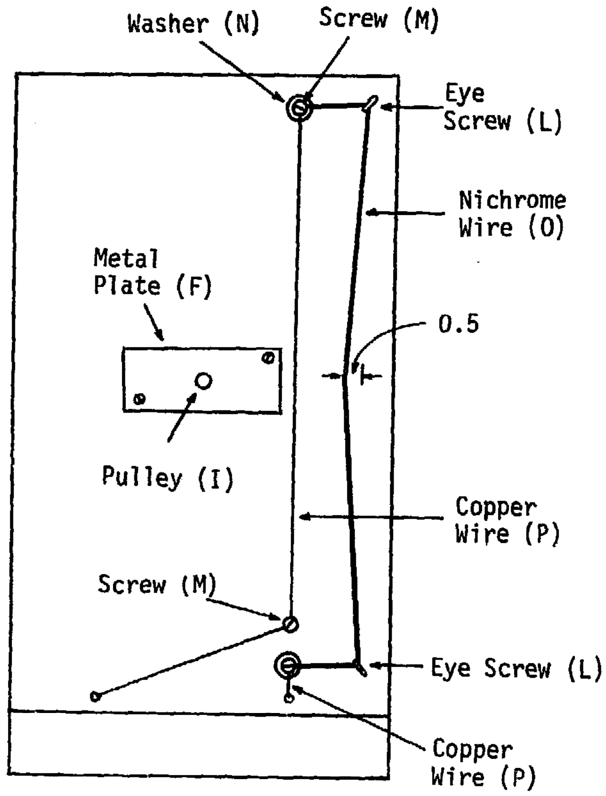
the support, so that the needle (H) may be pivoted horizontally through the holes.

Use a file and sandpaper to make a groove in the wood dowel (I) forming a pulley, thus preventing string from slipping off it. Drill a small hole in the end of the pulley (I) so that it may be slipped onto the end of the needle (H), and fix it firmly in position with the help of glue.

Make a pointer from the soda straw (J) and attach it to the needle about 2 cm from the end of the straw.

Cut a semicircular scale (diameter 12 cm) out of cardboard (K), and glue it to the vertical support behind the pointer.

(3) Wiring



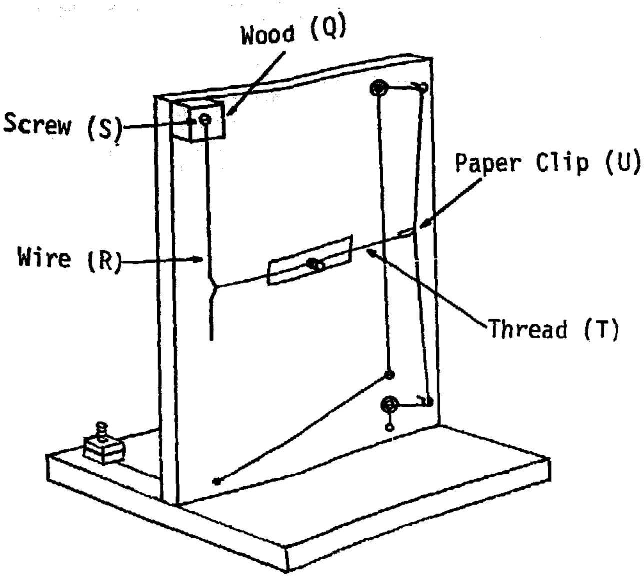
Back View

Fix two eye screws (L) into the rear right-hand side of the support. About 2 cm to the left of each eye screw fix a small wood screw (M) and a washer (N).

Connect the nichrome wire (O) from one wood screw, through both eye screws, to the other wood screw. The length of the wire should be adjusted so that it needs to be pulled about 0.5 cm from the vertical, at its center point, in order to make it completely taut.

Drill two holes in the vertical component of the support to carry electrical wire from the rear of the support to the front. Make one hole (0.2 cm diameter) through the support about 1 cm beneath the bottom wood screw and a second hole at the same height, but on the left side of the support. Connect a length of copper wire (P) from the lower wood screw, through the nearest hole in the support, to the nearest terminal at the front of the base. Connect a second length of wire (P) from the upper wood screw, through the second drill hole, to the remaining terminal. It is convenient to keep the second copper wire away from the middle of the support and the pulley system, with the help of a third wood screw (M).

(4) Spring System



Back View

Attach the small wood block (Q) to the rear of the support at the top left-hand corner. Insert a screw (S) into the block and fasten the end of a length of steel wire (R) between the screw and block so that the wire is held rigidly in a vertical position, thus serving as a spring.

Attach the thread (T) at one end to the middle of the hot wire (O) with the help of a small paper clip (U). Wrap the thread around the pulley (I) once, and then tie the free end onto the spring wire (R). In order to do this make a small kink in the steel wire at the point of attachment of the thread, thus preventing the latter from slipping, and during the tying of the thread, make sure that the spring wire is pulled towards the hot wire. This insures that the thread is always under tension, and that the pulley (and hence pointer) responds readily to any movement of the hot wire.

c. Notes

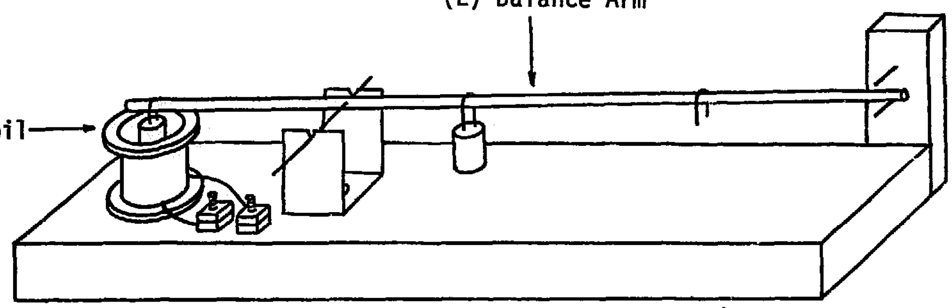
(i) The galvanometer may be calibrated by placing it in series with an ammeter (0 - 5 amps), a voltage supply (dry cells, battery, etc.) and a variable resistance.

(ii) The resulting scale will be nonuniform, the separation of points on the scale increasing with increasing amperage. The range of the scale for this particular design will be approximately 0 to 1.5 amps (DC).

(iii) The galvanometer will measure both DC and AC current equally well, since the extension of the hot wire (and hence the movement of the pointer) is dependent on the heating of the wire, which in turn is proportional to the square of the current passing through the wire.

(iv) The resistance of this galvanometer is approximately 4.5 ohms.

A4. Current Balance

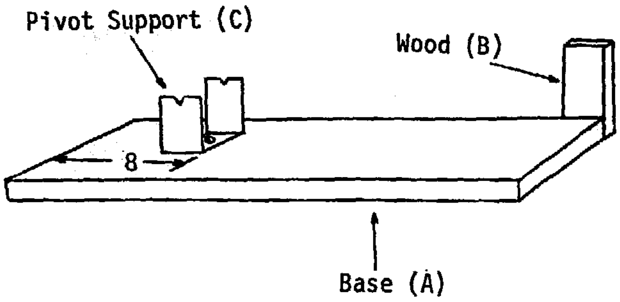


a. Materials Required

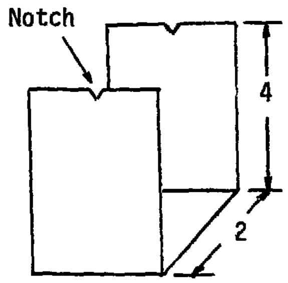
Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	22 cm x 5 cm x 2 cm
	1	Wood Strip (B)	6 cm x 2 cm x 0.5 cm
	1	Aluminum Sheet (C)	10 cm x 2 cm x 0.05 cm
	1	Screw (D)	1 cm long
(2) Balance Arm	1	Needle (E)	4 cm long, 0.1 cm diameter
	1	Soda Straw (F)	21 cm long, approximately
	1	Nail (G)	0.4 cm diameter
	1	Magnet Wire (H)	#30, 10 cm long
	--	Masking Tape (I)	--
	2	Pins (J)	--
(3) Coil	1	Sheet of Paper (K)	10 cm x 2 cm
	.1	Cardboard Sheet (L)	2 cm x 2 cm
	1	Magnet Wire (M)	#22, 400 cm long
	--	Masking Tape (N)	--
	2	Bolts (O)	0.3 cm diameter, 3.5 cm long
	4	Nuts (P)	0.3 cm internal diameter

b. Construction

(1) Base



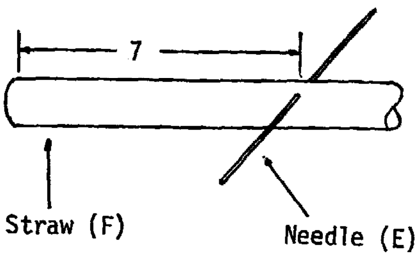
Fasten an upright piece of wood (B) to the rear of the base (A), and to one side. Make a pivot support from the sheet of aluminum (C). Drill a hole (diameter 0.2 cm) in the middle of the horizontal portion of the support, and attach it to the base with the screw (D).



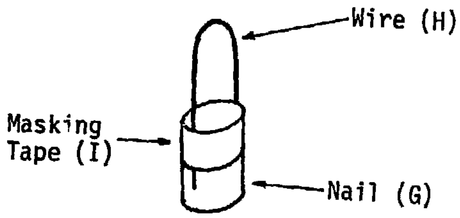
Pivot Support (C)

Using a small file cut a shallow, smooth notch in the top of each side of the support to hold a subsequent needle pivot in position.

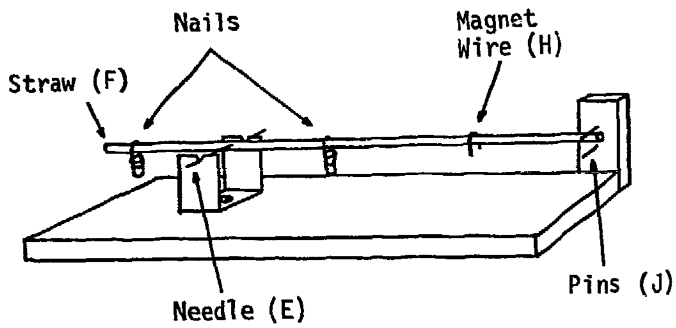
(2) Balance Arm



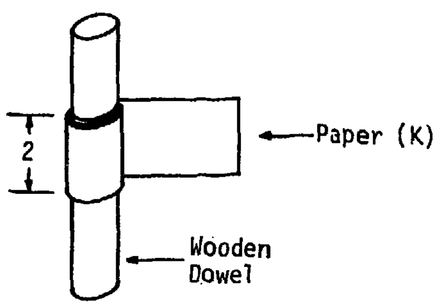
Insert the needle (E) through the top edge of soda straw (F) at a distance of 7 cm from one end. Balance the straw on the support.

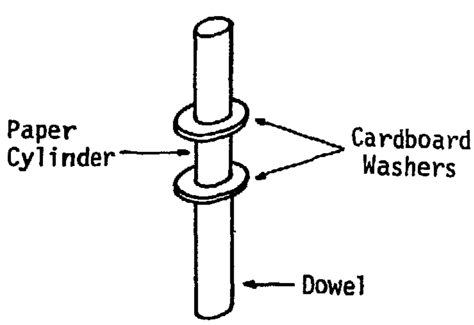


Cut two lengths from the nail (G), one 1.0 cm long and one 2.0 cm long. Attach a three centimeter-long loop of the magnet wire (H) to the end of each nail with the help of a strip of masking tape (I). Hang



(3) Coil





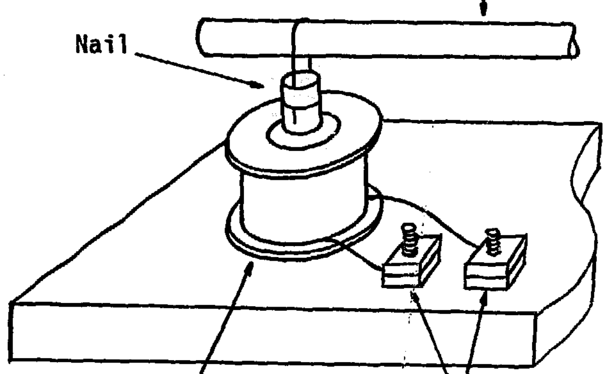
the short nail at the end of the short arm of the straw, and hang the long nail at an appropriate point on the other side of the pivot to serve as a counter-balance. A drop of glue (or a small piece of masking tape) can insure that the loops do not slip along the straw.

With the straw balanced horizontally note the corresponding point on the upright (B). Insert two pins (J) horizontally into the upright, one pin 0.5 cm above the top surface of the balanced straw, and the other 0.5 cm below the bottom surface, thus restricting the motion of the end of the straw to about 1 cm.

Set a length of magnet wire (M) on the straw to serve as a rider (see notes).

Wrap the paper (K) around a wooden dowel (1.0 cm diameter) to make a paper cylinder. Secure the loose ends of the paper with masking tape (N).

Cut two washers (internal diameter 1.0 cm, external diameter 2.0 cm) from the sheets of cardboard (L). Attach the washers to the ends of the paper cylinder with glue.



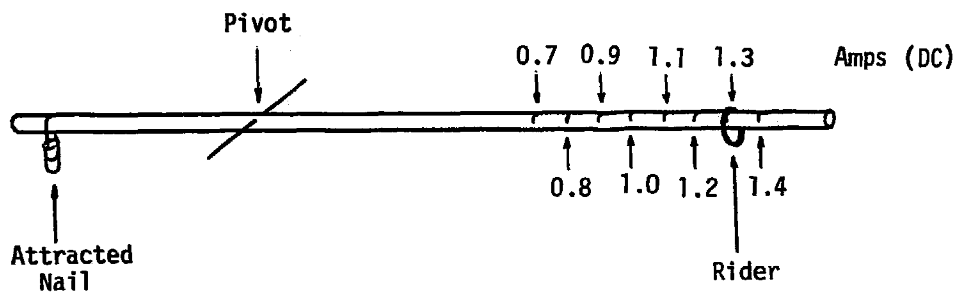
Wind the magnet wire (M) onto the paper cylinder to make a coil. Leave 10 cm of wire free at either end. Cover the last layer of wire with masking tape (N) to hold the coil in position. Remove the coil from the dowel, and mount it on the end of the base with glue in such a way that the axis of the coil is directly beneath the nail suspended from the end of the straw balance arm.

Drill two holes (diameter 0.3 cm) in the base at any convenient point close to the coil, and make two terminals from the nuts (P) and bolts (O) as described under VIII/A2, Component (4). Fit the terminals in the two holes, and connect the wires from the coil to the terminals.

c. Notes

(i) The galvanometer may be calibrated by placing it in series with an ammeter, a voltage supply and a variable resistance, noting the position of the rider each time the straw balance arm is balanced and noting simultaneously the corresponding current through the coil.

(ii) A whole range of different scales may be produced simply by changing the mass of the rider on the balance arm. One such scale is illustrated below when the rider used was a 25 cm length of #26 magnet wire coiled into a loop, approximately 1 cm diameter.

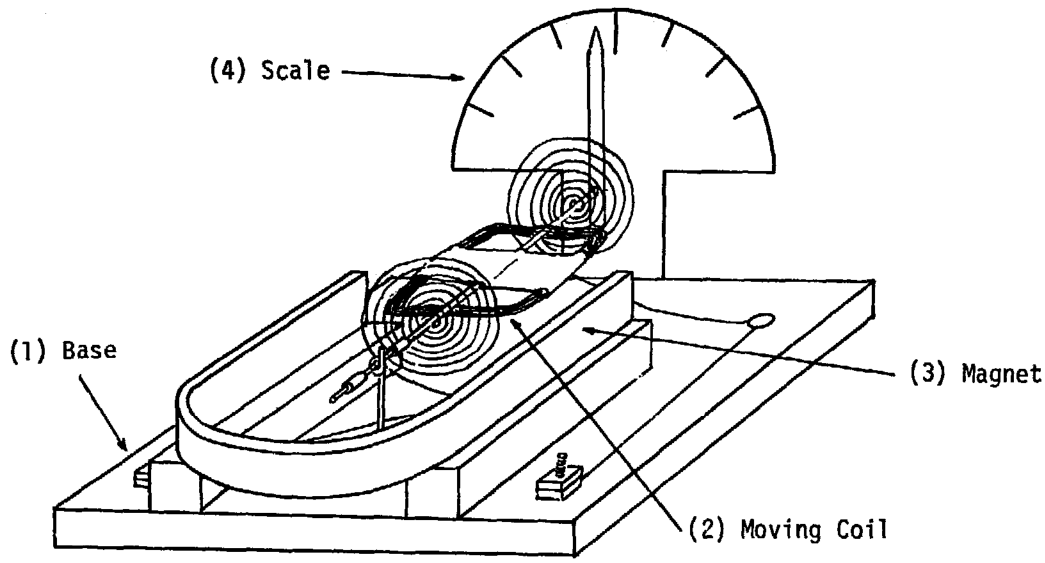


(iii) The resultant scale on the straw is linear. In other words, doubling the current passing through the coil doubles the force exerted by the coil on the nail, and the distance between the rider and pivot must be doubled to reestablish the balance of the straw.

(iv) The galvanometer will measure AC and DC currents equally well since the direction of the attraction exerted by the coil is not dependent on the direction of the current through the coil.

(v) The resistance of the galvanometer is approximately 0.1 ohms.

A5. Elementary Moving Coil Galvonometer



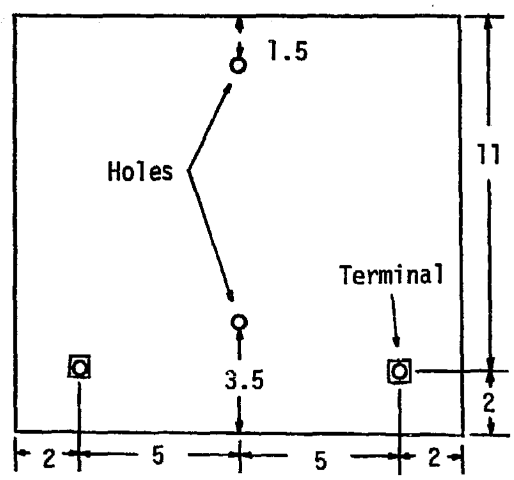
a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	14 cm x 13 cm x 1.5 cm
	2	Bolts (B)	0.3 cm diameter, 3.0 cm long
	4	Nuts (C)	0.3 cm internal diameter
	2	Coat Hanger Wire (D)	7 cm long, 0.2 cm diameter
(2) Moving Coil	1	Roll of Magnet Wire (E)	#26
	1	Coat Hanger Wire (F)	10 cm long, 0.2 cm diameter
	1	Masking Tape (G)	--
	2	Thumbtacks (H)	--
(3) Magnet	1	Horseshoe Magnet (I)	--
	2	Wood Strips (J)	Approximately 8 cm x 1.5 cm x 1.0 cm
(4) Scale	1	Straw (K)	6 cm long
	1	Cardboard Sheet (L)	10 cm x 10 cm

b. Construction

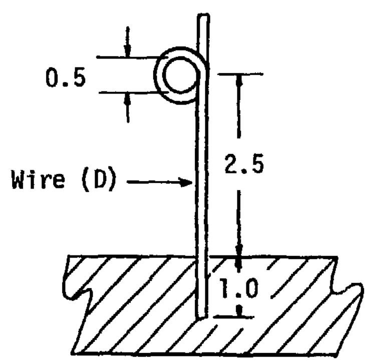
(1) Base

Make two terminals [see VIII/A2, Component (4)] from the nuts (C) and bolts (B), making sure to inset the boltheads into the bottom of the wood (A). Drill two holes (0.2 cm diameter, 1.0 cm deep) into the base to hold the vertical supports.



Wood (A)

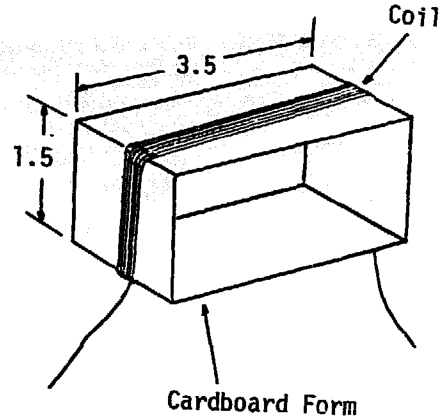
Make two vertical supports for the coil by twisting the coat hanger wire (D) into the shape indicated. Set the supports vertically upright in the newly drilled holes in the base.



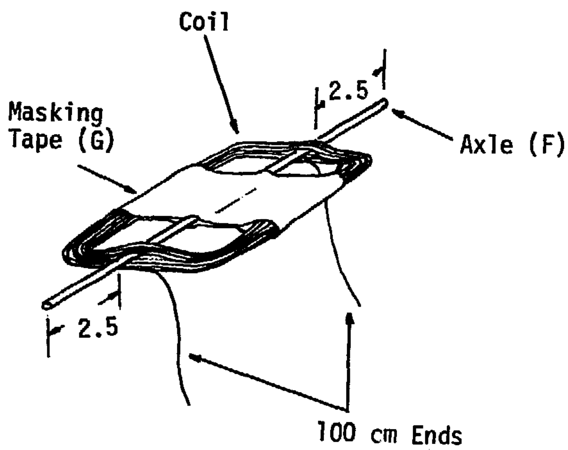
Side View

(Cross-section)

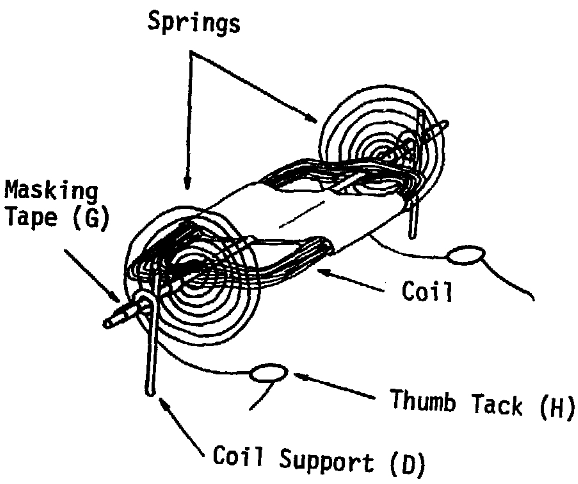
(2) Moving Coil



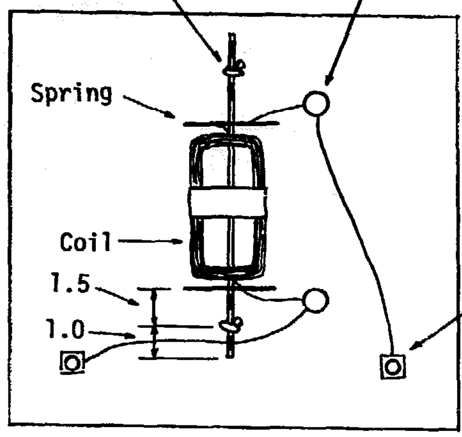
Wind 30 turns of magnet wire (E) around a cardboard form in order to make a coil of internal size 3.5 cm x 1.5 cm. Leave 100 cm of wire free at either end of the coil.



Thread the wire (F) through the middle of the coil to serve as the axle for the coil. Wrap masking tape (G) around the coil and axle to hold the coil firmly in position.



Fit the coil (F) into the coil supports (D) on the base. Wind the 100 cm of magnet wire (E) at either end of the coil into a spring, and attach the wire, just beneath each spring, to the base with the help of a thumb-tack (H). Each spring should contain about eight turns and be about 3 cm in diameter.



Top View

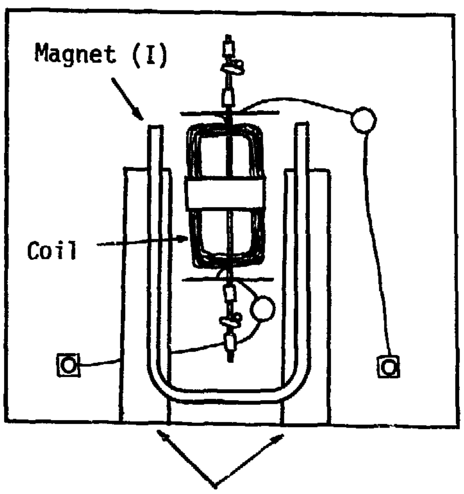
(The sensitivity of the moving coil increases with increasing number of turns and increasing diameter of the spring.) Connect the wire from the springs to the terminals on the base.

Prevent slipping of the axle on the supports by wrapping masking tape (G) around the axle either side of one of the supports.

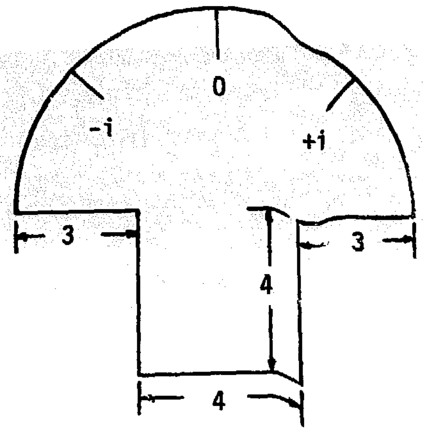
(3) Magnet

Procure a horeseshoe magnet (I) with pole heads at least 4 cm apart, and place it as shown around the coil. Make two wooden strips (J) which, when placed under the magnet, will bring the pole heads up to the same height as the coil. The ends of the magnet should be located opposite the middle of the coil.

Top View



(4) Scale



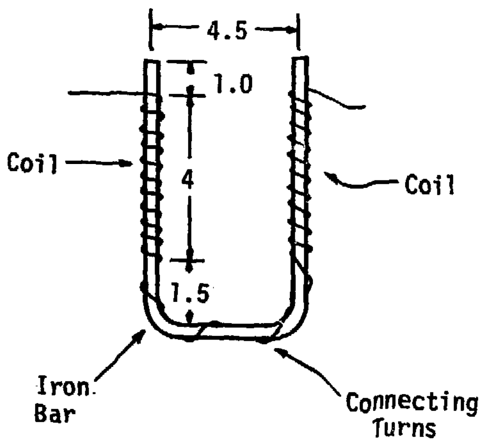
Take the straw (K) and, after piercing it 1 cm from one end, fit it on the end of the axle. A little glue will fix it firmly in position. Cut a suitable scale out of cardboard (L), and attach it to the base, so that it stands just behind the pointer.

c. Notes

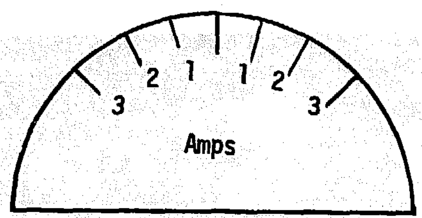
(i) The galvanometer may be calibrated by placing it in series with an ammeter, a voltage source and a variable resistance. The sensitivity of the galvanometer will depend very much on the strength of the horseshoe magnet used.

(ii) The galvanometer will measure DC current, but not AC.

(iii) If a suitable horseshoe magnet is not available, an electromagnet may readily be made. To do this, take a soft iron bar (17.5 cm x 2.0 cm x 0.3 cm), and bend it into a horseshoe shape as indicated. Take about 100 g of #26 magnet wire, and wind a coil on each side of the U-shaped bar. Each coil should be about 4 cm long, and should contain ten layers of wire. The coils should be connected in series to one another, simply by continuing the windings in the same direction around the bar from one coil to the other in a series of widely spaced connecting turns. The coils may be held in position by means of masking tape. If the coil is connected in series into a separate electrical circuit, it may be used in precisely the same way as the former horseshoe magnet.



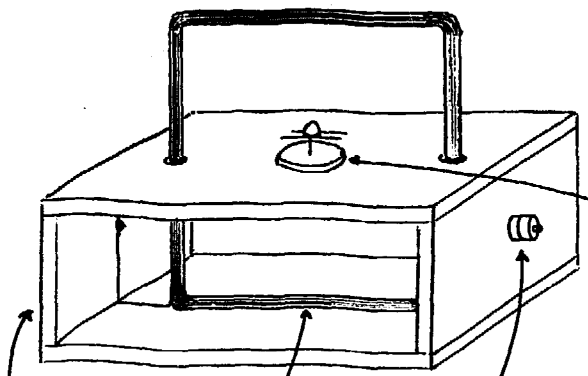
(iv) With a current of 0.5 amps through the electromagnet coils, a 2-amp current through the moving coil produced a deflection of approximately 30°. When the current through the electromagnet was increased to 1.0 amp, the deflection, due to a 3-amp current through the moving coil, increased to 45°.



Electiomagnet Current of Lamp

B. FUNCTIONAL TANGENT GALVANOMETERS

B1. Tangent Galvanometer ©



a. Materials Required

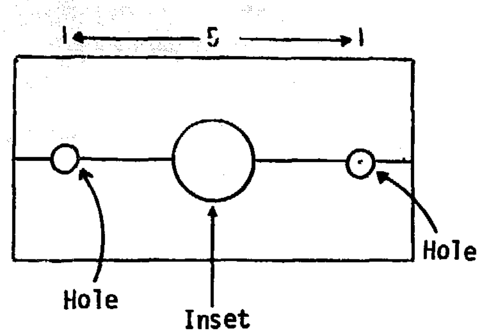
Components	Qu	Items Required	Dimensions
(1) Box Support	1	Wooden Base (A)	12 cm x 6 cm x 1 cm
	2	Wooden Sides (B)	6 cm x 2 cm x 1 cm
	1	Wooden Platform (C)	12 cm x 6 cm x 1 cm
	18	Small Wood Screws (D)	1.5 cm long
(2) Coil	1	Roll of Magnet Wire (E)	#24
	--	Varnish (F)	--
(3) Terminals	2	Brass Bolts (G)	0.3 cm diameter, 2 cm long
	4	Nuts (H)	0.3 cm internal diameter
(4) Compass	1	Wood Disc (I)	2.5 cm diameter, 0.3 cm thick
	3	Needles (J)	0.1 cm diameter
	1	Brass Rod (K)	0.5 cm diameter, 0.5 cm long

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 143-145.

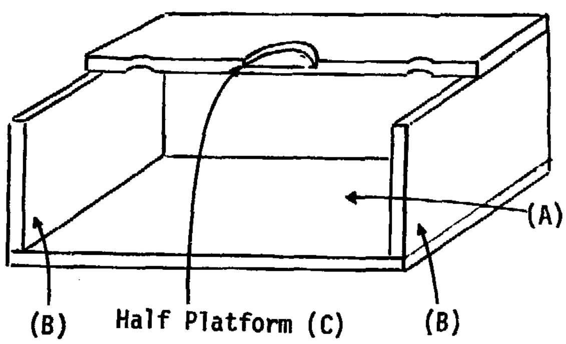
b. Construction

(1) Support

Make a four-sided wooden support from the wooden base (A), wooden sides (B) and platform (C). Fasten the base and sides together with small screws (D) and wood cement, but do not put the platform in position yet.

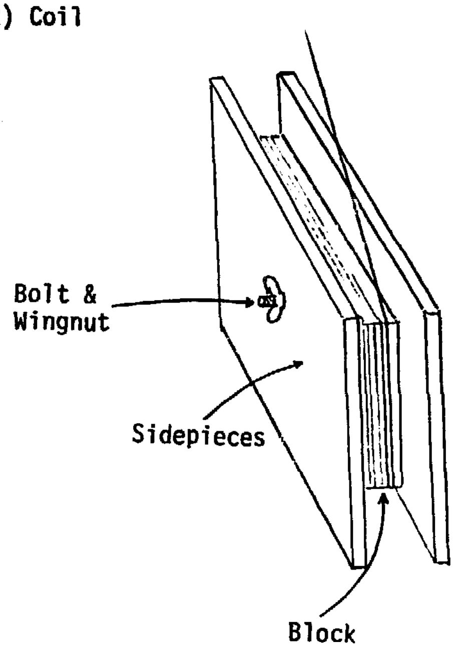


Drill an inset (2.5 cm diameter, 0.2 cm deep) into the middle of the platform, and two holes (1 cm diameter) right through the platform to take the coil. Cut the platform into two equal halves, fastening one half only in position with small screws and wood cement.

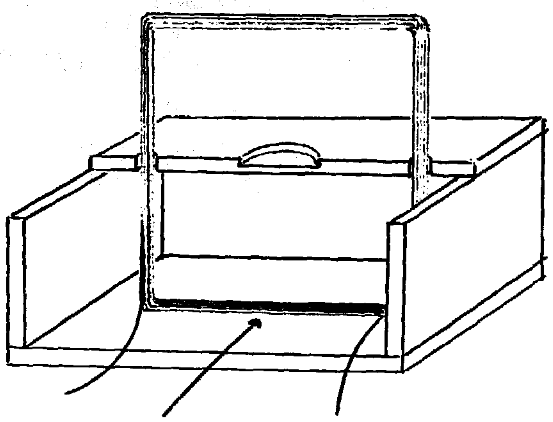


(2) Coil

To make the coil a simple winding device is desirable. This may be made from a block of wood (5 cm x 5 cm x 1 cm) and two cardboard sides (8 cm x 8 cm x 0.5 cm). Drill a hole through the middle of the block and sides and hold the parts together with a bolt and wing nut.



Wind 100 turns of magnet wire (E) onto the block, layer by layer, adding a coat of varnish (F) to each layer to hold the turns together. Make sure that about 20 cm of both ends of the



wire are left free to make appropriate connections.

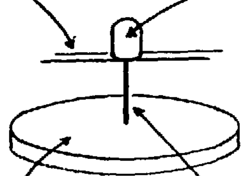
When the varnish is dry remove the coil from the block (simply by releasing the sides) and sit the coil vertically in the support.

Attach the second half of the platform with small wood screws and wood cement.

(3) Terminals

Use bolts (G) and nuts (H) to make two terminals as described under VIII/A2, Component (4). Fix one on either side of the support, and attach the two wires from the coil to the terminals. Don't forget to clean the ends of the wire with sandpaper.

(4) Compass

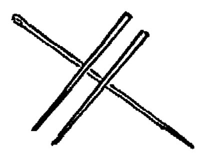


Use the wood disc (I) as the base of the compass. Alternatively, a cork disc would serve equally well, although less durable.

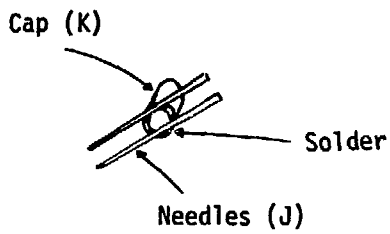
Cut a 1 cm length off the pointed end of a needle (J). Drill a small hole (0.1 cm diameter) in the middle of the base and set the needle in the hole with epoxy resin so that it stands vertically, pointed end uppermost.

Holding rod (K) firmly in a clamp, drill a hole (0.3 cm diameter) 0.3 cm deep along the axis. You now have a suitable cap to sit on the pivot.

Cut 2 cm lengths off the two remaining needles (J). Determine the center of gravity of each by balancing the needles over another needle. Mark in the position of the center of gravity of each of the two needles.



Hold the needles parallel to one another and drop some solder on the base of the cap. Immediately attach the needles (at their centers of gravity) to the cap by placing them in the still molten solder.



Finally, place the cap and needles inside a magnetizing coil (IX/A2) to magnetize them, and then place them on top of the pivot.

Note the ends of the needles which point to the North, and mark these (e.g., with paint).

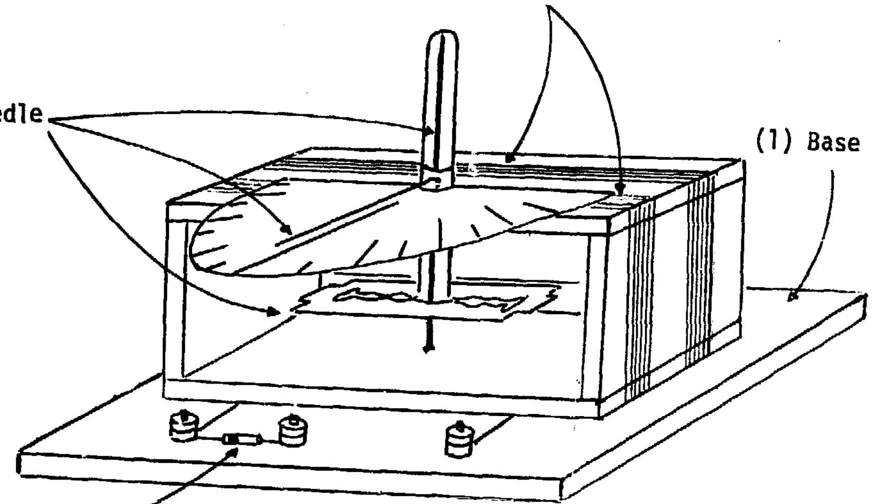
c. Notes

(i) The galvanometer should be set so that the plane of its coil is in a North-South direction, as indicated by the compass needle. A current passing through the coil will cause the needle to be deflected out of this plane, the angle of deflection depending on the strength of the current.

(ii) It is important that magnets and iron should be kept well away from the galvanometer during use to avoid influencing the compass needle.

(iii) The galvanometer will readily detect the differences in magnitude of currents produced by the various combinations of plates and electrolytes in the Chemical Cell (VIII/A1).

B2. Tangent Galvanometer with Shunts *



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Base	1	Wood (A)	10 cm x 10 cm x 1 cm
	2	Bolts (B)	0.3 cm diameter, 2.5 cm long
	4	Nuts (C)	0.3 cm internal diameter
(2) Coils	2	Wood (D)	8 cm x 5 cm x 0.5 cm
	2	Wood (E)	3 cm x 5 cm x 0.5 cm
	1	Magnet Wire (F)	#26 (diameter 0.05 cm), length approximately 16 meters
	--	Masking Tape (G)	--

*Adapted from Fr. George Schwarz, A Don Bosco Laboratory Manual, (Philippines: Unpublished Papers).

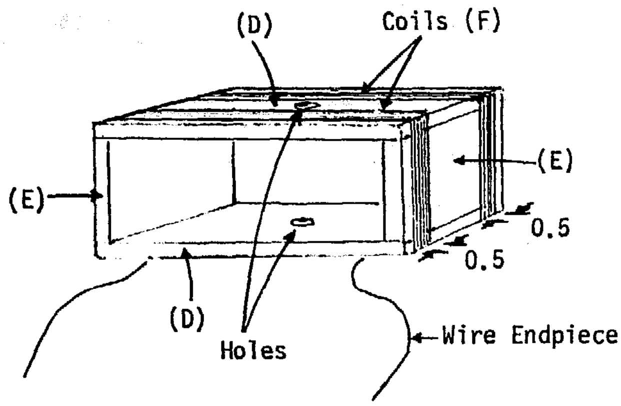
(3) Magnetic Needle Assembly	1	Needle (H)	10 cm long, 0.1 cm diameter
	1	Razor Blade with Double Edges (I)	--
	1	Glass Tube (J)	6 cm long, 0.5 cm external diameter
	2	Screws (K)	1.5 cm long
	1	Cardboard Sheet (L)	2.5 cm x 2.0 cm
	1	Pin (M)	2.5 cm long, approximately
	3	Cardboard Sheets (N)	8 cm x 4 cm
(4) Shunts	1	Nichrome Wire (O)	#24, 0.17 ohms (approximately 5 cm long)
	1	Resistor (P)	1,000 ohms (from radio shop)
	1	Bolt (Q)	0.3 cm diameter, 2.5 cm long
	1	Nut (R)	0.3 cm internal diameter

b. Construction

(1) Base

Drill two holes (diameter 0.3 cm) in Wood (A) about 3 cm apart and close to one edge to take the terminals. Use bolts (B) and nuts (C) to make two terminals as described under VIII/A2, Component (4), and fit them through the holes in the base. The boltheads should be countersunk into the bottom of the base so that the latter sits flat on any horizontal surface.

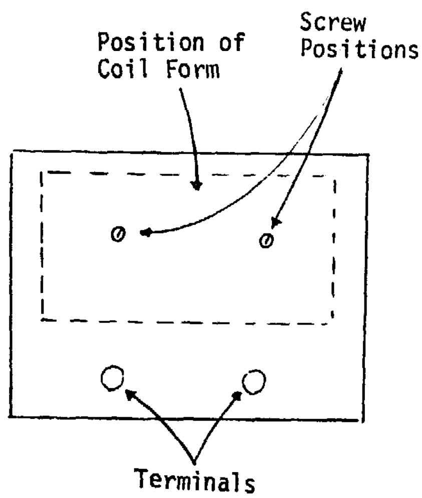
(2) Coils



Make a wooden form using wood (D) for the top and base and wood (E) for the side pieces. Glue the pieces together.

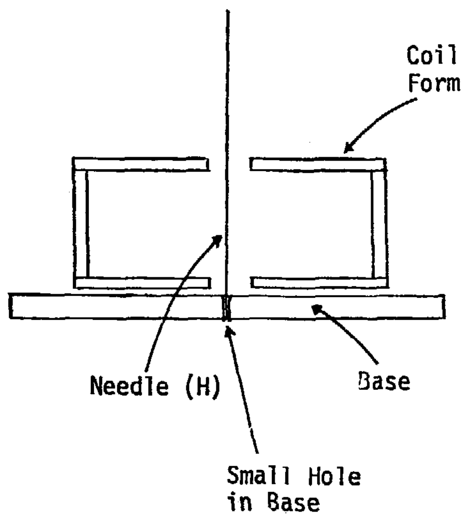
Drill a hole (1.0 cm diameter) in the middle of the top, and an identical hole (1.0 cm diameter) directly beneath in the middle of the base of the form.

Wind magnet wire (F) around the form to make two coils which are connected in series to one another, and which are wound in the same direction around the form. Wind 20 turns of wire into each coil, and locate these close to the opposite edges of the form. Make sure that about 10 cm of each end of the wire is left free. After winding the coils, cover the final layer of turns with a layer of masking tape (G) to hold the coils in position.

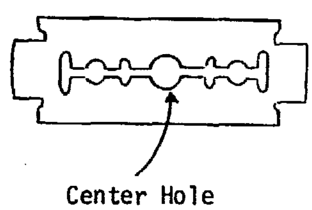


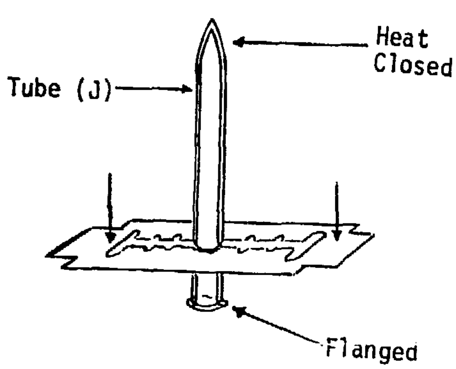
Drill two appropriate holes through the base in order to attach the coil form to the base with screws, but do not screw the form on to the base yet.

(3) Magnetic Needle Assembly

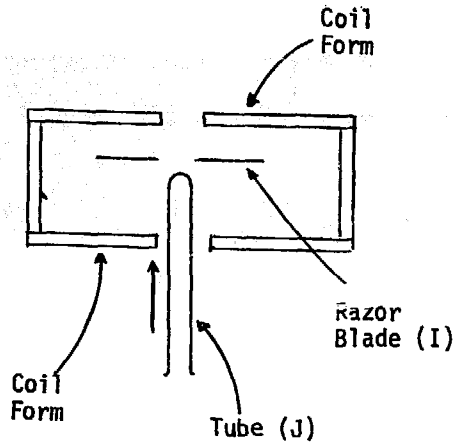


Drill a hole (0.1 cm diameter) in the base in the position that corresponds to center of the larger hole in the base of the coil form. Cut the end (containing the eye) off needle (H) to make it 8 cm long, and set the blunt end of the needle firmly in the hole in the base, so that it stands vertically with the point upwards. A little epoxy resin may be required to hold the needle firmly in the hole.

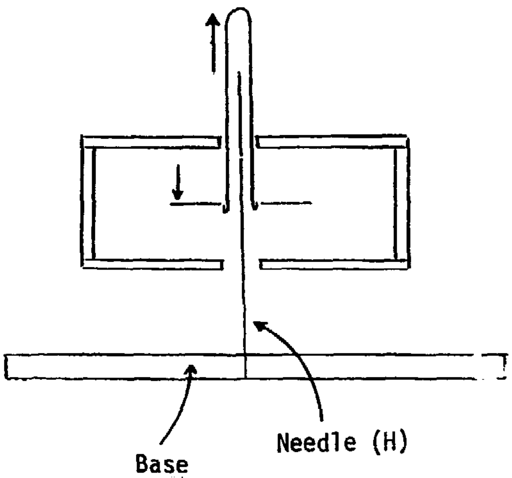




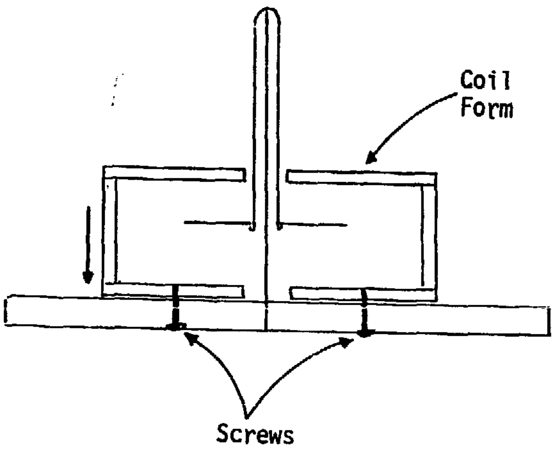
Take a double-edged razor blade (I) which contains a center hole, and magnetize it with the help of a magnetizing coil (IX/A1). Measure the size of the center hole (probably about 0.5 cm diameter), and take a glass tube (J) with the same external diameter as that of the center hole. Heat close (CHEM/I/D5) one end of the tube and create flanges (CHEM/I/D7) at the open end. The flanges on the tube will prevent the razor blade from slipping off the tube, so long as the latter is held in a vertical position.



To put the magnetic needle assembly together, hold the razor blade horizontally inside the coil form. Insert the glass tube through the base hole in the form, and then through the hole in the blade.

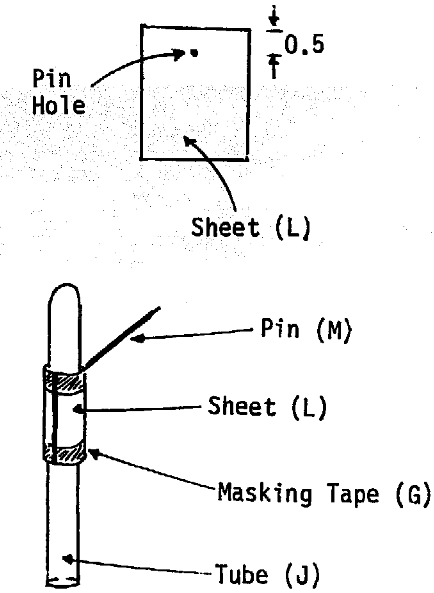


Lower the blade onto the flanges of the glass tube, and raise the tube partially through the upper hole in the form.



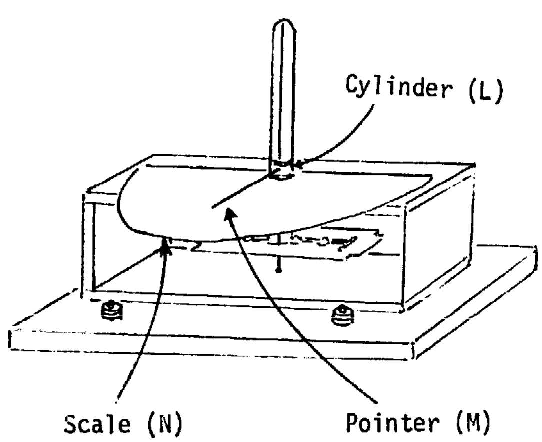
Lower the coil form and tube together onto the needle projecting vertically from the base. Take two screws (K) and firmly attach the base and coil form together.

Connect the loose wires from the coils to the terminals, making sure that all enamel has been removed from the wire ends.



Take the thin sheet of cardboard (L), and thrust pin (M) through the sheet at about 0.5 cm from the middle of the top edge. Bend the cardboard around the glass tube (J) to form a tight cylinder from which the full length of the pin will protrude. Fasten the free ends of the cardboard sheet together with masking tape wrapped around the cylindrical sheet.

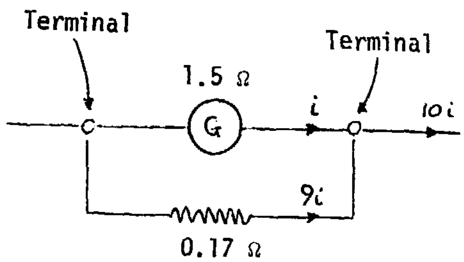
Lower the cardboard cylinder onto the tube until it touches the razor blade. The pin should clear the top of the form by about 0.5 cm, and will serve as a pointer to record the motion of the magnetized needle below.



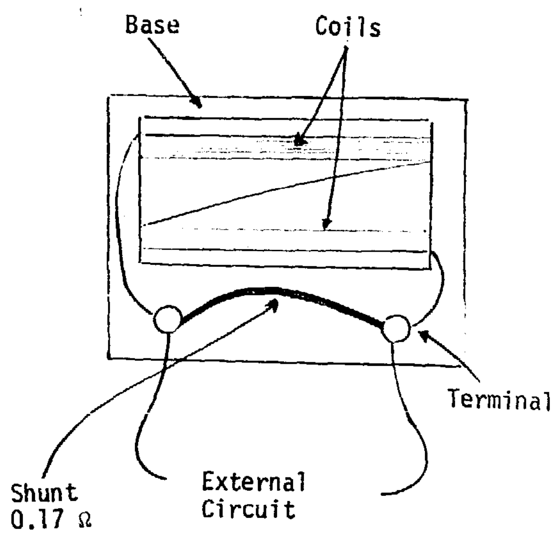
Cut a semicircular disc (diameter 8 cm) out of the cardboard sheet (N), and set it on top of the coil form to serve as a scale. Mark the position of the cardboard on top of the form, so that the cardboard scale may be replaced in exactly the same position whenever it is removed.

(4) Shunts

Set the plane of the galvanometer coils in a North-South direction so that the longitudinal, horizontal axis of the magnetized razor blade is in the same plane as that of the coils. The direction of the pointer should be set at 90° to this plane. Now calibrate the galvanometer by placing it in series with a milliammeter (0-100 milliamps), a voltage supply (dry cells, battery, etc.) and a variable resistance. The resultant scale will swing from the center zero position of the pointer through about 90°. If the direction of the current through the coil is reversed, a deflection (and hence scale) in the opposite direction will be obtained.



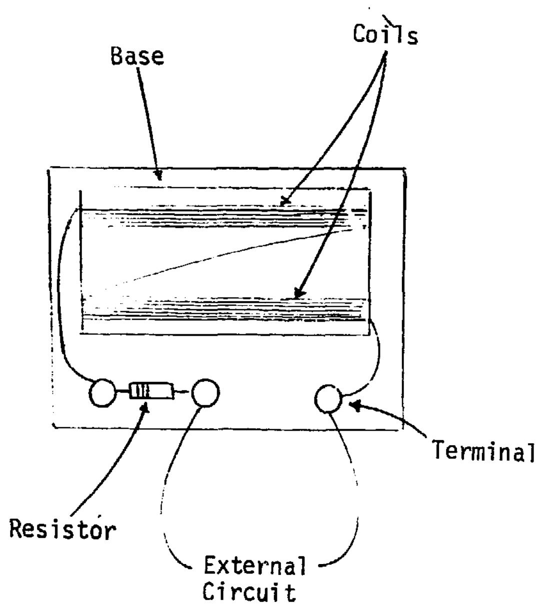
Take a suitable length of nichrome wire (0) and connect it across the galvanometer terminals. In this case, since the resistance of the galvanometer is 1.5 ohms a wire of resistance 0.17 ohms (5 cm of #24, U.S. Standard Plate guage, nichrome wire, 20% chrome, 80% nickel) would result in 1000 milliamps (1 amp) producing a full scale deflection instead of 100 milliamps doing this.

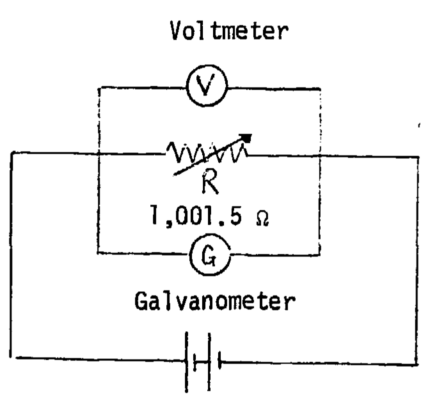


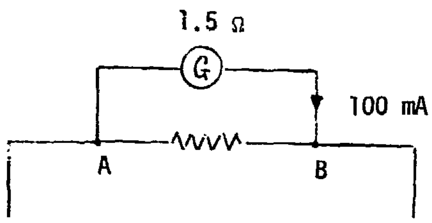
Top View

With the resistance wire across the terminals recalibrate the galvanometer in the usual way with a fresh cardboard sheet for a new scale.

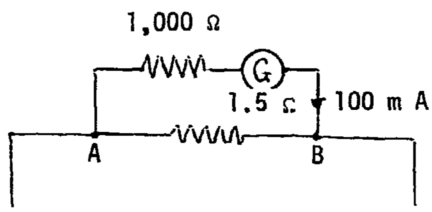
To convert the galvanometer to a voltmeter, add a 1,000 ohm resistor (P) in series to the galvanometer. To do this use bolt (Q) and nut (R) to make a terminal as described under VIII/A2, Component (4), and add it to the base between the existing terminals. Then connect the resistor (obtained from a radio shop) across two adjacent terminals as illustrated. Recalibrate the modified galvanometer by placing it in parallel across a variable resistance, and comparing the potential at any moment with a commercial voltmeter, also placed in parallel with the variable resistance.







V_{AB} = 0.15 volts

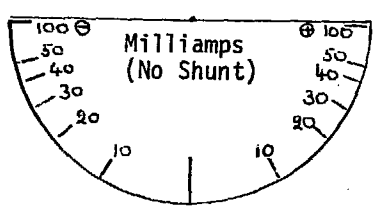


V_{AB} = 100 volts

Without a resistance in series, the full-scale deflection of the galvanometer would only measure 0.15 volts across the terminals. With the 1,000 ohm resistance in series, the full-scale deflection of the galvanometer would measure 100 volts across the terminals. More important, the current taken through the galvanometer, compared with that in the circuit being measured, would be negligible.

c. Notes

(i) The resultant scales will be nonuniform, sensitivity falling off with increasing voltage as indicated. The scale will indicate the direction of the current through the galvanometer.

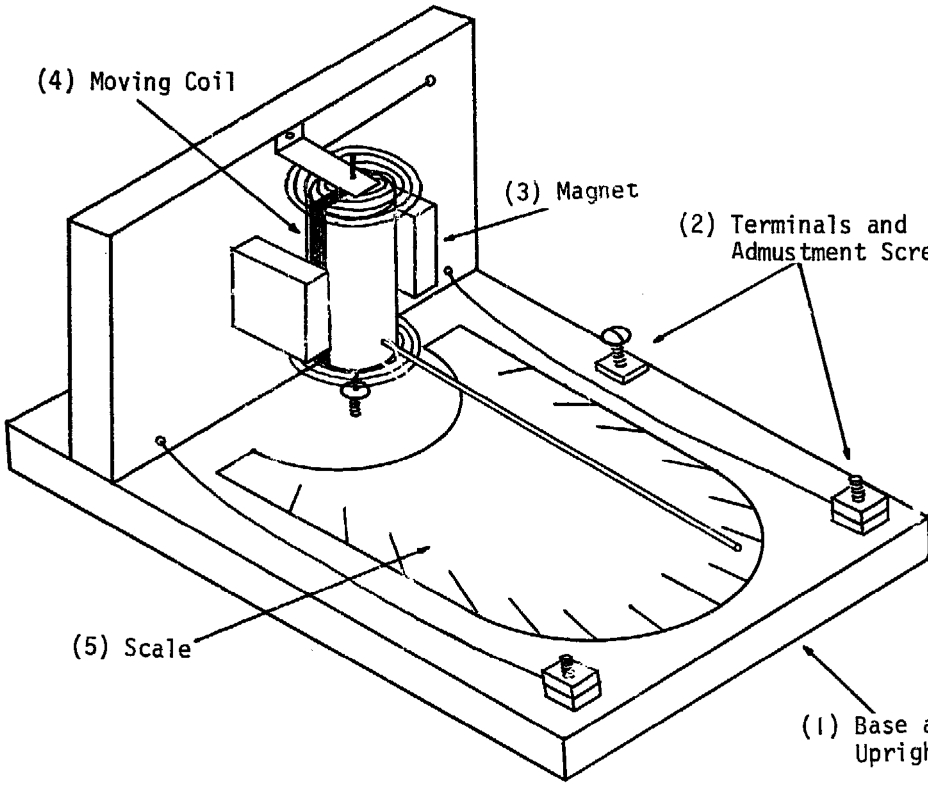


(ii) The galvanometer cannot measure AC current.

(iii) This galvanometer is relatively simple to make, it is surprisingly sensitive, and in combination with the shunts may be used for a wide range of measurements of amperage and voltage.

C. FUNCTIONAL MOVING COIL GALVANOMETERS

C1. Moving Coil Galvanometer ©



a. Materials Required

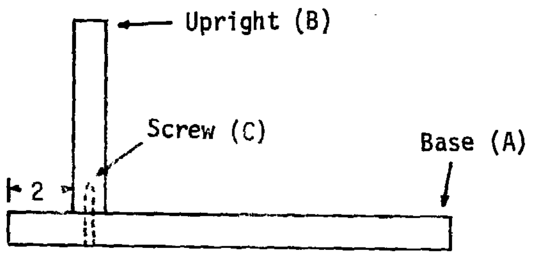
Components	Qu	Items Required	Dimensions
(1) Base with Upright	1	Wood (A)	14 cm x 11 cm x 1 cm
	1	Wood (B)	6 cm x 11 cm x 1 cm
	2	Wood Screws (C)	2 cm long

© From Reginald F. Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 153-158.

(2) Terminals and Adjustment Screw	2	Brass Bolts (D)	0.3 cm diameter, 2.0 cm long
	4	Nuts (E)	0.3 cm internal diameter
	1	Bolt (F)	0.2 cm diameter, 2 cm long
	1	Nut (G)	0.2 cm internal diameter
	2	Thumbtacks (H)	--
(3) Magnet	1	Horseshoe Magnet (I)	Separation of poles between 3.0 cm and 3.5 cm
(4) Moving Coil	1	Wooden Dowel (J)	2 cm diameter, 3 cm long
	1	Galvanized Wire (K)	7.5 cm long, 0.1 cm diameter
	1	Needle (L)	0.1 cm diameter, 5 cm long
	1	Box of Nails (M)	2 cm long, diameter as small as possible
	1	Roll of Magnet Wire (N)	#22
	2	Pieces of Magnet Wire (O)	#30, 50 cm long
	1	Wood Screw (P)	0.8 cm long
	1	Brass Strip (Q)	3.5 cm x 1.0 cm x o.05 cm
	1	Wood Screw (R)	0.8 cm long
(5) Scale	1	White Paper (S)	10 cm x 10 cm

b. Construction

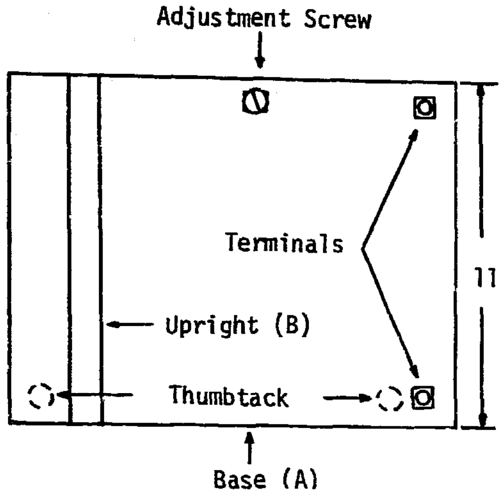
(1) Base with Upright



Side View

Attach the wooden upright (B) to the base (A) with two screws (C) from beneath the base and with wood cenent to make a firm joint. Leave approximately 2 cm behind the upright.

(2) Terminals and Adjustment Screw

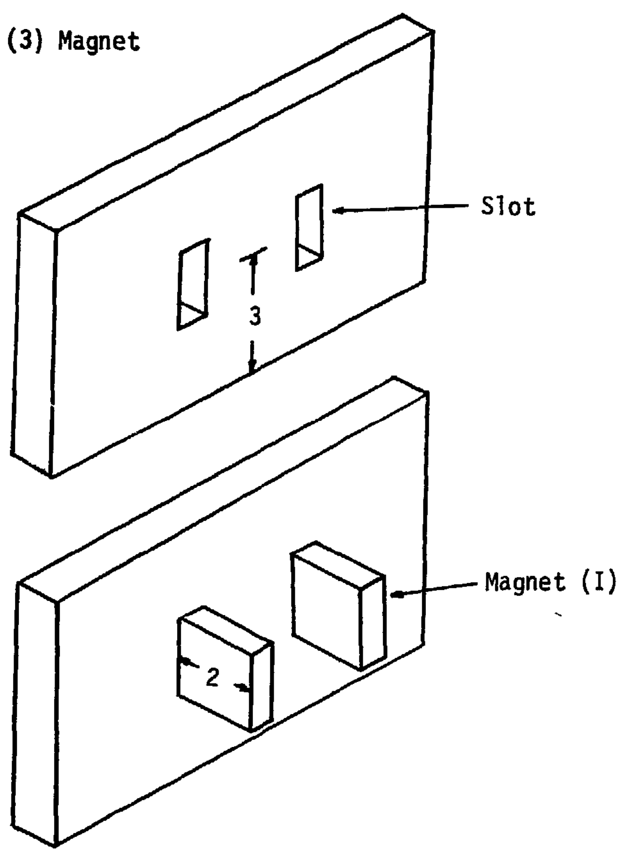


Top View

Make two terminals in the front of the base from the brass bolts (D) and nuts (E) [See VIII/A2, Component (4)].

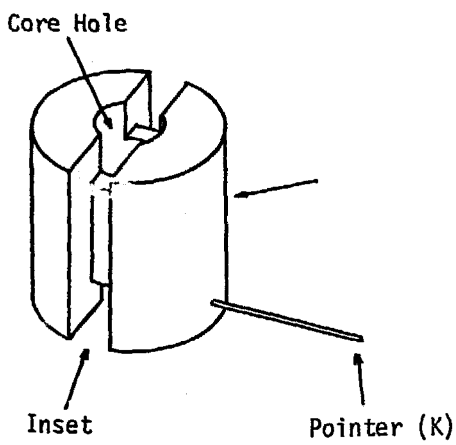
Make an adjustment screw [as described under IX/A3, Component (1)] from the bolt (F) and nut (G) to fit in one side of the base. At opposite corners of the other side of the base, insert two thumbtacks (H) to the bottom so that the base is rested on three points, the adjustment screw and thumbtacks.

(3) Magnet



Obtain a strong horseshoe magnet (I) in which the separation of the two sides of the horseshoe is approximately 3 cm (or a little more). Make slots in the upright (B) as illustrated to allow the magnet to be pushed through the upright so as to protrude a distance of 2 cm. Once the moving coil (below) has been fixed finally in position, fix the magnet firmly in the upright with epoxy resin. The slots are most easily made before the upright has been screwed to the base.

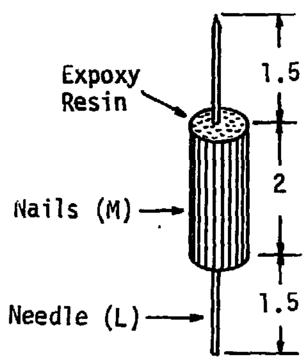
(4) Moving Coil



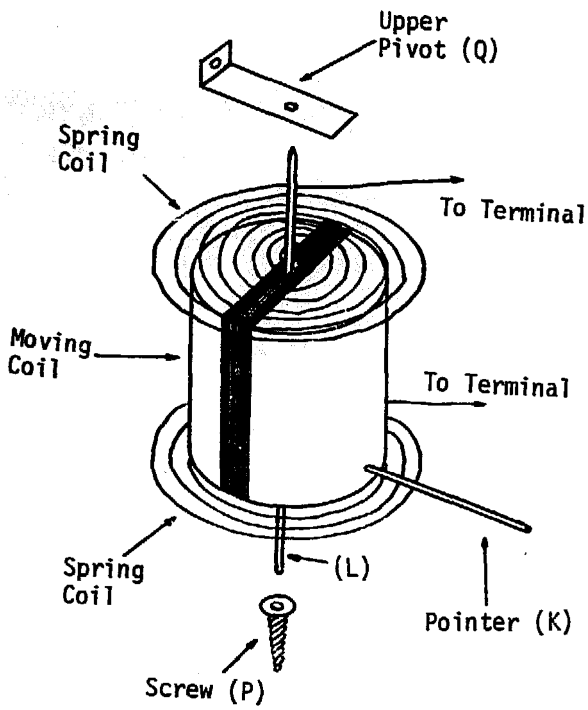
Make an inset (0.5 cm wide, 0.5 cm deep) around the wooden dowel (J) specifically to hold a coil. Drill a hole (0.8 cm diameter) along the axis to take the pivot and soft iron core.

Bore a hole (0.5 cm deep, 0.1 cm diameter) horizontally into the bottom of the core at right angles to the plane of the inset (and coil).

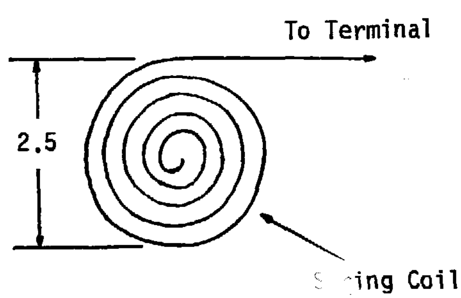
Then, fit the galvanized wire (K) into the hole with epoxy resin to serve as a pointer.



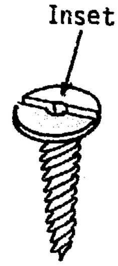
The needle (L) will serve as a pivot. Cut off the heads of the nails (M), and make the length 2 cm. Pack the nails into the hole through the middle of the wooden core (J), placing the needle (L) in the very center of the hole, so as to protrude an equal distance from either end of the core. Bind the newly created core and pivot firmly in position with a liberal coating of epoxy resin over the nail ends and around the needle.



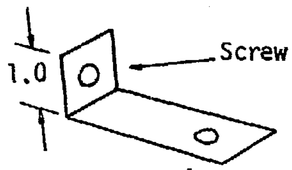
Wind 40 turns of magnet wire (N) around the inset of the core, making sure that both ends are left free. Clean the ends of the wire with sandpaper and solder each end on to another length of very fine magnet wire (O) from which fine spring coils may be made around the top and bottom portions of the pivot.



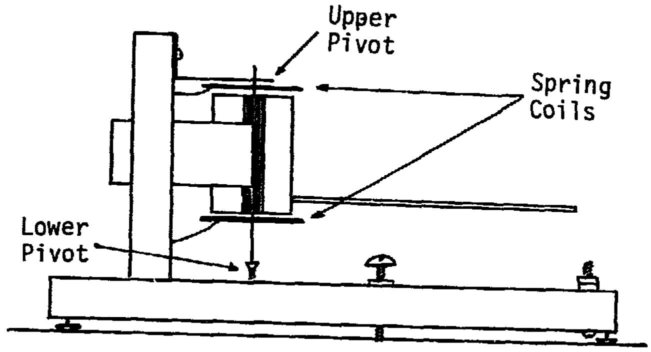
The sensitivity of the spring increases as the number of turns wound into the spring increases, and as the diameter of the spring increases. Once each spring has been wound, avoid subsequent damage during construction by holding it between two pieces of cardboard which may be taped to the wooden core.



Insert the wood screw (P) into the base at a point 2 cm from the front of the upright and centered. Drill an inset (0.2 cm deep) into the head of the screw so that it will serve as a lower pivot for the coil.



Bend the strip of brass (Q) to form an "L" shape. Drill a screw hole (diameter 0.3 cm) in the short end and a pivot hole (diameter 0.2 cm) at a distance of 0.5 cm from the other end. Slide the strip over the pivot needle, and screw the strip to the upright, with the screw (R).



Side View

Connect the wire from the two ends of the springs to the two terminals. One of the best ways of doing this is to drill small holes in the upright (opposite the springs) threading the wire through the holes. If two more holes are drilled through the upright near the bottom (one on either side) the wire may be threaded back through the upright to the terminals.

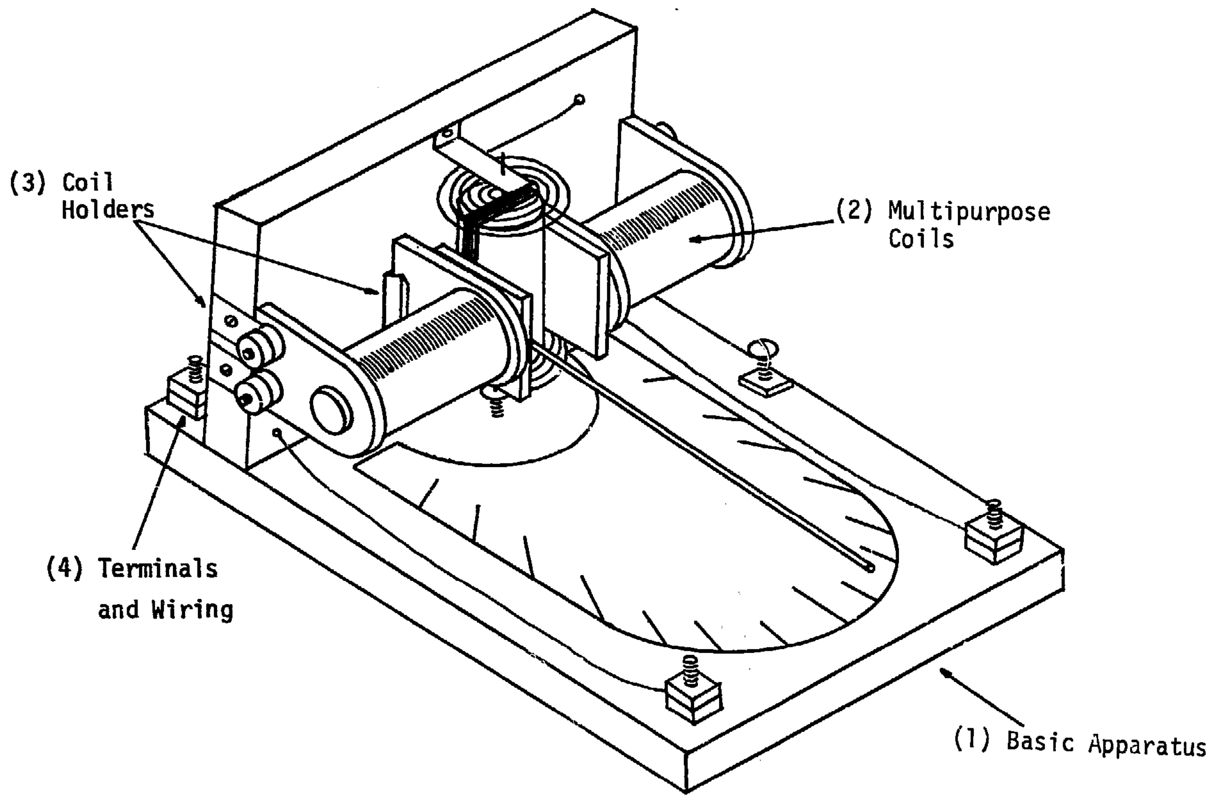
(5) Scale

Cut a sheet of paper (S) and paste it on the base. Taking the lower pivot as the center point, mark off a scale to indicate every 10^o movement of the pointer. The scale may later be recalibrated in amps or volts as desired.

c. Notes

(i) Should there be any difficulty in obtaining a suitable, strong horseshoe magnet, then multipurpose coils may be used as described in the next item.

C2. Moving Coil Galvanometer with Multipurpose Coils ©



a. Materials Required

Components	Qu	Items Required	Dimensions
(1) Basic Apparatus	1	Moving Coil	X/C1, all components except component (3)
(2) Multipurpose Coils	2	Multipurpose Coil with Cores (B)	IX/A2
(3) Coil Holders	4	Brass Sheets (C)	3.0 cm x 0.8 cm x 0.05 cm
	4	Screws (D)	0.8 cm long
	2	Brass Sheets (E)	2 cm x 2 cm x 0.02 cm
	4	Screws (F)	0.8 cm long

© From Reginald F Melton, Elementary, Economic Experiments in Physics, Apparatus Guide, (London: Center for Educational Development Overseas, 1972), pp 159-161.

(4) Terminals and Wiring	2	Brass Bolts (G)	0.3 cm diameter, 2 cm long
	4	Nuts (H)	0.3 cm internal diameter
	1	Roll of Magnet Wire (I)	#24

b. Construction

(1) Basic Apparatus

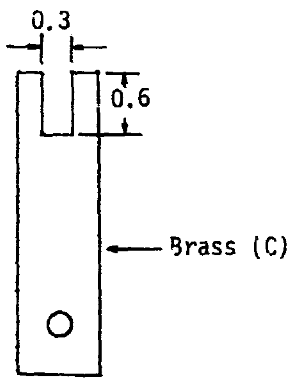
Make the moving coil galvanometer as described under X/C1, but do not make component (3) of the item or the holes in the upright to take a magnet. The finished product will in fact be the basic apparatus (A).

The subsequent making of the coil holders and addition of further terminals to the basic apparatus is likely to damage the moving coil springs unless these are carefully protected. It is therefore suggested that the springs be held between cardboard sheets taped to the wooden core while further modifications are made.

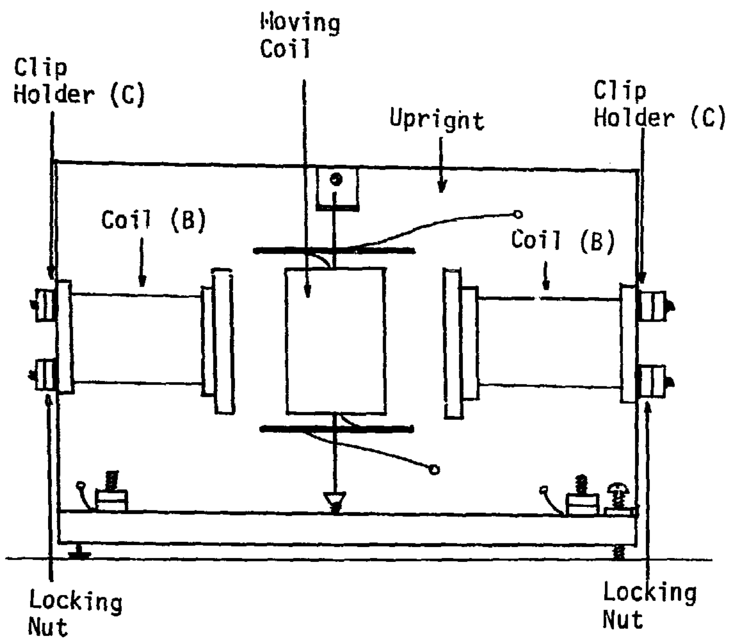
(2) Multipurpose Coils

Make two multipurpose coils (B) complete with soft iron cores and pole heads as described under IX/A2.

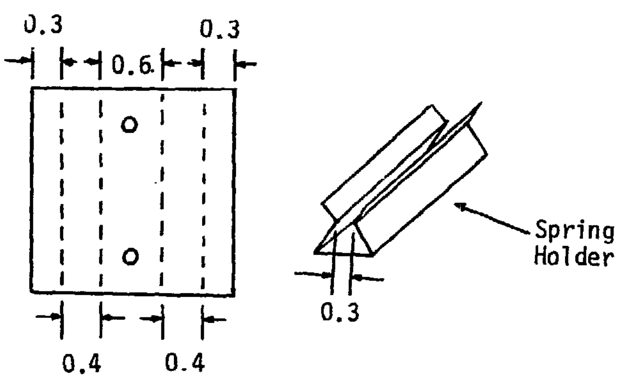
(3) Coil Holders



Cut four clip holders from the four brass sheets (C), making a screw hole at one end and a small slit at the other. Fit the four slits in the holders under the locking nuts of the four terminals of the multipurpose coils (B). Then position each coil in turn on the upright so that the pole head is at exactly the same height above the base as the moving coil core. In this position screw the clips firmly onto the edge of the upright with the screws (D).

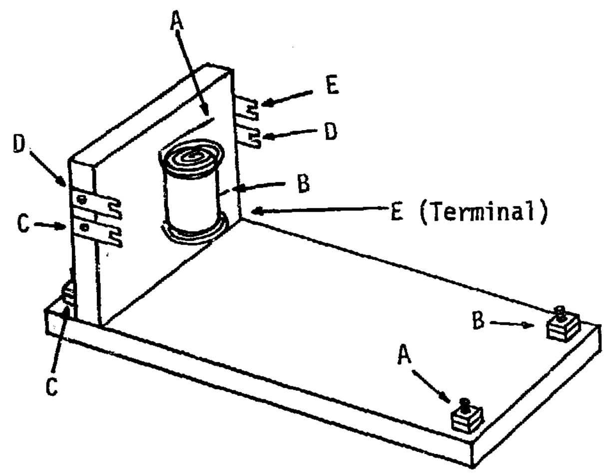


Front View



Make two spring holders from the two brass sheets (E) and slip these on the free ends of the multipurpose coils to determine where they should be attached to the upright. Having marked in the position, screw the

(4) Terminals and Wiring



holders onto the upright with the remaining screws (F).

Use the bolts (G) and nuts (H) to make two additional terminals as described under item VIII/A2, component (4). Attach them to the base, just behind the upright, and then connect the clips and terminals with magnet wire (I) so that electrical connections exist between points A to A, B to B, C to C, D to D and E to E, thus insuring that once the additional terminals are connected to a circuit, the resultant current will flow through the two coils in the same direction.

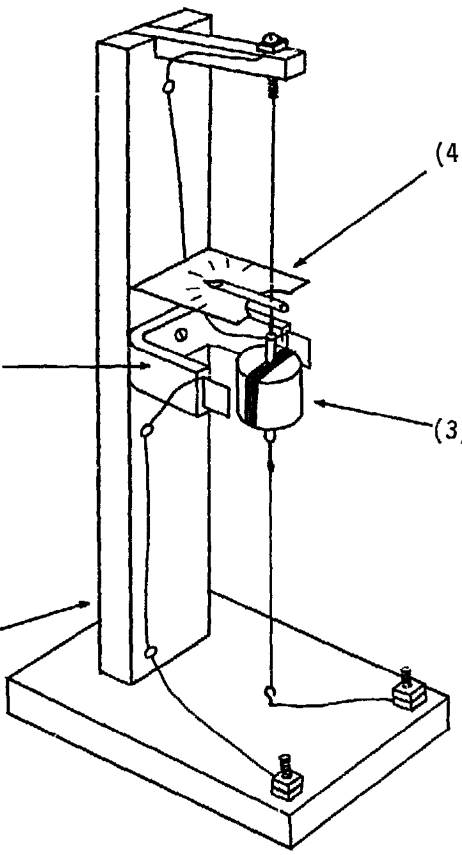
c. Notes

(i) Changing the direction of the current through the moving coil will change the direction of the deflection, so long as the current through the multipurpose coils remains in the same direction. The resultant scale is thus a center zero scale, with the deflection indicating the direction of the current. So long as the current through the moving coil and the multipurpose coils are independent of one another, this galvanometer cannot measure AC current.

(ii) The galvanometer may be calibrated in the usual way by placing it in series with an ammeter (0 $\rightarrow$ 2 amps), a voltage supple (cells, battery, etc.) and a variable resistance.

(iii) With a current of 0.25 amps flowing through the multipurpose coils, the galvanometer constructed had a range of 0 to $\pm$ 1.5 amps. When the current through the multipurpose coils was doubled to 0.50 amps the galvanometer was much more sensitive, and the same deflections produced a range of 0 to $\pm$ 0.85 amps.

C3. Moving Coil Galvanometer with Shunts *



a. Materials Required

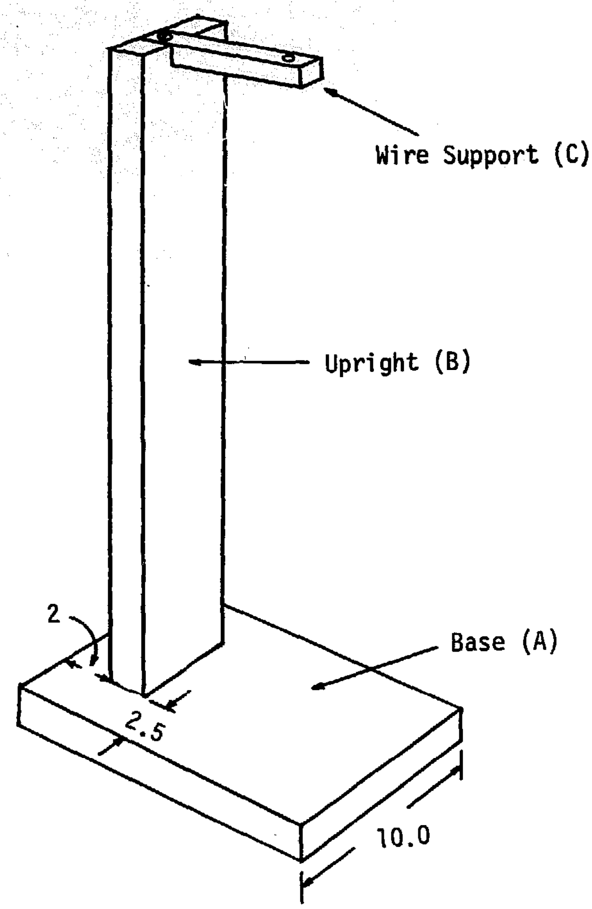
Components	Qu	Items Required	Dimensions
(1) Support	1	Wood (A)	15 cm x 10 cm x 2 cm
	1	Wood (B)	38 cm x 5 cm x 2 cm
	1	Wood (C)	10 cm x 1 cm x 1 cm
	1	Screw (D)	2.0 cm long

*Adapted from Fr. George Schwarz, A Don Bosco Laboratory Manual, (Philippines: Unpublished Papers).

(2) Electromagnet	1	Soft Iron Bar (E)	18 cm x 2.5 cm x 0.3 cm
	--	Masking Tape (F)	--
	1	Bolt (G)	0.3 cm diameter, 4 cm long
	1	Nut (H)	0.3 cm internal diameter
	1	Wing Nut (I)	0.3 cm internal diameter
	1	Magnet Wire (J)	#26 (0.05 cm diameter), 150 g
	1	Bolt (K)	0.4 cm diameter, 3 cm long
	2	Nuts (L)	0.4 cm diameter
	2	Bolts (M)	0.3 cm diameter, 3.5 cm long
	4	Nuts (N)	0.3 cm internal diameter
	4	Thumbtacks (O)	--
(3) Moving Coil	--	Washers (P)	0.6 cm internal diameter, 1.2 cm external diameter
	1	Wooden Dowel (Q)	0.6 cm diameter, 5.5 cm long
	2	Needles (R)	0.1 cm diameter
	1	Wooden Dowel (S)	3.0 cm diameter, 3.5 cm long
	1	Magnet Wire (T)	#26, 800 cm long
	2	Magnet Wire (U)	#30, 16 cm long
	1	Eye Screw (V)	--
	1	Magnet Wire (W)	#26, 7 cm long
(4) Pointer and Scale	1	Soca Straw (X)	5 cm length
	1	Cardboard Sheet (Y)	6 cm x 5 cm

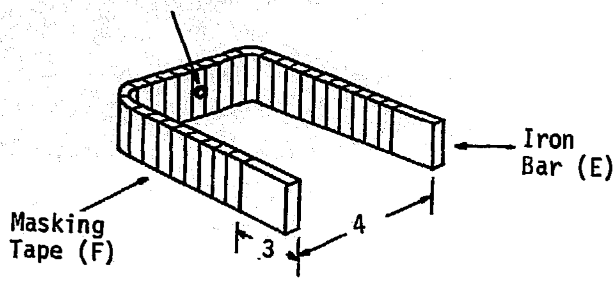
b. Construction

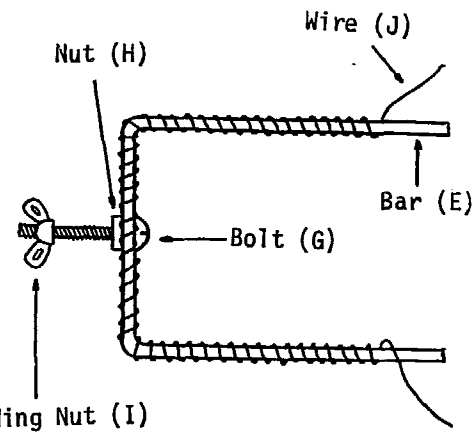
(1) Support

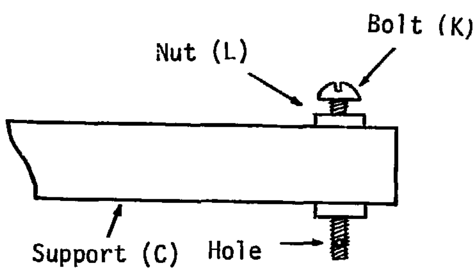


Use wood (A) for the base. Drill two screw holes in the base and attach a wooden upright (B), as indicated, with the help of screws and glue. Make a slot 1 cm wide, and 1 cm deep, in the top of the upright to hold wood (C), the wire support. Drill a hole (0.2 cm diameter) at one end of the support, so that the latter may be attached to the upright by means of a screw, and drill another hole (0.4 cm diameter) at the other end of the support to take a bolt. Attach the wire support to the upright with the help of the screw (D) and glue.

(2) Electromagnet







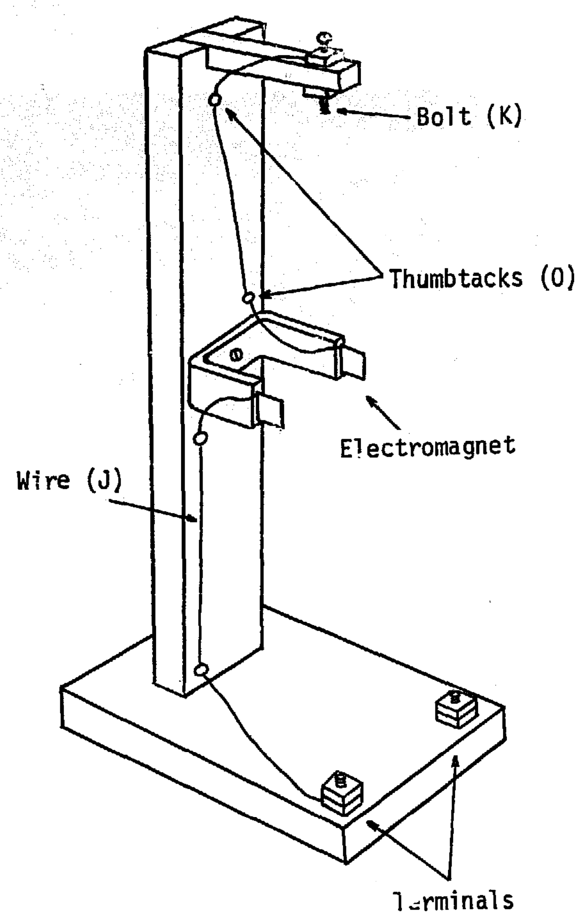
Side View

Bend the soft iron bar (E) into a "U" shape with the parallel sides 4 cm apart.

Wrap a layer of masking tape (F) around the bent bar, leaving the ends (3 cm lengths) clear. The tape will prevent the subsequent magnet wire from being scraped and bared on any sharp edges. Bore a hole (0.3 cm diameter) in the middle of the base of the U-shaped bar. Insert the bolt (G) through the hole, and attach it firmly to the bar with the nut (H). Wrap about 150 g of magnet wire (J) around the covered portion of the bar to make an electromagnet coil. Leave about 40 cm of free wire at either end of the coil. Cover the final layer of magnet wire with masking tape (F) to hold it firmly in position.

Drill a hole (0.3 cm diameter) through the middle of the upright, and attach the newly made electromagnet to the upright with the help of the protruding bolt and wing nut (I).

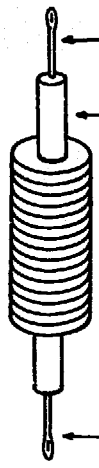
Drill a small hole (0.2 cm diameter) through the end of the bolt (K) furthest from the head. Insert the bolt through the hole in the end of the wire support, and hold it in position with two nuts (L) as illustrated.



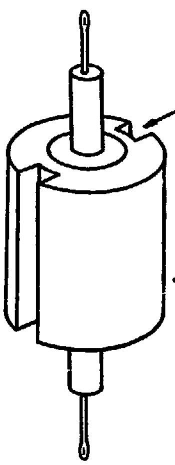
Drill two holes (0.3 cm diameter) into the front of the base. Make two terminals from the nuts (N) and bolts (M) as described under item VIII/A2, component (4). Set the terminals into the holes, making sure they are inset into the bottom of the base, thus leaving the bottom perfectly smooth.

Fasten one of the wires from the electromagnet to a terminal on the base, and the other wire from the electromagnet to the bolt (K) on the wire support. Make sure the enamel has been removed from the wire ends prior to connection. Use thumbtacks (O) to hold the wires in position on the upright.

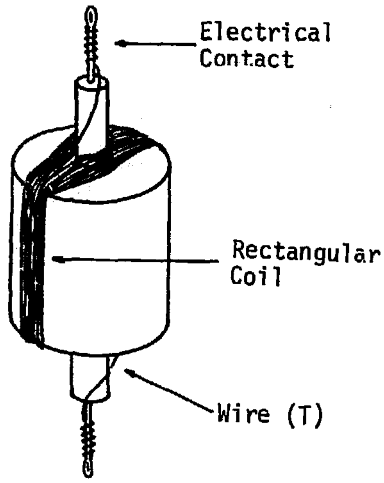
(3) Moving Coil



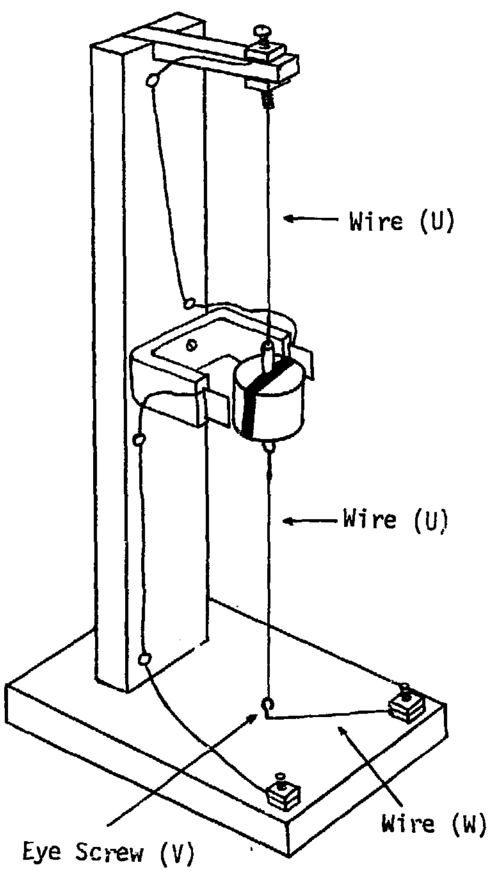
Slide the washers (P) onto the middle of the wooden dowel (Q). Add the washers until they make a stack 3.5 cm long on the middle of the dowel. Use epoxy resin to fix the washers in position. Drill a hole (0.1 cm diameter, 1 cm deep) into either end of the dowel. Cut two 2 cm lengths off the eye ends of the two needles (R), and insert these into the newly drilled holes (needle eyes projecting). Fix them firmly in position with the help of epoxy resin.



Cut a groove (0.5 cm deep, 1 cm wide) around the wooden dowel (S) to hold the subsequent magnet wire coil in position. Drill a hole (1.2 cm diameter) along the axis of the spool, and insert the newly made stack of washers on the dowel (Q). Use epoxy resin to hold this firmly in position within the dowel.



Take the magnet wire (T) and wind it around the dowel (S) to make a rectangular coil contained within the groove which was cut for this purpose. Bare the ends of the wire, and wrap them around the stem of the top and bottom needles (R) respectively, insuring good electrical contact between magnet wire and needle.

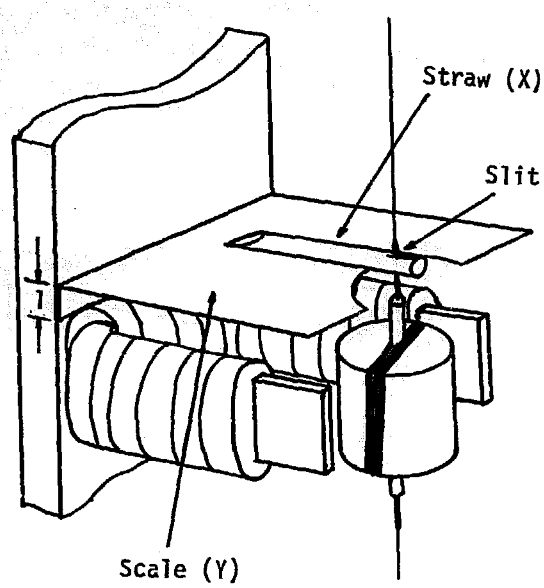


Bare one of the ends of the magnet wire (U) and wrap it around the eye of the needle in the top end of the dowel (S). Suspend the dowel and coil by the wire, so that the dowel hangs between the pole ends of the electromagnet. With the dowel in this position, fasten the other end of the magnet wire to the hole in the bolt in the wire support (after cleaning the end of the magnet wire).

Take the second length of magnet wire (U) and attach one end (after cleaning) to the eye of the needle in the bottom of the dowel (S). Insert an eye screw (V) in the base, directly beneath the dowel, and connect the other end of the magnet wire (bared) to the screw. The slack should be taken out of this bottom magnet wire.

Connect the eye screw to the unused terminal in the base by means of the remaining length of magnet wire (W).

(4) Pointer and Scale



A pointer for the galvanometer may be made from a soda straw (X). Make a small slit in the end, and fit it around the eye of the needle at the top of the dowel (S). A little glue will hold it firmly in position.

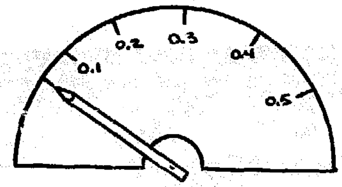
To make the scale, bend the 5 cm end of cardboard (Y) at 90^0 to make a 1 cm flap, and a flat surface 5 cm x 5 cm. Attach the cardboard to the upright (immediately beneath the pointer) with glue placed between the cardboard flap and the upright.

c. Notes

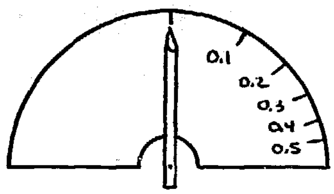
(i) The galvanometer may be calibrated by placing it in series with an ammeter (0 - 1 amp), a voltage supply (dry cells, battery, etc.) and a variable resistance. The resultant scale will not be uniform.

(ii) Changing the direction of the current through the moving coil changes the direction of the current through the electromagnet. As a result, the deflection of the pointer is always in the same direction, regardless of the direction of the current. The galvanometer thus measures AC and DC current equally well. (This would not be the case if a permanent magnet was used instead of the electromagnet.)

(iii) Strictly speaking, the earth's magnetic field should be taken into consideration in using this galvanometer. For most purposes in the secondary school, this confounding factor may be ignored. Hence, in calibrating the galvanometer it is useful to set the zero position of the coil at an angle to the line between the pole heads of the electromagnet, thus making full use of the scale.

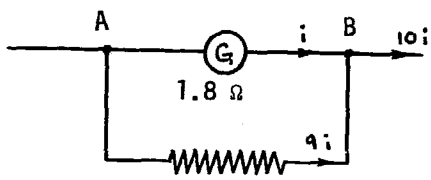


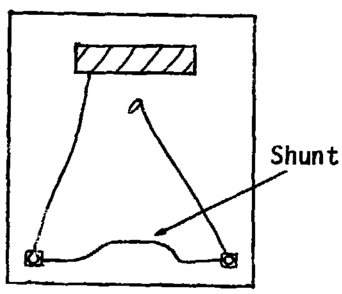
DC Amps



DC Amps

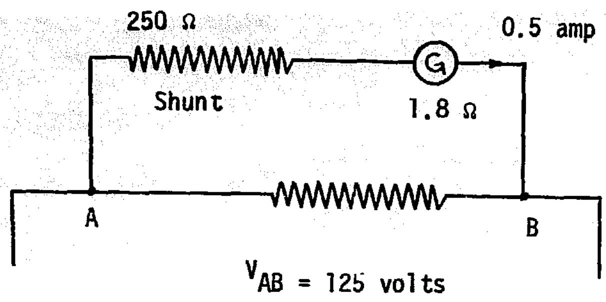
(iv) The resistance of the galvanometer is 1.8 ohms. Hence, if a shunt of 0.2 ohms is placed in parallel with the galvanometer, the scale of the latter will be multiplied by 10. The full scale deflection will thus correspond to 5 amp instead of 0.5 amp. Such a shunt may be made from a length of nichrome wire (approximately 5 cm of #24 nichrome, 20% chrome and 80% nickel) connected between the terminals of the galvanometer.

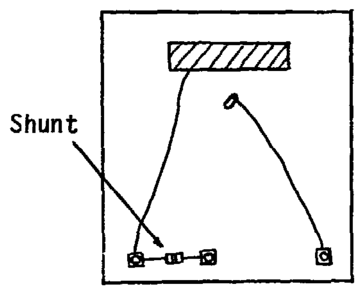




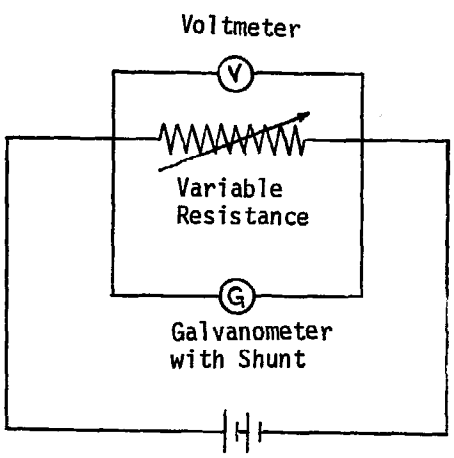
Top View
(Cross-section)

(v) If a 250 ohm shunt is added in series to the galvanometer, it may be used as a voltmeter, the full-scale deflection corresponding to 125 volts (DC). One way of conveniently doing this is to add a third terminal [see VIII/A2, component (4)] to the front of the galvanometer base, simply placing the shunt (obtained from a radio shop) across two adjacent terminals.





Top View
(Cross-section)



The modified galvanometer may then be calibrated by placing it in parallel across a variable resistance, and comparing the potential at any moment with that indicated by a commercial voltmeter, also placed in parallel across the variable resistance.

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A number of texts have proved to be extremely valuable references to the Inexpensive Science Teaching Equipment Project, and these are listed below.

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> This is a clear, well presented book which indicates how apparatus may be constructed for use in biology, chemistry, and physics classes at an introductory level.

The Association for Science Education, Science Master's Book, Part I of Series I to IV, Physics, (London: John Murray).

> The material for this series has been selected from the School Science Review, which is published quarterly by the Association for Science Education. It contains details of the construction of many items of equipment, and describes related experiments for use in physics classes at the secondary level.

Association for Science Education, The School Science Review, (London: John Murray).

> This is a quarterly journal which describes the construction of apparatus which may be used in the teaching of science at all levels.

Bulman, A.D., Model Making for Young Physicists, (London: John Murray, 1963).

> This is a useful book which indicates how students might make some 30 items of physics equipment.

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In addition to the above texts the materials from a large number of projects in the files of the International Clearinghouse on Science and Mathematics Curricular Developments at the University of Maryland have also been particularly valuable. Further details of these projects may be found in:

<u>The Seventh Report of the International Clearinghouse on Science and Mathematics Curricular Developments 1970</u>, (Maryland, U.S.A.: University of Maryland, College Park, 1970).

This is a source of information on curriculum projects throughout the world, and indicates materials available, project directors, publishers, etc. The Eighth Report will be available in late 1972.

ALPHABETICAL INDEX

Adventures with a Hand Lens

by: Richard Headstrom

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ADVENTURES
WITH A HAND LENS
Richard Headstrom

Richard Headstrom
ADVENTURES WITH A HAND LENS

With an ordinary magnifying glass and this book as your guide, 50 adventures in close observation await you. These entertaining nature studies take you on field trips in and around your home, calling attention to interesting features of dozens of familiar or overlooked plants, insects and other animals, and common materials like cloth, quartz and the paper on which this book is printed.

A great deal of basic natural-science theory and detail is presented in this delightful narrative. Flowers and grasses, fish scales, moth and insect wings, egg cases, buds, feathers, seeds, leaf scars, moss, molds, ferns, common crystals are among the many structures examined, often comparatively. Many natural processes and behavior patterns are observed—seed dispersal and other methods of reproduction, protective coloration, rusting, symbiosis, fertilization of the soil, breathing and case-building of insects, and many others, all with only an inexpensive hand lens as equipment and with "specimens" you probably pass by going for a walk. More than 200 labeled illustrations accompany the text.

The author is a former teacher and associate curator of the New England Museum of Natural History. No previous science background is assumed of readers, and curious readers of almost any age will find this book an interesting introduction to numerous facets of nature study.

Unabridged, slightly revised republication of 1962 edition. 209 illustrations by the author. 220pp. 5⅜ x 8. 23330-8 Paperbound

ADVENTURES WITH A HAND LENS

RICHARD HEADSTROM

Illustrated by the Author

Dover Publications, Inc., New York

Published in Canada by General Publishing Company, Ltd., 30 Lesmill Road, Don Mills, Toronto, Ontario.
Published in the United Kingdom by Constable and Company, Ltd., 10 Orange Street, London WC 2.

This Dover edition, first published in 1976, is an unabridged and slightly revised republication of the work originally published by J. B. Lippincott Company, New York, in 1962.

International Standard Book Number: 0-486-23330-8
Library of Congress Catalog Card Number: 76-10910

Manufactured in the United States of America
Dover Publications, Inc.
180 Varick Street
New York, N. Y. 10014

TO MY WIFE

In Appreciation of Her Help and Devotion

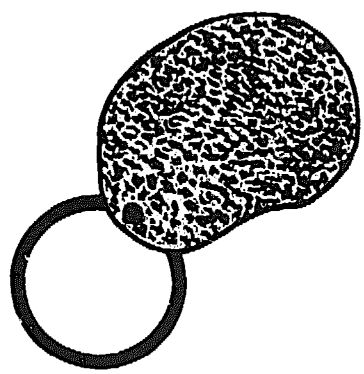
CONTENTS

INTRODUCTION

UNTIL ONLY A FEW YEARS AGO, as time is measured, man had lived on the earth unaware of what existed in the heavens, unaware of how plants and animals are put together, unaware of the countless numbers of tiny plants and animals that exist everywhere but are invisible to the naked eye. He could see and study only what was apparent. When his eyesight faded he was doomed to grope about in a world he could but dimly perceive.

Then, somewhere, someone happened to look through a piece of curved glass. Today we need not grope our way when eyesight begins to fade, nor suffer the results of defective vision. We can peer into the far reaches of the heavens and look at faraway stars and planets, we can study microscopic plants and animals, we can examine the cells of our bodies, we can record for our children and our grandchildren happenings in our own lives, and for posterity world-wide events as they occur, we can sit in our homes and be transported to places miles away and watch a sports spectacle or a political convention or some other event in progress. By means of a piece of curved glass, which came to be called a lens because it is shaped like a lentil, we can look at countless things we never suspected existed, or, if we do know of their existence, what they actually look like, for many of these things appear quite different, when viewed through such a piece of glass, from the way they appear to the naked eye.

And what do we call such a piece of glass? We call it a magnifying glass. But it has other names, too, such as hand lens, pocket magnifier, or reading glass. Whatever it is called, we can buy one almost anywhere for a few pennies to a few dollars, depending on its magnifying power.

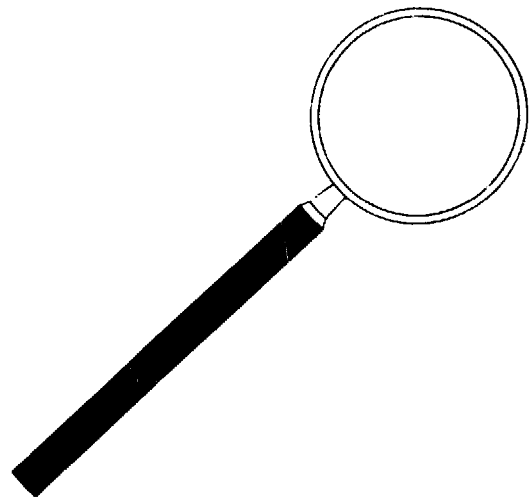


Folding pocket magnifiers made by Bausch and Lomb may be purchased with one, two, or three lenses and are perfect for viewing a wide variety of natural objects. Thus you may get a pocket magnifier with one lens having a magnification of three or five times; a magnifier with a double lens having a magnification of either three to seven times, four to nine times, or five to twelve times;

or a magnifier with a triple lens having a magnification of five to twenty times.

Somewhat more expensive models are the Coddington magnifier and the Hastings magnifier. Both may be obtained with magnifications of seven, ten, fourteen, and twenty times. A reading glass, also made by Bausch and Lomb, has a magnification of three times, and comes in different sizes with different focuses: one with a diameter of two and a half inches has a six-inch focus; one with a diameter of three and a quarter inches has a focus of eight inches; one with a diameter of four inches has a focus of ten inches; and one with a diameter of five inches has a thirteen-inch focus. The focus indicates the distance the lens must be held from an object to get a clear image.

So let us get a magnifier or hand lens and turn to the first Adventure and then to the others that follow. We shall discover many interesting things and have fun doing so.



ADVENTURE 1

We Peer through Our Lens at Some Familiar Objects

FOR OUR FIRST ADVENTURE we shall examine a few things we can find around the house. And what can we better start with than the paper on which these words are printed? Examine it with your hand lens or pocket magnifier. Next examine a piece of newspaper and then a piece of glossy paper from one of the better magazines, and finally compare all three with a piece of blotting paper. In which paper do you find a network of loose fibers? I think you will agree that in the blotting paper the fibers are more in evidence and that there are larger spaces between them. This is the secret of the blotting paper's action in absorbing ink. It all has to do with capillarity, which we can define simply as the creeping of a liquid into a very narrow space, and that is just about what the ink does when it passes into the blotting paper.

Now look at a piece of fabric and see how it appears under a lens. Hold up to the light a towel, or shirt, or skirt, or handkerchief and examine a section of it with your lens. You will observe threads running crosswise. (*Figure 1*). The threads running lengthwise are called the warp; those running crosswise the woof. It is said that the number of threads per inch is an indication of quality or strength. Select a square-inch area of any fabric and count the number of threads in the woof. A high thread count indicates good quality or that the fabric is strong and will wear well; a low thread count indicates the opposite. While you are still holding the fabric to the light, note if there is any unevenness in the weave. If there are spots which appear thinner than others or if the fabric is woven unevenly, the material will wear unevenly.

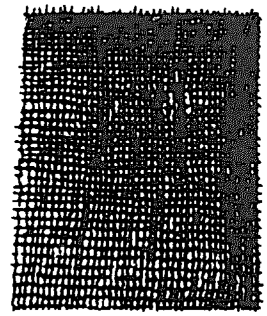


Figure 1
SECTION OF FABRIC

Most of us regard an egg merely as an article of food, and though we all know that a chicken can be hatched from it we give little thought to this miracle. You will learn how an egg is put together and how a plant or animal develops from it. For the present all

Figure 2
GROUND COFFEE

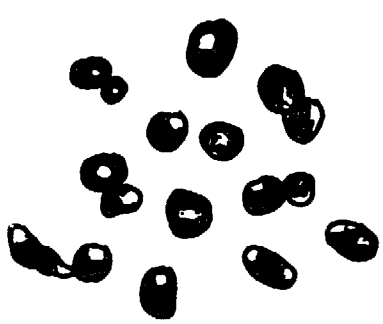


Figure 3
INSTANT COFFEE

we are interested in is the shell of our breakfast egg.

A chicken can be hatched from it, but only under certain conditions. First of all the egg has to be a fertile one, and secondly it has to be incubated. That the developing chick may have air, there must be some way for the air to enter the egg. There must also be some way for waste gases to escape, for every living thing gives off waste gases, and if they are allowed to accumulate they have a toxic effect on the organism. Look at the shell of an uncooked egg through your lens or, better still, hold a piece of shell from your breakfast egg up to a light. You will see numerous small openings, or pores. It is these openings, or pores, which provide for the entrance of air and the escape of the poisonous gases.

Speaking of the breakfast egg calls to mind our breakfast cup of coffee. Spread a little ground coffee and a little instant coffee on a piece of white paper and look at them with your lens. You will find that they differ markedly in appearance. The ground coffee will appear as shown in *Figure 2*. The instant coffee will appear as tiny brown beads or tiny brown bubbles (*Figure 3*). Instant tea appears much like instant coffee, although the beads appear larger, or at least those I have examined do. Regular tea differs considerably in appearance since it is simply the dried leaves of the tea plant or, if obtained from a tea bag, pieces of the leaves which have been shredded (*Figure 4*).

In many families breakfast is followed by a cigarette. Here is another very commonplace article which few of us have ever troubled to examine closely. If a member of your family smokes cigarettes, inspect the tobacco. You will find it consists of very small pieces of the tobacco leaf, which you would naturally expect to find (*Figure 5*). Examine the filter, too, if the cigarette is provided with one. And while we are on the subject of cigarettes and smoking, view the head of a paper match and the ashes of either a cigarette or cigar. You will find that the ashes look like the gray incrustations we often find on rocks and which we will study in a later Adventure.

Dust is an accumulation of all sorts of debris. It frequently figures in mystery stories and also in real-life police investigations. Criminals have been detected and convicted by dust found on their clothing, but we are not interested in criminal detection; rather in the substances we can identify in some sweepings. Sweep up a little dust from the floor or elsewhere onto a piece of white paper. See how many substances you can recognize.

In many ways soil is as interesting as dust, for you never know what you may find in the

Figure 4
SHREDDED TEA LEAVES

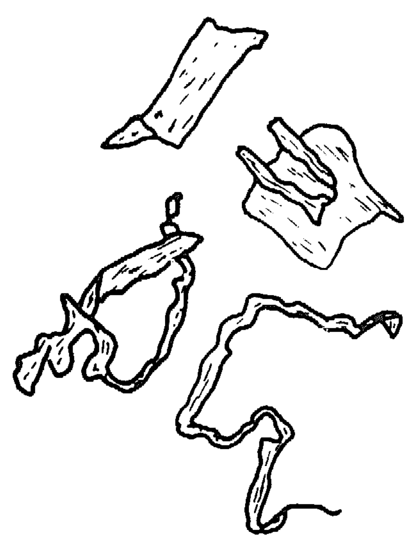


Figure 5
CIGARETTE TOBACCO

way of very small animals, seeds, and the remains of plants and animals. Also an examination of soil will enable you to determine what kind it is and whether it is suitable for a garden. Get an old spoon, go outdoors and dig up a spoonful of soil, bring it indoors, and spread it out on a piece of white paper. Good garden soil should contain a maximum of humus, which is formed by the partial decomposition of dead plants and animals or parts of them, and a minimum amount of sand and clay. Perhaps you may be able to identify some of the plants and animals from their remains (*Figure 6*). There are people who are experts in such matters.

Figure 6
SOIL PARTICLES

ADVENTURE 2

We Listen to Some Music and Discover How It Is Played

THE CHIRPING OF CRICKETS is a familiar sound on a summer's night, especially to those who live in the country. Only the males chirp. Why, I don't know. It was believed at one time that they play their fiddles to attract the females. But it has since been shown that the females pay no attention to the males' serenades. Someday we may know the reason. What we are primarily interested in is how the male crickets play. The best way to find out is to get one or two of them and observe them at close quarters. Incidentally, crickets make excellent pets and may be kept in a large jar or similar container with a little soil on the bottom. They can be fed bits of melon and other fruits, lettuce, and moist bread. A little bone meal should also be supplied to reduce cannibalism. If eggs are laid and you want to hatch them, sprinkle the soil with water as you would for plants. The female, by the way, can be distinguished from the male by the presence of a long, swordlike ovipositor, or egg-laying apparatus, extending from the end of her body.

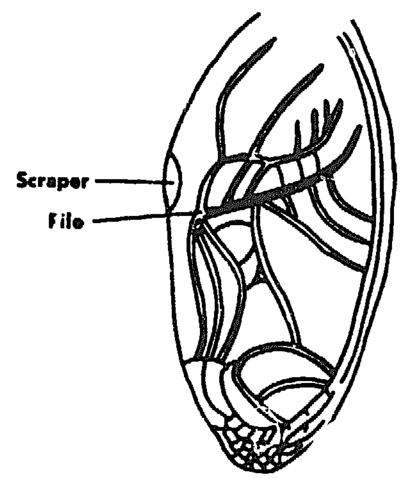


Figure 7
FOREWING OF MALE CRICKET

To return to our question of how a male cricket plays, observe that when he does so he lifts his wing covers at an angle of forty-five degrees and then rubs them together. Actually it isn't quite as simple as that. If you examine one of the wing covers with your lens, you will note that the venation is of a peculiar scroll pattern which probably serves as a framework for the purpose of making a sounding board of the wing membrane by stretching it out as a drumhead is stretched. Also note that near the base of the wing cover there is a heavy cross vein covered with transverse ridges called the file (*Figure 7*). Next find on the inner edge of the same wing near the base a hardened area. This area is called the scraper (*Figure 7*). When the cricket sounds his notes, he does so by drawing the scraper of the underwing cover against the file (*Figure 8*) of the overlapping one. We

Figure 8
SECTION OF FILE

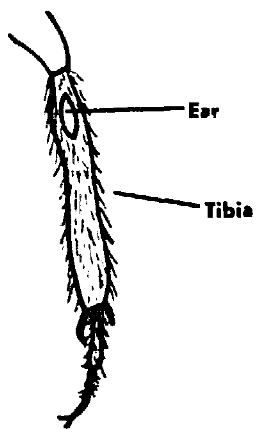


Figure 9
FRONT LEG OF CRICKET

can produce a similar sound by running a file along the edge of a tin can.

As the wing covers are excellent sounding boards and quiver when the note is made, the surrounding air is set into vibration, thus creating sound waves which can travel a considerable distance. An interesting sidelight in regard to this sounding device is that the cricket can alternate his use of the wing covers, that is, he can use first one wing cover as a scraper and the other as a file and then reverse them. In this way he can reduce the wear and tear and prevent them from being worn out.

Now there doesn't seem to be much sense in a cricket's being able to produce a sound unless he can hear it. If you look on the tibia of the front leg, you will note a small white disklike spot (*Figure 9*). This is the ear and is visible to the naked eye.

ADVENTURE 3

We Give Seeds More Than a Passing Glance

WE ACCEPT SEEDS for what they are and give little thought to them. Yet if we were to look at them more closely, especially with our lens, we would be amazed at their infinite diversity. They are as variable as the flowers that produce them and some are equally as beautiful.

Although they are typically more or less globular or oval in shape (*Figure 10*), there

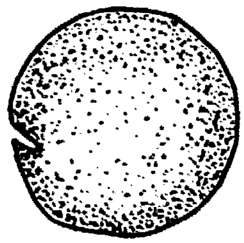


Figure 10
BOUNCING BET

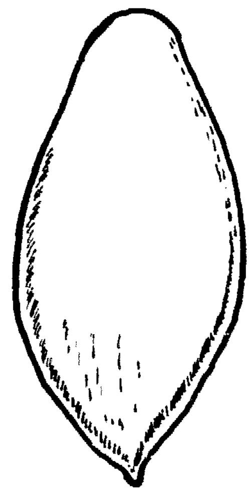


Figure 11
SQUASH

Figure 12
MARIGOLD

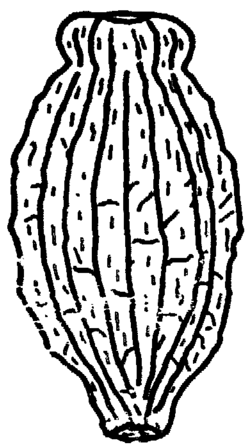


Figure 13
FOUR O'CLOCK

are seeds that are extremely thin and flat (*Figure 11*) or greatly elongated (*Figure 12*). Seeds, too, may be smooth or wrinkled or pitted or angled or furrowed (*Figure 13*). There are seeds that are twisted or coiled

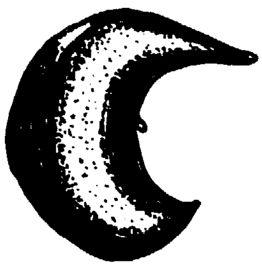


Figure 14
MOONSEED

(*Figure 14*) or otherwise irregularly distorted (*Figure 15*). Then there are seeds that are more or less covered with hairs or supplied with broad and extremely delicate membranous wings to make them wind-borne. In size the variations are equally pronounced. Some seeds are as fine as dust; others several inches in diameter; and, of course, there are seeds that represent all the gradations in between. But it is in the variety of color and color patterns that they show the most conspicuous external differentiation. I daresay we can find them matching every known color, from shining jet black through the gamut of blue, red, yellow, and other bright tints to the less striking and more somber brown and gray, to say nothing of the manifold designs produced by a blending of these colors.

Colors, needless to say, are not without some purpose. Seeds that are scattered by wind and water are, for the most part, inconspicuously or neutrally colored, but the bright and showy ones are designed to appeal to animal agents of dissemination. Although we may find the numberless variations somewhat surprising, what is even more surprising is that such an infinite variety should be produced under conditions that appear to be more or less uniform and constant. What may also seem incongruous is that plants that may appear superficially similar often produce seeds that are strikingly different, or that plants that are wholly unlike often produce seeds that are very much alike. Generally seeds are so characteristic that they serve as useful agents in classification, in some cases being so characteristically differentiated as to be an infallible clue to the identity of the plant that produced them.

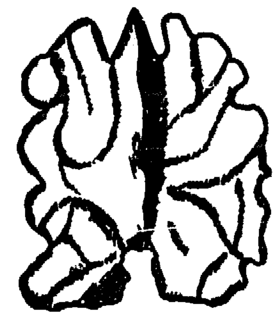


Figure 15
WALNUT

A seed is botanically a ripened ovule and consists of an embryo plant and its protective covering or coat. The unripened ovule is a small structure in the ovary of a flower and may readily be seen by cutting the ovary open with a razor blade or pocketknife. In most cases you will find many ovules. The ovule contains an egg cell and when this egg cell has been fertilized by a sperm cell, the ovule undergoes a number of changes and eventually develops into a seed. The sperm cell is contained in the pollen grain and must be transferred to the stigma of the pistil by some agent as the wind or an insect or by water or even by artificial means. Once the sperm cell has come in contact with the stigma, it makes its way down the pistil until it locates the egg, which it enters.

Obviously the embryo, which is a living plant whose growth has been temporarily suspended, is the most important part of the seed. Food, as a source of energy for the em-

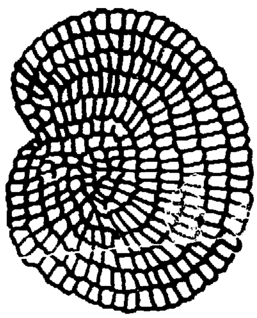


Figure 16
BABY'S BREATH

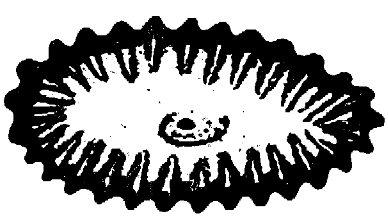


Figure 17
SPIDERWORT

bryo plant until it has developed to the stage where it can manufacture its own food, is stored within the seed. Long ago man discovered that he could make use of this reserve food for his own use. The seeds of wheat and rice are today the principal items of diet for millions of human beings, and countless others consume daily large quantities of such seeds as those of corn and barley, oats and rye. Beans and peas, which are also seeds, are eaten extensively. In addition to their value as food, man has found other uses for them. I might mention cottonseed oil, linseed oil, and coconut oil, which are used in the manufacture of substitutes for butter and lard, soap, and a variety of other products.

Although seeds exhibit a great diversity of surface markings (*Figure 16*) and configurations (*Figure 17*), they all agree in showing a minute pore or pit and a scar called the hilum. The pore or pit marks the position of the micropyle, an opening in the ovule through which the sperm cell entered on its way to the egg cell, and the hilum marks the place where the ovule was attached to the ovary. You should be able to find both of these structures with your hand lens (*Figure 18*).

Although seeds are more readily available during the summer and early fall, when they may be obtained from almost any plant outdoors, you should have no trouble in getting enough of them during the winter to observe the many variations I have mentioned. Your neighborhood hardware store may have some left from the preceding spring, and I would suggest you visit a local nursery. You should even be able to find some on your pantry shelves, for many seeds are used in cooking. As you examine different seeds, you will very likely begin to wonder how nature could design so many—I did when I first became interested in them. Perhaps it may also occur to you to make a seed collection. It is less expensive than collecting coins or postage stamps, and you should have a great deal of fun doing so.

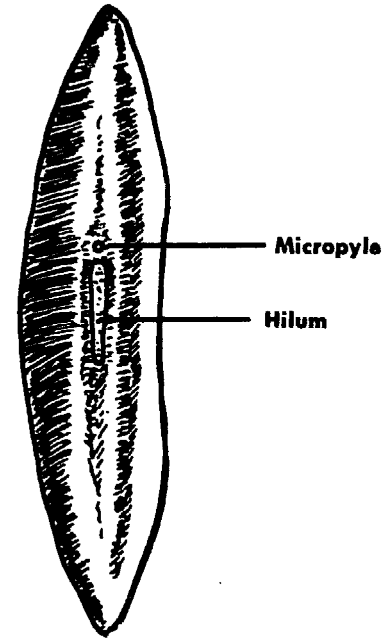


Figure 18
KIDNEY BEAN

ADVENTURE 4

We Become Better Acquainted with the Snail

Snails belong to a group of animals called the Mollusca. The word Mollusca is derived from the Latin *mollis,* which means "soft." Hence the group includes such soft-bodied animals as the snail, clam, oyster, squid, and octopus. All these animals have one thing in common—a shell. The shell may be a very simple and drab affair, or it may be highly sculptured and beautiful—to wit, some sea shells. It may also be in one piece, as in the snail, or it may consist of two parts, or valves, as in the clam. The shell of the land snail, which we often find in our gardens, is a spiral cone made from a substance secreted by certain cells and that hardens on exposure to the air. The snail's soft body is twisted and coiled like the shell and extends into the apex, but usually does not completely fill the shell to the tip.

A snail may seem such an insignificant sort of animal and its actions may not seem to bear watching, but I think you will be in for a surprise if you find one and observe its behavior through your lens. In this instance a reading glass will prove to be of greater advantage than a pocket magnifier. Place the snail in a tumbler and watch it climb up the glass sides. As you do so you will find that the snail's foot is one of the most wonderful means of locomotion ever devised by nature. Observe how the foot stretches out and holds on, then contracts, and then again stretches out. All this is accomplished by muscles. Observe, too, how a slime gland at the anterior end of the foot deposits a film of mucus on which the animal travels. It lays down a sidewalk, as it were, ahead of itself, and this sidewalk is always the same whether the path is rough or smooth, uphill or downhill.

Although the shell provides the snail with a maximum amount of protection, it would seem to be something of a disadvantage to carry it around wherever it goes. Yet in spite

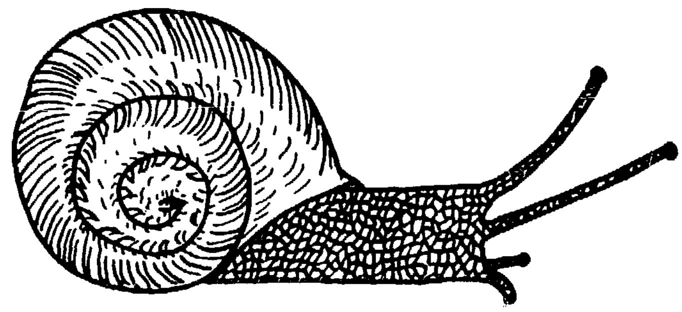


Figure 19
GARDEN SNAIL

of its cumbersome burden the little animal gets about remarkably well even though it will never set any speed records. Watch it for a while and you will discover that its pace is always about the same. It may be two inches per minute, ten feet per hour, or two hundred and forty feet per day if the animal keeps constantly on the move. It also appears to progress forward without any apparent muscular effort.

We frequently see on television and at the circus acrobatic stunts performed by contortionists. I doubt very much if these performers are any more loose-jointed than the snail. Watch the snail retire within its house. First it folds its foot lengthwise and then gradually withdraws it into the shell, the end on which the head is located first and then the hind end. Conversely, when the animal emerges, the hind end comes out first, and then the head and "horns." The "horns," of course, are not horns at all but tentacles (*Figure 19*). There are two pairs of tentacles (pond snails have only one pair, as you will discover should you find one), and both pairs are provided with little round, knoblike tips. On the longer pair the tips serve as eyes; on the shorter pair it is believed they function as organs of smell. It is said that a snail can detect food as far away as twenty inches.

You can determine this for yourself if you get a piece of apple or other soft food and place it at various distances. Observe how the animal uses its eyes to explore its surroundings and what happens if you place an object too close to it. Once it has located the piece of apple or fruit, you will find that it won't be long before it has made a good-sized hole in it. You will also observe that its table manners could be improved upon. It is a hopeless slobberer. The mouth is located directly below the tentacles and is furnished with one or more chitinous jaws and a long, ribbonlike tongue (the radula) that is covered with horny teeth. The snail uses its tongue as a rasp to file the surfaces of leaves or other food. The teeth vary in number, form, size, and arrangement in the different species of snails and are of considerable value in classification. If you want to examine these teeth more closely, you will need a microscope.

Before you return the snail to its natural environment, examine the skin with your pocket magnifier. It will remind you of an alligator's skin—rough and divided into plates with a surface like pebbled leather.

ADVENTURE 5

We Inquire into the Nature of Rusting

THE RUSTING OF IRON is a common occurrence, and we see evidence of it everywhere. Few of us have not sustained some loss or damage through rust, and perhaps a few of us have had the painful experience of having stepped on a rusty nail. The tendency of iron to rust is its most unfavorable property, and millions of dollars are spent annually to fight this enemy who, silently and unseen, is constantly bent on destruction.

You are taught in school that rusting is due to the action of oxygen in the air on the iron, which results in the formation of a reddish-brown substance called iron oxide. Actually it is not quite so simple. Furthermore, iron is not the only metal that can "rust." Most metals, when exposed to the air, are attacked by the elements and compounds present in the atmosphere. The phenomenon is generally known as corrosion; when applied to iron it is called rusting.

Examine a new and clean nail and note its appearance. Now wet it and leave it outdoors for a few days or until you observe brown spots on it. Look at these brown spots through your lens and you will find that they appear as incrustations that you can break off into small pieces with your fingernail. Next examine a really rusty nail—one that has been exposed to the air for a long time and is completely covered with rust. You will find that it will have the appearance of a tree trunk that is covered with a reddish-brown flaky bark (*Figure 20*). The flakes come off easily, as they might off a real tree, if you scrape them with your fingernail or a pocket-knife. If you scrape enough off you will eventually expose the iron as you would expose the wood of the tree if you removed all the bark. Here the analogy ends, of course, since the bark serves as a protective covering for the wood, whereas the reddish rust has no protective value. Quite the contrary, for as it gradually flakes off through the action of rain and wind, the exposed iron in turn rusts until eventually the iron nail has completely disintegrated, or, more accurately, been converted into iron oxide.

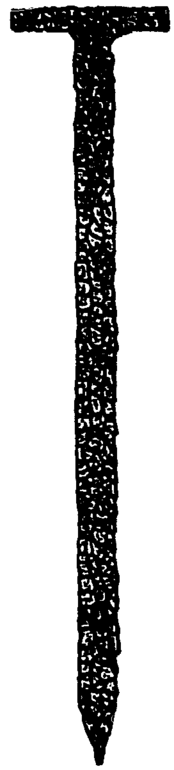


Figure 20
NAIL COVERED WITH IRON OXIDE

In regard to this rusting of iron we should note two interesting facts. One is that pure iron will not rust and secondly that iron will rust only in the presence of water. Why is this? Both are explained by the electrochemical nature of the rusting process.

You are doubtless familiar with the electric cell. An electric cell, as you may recall, consists of two dissimilar metals or of a metal and carbon placed in a solution of an electrolyte. An electrolyte is a substance that, when dissolved in water, will conduct an electric current. The electric cell was invented, or perhaps it is better to say that the principle involved was discovered, by an Italian scientist, Alessandro Volta, over a hundred years ago. In the simple electric cell, known as the voltaic cell, a strip of zinc and a rod of carbon are placed in a jar of sulphuric acid. When the two are connected by a piece of copper wire, an electric current flows. It all has to do with electrons and ion exchange. Chemical energy is converted into electrical energy, and a substance, zinc sulphate, is formed.

Now a piece of iron, such as the nail, is usually not pure, but contains carbon, and when wet has all the essentials for an electric cell, since the water contains dissolved carbon dioxide, which forms carbonic acid with the water and is therefore an electrolyte. Under these conditions a similar reaction occurs as in the case of the zinc and carbon. A compound called iron bicarbonate is first formed and this is converted by the oxygen in the air into the familiar rust, or iron oxide.

Obviously all we need do to keep iron from rusting is to keep it dry, which is not too easily accomplished. That is why we cover iron girders and other forms of structural iron with paint and cover our tools and garden implements with grease or oil when not in use. Any substance that is impervious to air and water will do. Certain metals, as zinc, cadmium, and tin, are more resistant to rusting than iron and are often used as a coating.

The iron is dipped into the melted metal and a thin layer of it adheres to the iron. Iron thus coated is called galvanized iron. Another method of attacking this age-old problem of rusting is to alloy iron with other metals. An alloy is merely a mixture of two or more metals. Stainless steel, for instance, which is useful in building streamlined trains, for metal trim on buildings and automobiles, and for kitchenware, is a mixture of chromium, nickle, and iron.

ADVENTURE 6

We Meet the Insect Brownies

THE INSECT BROWNIES are very small insects and are more appropriately known, at least to entomologists, as tree hoppers. They belong to the family of insects called the Membracidae and are very well named, since most of them live on trees and hop vigorously when disturbed. Not all of them, however, live on trees; some live on bushes and still others on grasses and other herbaceous plants.

If these insects are more correctly known as tree hoppers, why are they also called insect brownies? To answer this question, you first have to know what brownies are. In folklore they are believed to be good-natured goblins who are supposed to do various household chores by night. They have been pictured as whimsical little people with quaint, if not grotesque, faces. If you can picture in your mind these little imaginary people and then look a few of the tree hoppers full in the face, I think you will see the reason for calling them insect brownies.

A well-known entomologist once remarked that "Nature must have been in a joking mood when tree hoppers were developed." But I am not so sure that she was in a joking mood; on the contrary, I think she was quite serious when she designed these little insects, for their grotesque and bizarre appearance is not without value. They appear so much like spines and other plant structures in shape or form that they are not readily seen and thus escape detection by their enemies. The tree hoppers provide us with innumerable examples of what we call protective resemblance. I might mention just one—the common little tree hopper of the bittersweet. Its thornlike process resembles a thorn so closely that the insect can be distinguished from a real thorn only with difficulty.

How and where can we obtain these insects? You need an insect net, which you can make yourself or buy for a nominal sum, and a killing jar. The latter is merely a bottle with a screw cover with a piece of cotton attached to it so that the cotton will hang downward in the bottle. The killing jar serves as a lethal chamber, and in order for it to function all we need do is to soak the cotton in a fluid that will evaporate quickly. Carbon tetrachloride, which is used as a cleaning fluid and which can be purchased at a drugstore, will do nicely. It is not inflammable like alcohol or some other fluids we could use, but since it will kill the insects it is best not to inhale too much of it.

The best way to get tree hoppers is to walk through the grass of a field and swish the insect net back and forth through the grass or the wild flowers growing there. Do not swish your net among the branches of a shrub or tree, as it is very apt to get caught in them and tear. When you have passed your net through the grass a few times, examine it. You should find a large number of various insects crawling about in it. Now remove the cover from the killing jar and empty the contents of the net into the bottle, then replace the cover and wait a few moments until the fumes of the carbon tetrachloride have done their work. When all the insects are dead, remove the cover and shake the insects out onto a piece of paper or into a cardboard box where you can pick them over for tree hoppers. A pair of forceps or tweezers, such as you can get at the five-and-ten-cent store, will facilitate your handling the insects and will help you in holding them up when you examine them.

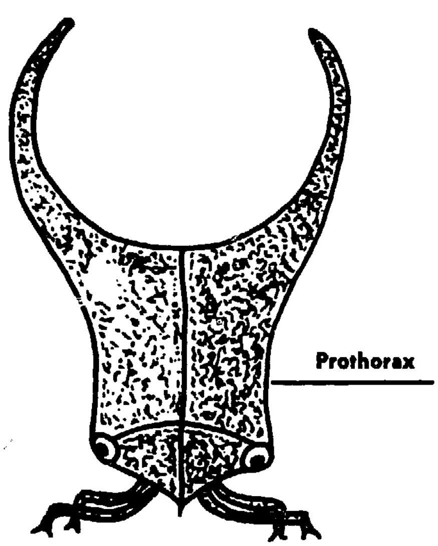


Figure 21
TREE HOPPER

As you view the tree hoppers through your lens, you will observe that the prothorax, which is the first segment of the thorax, the one next to the head, has been prolonged upward or backward or sideways according to the species you are viewing. It is this structure that nature has modified to produce the many strange and grotesque forms found among these insects (*Figure 21*).

Besides catching the tree hoppers with your net you might look over the twigs of various trees and shrubs and when you find them, which is not an easy thing to do, you can pick them off with your fingers or knock them into your killing jar. A common species you should have no trouble finding is the two-marked tree hopper (*Figure 22*). This species is very abundant on trees, shrubs, and vines and is gregarious, both adults and the immature forms being found clustered together. A good place to look is the bittersweet, where they are often found. If you find them, observe that no matter how the vine twists and turns they rest with their heads always toward the top. Can you suggest a reason for this? All tree hoppers suck the sap or juice of plants, and if they sit in this manner the sap can more easily flow down their throats.

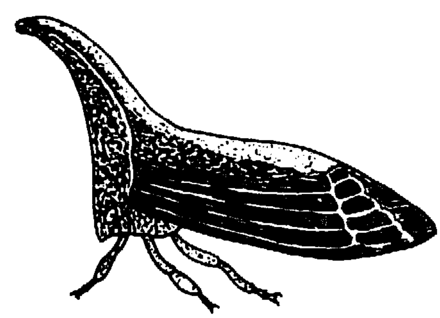


Figure 22
TWO-MARKED TREE HOPPER

Although tree hoppers suck plant juices, they do not occur in sufficient numbers to be of any economic importance. Sometimes the

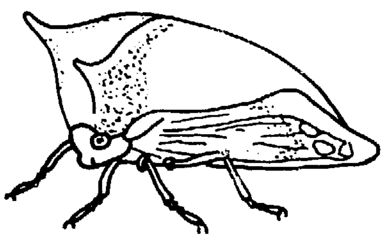


Figure 23
BUFFALO TREE HOPPER

females of certain species injure young trees by laying their eggs in the bark of the smaller branches and in the buds and stems. The buffalo tree hopper is probably the most injurious, often causing considerable damage to young orchard trees and to nursery stock. It is grass green in color and somewhat triangular in shape with a characteristic two-horned enlargement at the front (*Figure 23*).

ADVENTURE 7

We Visit Fairyland

LICHENS are of common occurrence except in the cities, where they do not seem to be able to grow because of the smoke and gases that pollute the air. We find them almost everywhere, and yet, in spite of their abundance, few people know what they are. Sometimes I wonder why it is that we so often fail to take more of an interest in things we see every day. How often have you observed the gray embroidery on a rock in a pasture, the yellow rosette on the trunk of a tree by the wayside, or the red coral on the decaying log or stump in the woods and given them only a passing glance? Perhaps they seem unimportant and therefore do not warrant our attention. But they are important, as we shall see.

Lichens are something of an oddity. They are not actually plants in the strictest meaning of the word, but a closely knit relationship of two entirely dissimilar plants living together for mutual benefit, a sort of partnership that biologists call mutualism. The two plants are an alga and a fungus. The alga is a relative of the simple green plants that are found on damp stones or on the shady sides of houses and trees. The fungus is a relative of the mushrooms that appear magically in our gardens after a heavy rain and the molds that so often appear on our foodstuffs, such as bread and jellies and cheese. The fungus has lost the ability, if it ever did have it, of manufacturing its own food, but instead has acquired the power of absorbing large quantities of water. If exposed to dry air the alga will perish, but when kept moist is capable of taking various elements from the air and converting them into food. So it is the function of the fungus to provide the partnership with water, and the alga to furnish the food.

Though the partnership may seem a strange one, it is a most successful one, for lichens can exist where no other plants can grow—on a bare alpine peak, in the arctic wastes, in a tropical desert. They need no soil—a bare rock will do or any kind of surface on which they can obtain a foothold. Because of their ability to live in such inhospitable places it would appear that they must be rather remarkable, as indeed they are. The mechanical contrivances that permit them to survive under what appears to be the most precarious of conditions have a strong appeal to the physicist, and the chemical processes that take place within them are of no less interest to the chemist, for among other things, they secrete powerful acids that etch the rocks and break them up, thereby providing needed minerals for their own survival. The biologist regards the lichens with even greater respect because they are able to create soil in which other plants can grow. They represent the pioneer stage in a series of stages called ecological succession, a term given to the transition of a barren area into the climax forest through the intervening steps of a small pool, then a larger pond, followed by the swamp and marsh, and then the meadow and field. You will learn more about this when you study biology or, more specifically, that phase of biology called ecology.

Apart from their primary purpose of converting inhospitable waste ground into a soil suitable for other plants to grow in, some species also serve as food for various animals, such as the reindeer and caribou. Perhaps you have heard of reindeer moss, which is a lichen and not a moss. Not to be outdone by the animals, man has also made use of lichens as food. The people in Sweden at one time made a bread from one of them, and another species was once used in a Siberian monastery for a beer. The manna of the Israelites is supposed to have been a lichen. Drugs as well as various dyes have been obtained from certain species. The litmus we use in our chemical laboratories is obtained from a lichen.

But I think we have talked enough about the lichens. Let us go outdoors and look at them. Where shall we go? To some neglected pasture? To the woods? It doesn't matter. Wherever we turn, whether it is the marsh, the shore of a pond, the bank of a river, the roadside, we find them decorating trees, stumps, fallen logs, fence rails, rocks, almost any surface that will provide them with a foothold. And how may we recognize them? Almost any flat or ruffled and rootless growth of almost any color is likely to be a lichen, particularly if it bears flattened dish-shaped or saucer-shaped colored disks or cushions or if it branches like a coral or if it hangs like fringes from the branches of a tree. Best of all, we can find them at any time of the year, though they are at their best in spring and fall or even in the winter, for they like moisture and in the dry atmosphere of summer tend to dry out. In the summer, too, many of them are hidden by the foliage and other leafy vegetation and sometimes are rather difficult to find.

The first lichen to attract our attention will

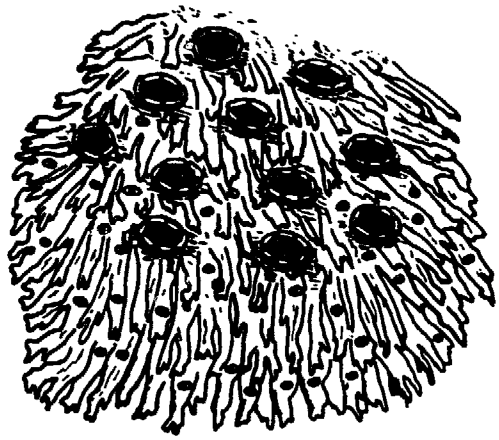


Figure 24
GRAY STAR LICHEN

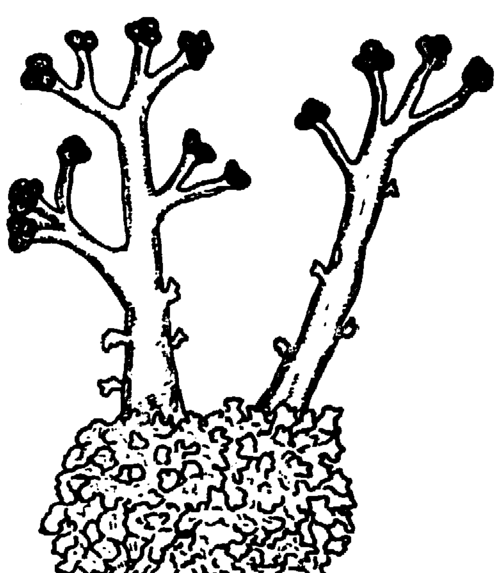


Figure 25
SCARLET CRESTED CLADONIA

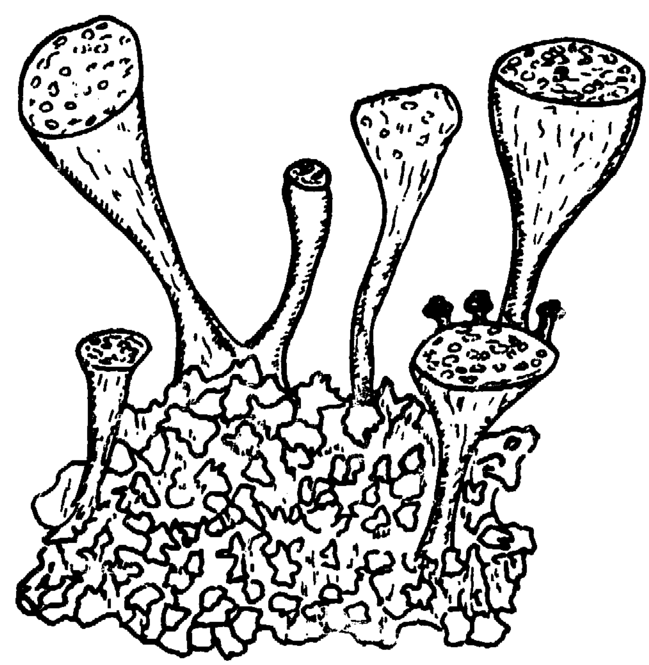


Figure 26
GOBLET LICHEN

probably be the gray star lichen since it is fairly common on trees and rocks. It is a small but rather conspicuous silvery-gray or slate-gray rosette (*Figure 24*). Let us look closely at it with our hand lens and we will find small, flat disks, dark brown or black or frosted pale gray, with pale gray rims that may be smooth, toothed, or broken (*Figure 24*). The flat disks are the fruiting structures in which spores are produced, which perform the same function as the seeds of the higher plants.

As we look about we observe on the ground a coral-like growth with small red knobs. We view it with our lens and discover a most pleasing color contrast as we compare the frosted green branches and the little red tips. This lichen is the scarlet crested cladonia (*Figure 25*), sometimes called British Soldiers. It is a very common species throughout the Eastern United States, occurring on the ground, on tree bark, on fallen and decaying logs, and sometimes on stones. The little red knobs or cushions are the fruiting structures.

We continue to examine various lichens as we find them, and as we peer at them through our lens we become breathless at the unexpected beauty as revealed by the glass. And this is what I meant by heading this Adventure as a visit to Fairyland. Minute candelabra will appear as if by magic, and you will see tiny goblets that may have served the potter as models for his art (*Figure 26*). Examine the unkempt and rather dirty incrustations on the surface of a rock and you may well wonder if some ancient sculptor did not find inspiration in the beautiful designs traced by them. The intricate tracery that many of the lichens have embroidered on a bare and rather forbidding surface are no less remarkable than those you will find in the ornamentation of some marble temple. But I will let you discover all this for yourself.

As you become better acquainted with the lichens, I think you will become fascinated, too, with the many curious names that have been given to them. Old Man's Beard, the Dog Peltigera, the Crumpled Bat's Wing, and the Mustard Seed are only a few. They are all well named, too, as you will observe when you find them. The most interesting of all the lichens is, perhaps, the Rock Tripe. With every change in humidity the lichen curls and uncurls, writhes and twists, alternately covering the rock on which it grows with a green and black coating.

Once you have become interested in these odd plants, you may want to build up a collection. They keep well, for the most part, and even when dry may be made fresh looking by adding a little water. All you need is a knife and a hammer and a cold chisel.

Lichens growing on trees or logs are easily removed with a knife and those found on the ground and in rotton wood may simply be lifted up. The ones that grow on rocks present a more difficult problem, and here is where you need the hammer and chisel. At first it may seem almost impossible to separate them from the rocks, but with a little patience you will soon learn how to chip away fragments of even the hardest stone.

ADVENTURE 8

We Examine a Feather

WE HAVE ALL HANDLED FEATHERS at some time but how many have looked at them closely or know how cleverly they are put together. There are several kinds of feathers, which vary somewhat in structure according to their function and position on the bird's body, but basically they are all the same. A typical feather is the contour feather. Contour feathers are the prevailing feathers. They are light in weight and provide a durable protective covering. They also serve as implements of flight. Equally important, they help to maintain the bird's body temperature. Air is an extremely effective insulating material and feathers are full of dead-air spaces. Perhaps you have observed birds fluffing out their feathers on a cold wintry day. This fluffing out, made possible by special muscles

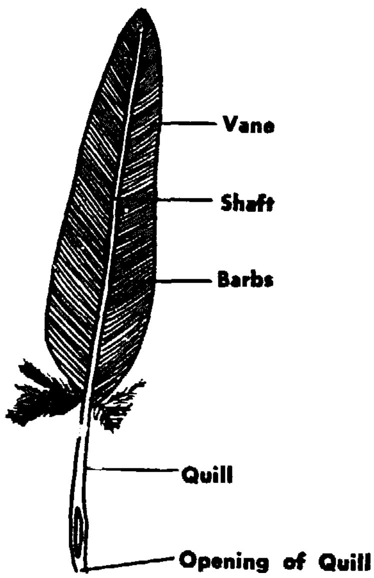


Figure 27
FEATHER

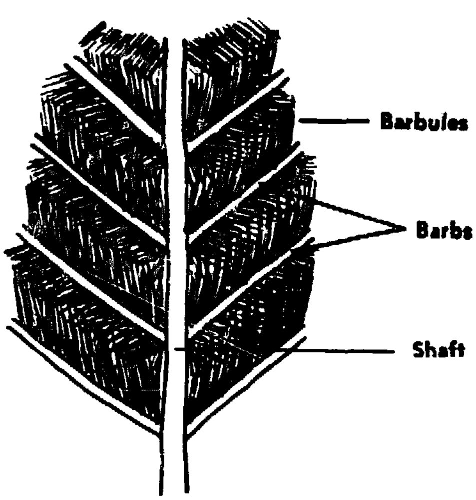


Figure 28
SECTION OF FEATHER

in the skin, increases the depth of insulating material by adding to the air spaces within the feathery layers. Conversely, on warm days the birds hold their feathers close to the body to allow some of the body heat to escape.

Feathers are easy to obtain, and you should have no difficulty finding one. Better get a contour feather, since this is the typical feather and best serves our purpose. The first thing you will probably notice about it is that it bears a superficial resemblance to a leaf (*Figure 27*) with its quill (petiole), shaft (midrib), and expanded portion, or vane or web (blade). But here the resemblance ends. Now examine the base of the shaft or quill and you will find it hollow, with a minute opening at one end. This opening is where the blood vessels entered the growing feather. Then note that the remainder of the shaft is solid and that the web, or vane, on each side is comparatively stiff and firm except where it was covered by the overlapping of other feathers where it is soft and downy.

Next hold the feather up to a bright light and look at a section of the vane through your hand lens. You will find that what appears at first to be a continuous leaflike surface is broken up into a series of barbs that are arranged on either side of the main shaft (*Figure 28*). Observe that they are set on a slight angle and more or less overlap at their edges. These barbs, in turn, are provided with innumerable little branches, called barbules, that overlap and interlock with the barbules of adjoining barbs (*Figure 28*). If your lens is of a high enough magnification (although you may need a microscope), you will further observe that the barbules are furnished with two kinds of projections called barbicels and hooklets (*Figure 29*). These barbicels and hooklets function as an interlocking device that gives the feather its consistency and stiffness and makes it impervious to air and water. It provides, however, a limited sliding arrangement of the barbules that gives more or less flexibility to the feather. The interlocking parts can readily be pulled apart, as you can find out for yourself by separating the barbs of the feather, and they can as easily be slipped back into place by drawing them through closed fingers. Birds repair such damaged feathers by drawing them through the bill.

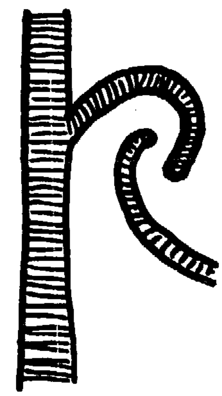


Figure 29
BARBICEL WITH HOOKLET

ADVENTURE 9

We Learn the Meaning of the Word Catkin

HEARING THE WORD "catkin" for the first time, you would suspect that it would have reference to the cat, and you would not be mistaken. The dictionary tells us that the word means "having some resemblance to a cat's tail." You have doubtless noticed in early spring countless tassels hanging from the twigs and branches of certain trees and shrubs. From their fancied resemblance to the cat's tail they were given the name "catkin," and though they are also known botanically as aments, they are today more generally called catkins. Actually they are flower clusters.

Flowers such as the rose and lily and tulip are borne singly at the end of a long flower stalk and are called single or solitary flowers. In most flowering plants the flowers are borne in groups or clusters. A group or cluster results from the branching of the main flower stalk and is known as an inflorescence. There are different kinds of inflorescences, as the raceme, spike, cyme, corymb, umbel and, of course, the catkin, depending on the manner in which the flowers are arranged.

The catkins of the speckled alder* are among the first to appear in early spring. This small tree, so named because its stems are sprinkled or speckled with numerous and conspicuous light gray spots that are actually breathing pores called lenticels, is a water-

* The speckled alder is a shrub of the northern states but a closely related species, the smooth alder, is widely distributed throughout the south. The two, which may often be found growing together where their ranges overlap, are very much alike in habit and the catkins of either may be examined since they are similar.

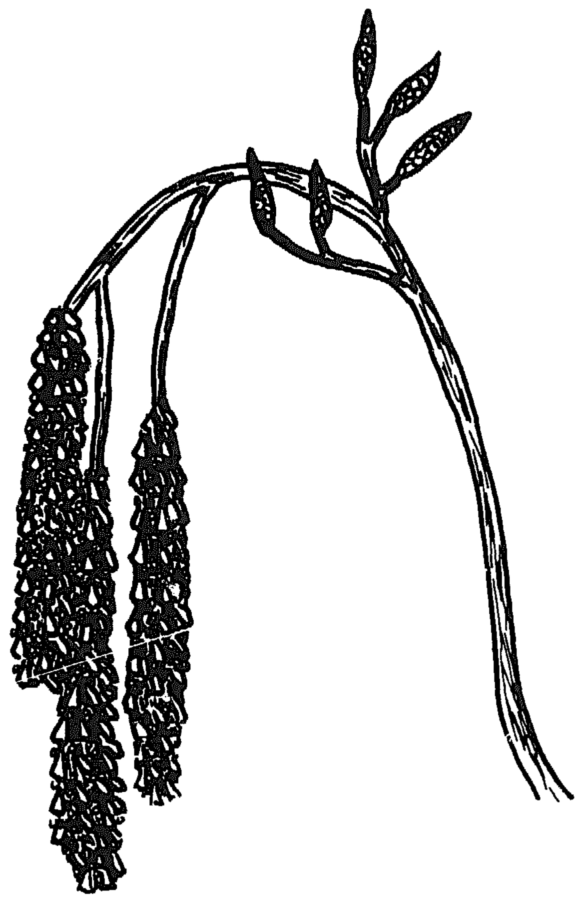


Figure 30
SPECKLED ALDER

loving plant and grows along the edges of ponds and streams and in swampy places. During the winter the unopened catkins are stiff and inflexible, but as the March sun climbs higher in the sky and the earth is warmed, the stiff fibers relax, the scales open, and the long, plumy tassels emerge to dance upon every passing breeze.

Let us examine one of these pendant tassels (*Figure 30*). As we look at it through our hand lens we find that it consists of brown and purple scales surmounting a central axis. We

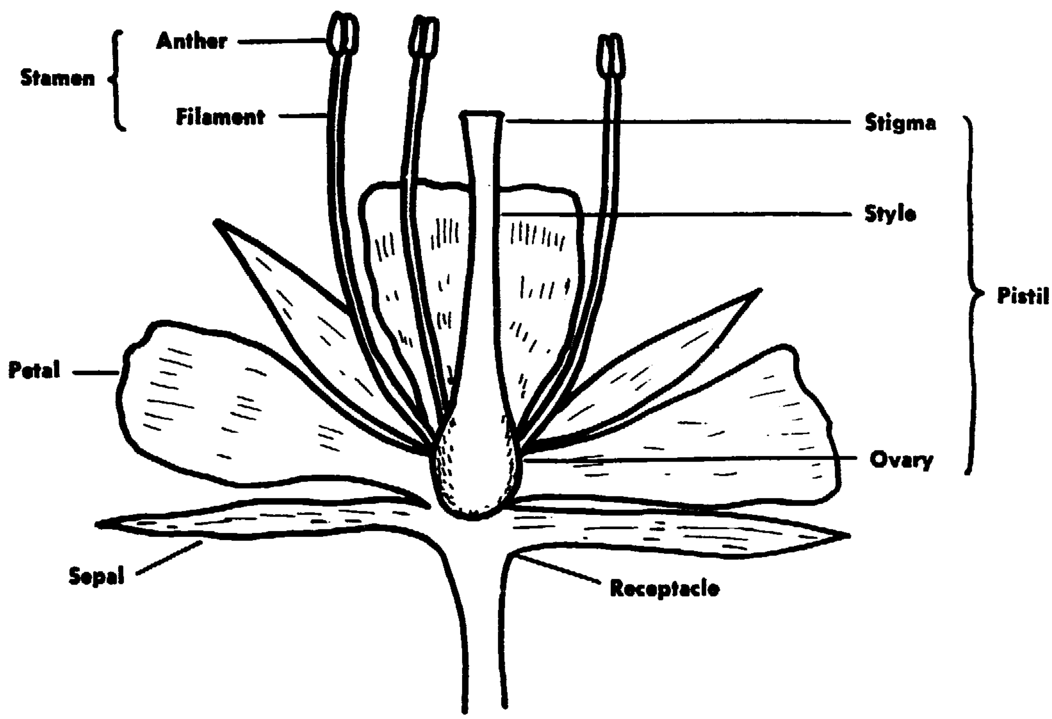


Figure 30A
DIAGRAM OF A SIMPLE FLOWER

further observe that the scales are set on short stalks and that beneath each scale are three flowers, each having a three-to-five lobed calyx cup and three-to five stamens whose anthers are covered with yellow pollen.

Let us pause at this point and recall our knowledge of botany. In spite of their striking external multiformity flowers are comparatively simple and uniform in their mode of construction. *Figure 30A* shows the diagram of a typical flower to which you can compare almost any blossom you have at hand. First we have the receptacle, which is the tip of the floral stem. Then we have the outer greenish leaves called sepals, which collectively are known as the calyx. Next we have the brightly colored leaves or petals, which collectively are known as the corolla. Within this corolla we have a whorl of appendages, the stamens. Each stamen consists of the filament, a slender cylindrical stalk bearing at its tip an enlarged rounded body, and of the anther, in which pollen grains, containing the male, or sperm, cells, are produced. Finally, within the whorl of stamens, and occupying the center of the flower, is the pistil, made up of modified leaves called carpels. The pistil consists of a cylindrical stalk called the style, with a rounded base, the ovary, and with a roughened area at the other end known as the stigma. The ovary contains a number of roundish bodies, within each of which, in a special sac, lies the female sex cell —the egg. When union of the egg cells and sperms has been effected—a process called fertilization—the roundish bodies, called ovules, develop into seeds.

Modifications and variations of such a typical flower frequently occur. As we look carefully at the flowers of the alder, we note that the pistil, an essential floral structure, is missing.

Now recalling our knowledge of botany,

we discover that the pistil, an essential floral structure, is missing. The absence of a pistil at first appears to be something of a puzzle until we examine one of the shorter erect catkins. Here we find that each of the fleshy scales, with which the catkin is provided, encloses two flowers, each having a pistil with a scarlet style. So there are two kinds of catkins on the alder, one having flowers with stamens only and the other with flowers having only pistils. In other words, we have what are known as staminate and pistillate catkins. Where both are found on the same tree, as in the alder, the tree is said to be monoecious.

Examining the flowers still further, we also observe the absence of petals. As the pollen grains are transferred from one flower to another by the wind, the petals would only be a hindrance and impede the wind from picking up the grains and acting as an effective agent of pollination. Here is an adaptation of distinct advantage to the plant.

Once pollination has been carried out, the pistils develop into small cones that resemble miniature pine cones. They consist of woody scales that protect the seeds formed beneath them. When the seeds are fully matured, the scales open and release the seeds, which are also scattered by the wind.

Next let us turn our attention to the pussy willow, whose furry catkins are a familiar

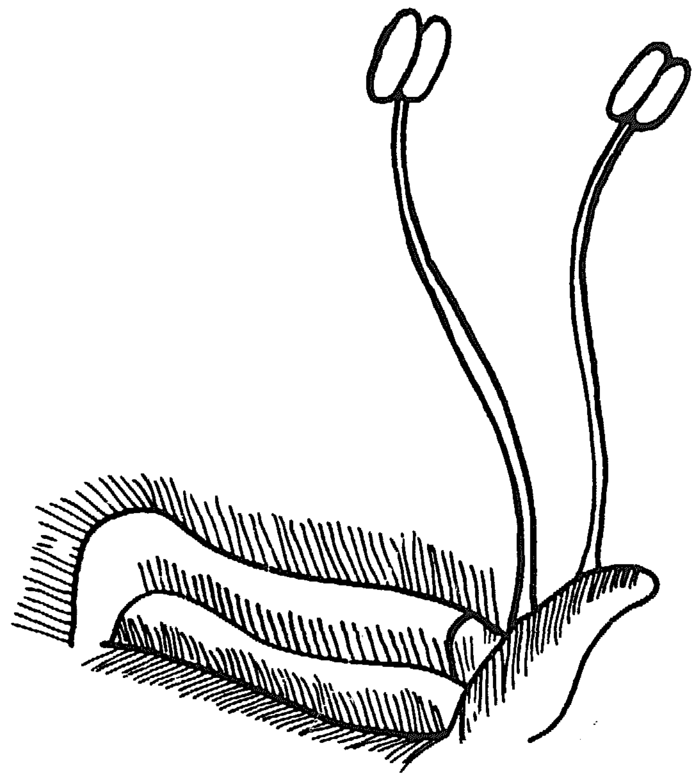


Figure 31
STAMINATE FLOWER OF PUSSY WILLOW

sight in early spring throughout the Eastern and Central states. Unlike the alder, the pussy willow is dioecious, that is, the staminate and pistillate catkins occur on separate plants. Thus it will be necessary for us to locate two separate pussy willows, but this should not be difficult, since the plant is common and abundant. We can easily recognize the staminate plant because the catkins are profusely covered with yellow pollen. When we examine the flowers with our lens, we find that they each have two stamens (*Figure 31*).

Figure 32
PISTILLATE FLOWER OF PUSSY WILLOW

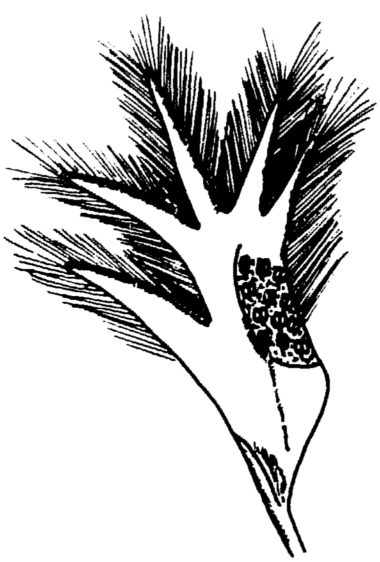


Figure 33
STAMINATE FLOWER OF ASPEN

Now let us examine a pistillate catkin, which we can identify by the absence of the yellow pollen and by the very shape of the flowers themselves. When we do so we find that each flower has only a single pistil, with two more or less divided stigmas (*Figure 32*). If we keep the pistils under observation for a few days, we will find that they develop into conic-shaped capsules. These capsules contain the maturing seeds, and when the latter become fully developed the capsules will open. The seeds are furnished with long silky down that catches in the wind, an effective means that the pussy willow, in common with other plants, has evolved to ensure a wide distribution of its seeds.

The aspen is said to be the most widely distributed tree in North America. Most of us know it as the quaking aspen, because its leaves quiver or tremble in the slightest breeze. The catkins appear before the leaves, are furry, and show a touch of pink. The tree may be readily identified by its gray-green bark. Like the willow, the aspen is also dioecious. Note how the scales of the staminate flowers are deeply cut into three to four linear divisions and how they are fringed with long, soft gray hairs (*Figure 33*). The stamens number from six to twelve. The stigma is two-lobed (*Figure 34*), and the ovary is surrounded by a broad, oblique disk.

There is considerable variation in the flowers of the alder, willow, and aspen, even as there is in the more showy flowers. The variations may be small and seemingly insignificant, and yet they help us to identify and classify the plants. Of course, there are many other trees that bear catkins, among them being the birches, oaks, and hickories, and when they appear, examine them and note further variations. The staminate catkins of the black birch are fairly long, pendulous, and occur in clusters of threes; the pistillate catkins are much shorter, erect and solitary. The staminate catkins of the shagbark hickory are similar, but the pistillate ones occur on two- or five-flowered terminal spikes. Then in the white oak the staminate flowers are yellow, the pistillate red.

Figure 34
PISTILLATE FLOWER OF ASPEN

ADVENTURE 10

We Study the Wings of Insects

WE UNDERSTAND, of course, how insects and birds and airplanes can move through the air —it all has to do with air pressure and air flow and similar phenomena. Now has it ever occurred to you to examine a fly's wing with a hand lens? Probably not, so let us look at one and see what we find.

The best way to capture a fly without damaging it is with the killing jar, which we described in Adventure 6. Wait until a fly alights on a flat surface, since it will then have the least chance of escaping, and then approach it stealthily with the uncovered jar and quickly place the jar over it. The startled insect will fly into the jar, and then you can replace the cover.

When the fly has inhaled enough of the poisonous fumes and shows no further signs of life, remove it from the bottle and examine one of the wings with your lens. It will appear as a piece of transparent parchment divided into a number of areas by thickened structures (*Figure 35*). Since a wing is a saclike fold of the body wall, it obviously must consist of two walls, but, looking at it, you would never suspect that such is the case, the two walls having been so closely fused together that the wing appears as a single membrane. The dual nature of the wing may be seen, however, along certain thickened lines where the two walls remain separated. These thickened lines are hollow and form the framework of the wing. They are called veins. Note how they are arranged. This arrangement is peculiar to the housefly, and in no other insect will you find them arranged in precisely the same way. Veins are known by certain terms according to their position. Thus veins are known as the costa, subcosta, radius, media, cubitus, and anal. The areas into which the veins divide the wing are called cells, and

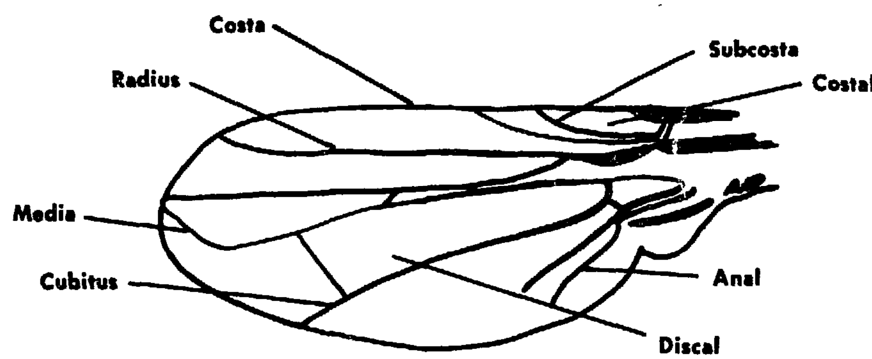


Figure 35
WING OF HOUSE FLY

these too are known by various terms, as discal, costal, etc., or they may be merely indicated by letters, as R_1, R_2, R_3, etc. The arrangement of the veins is known as venation or neuration and serves as a means of classifying insects. As a matter of fact, the wings of insects present such countless differences that an expert can usually refer a detached wing to its proper genus and often to its species even though there are at present almost a million known species.

With a few exceptions wings are usually present in adult insects. They are more or less triangular in shape, with three margins: front (costal), outer (apical), and inner (anal); and three angles: humeral (at the base of the costa), apical (at the apex of the wing), and anal (between outer and inner margins) (*Figure 36*). Typically there are two pairs of wings in an insect, although in some species

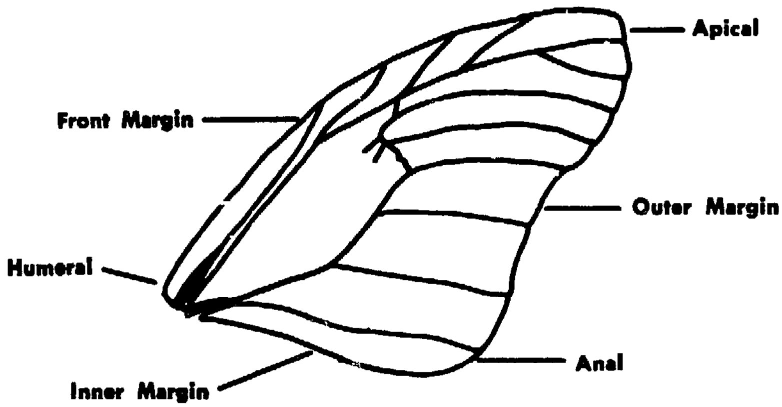


Figure 36
DIAGRAM OF A WING SHOWING ANGLES AND MARGINS

the females are wingless and in the vast group of true flies (Diptera) the second pair has been lost, having been replaced by knobbed, threadlike organs called halteres. The halteres appear to function as balancers, for the fly can no longer maintain its equilibrium if one of them is removed. See if you can locate them.

Next examine the wing of some other kind of insect—a butterfly, dragonfly, grasshopper, a beetle, a bee—better still, a number of them. As you do so, you will find that the front wings are variously modified, in some insects being more useful for protection than for flight. In grasshoppers (Orthoptera) the front wings are leathery and are called tegmina; in the beetles (Coleoptera) they are

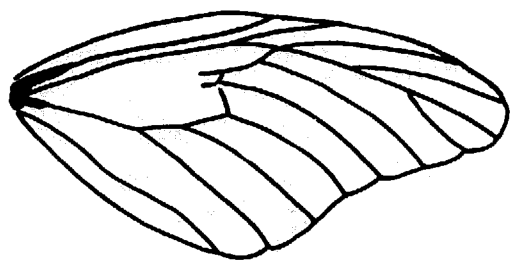


Figure 37
WING OF MONARCH BUTTERFLY

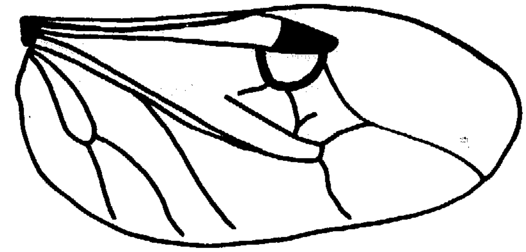


Figure 38
WING OF COLORADO POTATO BEETLE

usually horny and are known as elytra; and in the true bugs (Heteroptera) the base is thickened and the apex of the wing remains membranous, forming what is called a hemelytron. You will also observe, of course, that the veins in the wings of these various insects are differently arranged. The wing of the Monarch Butterfly is shown in *Figure 37*, and the wing of the common and destructive Colorado Potato Beetle is pictured in *Figure 38*.

I think you will agree that in flying an insect can make greater use of its wings if the fore and hind wings act in unison, much as the members of a boat's crew can attain greater efficiency with their oars if they all pull together. The synchronous action of the

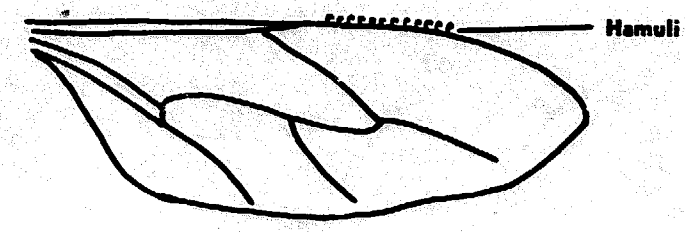


Figure 39
HIND WING OF HONEYBEE

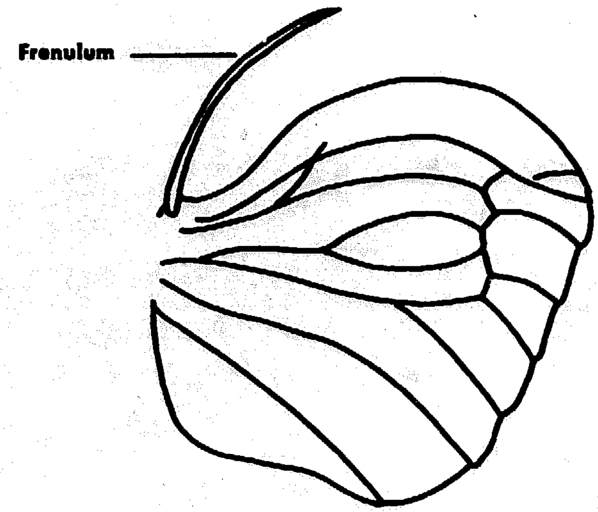


Figure 40
HIND WING OF A MOTH

fore and hind wings is attained in insects by the fore wing's overlapping the hind wing, but in some species certain structures have been developed that fasten the two wings of each side together. Obtain a honeybee and examine the outer coastal margin of the hind wing (*Figure 39*). You will find a row of hooks called hamuli, which fasten into a fold on the inner margin of the fore wing. Next examine the hind wing of a moth, where you will find at the humeral angle a strong, spine-like organ or a bunch of bristles called the frenulum, or little bridle. As a rule the frenulum of the female consists of several bristles; in the male it is a single, strong, spinelike organ (*Figure 40*). In the males of certain moths where the frenulum is highly developed, the fore wing has a membranous fold for receiving the end of the frenulum.

ADVENTURE 11

We Watch Some Acrobats Perform

WE DON'T HAVE TO WAIT for the circus to come to town to see acrobats. The acrobats I am thinking about we can find, figuratively, in our own back yard or, put more accurately, in the nearest pond. You may not find them performing the death-defying feats that those beneath the Big Top execute, but I think you will find them just as interesting.

Just what are these acrobats? They are small animals shaped like fleas, with arched backs and narrow bodies, with climbing legs on the thorax, and swimming and jumping appendages on the abdomen. They belong to a group called the Amphipoda and are really accomplished water acrobats, as you will agree when you have watched them for a time, for they can climb and jump, swim or glide with equal ease. As these acrobats are too small really to be watched in their native habitat, it is best to take a few of them home and transfer them to an aquarium, where they may be better observed.

There are several species of fresh-water amphipods, but one of the most common and abundant is Hyallela. In the spring it gathers in large numbers in mats of the alga Spirogyra to feed on the dead filaments, and this is a good time to collect it, although we can find it at almost any time of the year, even in winter. Hyallela does very well in an aquarium planted with some living water plants, as Elodea, Nitella, or Myriophyllum, and containing a few dead leaves. All of these can be obtained from almost any pond. The aquarium should be prepared and ready to receive its occupants. Hyallela may be taken from the pond by submerging a wide-mouthed bottle and letting the water flow in, or it may be collected with a pan or water net; in fact almost anything can be used that will hold water. Hyallela is about half an inch long and thus large enough to be seen with the naked eye. I have pictured it in *Figure 41* so that you will readily recognize it as it moves about in the water.

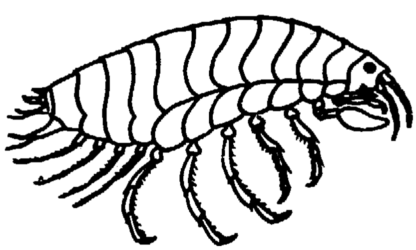


Figure 41
HYALLELA

Because it is large enough to be seen with the naked eye, you can easily observe some of its habits, such as feeding and mating, without the use of your hand lens. But one of the most interesting phases of its behavior, for which you will need your lens to observe properly, is when it casts off its skin. Hyallela is a distant cousin of the lobster, crab, and crayfish, and if you know your zoology you know that these animals are crustaceans. The word "crustacean" is derived from the Latin *crusta,* which means "crust" or "shell" and refers to the hard outside covering possessed by these animals. This hard outer covering is made largely of a hard, inelastic material called chitin. Since this material cannot stretch, these animals periodically reach a point where growth can no longer take place beneath the hard covering. So it must be discarded. The casting off of this outer covering is called molting and is repeated a number of times, depending on the species, until full growth is attained. The molting process, which is in itself interesting to watch, can very well be observed in the case of Hyallela simply because it occurs so slowly. I don't want to describe it—I would rather have you watch it yourself and see how it takes place.

ADVENTURE 12

We Go Botanizing

THE STUDY OF FLOWERS can be made highly absorbing because of their great diversity. Let us, for instance, examine the dandelion with our hand lens. Its appearance when viewed through the glass will be quite unlike what you saw with your naked eye. You will find that instead of being a single flower, which many suppose it to be, it is composed of many small flowers, and if you were to count them you would find that there would be somewhere between 150 and 200 of them. Each one of them is a perfect flower or floret;

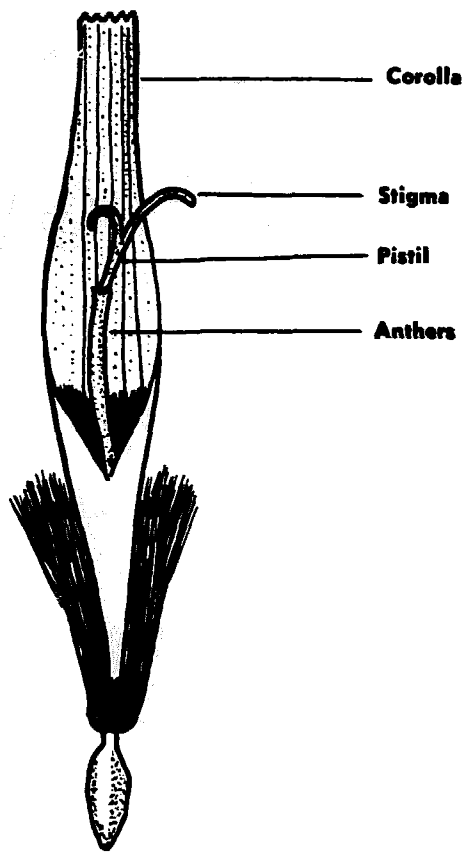


Figure 42
DANDELION

that is, each has both stamens and a pistil, but with a corolla consisting of a tube and a ray upon one side only. This corolla is straplike, with five teeth at the apex (*Figure 42*).

Once upon a time, this flower may have been a five-petaled blossom, for the five teeth at the top and the five lines descending from them would seem to indicate that once-distinct parts had been welded together to form a more showy and suitable corolla. Next see if you can find the five anthers that form a tube from which the pistil extends with its two-lobed stigma. You will note as you examine several of the florets that they may all be in various stages of development. The florets in the outer row of the dandelion head blossom first. After a corolla has opened, there first appears the anther tube, and then later the pistil, which gradually rises out of the anther tube and extends above it, when the stigma lobes quirl back.

Next let us examine the white clover. What appears at a casual glance to be a single flower is composed of a number of small flowers or florets. Each floret has a tubular calyx with five delicate points and a little stalk, and the corolla of five petals, which are very unequal, reminds us of the sweet pea (*Figure 43*). The superior petal, known as the standard or banner, more or less completely encloses the two lateral ones, and the two lower ones are more or less united into what is known as the keel. There are ten stamens, nine of which are united and one is free (see if you can find them), and one pistil. Incidentally, both the dandelions and the clover represent the type of inflorescence (see Adventure 9) called the head, which can be defined as a dense cluster of sessile or nearly sessile flowers on a very short axis. (Sessile flowers are flowers that are attached directly to the main stem without having a stem or stalk of their own.) Such a dense cluster is obviously more showy than the small florets and therefore more effective in attracting insect visitors.

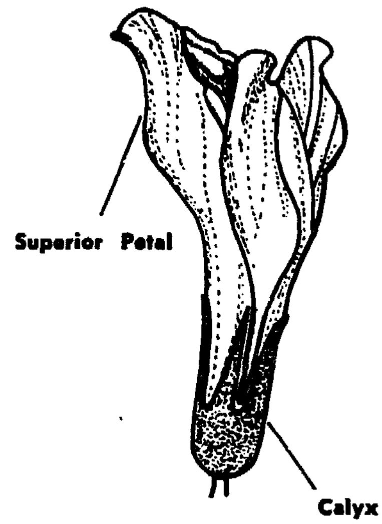


Figure 43
WHITE CLOVER

In early spring the bluets are a familiar sight in the fields and meadows of the Eastern and Central states. They are light blue, pale lilac, or nearly white with a yellowish center. Whatever the color, if we examine one of the flowers with our lens we observe that it is funnel-shaped with four pointed, petal-like oval lobes. An interesting feature of this plant is that it produces two kinds of flowers, which, however, are not found in the same patch. So if we want to examine both kinds we must look in different patches. If we select a flower from one patch, we may find that the two-lobed stigma extends above the opening of the corolla tube, and if we open the flower we will find four anthers fastened to the sides about halfway up (*Figure 44*). Now if we

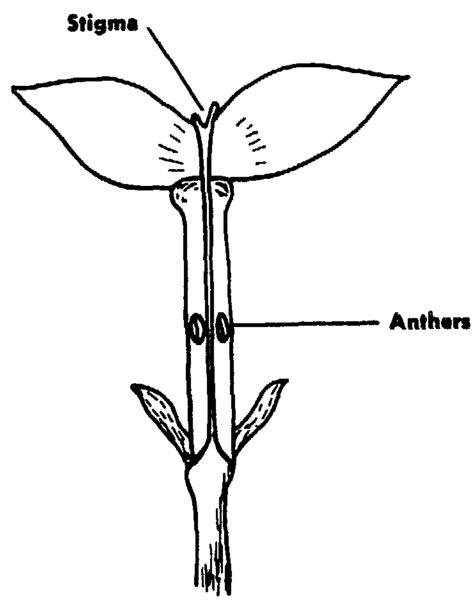


Figure 44
BLUET FORM A

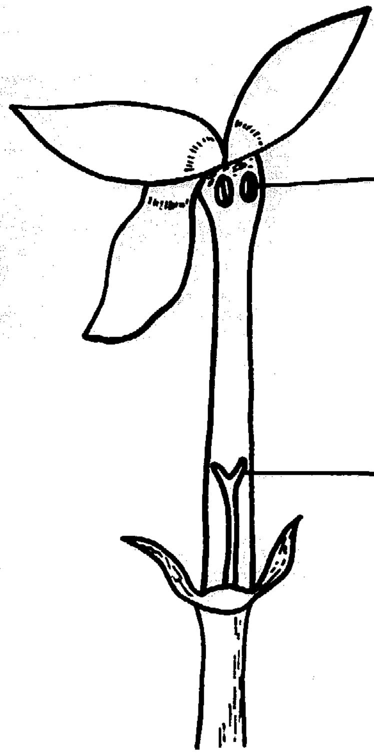


Figure 45
BLUET FORM B

move to another patch and select a flower from it, we find four anthers near the opening of the tube, but the stigma is not visible. If, however, we open the flower we find the stigma about halfway up the tube (*Figure 45*), in other words, just the reverse of what we found in the first flower. Thus, we have two kinds of flowers: Form A and Form B. The reason for the two kinds is, of course, to secure cross-pollination. An insect visiting Form A (*Figure 44*) gets its tongue dusted with pollen from the anthers at the middle of the tube. This pollen is brushed off by the stigma of Form B (*Figure 45*). Conversely, an insect visiting Form B gets the base of its tongue dusted with pollen, which is removed by the protruding stigma of Form A.

One of the more conspicuous wild flowers of summer is the wild carrot, also known as Queen Anne's Lace (*Figure 46*). The large white, circular, flat-topped clusters (known as umbels) are familiar in fields, along roadsides, and in waste places. When viewed with the naked eye the clusters appear to be a lacework of some beauty, but it is only when we examine them with our lens that we can appreciate their delicate structure and perfection of detail. One of the first things we notice is that the flowers are of unequal size, but each with five petals and five stamens and two styles. We also observe that what appeared to the naked

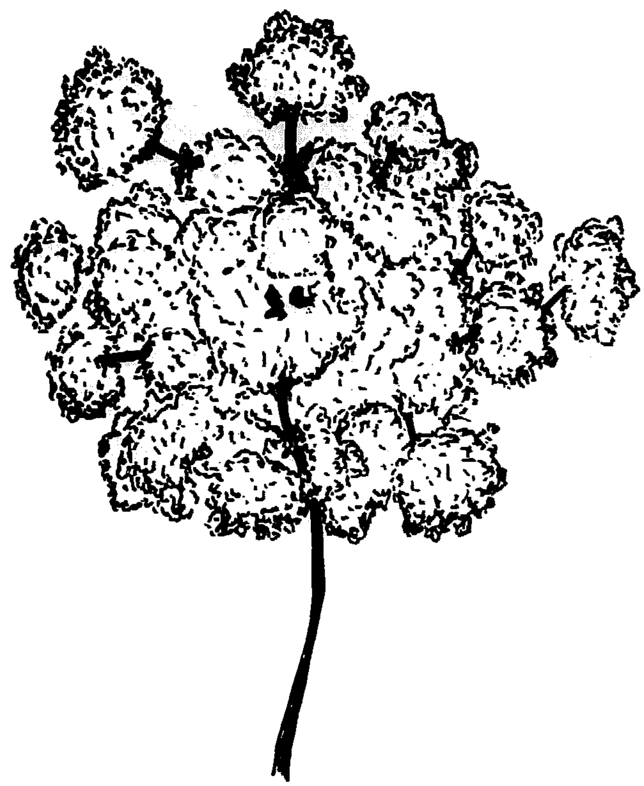


Figure 46
WILD CARROT

eye to be a single cluster is actually composed of a number of small clusters. A very odd feature of the cluster (I am now speaking of the entire cluster) is that at the very center there is a large floret with delicate, wine-colored petals. This floret, as you will note, is not a part of any of the smaller clusters but is entirely separate and is set upon its own isolated stalk. The presence of this striking floret in the very center of the wide, circular flower cluster is a mystery—I know of no one who has been able to account for it. Even-

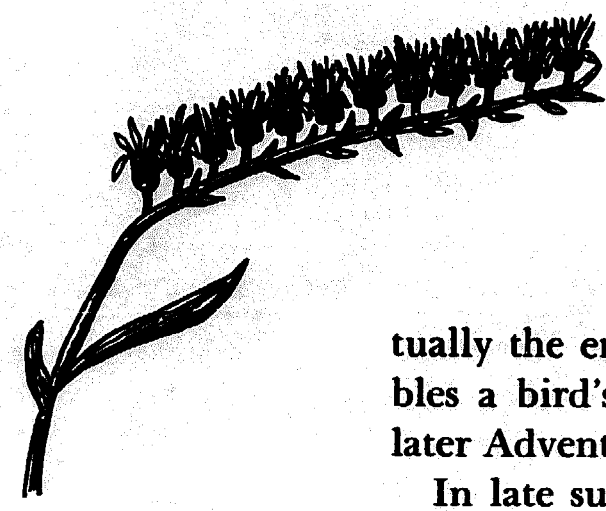


Figure 47
GOLDENROD

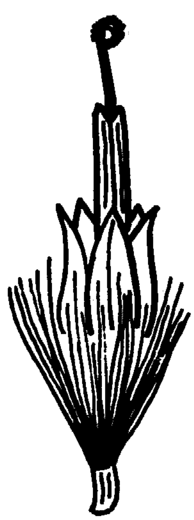


Figure 47A
DISK FLOWER OF ASTER

tually the entire cluster dries up and resembles a bird's nest. We shall refer to it in a later Adventure.

In late summer and early fall the goldenrods dress the fields with their waving wands in a cloth of gold. Let us detach one of the flowering stems and look at it through our lens. What we find is a surprising row of tiny yellow goblets (*Figure 47*). The asters, too, are a familiar sight at this time of the year and to the eye appear as central yellow disks surrounded with an outer ring of what appear to be petals, variously colored in white or tints of blue, violet, or purple. If we were to examine any one of them with our lens, we would discover that the central disk is composed of many erect tubular blossoms that, yellow at first, change later to purple or brown with age. They are known as the disk flowers (*Figure 47A*). The so-called petals are elongated, strap-shaped blossoms known as the ray flowers (*Figure 47B*). Comparing them carefully, we find them unlike for the reason that the ray flowers are pistillate, that is, with pistils only, whereas the disk flowers are perfect, meaning that the disk flowers have both stamens and pistils—in other words, both male and female organs of reproduction. The ray flowers are female only.

The evolutionary changes that brought about the present floral arrangement in the asters—for they were not originally as they are today—make a most interesting story, but too long a one for this book. What we can say is that, as the flowers and insects developed side by side and each became more and more aware of each other's requirements, mutual adaptation followed. The flowers that offered the greatest benefit to the insects and advertised their wares most blatantly, and in turn employed their insect visitors to the fullest in distributing their pollen, were the most successful. This is what the asters, as well as other flowers, were able to do.

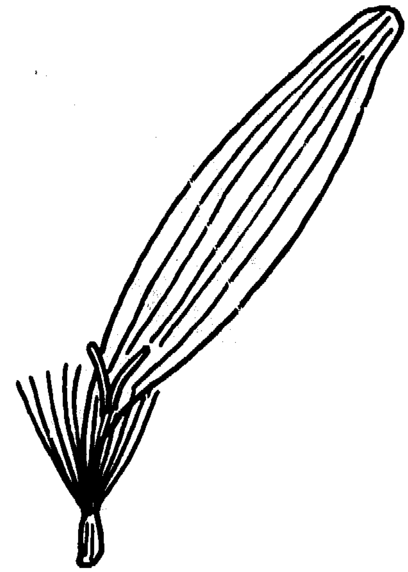


Figure 47B
RAY FLOWER OF ASTER

ADVENTURE 13

We Compare Insect Antennae

YOU HAVE DOUBTLESS read of how ants communicate with one another by means of their antennae, or feelers. Perhaps you have actually seen them do so.

Let us pick up the ant and examine its antennae closely with our lens. We find that it is composed of a number of segments joined together in a linear series and that its entire appearance is quite different from when

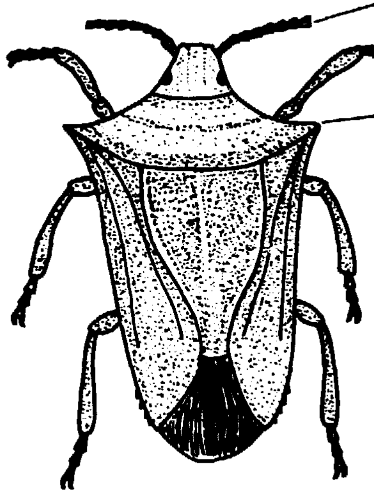


Figure 48
BROWN STINKBUG

viewed with the naked eye. Next let us count the many segments. Perhaps we may have to repeat our count several times before we are sure of the correct number.

The antennae of insects are commonly regarded as organs of touch. However, in the ant's antennae, segments eight through twelve have been modified for the purpose of detecting odor. By means of the twelfth segment the ant can detect the odor of any descendant of the same queen and thus be able to recognize the members of its own community wherever it may find them. The tenth segment enables the ant to recognize the odor of its own feet and thus be able to retrace its own steps. Lastly, the eighth and ninth segments provide the ant with the means and intelligence of caring for the young. If an ant should be deprived of these five end joints of its antennae, it has no further caste as a social ant and loses its standing in the community.

Now that we have found that the antennae of insects are composed of segments joined together in a linear series and that the segments may be variously modified to perform certain functions, let us examine the antennae of a few other species, and as we do so we will find that the antennae differ, not only in form, but, in some species, between the male and female. The stinkbugs are a group of fairly common insects abundant on various plants. The rather crude, if not vulgar, term that has been fastened on them is due to a fluid secreted through two openings on the lower surface of the thorax. Another name for them is shield bugs, because of the large scutellum, or shield-like area. If we look on tomato, eggplant, and related plants, we should have no trouble finding the brown stinkbug, also called the spined stinkbug. It is a medium-sized brown species with an angle on each side of the pronotum (*Figure 48*). Examining the antennae with our lens, we note that the segments are all of a nearly uniform size, giving the entire antennae a threadlike appearance. Scientists call this type of antennae filiform (*Figure 49*).

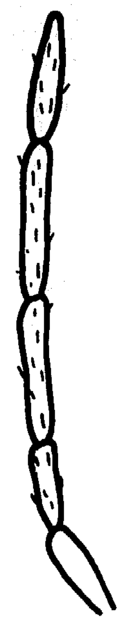


Figure 49
FILIFORM

Next let us visit a pond or stream where we want to examine the antennae of a dragonfly. To do so we must take along our insect net (see Adventure 6). Dragonflies are not easy to capture, particularly some of the larger species, which are expert flyers. One of the common and abundant species is the white-tail, which is easy to recognize since the males are powdered with white, so let us concentrate on capturing one of these. When we finally do so and examine one of the antennae, we observe that the segments are successively smaller and smaller, the entire organ tapering to a point. In other words, the

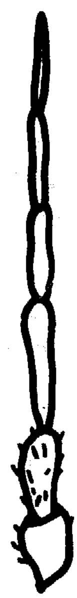


Figure 50
SETACEOUS

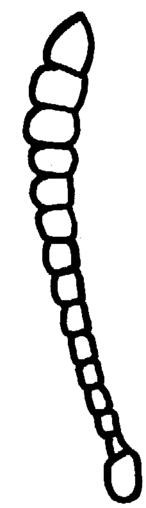


Figure 51
CLAVATE

antenna appears bristle-like, and here again the scientists have a word for it, setaceous (*Figure 50*).

Since we are outdoors with a butterfly net, we may as well next turn our attention to the monarch or milkweed butterfly. Most of us are acquainted with this rather large, ruddy-brown butterfly we see flying over fields and along roadsides and occasionally in our gardens during the summer months. Its caterpillars feed exclusively on the milkweed, hence its name. The monarch has antennae quite unlike those of either the stinkbug or dragonfly, as you will discover when you capture one and look at its antennae. You will note (*Figure 51*), that they

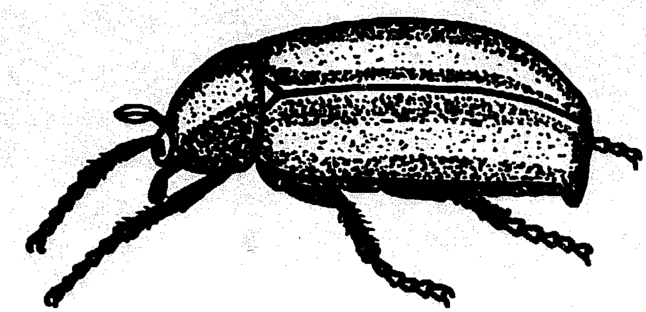


Figure 51A
JUNE BEETLE

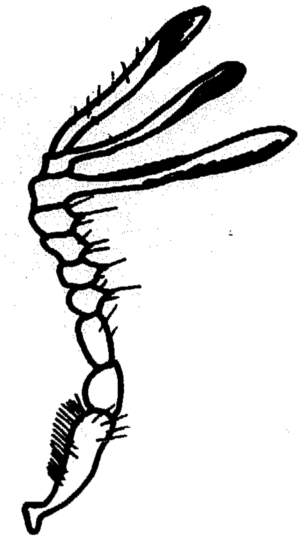


Figure 52
LAMELLATE

are club-shaped (clavate), the segments becoming gradually broader so that the entire structure has the appearance of a club.

Another insect whose antennae we should also examine is the June beetle (*Figure 51A*). This is the large mahogany-brown beetle that makes its appearance in May or June and may often be found flying about our porch lights at night. Sometimes it bangs against our screens with a resounding noise that is quite startling. You will find that the segments that compose the tip or knob are extended on one side into broad plates, forming a somewhat lamellated (plated) structure, whence the term "lamellate" for this type of antennae (*Figure 52*). If you are not

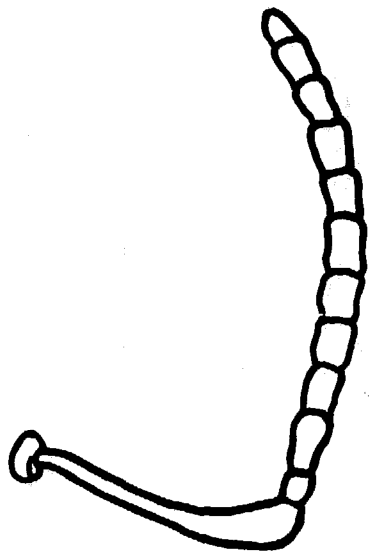


Figure 53
GENICULATE

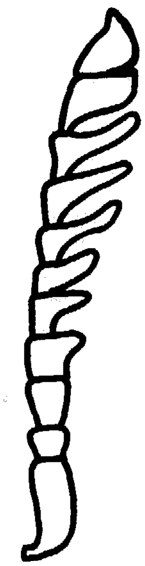


Figure 54
SERRATE

too timorous about going after a bumblebee, you will find that the antennae of this insect are oddly shaped. All of the insects we have discussed so far may be examined without danger while alive, but it is inadvisable to examine a bumblebee in this fashion. It is best to capture one with a butterfly or insect net and then place it in a killing jar* until life has been extinguished, when it may be handled safely. You note that the antennae are bent abruptly at an angle like that of a bent knee. This type is called geniculate (*Figure 53*).

There are many other forms of antennae,

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* See Adventure 6.

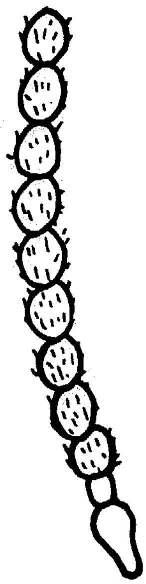

Figure 55
MONILIFORM

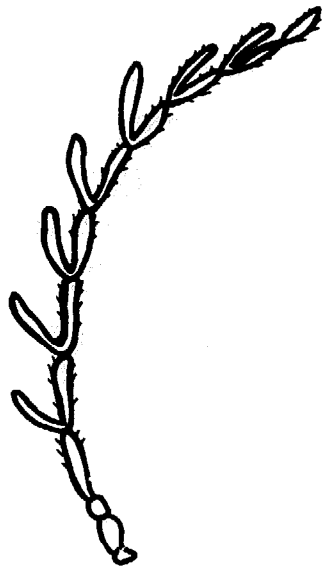

Figure 56
PECTINATE

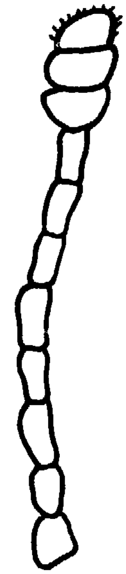

Figure 57
CAPITATE

as you will discover by examining various insects: sawlike (serrate, *Figure 54*), in which the segments are triangular and project like the teeth of a saw; necklace-form (moniliform, *Figure 55*), in which the segments are more or less spherical, suggesting a string of beads; comblike (pectinate, *Figure 56*), in which the segments have long processes on one side, like the teeth of a comb; or in some species the antennae may have the last segment greatly enlarged, forming a large knob (capitate, *Figure 57*).

Finally, if you were to compare the antennae of the male and female cecropia moth or those of the male and female mosquito, you

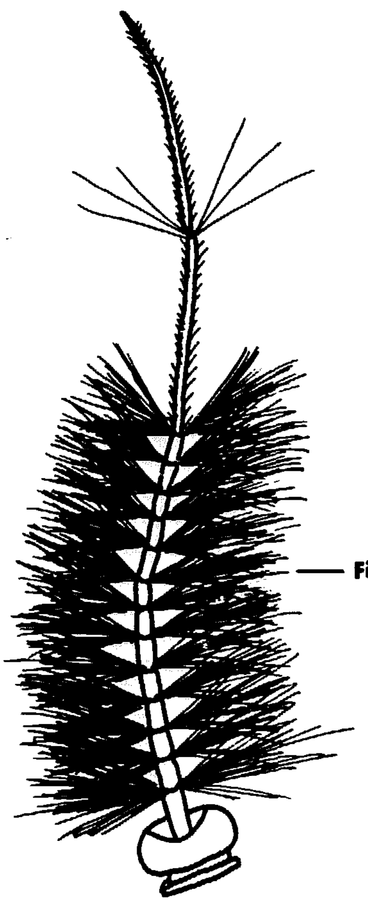

Figure 58
ANTENNA OF MALE MOSQUITO

would find that those of the male cecropia are larger and more feathered than those of the female. The reason for this is that the male seeks out the female by means of the sense of smell and depends on his antennae to detect the odor given off by the female. In the case of the mosquito, the male uses his antennae to locate the female through the sense of hearing, the delicate fibrillae of the antennae (*Figure 58*) being sent into sympathetic vibration by the note of the female, much as our radio and television aerials pick out the waves sent out by the transmitting stations. Besides serving as organs of touch, smell, and hearing, antennae also function in some species, as in the water scavenger beetle, as respiratory organs. Some male insects use them in mating.

We may now ask how insects perceive the various stimuli that enable them to react and behave as they do. To learn how they do this, we need only to re-examine the antennae a bit more closely, and in some cases a microscope might be required, when we find that for the perception of sensory impressions the integument, or external covering, of the antennae has been further modified into cones (*Figure 59A*), peglike projections (*Figure 59B*), bristles or fine hairs (*Figures 59C and D*), plates (*Figure 59E*), and flask-shaped cavities and the like (*Figure*

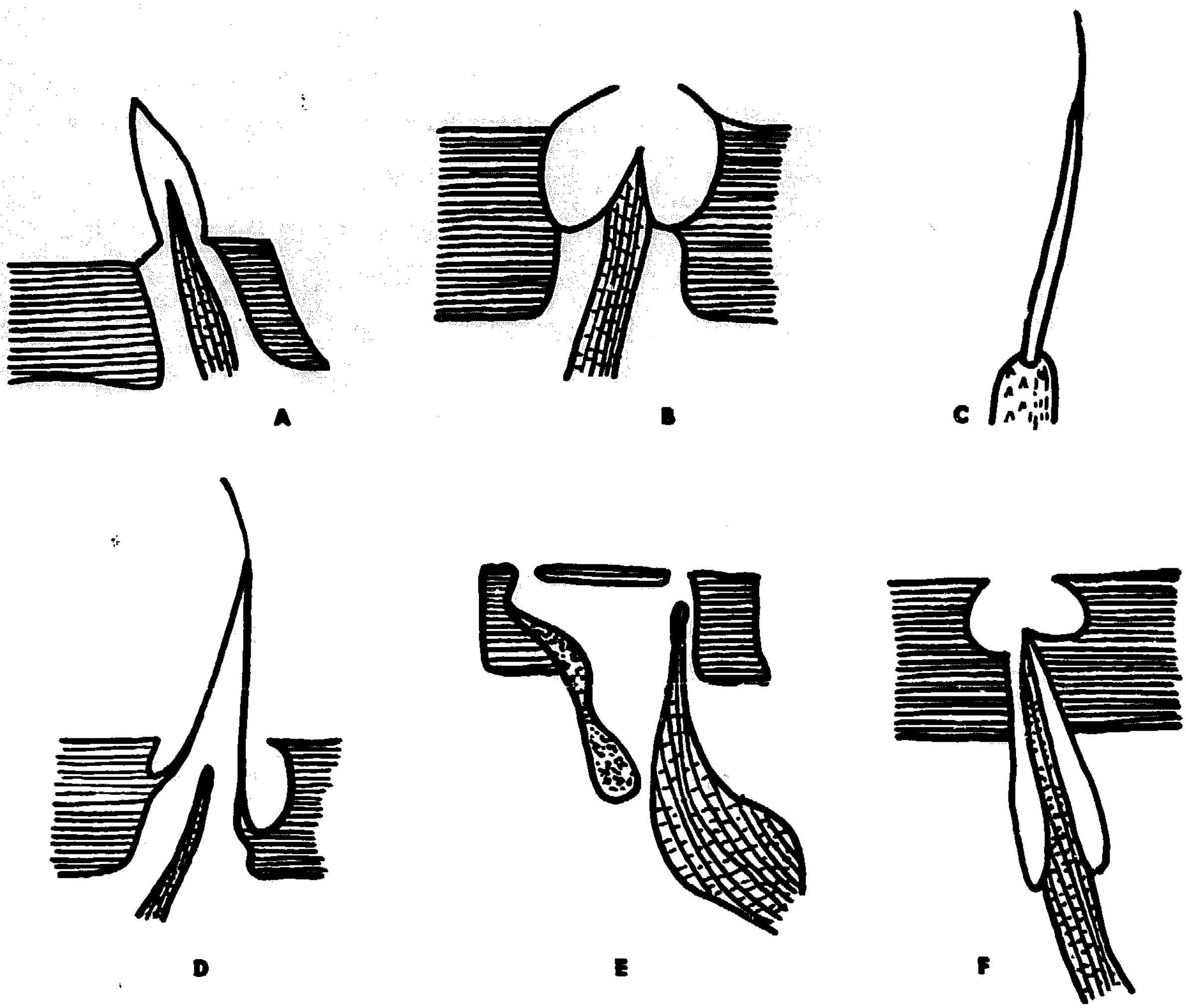

Figure 59
ANTENNAL SENSE ORGANS

59F). It is these adaptive structures that serve as sense organs and that respond to the stimuli of sound, smell, and touch. The subject is an exhaustive one and obviously we cannot go into detail here, but if you would like further information I would suggest that you consult any standard textbook on insect anatomy and physiology.

ADVENTURE 14

We See How Ants Keep Clean

Figure 60
ANTENNA CLEANER OF ANT

IN OUR LAST ADVENTURE we learned that insects use their antennae to detect sound and odors, and for various other purposes. In order to function successfully it seems rather obvious that these organs must be kept clean. Ants, then, have a utilitarian reason for personal grooming, and as we have combs and brushes, so, too, do they have means of removing dirt and other debris from their bodies. Let us see what they are.

If you have not already observed ants in the act of cleaning their antennae, I would suggest that you get three or four of them and place them in some kind of a container that would serve as a sort of observation chamber. A large glass dish filled with earth and provided with a cover so that the ants cannot escape would do nicely. It might be well before watching them at their ablutions to examine first the front leg with your lens. You will note a curved, movable, comblike spur on the distal end of the tibia, and opposite it, on the base of the metatarsus, a concavity tipped with hairs (*Figure 60*). This is the antenna cleaner. In cleaning its antenna the ant, as you will observe, lifts its leg over the antenna and then draws the antenna through the space between the spur and hairs, which effectively act as a brush. A dirty brush is of little value, so after cleaning the antennae the ant proceeds to do the same with the

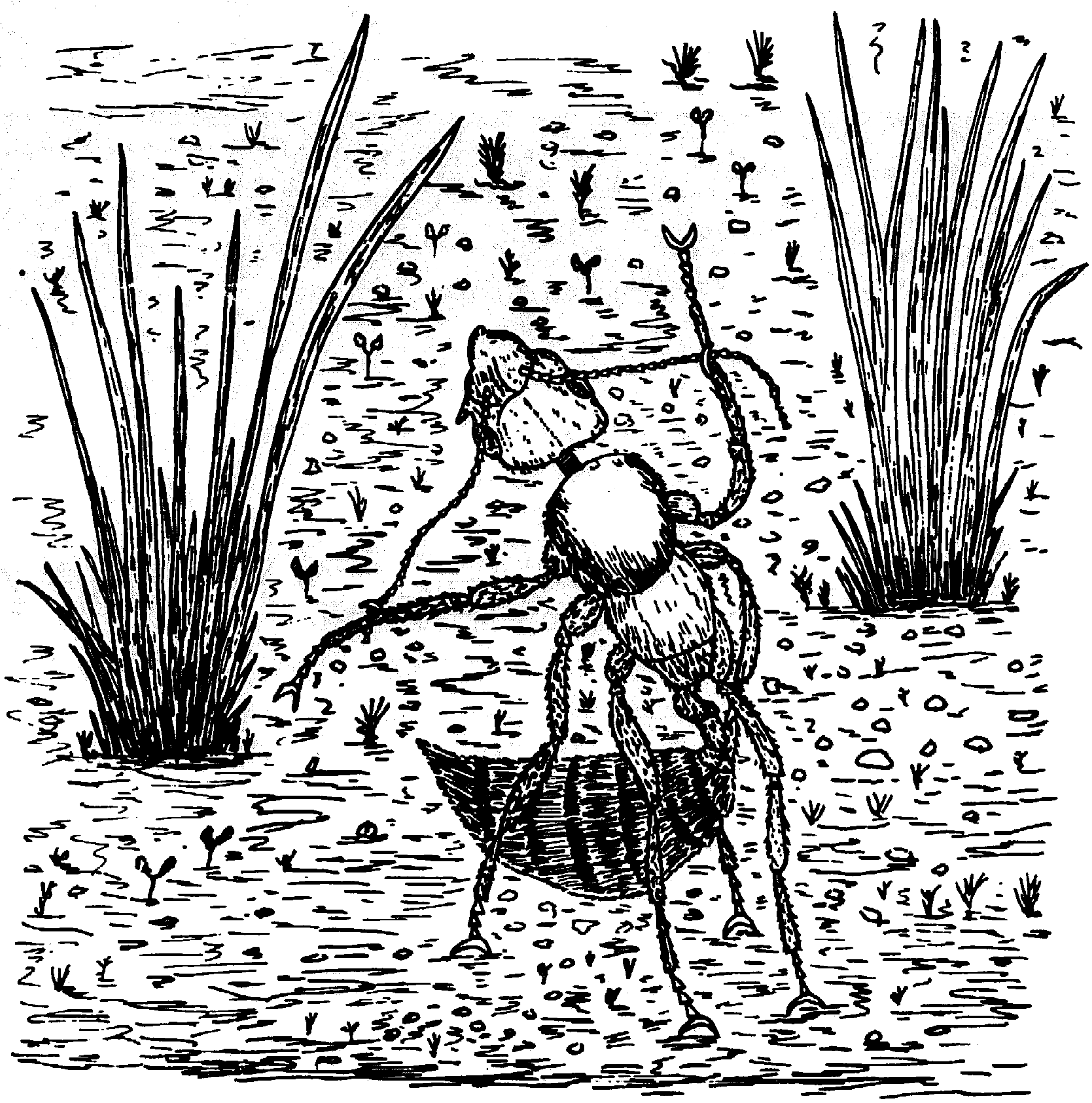

Figure 60A
ANT COMBING ANTENNAE

brush, licking it clean by passing it through its mouth. The performance is interesting and amusing to watch (*Figure 60A*).

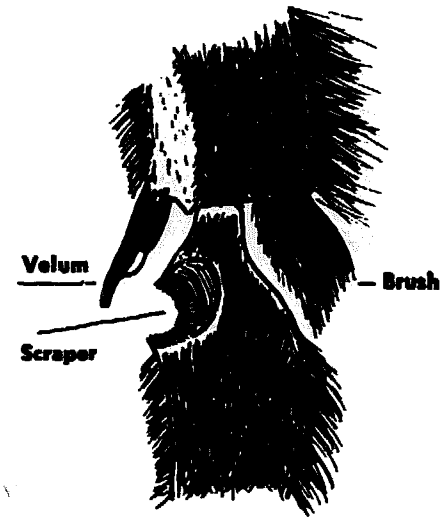

Figure 61
ANTENNA CLEANER OF HONEYBEE

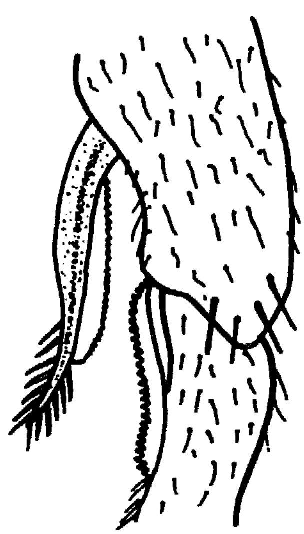

Figure 62
ANTENNA CLEANER OF YELLOW JACKET

The honeybee is also provided with an antenna cleaner. If you obtain a bee (be sure to use your insect net and killing jar,* because you do not want to get stung, which can be a very painful experience) and examine the front leg with your lens, you will find a concavity, or semicircular scraper, on the tarsus (*Figure 61*). When the bee wishes to clean its antennae, it raises its leg and passes it over an antenna, which then slips into the scraper. The bee now bends its leg at the joint where the tibia and tarsus meet, and as the leg is bent, an appendage, called the velum, falls into place to complete a circular comb through which the antenna is drawn. The comb itself is cleaned by means of a brush of hairs on the front margin of the tibia (*Figure 61*).

A third insect also provided with a cleaning structure is the yellow jacket. The yellow jacket is a wasp, and you have doubtless often seen it, for it is quite common. There are a number of species of yellow jackets, but they are all very much alike, small in size and black and yellow in color. They make a nest of paper which most of them place in the ground, although a few species build the nest in a stump or under some object lying on the ground. If you examine the foreleg of one of these wasps (and I must caution you that

* See Adventure 6.

wasps can inflict a severe sting, so use your net and killing jar), you will find that its antenna cleaner is really a comb in every sense of the word and quite ornate at that (*Figure 62*).

ADVENTURE 15

We Find out how the Earthworm Moves

MANY YEARS AGO Charles Darwin, whose book *On the Origin of Species* is a milestone in the history of biology, wrote another book, *The Formation of Vegetable Mold through the Action of Worms*, in which he shows how valuable the earthworm is to the farmer because of its underground activities. To most of us the earthworm seems of no possible use except as bait for catching fish, but actually it is among our best friends, for, unseen, it works day and night, harrowing and fertilizing the soil for our benefit. It burrows into the ground from twelve to eighteen inches and brings the subsoil to the surface. It also grinds the soil in its gizzard and turns it into a finer texture than we are able to do; it even fertilizes the soil by secreting lime that neutralizes the acids in it.

The earthworm is not only a mere tiller of the soil, it is also an agriculturist, for it plants fallen seeds by covering them with soil and cares for the growing plants by cultivating the soil around the roots. Furthermore, it enriches the soil by burying the bones of dead animals, shells, leaves, twigs, and other organic matter that, upon decaying, furnishes the necessary minerals to the plants. It even provides drainage by boring holes to carry off the surplus water, and by so doing also promotes aeration.

As you can see, the earthworm is not so useless after all. The changing character of the landscape and much of the beauty of our fields and forests can be attributed to the labors of this diminutive workman. The familiar mounds of black earth or castings that can often be seen on the ground are particles of soil swallowed in their burrows and brought to the surface. Since there may be as many as fifty thousand worms in an acre of ground, Darwin estimated that more than eighteen tons of earthy castings may be carried to the surface in a single year on one acre of ground, and in twenty years a layer three inches thick would be transferred from the subsoil to the surface. Then he goes on to say that "it may be doubted if there are any other animals which have played such an important part in the history of the world as these lowly organized creatures." That their work is of tremendous agricultural importance can hardly be disputed. Remember this the next time you impale one on a hook.

We are not particularly interested here in the agricultural activities of the earthworm,

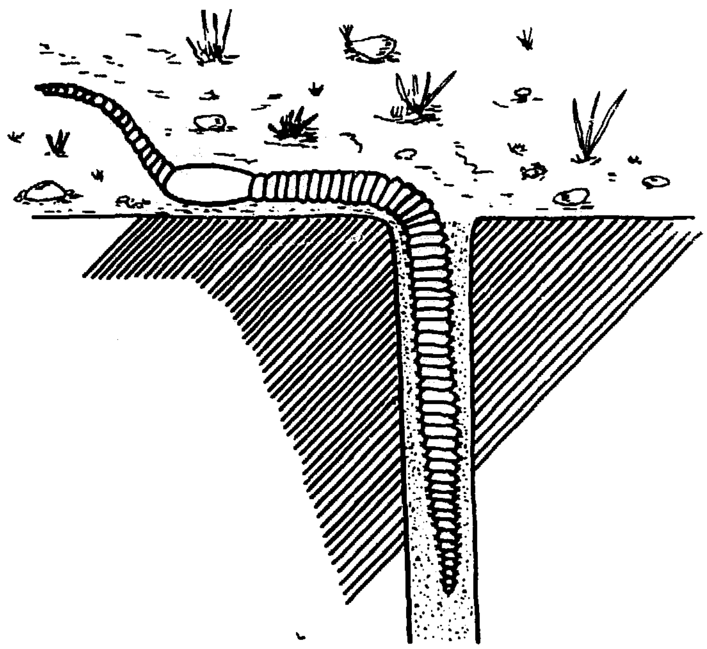

Figure 63
EARTHWORM IN ITS BURROW

but rather in the way it gets around. No doubt you have seen an earthworm wriggling over the ground, but have you ever wondered how it does so with what appears to be a relatively smooth body? It would seem that all the earthworm could accomplish by means of its wriggling movements would be merely to thrash about in one spot. Again, have you ever seen a robin tugging away at a protesting worm, or tried yourself to pull one out of its burrow and to your surprise found it was not an easy thing to do? You found it anchored there but did you ever wonder why it was so difficult to dislodge (*Figure 63*)? The explanation is a simple one. If you take hold of an earthworm and run your fingers along its sides or lower surface, you will find it rough to your touch. The effect is much the same as if you ran your finger over a stiff toothbrush.

In both instances the roughness is due to stiff bristles. Examine the earthworm with your lens and you will see these stiff bristles projecting from the body. There are four pairs of these bristles, or setae, as they are called, on every segment of the body except the first three and the last. (You will have noticed by this time that the body of the worm is composed of a linear series of segments, hence the animal is known as a segmented worm). The bristles protrude from small sacs in the body wall and can be extended or retracted by special muscles. If the earthworm wants to remain fixed in its burrow, all it has to do is to extend the bristles out beyond the body surface and into the sides of its burrow and it will be securely anchored, much as an anchor holds a ship in place. Of course you can dislodge an earthworm from its burrow by the use of superior force, but you will very likely injure it or even kill it.

The presence of these bristles also explains how the earthworm can move over the surface of the ground or in and out of its burrow, although as a rule it rarely leaves its burrow, because the worm, for some reason, cannot seem to find its way back once it has left. Watch the worm crawl over the ground and you will observe that it makes its way along by first extending the anterior part of its body, anchoring this part of the body by means of its bristles, and lastly drawing up the posterior part. The bristles on this part are then extended into the ground, those of the anterior part are retracted and the anterior part extended lengthwise over the ground. All this is accomplished by two sets of powerful muscles, one set running circularly around the body, the other lengthwise. You can see the movements of these muscles if you look closely. While you have the earthworm in your hand, look at one of the segments with your lens about part way between the pair of bristles on the side and the pair on the lower surface. You should find a small pore, or opening. This is the external opening of the excretory system and is called the nephridiopore. There is a pair of them on every segment except the first three and the last. Now look on the upper surface of the animal and you will observe a reddish-purple line. This is the main blood vessel, and you can see the pulsations as the blood flows through it. You will also note at the anterior end a fleshy lip called the prostomium. The prostomium is used to push food into the mouth. You can watch its actions through a reading glass if you place a worm in a glass dish containing some earth and give it small pieces of a lettuce or cabbage leaf.

ADVENTURE 16

We Discover that There Are Different Kinds of Hairs

HAVE YOU EVER GRASPED a petunia leaf and found it sticky or clammy to the touch? Did you ever wonder why? Look at the lower surface with your lens and you will find it covered with numerous fine hairs. Hold the leaf up to a bright light and the hairs seem to glisten. The tips are glandular and secrete a sticky material that reflects the light, making them sparkle or glitter. Touch a geranium leaf and you will find it sticky too, and for the same reason, as you will discover if you examine the lower surface. There are other plants that are similarly furnished with glandular hairs, as the tarweeds, tobacco, Chinese primrose, and pumpkin and squash and other members of the gourd family.

As a matter of fact, many plants are provided with hairs, but not all are sticky; to the touch they feel much like those on our own bodies. Hairs are outgrowths of the epidermal, or surface-layer, cells and may consist of only one cell (*Figure 64*), when the epidermal cell and hair are one and the same,

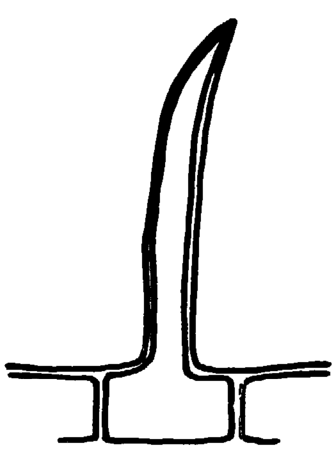

Figure 64
UNICELLULAR HAIR

or they may consist of many cells (*Figure 65*). In the latter instance the hair is a filament that decreases in size from the base to the apex. A glandular hair bears at the upper end a rounded head (*Figure 66*). Hairs entrap air, which reflects light and makes them appear white or nearly so.

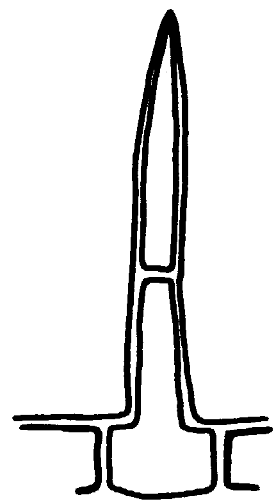

Figure 65
MULTICELLULAR HAIR

In some plants the hairs may form only a slight downy covering, or they may form a woolly or feltlike mass. The leaves of the common mullein are so woolly that certain small insects, as the thrips, find a good winter retreat among them. The hairs form a dense network, and if you look closely at a single hair you will observe that it is much branched (*Figure 67*). The mullein is a very common and picturesque plant of rocky pastures, roadsides, and waste places and can easily be recognized by its long stem, which extends as high as six or seven feet. The large, rather succulent and velvety-appearing leaves seen at a first glance to be good eating, but if you have the courage to bite into one of them you will quickly find out why sheep and other grazing animals leave them alone. Hairs, then, are something of a protective device, although in some instances they may not be very effective. Hairs are also supposed to retard transpiration or to reduce water loss through evaporation. Research has shown that, although dead hairs may accomplish

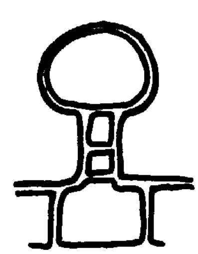

Figure 66
GLANDULAR HAIR

something in this respect, living hairs are useless for the purpose.

The pearly everlasting is another densely woolly plant found in old fields and along roadsides from summer to fall. If you are unacquainted with it, you may easily recognize it by its linear leaves and white tubular flowers in clusters at the summit of cottony stems, the stems as well as the leaves being profusely covered with hairs. Look at one of the leaves with your lens and you will find that it is covered with such a dense layer of what appears to be cotton fibers that it disguises all venation except the midrib.

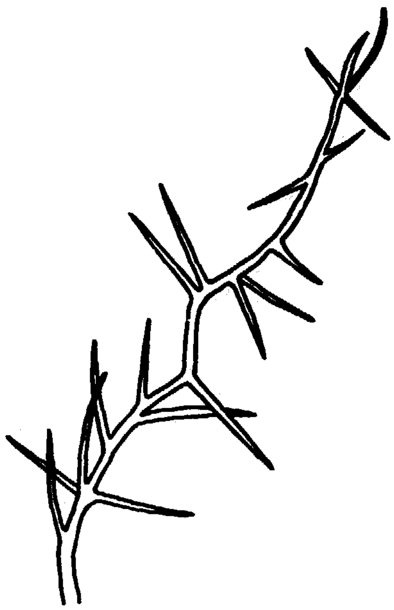

Figure 67
HAIR OF MULLEIN LEAF

If you find in someone's garden the plant variously called lamb's-ears, bunnie's-ears, or woolly woundwort, you will note that the plant appears entirely white due to the dense covering of hairs. Examine the hairs with your lens and you will find them to be smooth and silken, and when you rub them with your finger they will feel just like fur. Another garden plant you should locate, if possible, is the vervain mallow, or European mallow, because the hairs with which it is covered are star-shaped. Each hair consists of a short stalk from the upper end of which a number of branches radiate out at right angles like the points of a star (*Figure 68*).

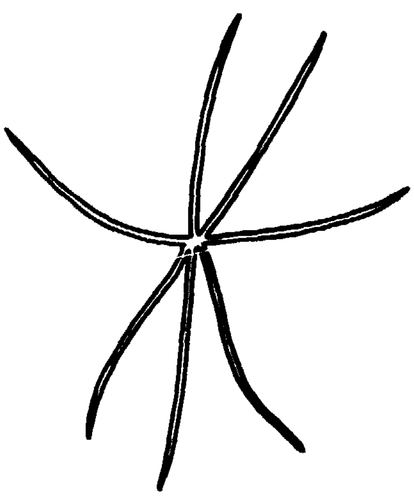

Figure 68
HAIR OF MALLOW

The leaves of the bush clover, a common plant in pastures, thickets, and open woods, are provided with finely appressed hairs on the lower surface. In other words, the hairs lie close and flat to the surface, as shown in *Figure 69*. Note the bristles at the tip of the leaflets. In some plants, notably the thistle, the hairs have become stiff and bristle-like, and when viewed with the lens appear a most effective deterrent to animals. As you examine various leaves at random, you will find other variations, too, as in the oleaster (*Figure 70*) and buffalo berry, whose leaves bear shield-shaped hairs that consist of a single scalelike expansion at the end of a short stalk.

Figure 69
HAIRS OF BUSH CLOVER

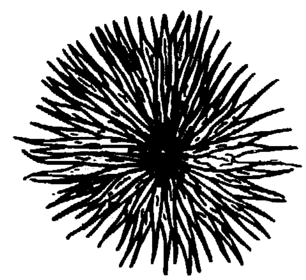

Figure 70
HAIR OF OLEASTER

ADVENTURE 17

We Spy on the Aphids

Aphids are sometimes called plant lice, but the word, though descriptive, is a misnomer, since they are not lice at all. Since they sometimes infest a plant in such numbers that you can hardly see anything else and because they are sucking insects, as are the lice, someone once thought the name appropriate and it has stuck with them ever since. They are somewhat flask-shaped in outline, with two large eyes set rather apart (*Figure 71*). Most aphids are green in color, but there are some species that are otherwise colored, and a few have the most bizarre and striking ornamentations.

Aphids are abundant and occur on almost

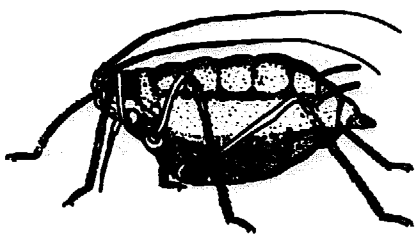

Figure 71
APHID

every kind of plant, so you should have no difficulty in locating a colony. They are visible to the naked eye but can be observed best with a lens. Note that they are in all stages of development and in various positions: some of them have their beaks in the tissues of the plant in the process of sucking the juices, with their hind legs high in the air and their antennae curved backward; others have their beaks tucked under their bodies, walking slowly about stiff-legged, perhaps looking for some likely spot in which to thrust their beaks; while others just sit quietly gazing out at the world with their large eyes. Sometimes there are so many clustered on a stem that those moving about must climb over the backs of the others, and the smaller ones are so tightly pressed between the larger ones that it seems as if they would be squeezed to death. These little insects may appear innocent enough, but they are actually very destructive to plant life, and if it were not for their enemies they would become a real menace.

You will note that all the aphids are wingless. They are all females, too. Now what is most interesting is that, without the aid of males, these females produce living young, which in turn, also being females, produce more young. This continues for generation after generation until the plant becomes so crowded that it cannot possibly support any more. What happens then? When the colony has reached such a size, winged females are produced that fly to another plant. Usually it is the same kind of plant, but in some species of aphids it may be a different kind of plant. In either case these winged females start another series of wingless generations. You can readily see why there are so many aphids. Even through a single female doesn't produce many young, the young are all females that in turn produce more females.

This sort of thing cannot continue forever, of course, especially when cold weather comes. As adults the aphids cannot survive the winter, but as they found out how to cope with overcrowding they also discovered how to solve the problem of low temperatures. When the first cold days of autumn herald the approach of winter, perfect winged males and females are produced. The males and females mate and the females lay their eggs in the crevices of bark or at the base of buds and branches. The eggs remain unhatched through the winter and in the following spring, or in midsummer, according to the species, hatch into young. These young establish themselves on a favorable plant and within a few days produce young that, of course, are females, and the cycle starts all over again. The young females that hatched from the eggs are known as "stem mothers" because they initiate the new colonies.

Another odd and interesting facet in the life history of the aphids is that during the successive generations a number of different forms may be produced in each species. In one species as many as twenty-one different forms have been noted. This makes the study of aphids rather confusing. Hence it is very likely that the four hundred or so aphids that have been described from the United States as distinct species may actually be forms of a smaller number of real species.

Aphids appear to be utterly defenseless and they are for the most part, but some of them can secrete a waxy substance in the face of an enemy and thus effect their escape. Most aphids also secrete a sweetish substance called honeydew, which has a particular appeal to bees, wasps, and ants. The bees and wasps take it where they can find it but some species of ants go to considerable lengths to care for the aphids, herding them as "cows" and protecting them against enemies, so that they always have a supply at hand. As you watch the aphids through your lens, you may see some ants stroking the aphids with their antennae until they respond to such caresses with a glistening drop of the fluid, which is immediately snatched up by the ants.

ADVENTURE 18

We Become Familiar with the Eating Habits of Insects

IN OUR LAST ADVENTURE we observed how the aphids obtain their food. They have, as we noted, a long beak which they insert into the tissues of plants and which is an effective piercing and sucking organ. We cannot see the sucking apparatus unless we dissect the insect, but it consists essentially of a sort of bulb which functions much like a medicine dropper. Unlike other groups of animals, whose mouth parts are more or less constant, those of the insects differ in the various orders and represent many interesting and highly adaptive modifications.

For instance, the mouth parts of the butterfly form a tool which is effective for obtaining nectar, but is quite incapable of piercing plant tissue. It is basically a long tube called the proboscis (*Figure* 72), which is held ordinarily coiled beneath the insect's body, but at the time of feeding is uncoiled and extended into the nectary of the flower. You can observe the manner in which this is done by taking up a position near a flower and by means of a reading glass watch what happens when a butterfly alights.

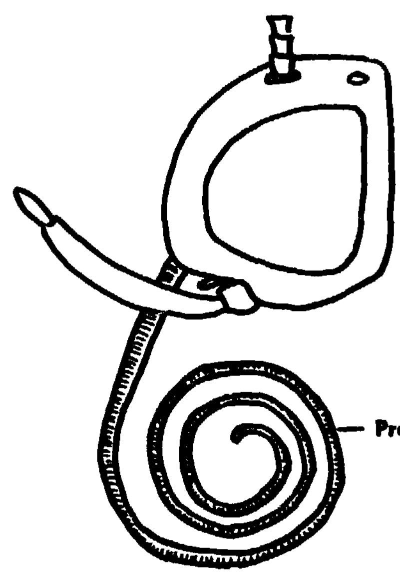

Figure 72
MOUTH PARTS OF BUTTERFLY

All insects, of course, do not obtain their food from plant juices or nectaries; many of them feed directly on the plant tissues such as leaves, biting off small pieces and then chewing them much as we might eat an apple. Watch a grasshopper feed (and here again a reading glass is best) and you will observe the upper jaws, or mandibles, which look like a pair of nippers, cut out pieces of leaf or grass blade (*Figure 73*). Note, too, that the jaws move sideways instead of up and down, as they do in most animals provided with jaws. You will further remark that the grasshopper is provided with two pairs of appendages (not the antennae), with which it constantly taps the leaf as it eats. Called palpi, they are organs of touch and are used to test the leaf to make sure it is good to eat before the insect bites into it.

Some people seem to think that the grasshopper's face has a rather droll expression (*Figure 73*). It is a long face, not unlike that of a horse, and not particularly prepossessing, and yet it is not without a certain strength of character if we can read character into the face of an insect. As we watch it feed it seems to do so with a certain air of smugness and takes each bite as if it really enjoyed eating. Considering the damage grasshoppers inflict on our crops, they probably relish the gastronomic delights we provide them.

While you are watching the grasshopper dine, note the two large eyes, which you can hardly miss. Examine them closely and you will find that each is divided into a number of small divisions or areas that are commonly more or less hexagonal. Each of these areas

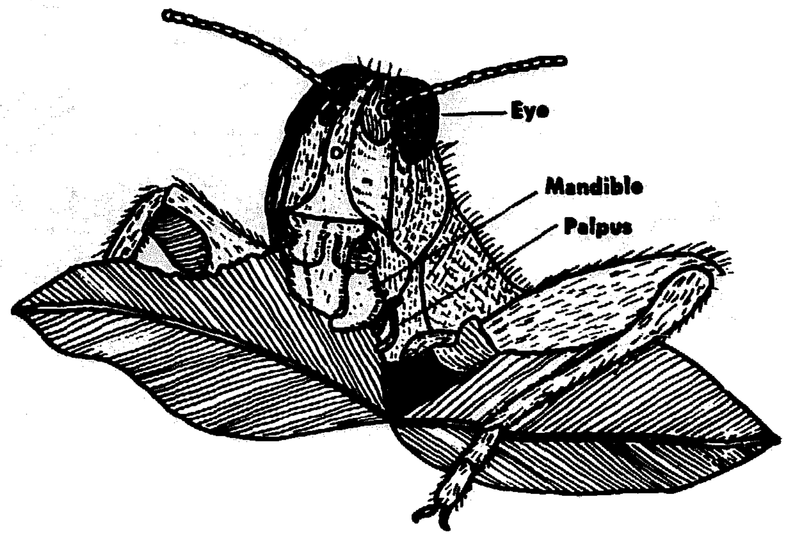

Figure 73
GRASSHOPPER FEEDING

is called a facet and is the outer surface of a single eye, so what appears to be a single large eye is actually composed of a number of individual smaller eyes. These compound eyes of the grasshopper (and other insects as well) form what is known as a mosaic image. The number of facets varies in different insects. There are four thousand of them in the eye of the ordinary housefly, but this is a small number compared to the seventeen thousand of the swallowtail butterfly or the twenty-seven thousand in a sphingid moth.

There are two general types of mouth parts in insects, the sucking type, as in the butterfly and aphid, and the biting type, as

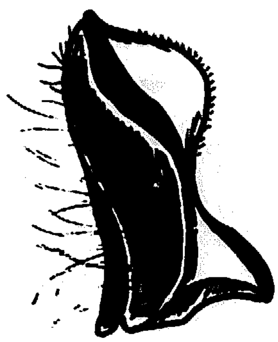

Figure 73A
MANDIBLE OF HONEYBEE

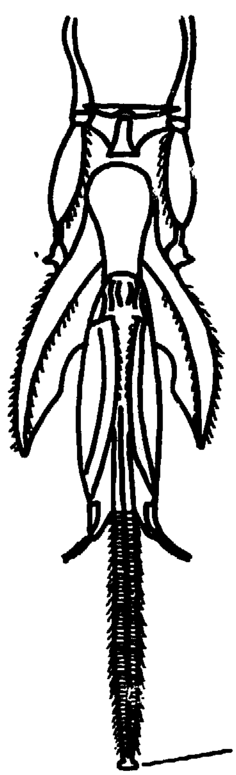

Figure 74
MOUTH PARTS OF HONEYBEE

in the grasshopper. Now some insects have both kinds, as the honeybee, but these insects are essentially sucking species, the mandibles, which are the biting tools of the grasshopper, being modified for some other use. If you examine the mouth parts of the honeybee through your lens, you will observe that the mandibles (*Figure 73A*) are well-developed instruments for cutting and that the remaining mouth parts form a highly complex suctorial apparatus. Look also at the tongue and you will note that it terminates in a "spoon" and is clothed with hairs of various kinds (*Figure 74*). The spoon is used for gathering nectar and for other mechanical purposes.

Next time a mosquito bites you capture it but don't crush it, and examine it after first killing it in your insect-killing jar. You will discover that the mandibles, together with the lower jaws, or maxillae, have become modified into piercing organs. They are used to puncture the skin, after which the blood is sucked up. Only the female bites. What, then, does the male do? The male rarely sucks blood, because it is unable to puncture the skin, the mandibles having become aborted and the maxillae only slightly developed. Hence the male has to depend on nectar and the juices of ripe fruits or other sweet substances.

ADVENTURE 19

We Look a Spider in the Eye

HAVE YOU EVER LOOKED a spider in the eye? Probably not, for few of us ever have the occasion to do so. But let us do it and see what we find.

One of the jumping spiders will do nicely, as they are quite common and easy to find. We need not be afraid to handle spiders, for they are quite harmless, contrary to what most people think. True, they are all poisonous, but the amount of poison they can inject into our skin is so small that we would hardly notice it unless, of course, we are allergic to spider venom. However, it might be best, after capturing a spider, to put it in the killing jar before examining it. There is one spider, the black widow, which has spread over most of our country and can inject enough venom to prove dangerous and in some cases to produce fatal results. So beware of any coal-black spider that is marked with red or yellow or both.

To return to our jumping spiders. They are common on plants, logs, fences, and the sides of buildings, and we need only to step outdoors to find them. They are small or of medium size, measuring about a fourth of an inch or less in length, with short, stout legs, and usually of bright color. They readily attract our attention by their quick jumping movements. Watch one of them for a few moments and you will find that it can move sidewise or backward with great ease. You will also observe that these spiders spin a dragline with which they regain their original position after having leaped in pursuit of some passing insect.

Having watched the antics of the jumping spiders for a while, we now capture one and place it in our killing jar, and when all life has ceased we look at its face with our hand lens. You will be surprised to find that instead of having two eyes the spider seems to have more than that number. Actually the spider has eight eyes, although you may have to look closely to find them all (*Figure 75*). The presence of eight eyes in the jumping spider is not an abnormal phenomenon, as you may think. It is, on the contrary, the normal number in spiders, although in some species two, four, or even six may be lacking.

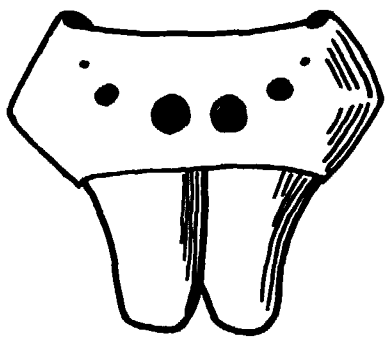

Figure 75
EYES OF JUMPING SPIDER

As we study the eyes carefully we also observe that they vary in size and in arrangement on the head (*Figure 75*). The number and arrangement of the eyes and also, in some instances, the relative size are characteristics much used in classifying spiders. In other words, if you found a spider and wanted to identify it, you would examine the eyes and note the above characteristics, which would serve to indicate the group to which it belonged. From that point it would be relatively easy to complete your identification.

A spider's eyes have been given different names, according to their position. The normal position of the eyes is in two transverse rows each containing four eyes. The two intermediate eyes of the first row are called the anterior median; the two intermediate eyes of the second row are called posterior median; and the one at each side of the first row anterior lateral and the one at each end of the second row posterior lateral (*Figure 76*).

In the jumping spiders we have a departure from the normal arrangement and also a marked difference in the relative size of the different pairs, characters that enable us to recognize this group at a glance. Instead of two rows there are three. The first row is somewhat curved and consists of four eyes: the anterior median, which are very large, and the two anterior lateral, which are smaller. Behind this first row is a second row, of two eyes: the posterior median, which are very small, and you may have to look very closely to locate them. Behind these two small eyes is still a third row, of two eyes: the posterior lateral.

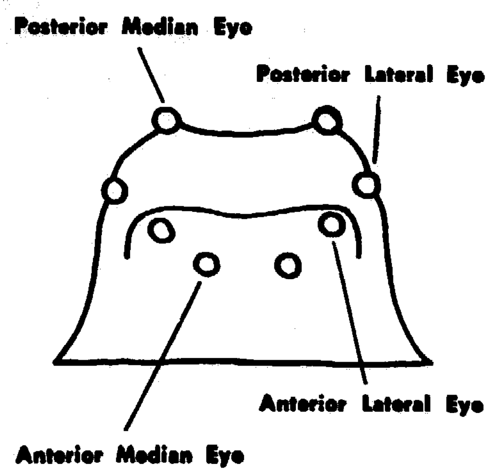

Figure 76
EYES OF A SPIDER

One more word about the eyes of spiders. Two types of eyes are usually recognized: the so-called nocturnal eyes and the diurnal eyes. Spiders that live in the dark or frequent shady places have eyes that are pearly white in color—they are nocturnal eyes. Diurnal eyes, which are typical of most spiders, lack this pearly luster and are variously colored.

One of the most common of our spiders and one we can find at any time of the year is the domestic spider. This is the spider that spins the somewhat unsightly webs we find in a neglected room. It is an exceedingly variable species in color and markings, and if you were to collect a number of them you might well believe that they represent several species. Examine the eyes of this spider and you will find that they are arranged in the normal position of two rows, the anterior row being straight or nearly so (*Figure 77*). Also observe that the two middle pairs of eyes are of the same size and separated from one another and that the lateral eyes of each side are contiguous, that is, adjoining or in contact with one another.

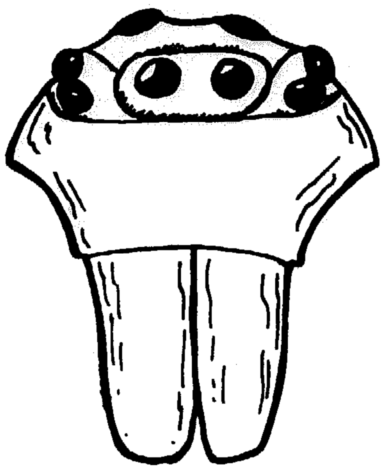

Figure 77
EYES OF DOMESTIC SPIDER

In the early spring, before the grass has grown tall, we often find rather large active spiders running over the ground, sometimes carrying the egg sac attached to them. They are the wolf spiders, hunting spiders which chase their prey. They live on or near the ground and often lurk under stones, especially in damp places. Many species dig tunnels in the earth, and some of them build a turret about the mouth of the tunnel. The famous tarantula of Southern Europe, whose bite was once supposed to cause the dancing madness, belongs to this group.

The eyes of these wolf spiders are arranged in three rows, as in the jumping spiders, but the relative proportions are very different from what we found in the jumping spiders. The first row consists of four small eyes (*Figure 78*), and the two posterior rows each of two large eyes, the posterior lateral eyes being situated far behind the posterior median eyes.

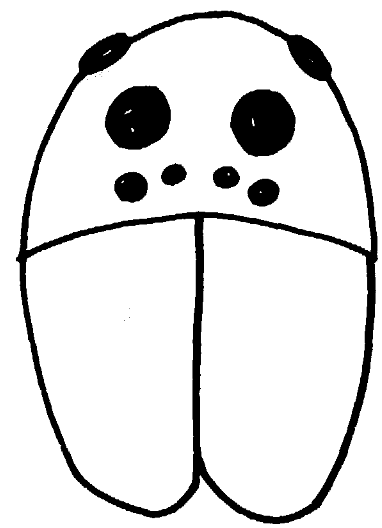

Figure 78
EYES OF A WOLF SPIDER

In the crab spiders we find that the eyes are quite unlike those of the spiders we have examined, not only in size but also in their arrangement. The eyes are all small, dark in color, and arranged in two curved rows. The crab spiders are well named. They have a short and broad body similar to that of the crab and hold their legs in a crablike attitude. Furthermore, they seem to be able to walk more easily sidewise or backward than forward. They are common and rather abundant. Some of them are able to run swiftly and chase their prey; others prefer to lie in wait and pounce on an unsuspecting victim as it passes by. We find them living chiefly on plants and fences and most of them are marked with gray and brown, but a few of them, which conceal themselves in flowers, are brightly colored for purposes of camouflage. One species of crab spider is remarkable for the change in color it undergoes as it

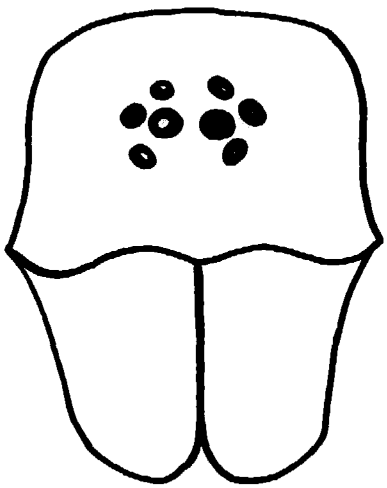

Figure 79
EYES OF GRASS SPIDER

migrates from one colored flower to another. In the spring and early summer it is usually found in white flowers when it is white, thus not only escaping detection by visiting insects but also capturing them without much trouble; later in the season it migrates to yellow flowers, such as goldenrod, and then turns yellow, being then so effectively concealed that it becomes very difficult to locate among the blossoms.

As the summer begins to wane, large, beautiful webs, often as much as two feet in diameter, begin to appear on the grass in meadows and pastures or on other herbaceous growth in marshy places, sometimes even on the shrubs in a garden. You have doubtless seen these webs and perhaps marveled at their construction. You are also probably acquainted with the spider that builds these webs, for it is a fairly large spider and beautifully marked with bands and spots of bright orange. The next time you see one—we know it as the orange garden spider—look at its face with your lens and note that the eyes are all alike, the second row being strongly curved.

Variation seems to be the keynote in the nature world, for differences, though minor, seem to be everywhere, and as we continue to examine the eyes of various spiders we find all sorts of arrangements, though basically they are much the same. In the grass spider, for instance, the two rows of eyes are so strongly curved backward that the anterior median and the posterior lateral eyes form nearly a straight line (*Figure 79*). Speaking of variation, there is a wide range in the size of this spider as well as in the general color. There is also considerable variation in certain structures. All of this makes for considerable confusion, not alone for the amateur student of spiders, but also for the specialist. The grass spider is well named, because its webs are commonly found on grass. Indeed, we seldom realize the immense numbers of webs spun upon the grass by this spider, except when, in early morning, they are made visible by the dew that has condensed upon them. At such times the grass appears to be covered with an almost continuous carpet of silk.

ADVENTURE 20

We Investigate the Structure of Grass Flowers

THE GRASSES are a basic form of plant life, performing a dual function as soil binders and as a source of food for many different kinds of animals, including man, since corn, wheat, rye, oats, sugar, and rice are species of grass. In some parts of the world grasses also provide shelter and clothing in the form of bamboo. From earliest spring until late

Figure 80
SPIKE

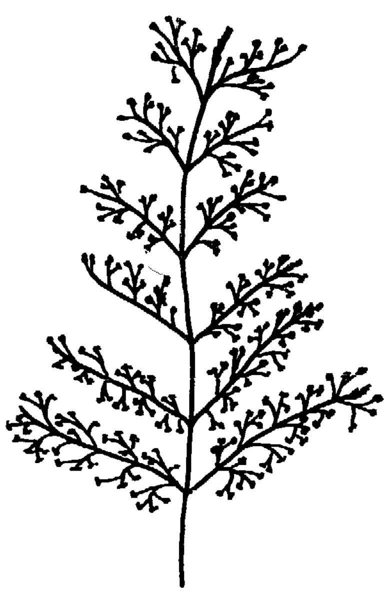

Figure 81
PANICLE

autumn the grasses bloom along the wayside and woodland trail, in gardens and orchards, along the banks of winding streams and in waste places, fields, and meadows. Examine the tiny blossoms with your hand lens and you will discover an infinite variety of form and color, and if they are not so garishly or brilliantly colored as the showier flowers more familiar to us, I think you will agree that they are just as beautiful in their rose and lavender, purple and green tints.

As you know, a typical flower consists essentially of sepals and petals, stamens and pistils. When you first look at a grass flower it will appear to bear little resemblance to a lily, which is a typical flower, and if you were to compare the two they would seem to have little in common, that is, structurally. Yet, if the lily you selected for comparison bloomed in a spike and you were to visualize such a lily crowding its flowers, and you were further to reduce the petals to mere scales, the lily would have a reasonably grasslike appearance.

The flowers of grasses are borne in clusters called spikelets, which vary in size and number and which, in turn, are arranged on the main stem in the form of a spike (*Figure 80*) or panicle (*Figure 81*). In a spike the lower spikelets bloom first or from below upward, but in a panicle the uppermost spikelets are

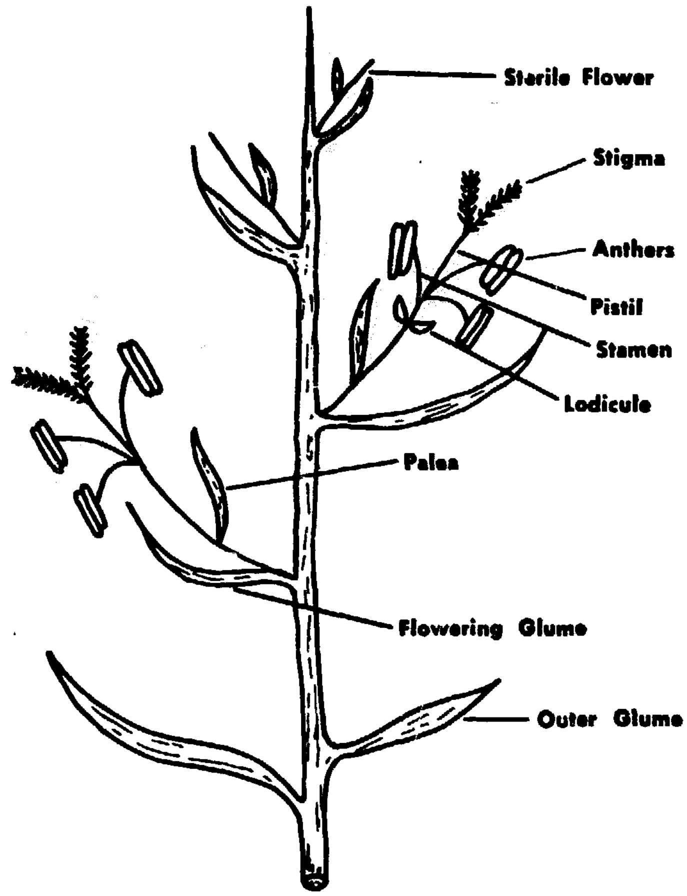

Figure 82
DIAGRAM OF A GRASS FLOWER

the first to blossom, followed successively by those beneath.

When we examine a grass flower carefully with our lens, we find that the sepals and petals have given way to modified leaves called bracts. (And bear in mind that sepals and petals are also modified leaves.) These bracts are called scales or glumes (*Figure 82*) and surround each flower (which the sepals

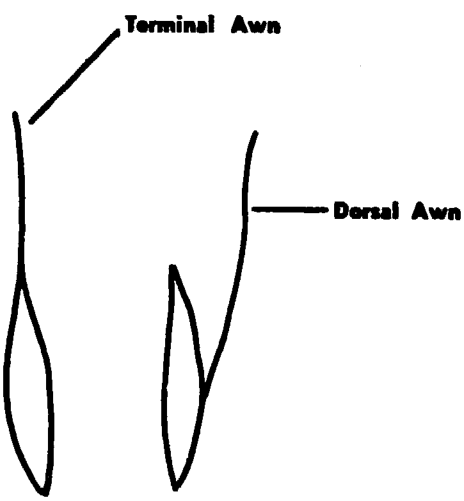

Figure 83
AWNED GLUMES

and petals also do in the more conventional flower). The glumes, which are called flowering glumes since there are other kinds, exhibit many interesting peculiarities, often bearing a bristle-like appendage called an awn (*Figure 83*). Awns may be straight, bent, or twisted and either terminate the glumes, when they are known as terminal awns (*Figure 83*), or are borne on the backs of the glumes, when they are said to be dorsal (*Figure 83*). A flowering glume is keeled when it is flattened and folded so that its two edges are brought closely together and the midvein is prominent as a ridge on the back of the scale. When the veins of the glumes are conspicuous, the glume is considered to be three-nerved, five-nerved, seven-nerved, or nine-nerved, according to the number of prominent veins (*Figure 84*).

We had to digress for a moment in order to provide a description of the flowering scales, but now, to return to the flower, we observe that opposite the flowering glume is an awnless glume called the palea (*Figure 82*). It is usually thin in texture and two-nerved, showing two green keels. At the base of the flower are usually two (rarely three) minute, thin, and translucent glumes called lodicules (*Figure 82*). The lodicules are rarely noticed except at the time of flowering, when for a short time they become swollen with sap and, by pressing the flowering glume and palea apart, cause the blossom to open.

As we examine various grass flowers, we find that most of them are perfect, that is, bear both stamens and pistils (*Figure 82*). There are one to six (usually three) stamens whose very slender filaments bear two-celled anthers. The anthers are lightly attached near the middle to the apex of the filament and when they tremble in the wind easily discharge the pollen grains. Since the grasses must depend upon the wind for pollination, a vast number of pollen grains are produced to ensure sufficient seed. It has been estimated that a single anther of rye contains no less than twenty thousand pollen grains. You will find that most grasses of spring have larger anthers than those of midsummer, but brilliant colors, ranging from yellow to orange and crimson, and from lavender to deep purple, appear in the anthers throughout the entire flowering season. The feathery stigmas frequently show a conspicuous color too.

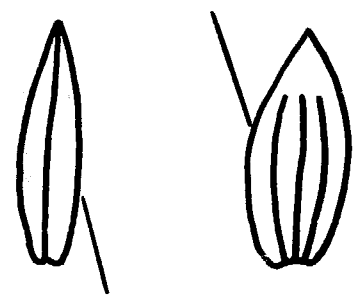

Figure 84
KEELED GLUMES

ADVENTURE 21

We Hunt a Lion

YOU WILL RECALL that in the discussion of the aphids (Adventure 17) I said that these insects could become a scourge if it were not for their enemies. One of the most effective in keeping them in check is the aphis lion.

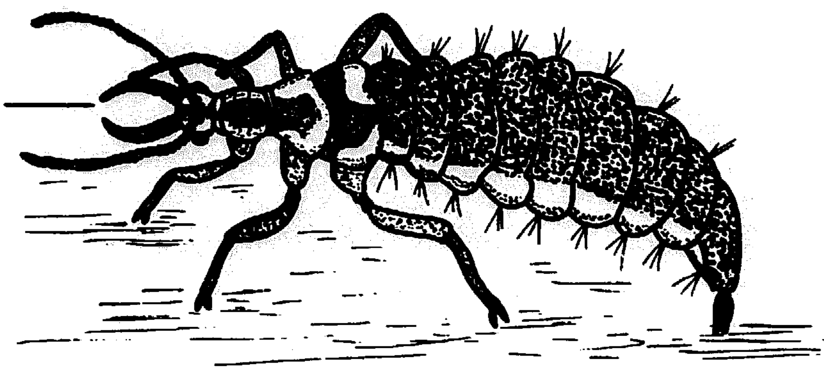

Figure 85
APHIS LION

The aphis lion is not a particularly prepossessing-looking creature, as you will see when you look at one through your lens, with its spindle-shaped body and its peculiarly long, sickle-shaped jaws, which project from its head (*Figure 85*). These jaws are effectual instruments for grasping the soft-bodied aphids and, since they are hollow, with an opening at each end, the opening at the base leading into the lion's throat, they also serve as efficient suction tubes.

Though the aphis lion bears no resemblance to the four-footed mammal of the jungle, it is well named if we think of it in predatory terms. It is a bloodthirsty creature, preying almost exclusively on aphids and sucking their blood until nothing is left of a victim but a shriveled-up mass of skin. Com-

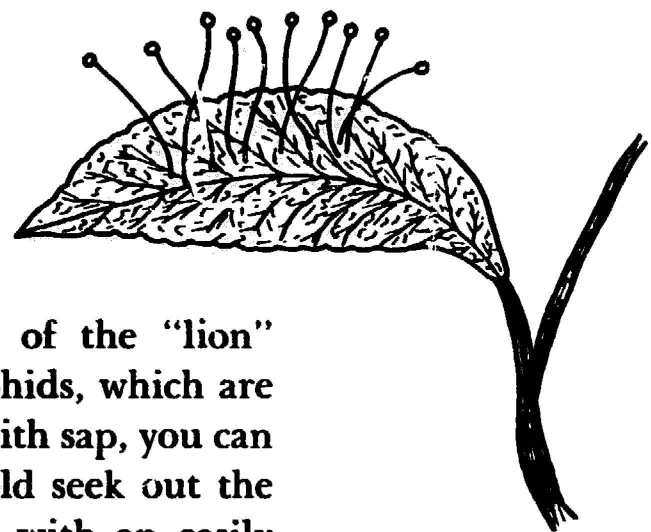

Figure 86
EGGS OF APHIS LION

paring the evil-looking jaws of the "lion" with the soft bodies of the aphids, which are usually extended or swollen with sap, you can readily see why the lion would seek out the aphids, since they provide it with an easily available food supply. Usually the lions are not hard pressed to locate the aphids, since the mother aphis lion generally lays her eggs in a colony of aphids so that her young, when they hatch, have food ready at hand.

After you have watched an aphis lion feed on the aphids, look for the eggs. They are easily seen for each egg is placed on the tip of a slender stalk (*Figure 86*). Examine the eggs carefully and you should be able to detect the little doubled-up and still-unhatched lions. You may even find one about to emerge from its egg. Watch closely and you will see the jaws thrust through the shell, opening it, as it were, for a peephole. Then the head gradually appears, followed by the legs and finally by the spindle-shaped body. Now what does this newly emerged lion do? It appears in no hurry to descend the stalk, but clings to the eggshell while it looks about at its new surroundings. Eventually, as if it were satisfied with what it sees, it begins to climb about the eggshell until it discovers the stalk. Since there is now no place to go but down the stalk, it grasps the stalk with its first pair of legs and with the help of the other two pairs of legs begins a careful descent, a feat for a creature only a few minutes old and with no previous experience at such gymnastics. At last it arrives safely on the surface of the leaf and pauses for a moment to look around. Spying the nearby aphids and without further ado, it proceeds to satisfy its hunger.

You may ask why the eggs were placed separately on the tips of stalks instead of being laid in a mass on the surface of the leaf. The explanation is a simple one and at the same time illustrates an interesting provision of nature. The carnivorous lions that hatch from the eggs would just as soon eat one another or the unhatched eggs as search for aphids. But as the eggs hatch one at a time and since there is nothing to eat but an inedible stalk, the newly hatched "lion" must perforce descend the stalk in order to find something to eat. Of course, it could ascend the neighboring stalks and feed on its unhatched brothers and sisters, but how much better merely to seize the helpless and defenseless aphids that are at hand for the taking.

The mother aphis lion appears so entirely unlike her offspring that it would be difficult to believe they are related. Have you ever observed a small green insect with golden eyes and delicate, lacelike wings flying about? That is the mother, commonly known as the lacewing but sometimes as the golden-eyed lacewing.

If you can find a mother lacewing in the act of laying her eggs, watch how she does it. You will need your lens, of course, or, better still, your reading glass. You will observe that first she deposits a drop of sticky fluid that she ejects from the tip of her body on the surface of the leaf. Then she lifts up her slender abdomen and spins the drop into a thread, a half inch long or more, that hardens almost immediately upon exposure to the air. She next lays an oblong egg about the size of a pin point on the tip of the thread or stalk and, with this accomplished, proceeds to spin another stalk and lay another egg. She repeats this performance until she has laid her full complement of eggs.

ADVENTURE 22

We Trace a Tadpole's Development

THE STUDY OF NATURE or the outdoors is the study of life itself. No one has yet been able to define life to anyone's complete satisfaction, and, of course, no one has been able to create life, although we seem to be on the verge of doing so. How a complex organism can develop from a microscopic egg, after it has been induced to grow through union with a microscopic sperm, is still one of the greatest mysteries, even though we know a great deal of what takes place.

Let us watch a tadpole develop from an egg. As this is a seasonal occurrence, we must be prepared to collect the eggs as soon as they are laid. Frog eggs are usually laid in April, but the exact time depends on the locality and the weather. About the first of the month prepare an aquarium or battery jar to receive the eggs. The aquarium or jar should have several inches of clean soil and of water and be planted with several washed aquatic plants to provide aeration. Then select a pond or spring pool—one near your home if possible—where you know frogs congregate each spring to mate, and visit it every day, taking along a bucket or pail, until you find the eggs. They are laid in rounded, gelatinous masses in shallow water and may be attached to sticks and grasses or left free in the water. In the masses the eggs look like small beads, each surrounded by a transparent covering. The jelly protects the eggs from injury and makes it more difficult for fish to eat them. Transfer the eggs to the bucket with your cupped hand, or take along a small pan or dipper for the purpose. Be careful not to pour the eggs or disturb them unnecessarily. As the eggs begin to develop within two or three hours after they have been laid, it is important, if you want to watch the development of the tadpole from the very beginning, to collect the eggs as soon as possible after they are laid.

On arriving home with the eggs allow them to remain in the bucket until the temperature of the water is the same as that of the water in the previously filled aquarium or jar. When the temperatures are the same, transfer the eggs to the aquarium or jar, using the same care as when you collected them. A mass of frog eggs the size of your hand requires about five gallons of water for proper aeration, so if you have a smaller or larger aquarium use only a proportionate size of the egg mass.

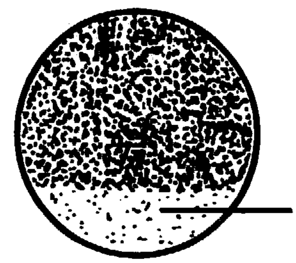

Figure 87
EGG OF FROG

Now examine an egg with your lens. You will find it extremely small (about one and a half millimeters in diameter), surrounded by its perfectly transparent sphere of jelly. Note that about two thirds of it is velvety black in color, the remainder, or lower side, creamy white. The black area is the future tadpole and the white area is the food yolk for growth (*Figure 87*).

The first sign of beginning development is a slight increase in size. At the same time the black area spreads until the visible white portion becomes no larger than a pin point. Then a groove appears in the mid-line at the top of the egg. This groove increases in length until it completely encircles the egg, and provides external evidence that the egg has divided into two equal parts (*Figure 88A*). Next a second groove appears at right angles to the first and rapidly encircles the egg until it has become divided into four nearly equal parts (*Figure 88B*). A further subdivision is made by a horizontal partition instead of a vertical one. This partition and its external groove are somewhat above the center of the egg so that the upper portion is smaller than the lower (*Figure 88C*). From this time on further subdivisions are more rapid and more irregular and it becomes increasingly difficult to follow them since they become too small to be readily seen. What you have actually seen so far is the egg, which is a single cell, first dividing into two cells, then the two cells dividing into four, and so on until there is eventually formed a ball-like mass of many, many cells. Biologists call this mass of cells a blastula, but we shall continue to refer to it as the egg.

If you look carefully at an egg on the second day (after they are laid), you should see a dark crescent-shaped line on one side just below the middle (*Figure 88D*). Twelve hours later you will find that this crescent has be-

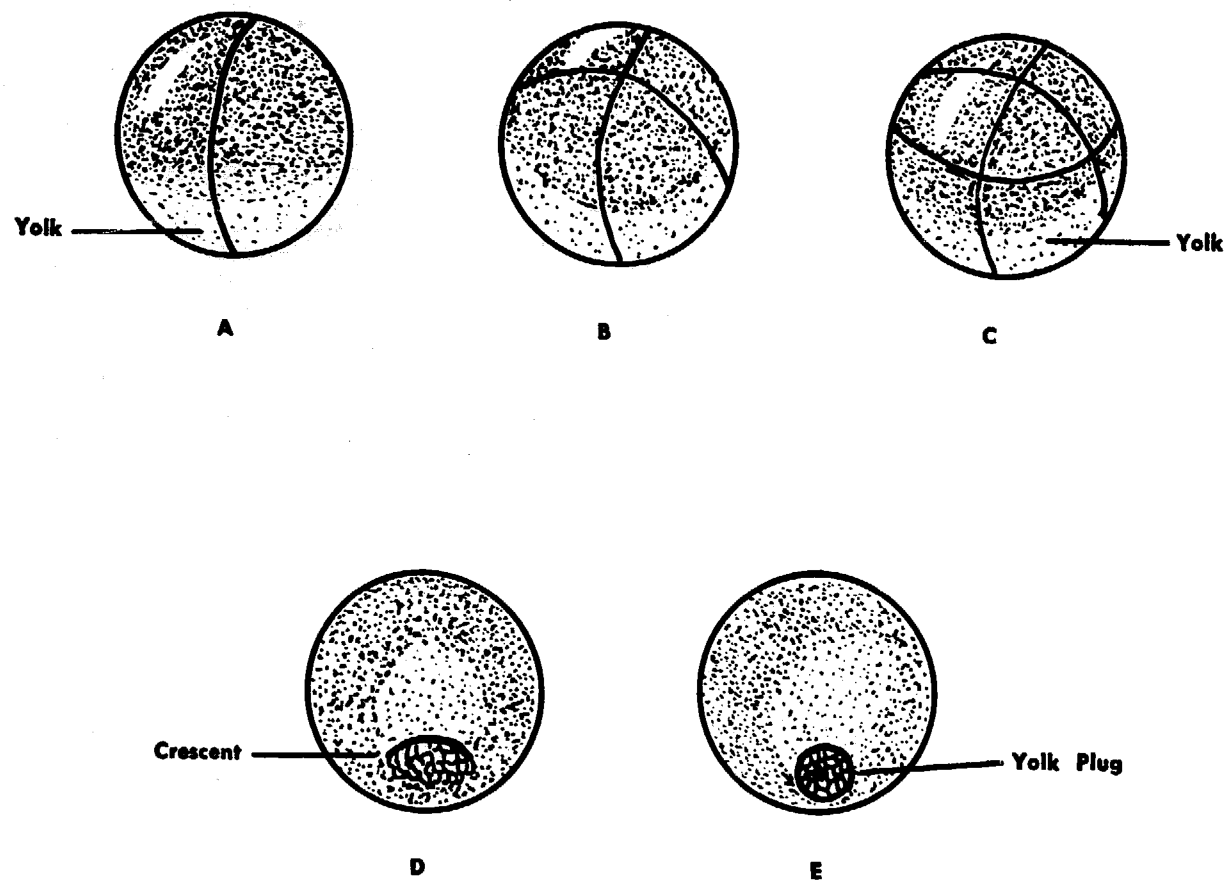

Figure 88
DEVELOPMENT OF FROG'S EGG

come a circle (*Figure 88E*). You will now also observe that the black surface of the egg has spread almost to the edges of the circle and that the circle itself encloses a mass of white yolk that protrudes like a small cushion. This circle, with its protruding plug of yolk, is the external indication that the cells have begun to separate and are beginning to form the digestive tract. As this tract begins forming at the posterior instead of the head end, the yolk plug marks a point very near the posterior end of the tadpole, or young frog.

On the third day you will find that the eggs have become elongated and that a groove is forming lengthwise along the top (*Figure 89*). Since this groove marks the back of the developing tadpole, it is easy to see which is to be the head and which is to be the tail and which are to be the right and left sides.

By the fourth day the eggs have greatly changed. They have become more elongated and the yolk plug has retreated. The groove, which began so simply, has now become extended along the entire length of the back (top of egg) and two folds of the surface are slowly rolling in over it, one on each side. Both the groove and the folds will form a tube that is the beginning of the nervous system, the head end forming the brain and the remainder the spinal cord.

You will observe that on the next day the eggs have become even more elongated and also that the head and tail ends have curved somewhat to one side. Note, too, that the line of the back is nearly straight and that the yolk side is very convex. The nerve tube now appears to be entirely closed in, but the folds persist over the head and along the back. The projection that is to form the tail is quite noticeable.

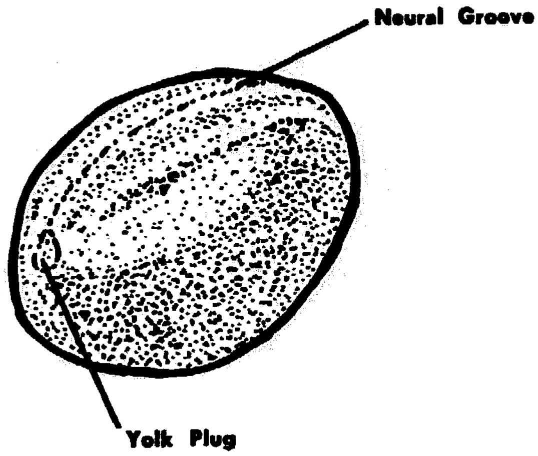

Figure 89
FORMATION OF NEURAL GROOVE

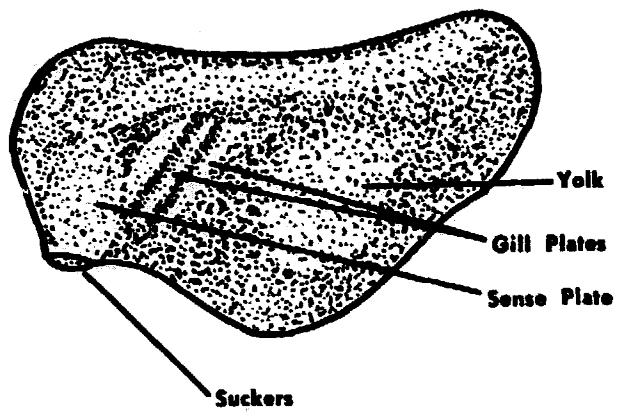

Figure 90
OLDER EMBRYO

Look at the egg, or the developing embryo, either from above or from below, and you should see slight projections or swellings in the region of the head and neck (*Figure 90*). The largest swelling (sense plate) will become the facial part of the head, with upper and lower jaws, mouth, and nostrils. The three smaller swellings will become the gills. There is also a blunt projection or swelling on the lower part of the head end. Viewed from the front, it becomes one side of a horseshoe-shaped structure and will eventually develop into a pair of suckers that will be used by the tadpole to attach itself to waterweeds.

By the end of the sixth day the young developing tadpoles have become even longer and more curved. The body is thinner, the head and tail ends are unmistakable, and the swellings on the sides of the neck more distinct. On the following day the head is more delineated and the tail is longer and clearly finned at its edges. You may observe the tadpoles move occasionally.

Nine days after the eggs are laid the tadpoles are out of the jelly, clinging, by means of their suckers, to the deserted jelly mass or water plants. The suckers do not act in the way their names would seem to imply but function by reason of a sticky substance or cement they secrete. If all the tadpoles are not out of the jelly, you should be able to see some of them hatch from the egg: with a vigorous wriggle a tadpole escapes from the egg, the jelly ruptures, and the tadpole is free. Note that the tadpoles are very slender and black and that the transparent tail is quite conspicuous. Observe, too, that the swellings at the sides of the neck are branched, fingerlike gills. With your lens examine the tadpole closely and you will see the swellings that are to become eyes, and an opening just forward of the suckers that is to be the mouth.

On the following day all the tadpoles should be out of their eggs. They hang quietly from the water plants or circle about with vigorous wrigglings of the tail whenever disturbed. Through the next few days further changes take place. The tadpoles become longer, although the increase in length is mainly in the tail, and they also become wider, due to the further development of internal organs. Then, on the sixteenth day, they are swimming about rapidly, with mouths open, and nibbling at the water plants. They are no longer jet black but rather brownish, with a fine mottling of gold spots on the back.

ADVENTURE 23

We Encounter Some Hitchhikers

MANY OF THE WAYS in which nature has contrived to effect seed dispersal are most ingenious. The seeds of some plants, as those of the dandelion, are provided with silken hairs that catch in the wind; others are able to float on water and in that manner are transported to distant places. Then there are those plants that shoot or propel their seeds considerable distances into the air, as the witch hazel. Finally, we have the plants whose seeds are furnished with structures that catch in the fur of animals or in our clothing when we come in contact with them.

Most familiar of these so-called "hitchhikers" are the burs that occur on a familiar and rather rank-odored weed called the burdock, which is common along roadsides and in waste places. The leaves are large, dull green, and woolly on the lower surface, and the flowers, which blossom in globular flower heads, are small, light magenta, and often nearly white. When the flowers have "gone to seed" or, more accurately, have developed into fruits, the entire flower head has become the bur shown in *Figure 91*. If we look at it through our lens, we can readily see why it clings so tenaciously to our clothing. It consists of a number of individual fruits called akenes (sometimes spelled achenes), and if you examine one of these akenes closely you will find it appears as in *Figure 91A*. It is somewhat oblong in shape, three-angled, ribbed, and truncate, that is, one end appears as if cut off transversely. The other end is fashioned in the form of a hook. Need we say more?

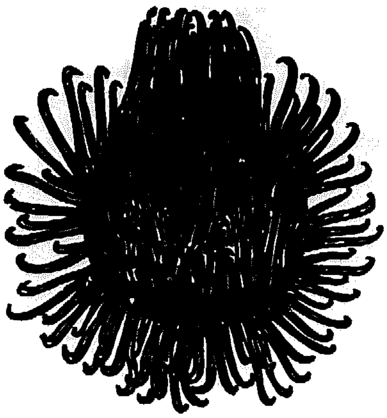

Figure 91
BURDOCK

Figure 91A
AKENE OF BURDOCK

Even more exasperating when it comes to removing them from our clothing are the beggar-ticks. The beggar-ticks are also akenes and are formed on a number of related plants, as the bur marigold, tickseed sunflower, Spanish needles, and the beggar-ticks, also known as the sticktight. These plants form a group of rather uninteresting weeds with various leaves and mostly yellow flowers. The akenes are much alike except that they may vary somewhat in shape, being wedge-shaped, linear, or oblong. The akene shown in *Figure 92* is from the beggar-ticks, which can usually be found growing in damp situations. Sometimes my trousers have been so completely covered with these akenes that it has taken me hours to get them off. Look at one with your lens and see why. *Figure 93* shows an akene from Spanish needles. It resembles the akene of beggar-ticks except that it is four-awned, whereas the former is two-awned.

If we should walk in the woods during July or August, we would likely come upon a plant having a generally leafless flower stem with a scattered cluster of very small magenta-pink or lilac flowers and known as the tick trefoil. A few weeks later, were we to return to this same plant, we would find that the flowers had developed into seed pods shaped somewhat like that in *Figure 94*. To our naked eye there would be no apparent reason why these seed pods should become attached to our clothing, as they do should we brush against them. But we need only to view them through our lens to see that they are provided with minute hooked hairs that are as effective in hitchhiking a ride as the barbed akenes of the beggar-ticks or the hooked akenes of the burdock. There are many species of tick trefoils, each with its own characteristically shaped seed pods, so that if you find pods slightly different in shape from that illus-

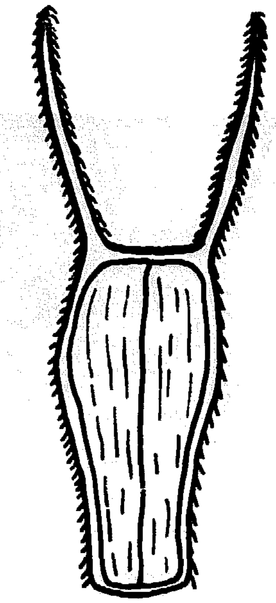

Figure 92
BEGGAR-TICKS

Figure 93
SPANISH NEEDLES

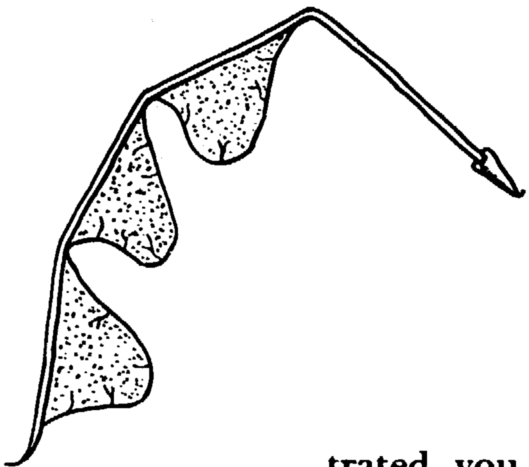

Figure 94
TICK TREFOIL

trated, you know the reason why.

Frequently a plant has some characteristic structure that has invited a variety of names descriptive of that particular structure. Such a plant is the one commonly called cleavers or goose grass. Other names, such as catchweed, burhead, cling-rascal, scratch grass, wild hedgeburs, stick-a-back, and grip or gripgrass, are more appropriate. Perhaps most of these names have been given to it because the stems are furnished with backward-hooked prickles, but they are also descriptive of the burlike fruits, which occur in pairs and which are covered with short, hooked bristles (*Figure 95*). Look for this plant in shady thickets and along roadsides. You can recognize it by its prickly, reclining stem and by the two tiny white blossoms.

There are many other plants whose fruits have been modified for transportation by animals. One of them is the cocklebur, whose burs are provided with hooked prickles (*Fig-*

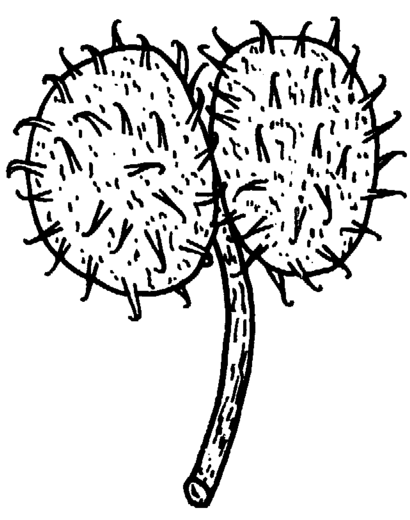

Figure 95
CLEAVERS

ure 96). Look for it in waste places. Another is the wild carrot, or Queen Anne's lace, whose flat-topped clusters of white flowers are conspicuous on the summer landscape. The fruit is oblong in shape, rather flattened, and has four wings armed with bristles. As you look at these and many others in the course of your explorations, you will become increasingly aware of the countless designs that nature has devised for the survival of the many different plant species.

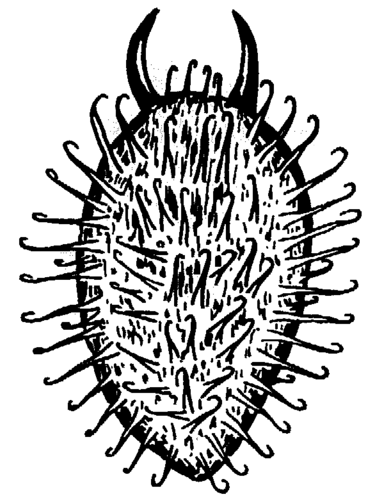

Figure 96
COCKLEBUR

ADVENTURE 24

We Make the Acquaintance of Some Housebuilders

CADDIS WORMS are not worms, but the larval form of the caddis fly, an insect that looks something like a moth except that its body is more slender and it is more delicately built.

Caddis worms are of considerable interest because they build houses or cases that they carry around much in the manner of the snails. But whereas all kinds of snails build houses of the same kind of material, the caddis worms use different materials. Some build of sticks, which they fasten together lengthwise, and some put the sticks together crosswise, like log cabins. Others construct their houses out of a hollow stem or of bits of leaves (*Figure 97*), and still others make use of sand (*Figure 98*) and pebbles (*Figure 99*). Then there are those that make use of rubbish and

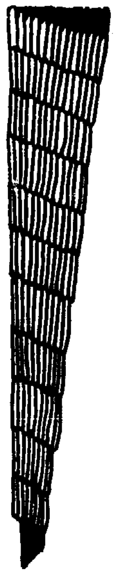

Figure 97

CASE MADE FROM BITS OF LEAVES

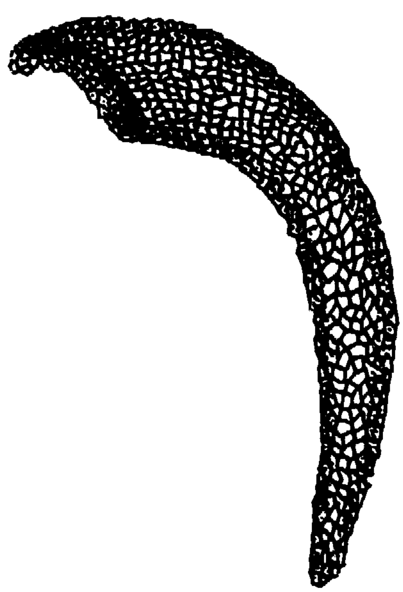

Figure 98

CASE MADE OF SAND GRAINS

silk and fashion these materials together in the form of a little cornucopia. All of them, however, use their own saliva to cement the materials together. Since each species builds its own distinctive dwelling, each kind of house is thus a clue to the identity of its occupant.

Caddis worms may be found in almost any brook or pond throughout the summer, and a few can be found even in winter. They can be seen with the naked eye seemingly as pebbles or sticks or dead leaves moving in the water. Only by means of our lens, however, can we learn how the houses are put together or study the occupants. We can easily remove them from the water by picking them up with our fingers or by using a pan or scoop.

As you examine the dwelling you will see that it is open at both ends, with a front and back door, as it were. The caddis worm may not be visible at first, for as you remove it from the water it becomes frightened and retires into the house. If you do not disturb it, its dark-colored head will soon appear and then emerge, followed by the six pairs of legs. This is how it appears as it moves about the bottom of the brook or pond.

Now take hold of it and by pulling gently remove it from its house. First of all note that it is wormlike in form (*Figure 100*). Next observe the little tassels of short, threadlike white gills along the sides of the abdomen. Water is made to pass over these gills by undulating movements of the body. The water enters through one opening of the house, flows over the gills, and then out through the other opening, hence the reason for front and back doors. See if you can locate three tubercles (*Figure 100*). They serve to keep the body from pressing against the edge of the opening and thus preventing the water from entering.

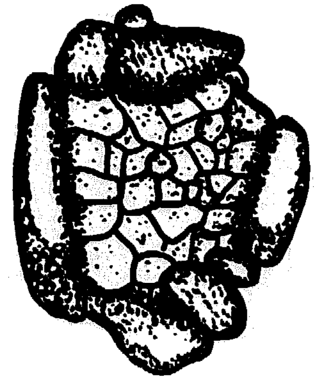

Figure 99
CASE MADE OF PEBBLES

The caddis worm manages to hold on to its house, as it crawls about, by a pair of curved hooks (*Figure 100*) that are called grabhooks.

Unlike the snail, which is attached to its house, the caddis worm is not grown fast to its case. You can discover this by holding the case down on a flat surface with its occupant wrong side up, using your finger or a pair of forceps for the purpose. After a few struggles the caddis worm will succeed in turning itself over within its case.

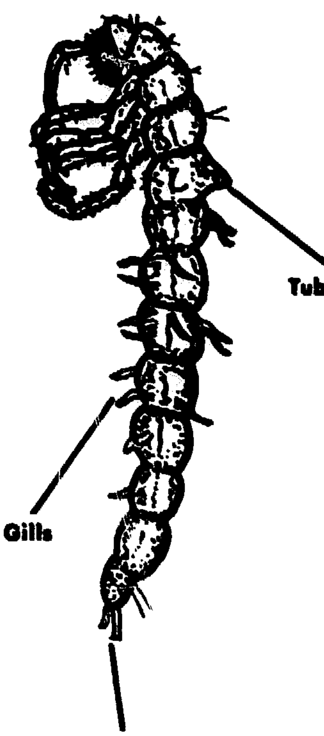

Figure 100
CADDIS FLY LARVA

Although you may not be able to observe to the smallest detail how a caddis worm builds its house, you can watch the general procedure. Get a caddis worm that is about half grown, remove a section of the front part of its house, and then place the insect in a tumbler with a little water in it and containing a few bits of brightly colored flower petals. Within a few hours the little house will look like a blossom, with several rows of petals rimming the opening.

ADVENTURE 25

We Come Upon Some More Housebuilders

In our last adventure we discussed the portable dwellings of the caddis worms. These insects are not the only ones that build temporary shelters, although they are probably the most advanced in this form of insect behavior. Actually most orders are represented by species that illustrate the habit.

These shelters, or houses, or dwellings, as we have variously called them, are known more accurately as cases, and the insects that construct them as case-makers or case-bearers. As we shall see, not all cases are portable; some are permanently or semi-permanently attached, and even the portable ones are never completely portable, for they become attached to some object when the larvae are ready to pupate. This is equally true of the caddis worms.

As the case-making insects represent almost all the orders, we would expect that the cases they construct would vary in form and materials used as much as the insects themselves exhibit different types of behavioral patterns. Thus we have cases that are very simple affairs, while others are more complex. Some are merely a sheet of silk or a silken tube; others consist of various materials added or blended with the silk, but all have in common the use of silk as the primary material.

Much can be written about the origin and development of the case-making habit, but what we are particularly interested in at present is to find and examine a few typical cases and to observe how they are put together. Since many of them serve as winter retreats for the hibernating larvae, we can engage in this study almost any time of the year. However, if we wish to observe the habits of the larvae, we can do so only when they are active and feeding, during the warmer months. An exception would be the clothes moths, which may be found throughout the year. It may be somewhat difficult to find these insects, for no one will admit their presence, since to do so would be a confession of neglect. Yet you may come across them sometimes. Should you do so, transfer a few of the cases with their occupants to a bottle or jar. You can then observe with your lens how the larvae have to enlarge their cases from time to time to accommodate an increase in size The cases are simply silken tubes in which bits of material on which the insects feed are sometimes incorporated (*Figure 101*).

Far more available are the curious baglike shelters of the bagworm (*Figure 102*). This

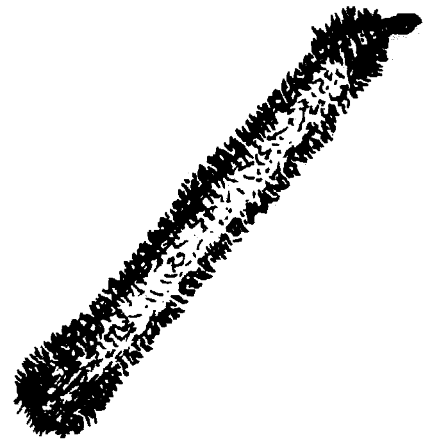

Figure 101
SILKEN CASE OF CLOTHES MOTH

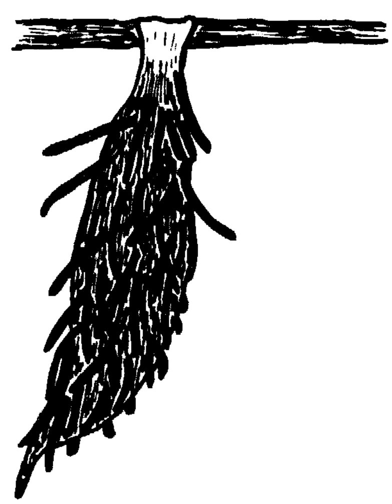

Figure 102
CASE OF BAGWORM

insect feeds on a variety of shade trees, shrubs, and hedges, but has a particular fondness for the arborvitae and red cedar, so look for the "bags" on these trees. The best time is during July and August, when the larvae are growing and feeding; they may also be found in the winter. As the cases measure from three quarters of an inch to one and a half inches long they are not difficult to find. Note that they are made of bits of bark or pieces of foliage bound together into a silk-lined case.

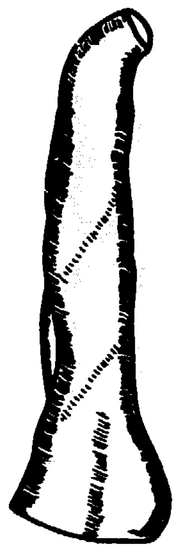

Figure 103
CASE OF CIGAR CASEMAKER

In some instances the cases resemble well-known objects. One such case is shaped in the form of a cigar (*Figure 103*), hence its maker is known as the cigar case-maker or case-bearer. It measures about five sixteenths of an inch in length and is brown in color. Being so small, it may take a little searching. A reading glass should help you to locate it. While you are searching for it, you may also keep your eyes open for a black case shaped like a pistol (*Figure 104*). Both the cigar case-bearer and the pistol case-bearer are pests of the apple and feed on the leaves to which they eventually attach their cases. The insects appear when the leaves begin to unfold, so the best time of the year to find them is in early spring or during the period of their larval development, from April to July.

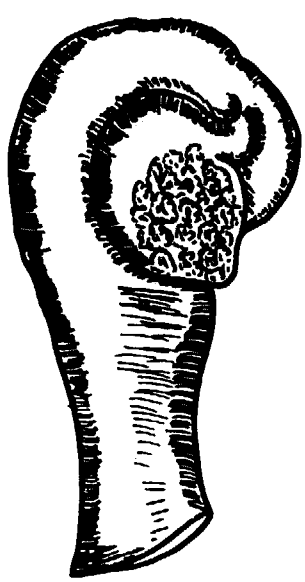

Figure 104
CASE OF PISTOL CASEMAKER

Frequently a small oval case about five eighths of an inch long may be found on a leaf of the sugar maple (*Figure 105*). The maker of the case, called the maple-leaf cutter, is a rather interesting little insect. The larva cuts an oval-shaped piece of leaf and attaches it to the leaf by means of silk. At first it lives between the leaf and the piece fastened down, but later it cuts around the oval piece of leaf and fastens the two together to form a new case, which, in turn, it attaches to the surface of the leaf. When it needs new feeding grounds it merely cuts the supporting strands and wanders off with its case.

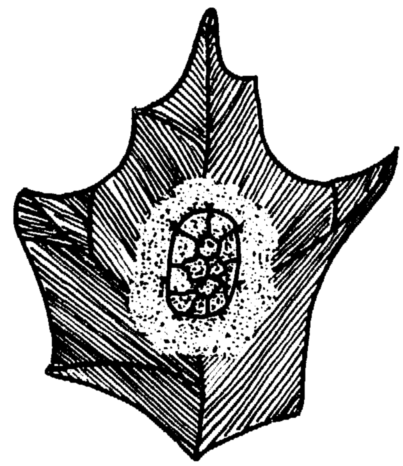

Figure 105
CASE OF MAPLE-LEAF CUTTER

These cases are only a few of the many you can find by exploring your neighborhood. The best time, of course, is during the summer, but, surprisingly, a few, as those of the resplendent shield-bearer (*Figure 106*), can be found on the twigs and trunks of various trees and shrubs during the winter. They are well worth the effort spent in looking for them, since they provide an interesting facet to the study of insect behavior, one of the most absorbing fields for investigation.

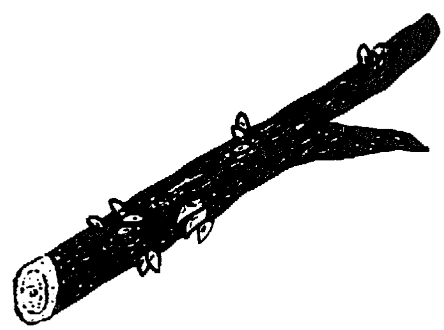

Figure 106
CASES OF RESPLENDENT SHIELD-BEARER

ADVENTURE 26

We Ascertain how the Leech Sucks Blood

Leeches are common in our ponds and streams, and most of us know them. Some of us have even had the unfortunate experience of having been bitten by them. Their bites are not dangerous except through an incidental infection of the wound, but they can cause an intense itching if they are removed before they are allowed to finish their meal.

Leeches are generally marked with concealing colors and patterns—browns, greens, and blacks—which serve to render them inconspicuous among the broken shadows and water-soaked leaves of their environment. Though some species feed on worms and snails, and a few are scavengers or even cannibals, most of them suck blood. Sometimes they attack animals, as frogs and turtles, in such numbers that they literally drain them of their lifeblood.

Leeches do not have to swim about in search of a meal. They are acutely sensitive to the slightest vibration of the water, to shadows passing over them, and to the smallest amount of any substance dissolved in the water around them. You can observe this for yourself by merely placing a few of them in a dish and then pressing your finger against the bottom of it. They will immediately begin to crawl about and restlessly explore the entire surface of the dish. Should they pass over your fingerprint, they would become quite agitated in response to its odor. Any movement in the water of a pond also makes them very excited. That is why, should you wade into a pond where leeches are abundant, they will become attached to your legs within a matter of minutes. Incidentally, this is a good way to collect them, but I would suggest that you wear rubber boots, since the leeches do not wholly rely on the odor of flesh and will just as readily become attached to boots.

Leeches have the means to fasten themselves to almost any kind of surface. Examine one and you will find a strong muscular sucker at each end, the posterior one being larger (*Figure 107*). Look at the posterior sucker through your lens and you will readily see why it functions as well as it does. You are familiar with the "plumber's helper," which consists merely of a rubber cup attached to the end of a wooden stick, or the small rubber suction cups that are used to display merchandise on a store window. Both of these devices and the leech's sucker operate in the same manner: by excluding air from within the cup the unequal air pressures thus created within the cup and on its exterior surface keep the suction cup in place.

When a bloodsucking leech (and bear in mind that I said not all leeches are bloodsuckers) finds a likely skin surface, it attaches its posterior sucker and then swings its head about in a manner of exploration. It prefers a spot where the skin is broken or is well supplied with blood vessels. Upon locating a satisfactory spot it presses down its anterior

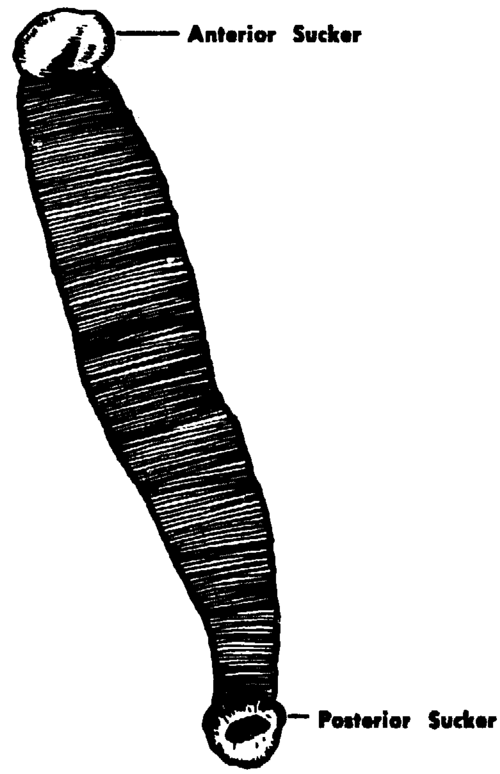

Figure 107
VENTRAL VIEW OF LEECH SHOWING SUCKERS

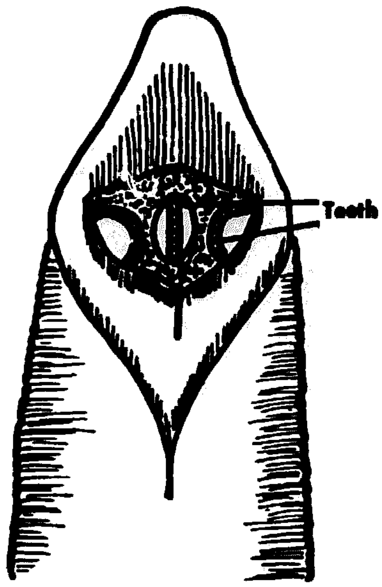

Figure 108
HEAD OF LEECH

sucker and then makes a wound in the flesh with its three jaws. Look at the anterior sucker and you will note the small, oval mouth. With your lens you should also be able to see the jaws and teeth (*Figure 108*). For sucking the blood the animal is provided with a sort of suction bulb in the pharynx, or throat cavity, which can be seen only upon dissection.

The salivary gland of the leech secretes a substance called hirudin, which prevents the blood from coagulating and keeps it thin so that it can easily be sucked up. When the jaws break the skin, this hirudin pours into the wound, which at first is painless, though it may itch intensely later on. If, however, the leech is permitted to finish its meal, there should be no itching. The reason is that the hirudin, which causes the itching, has by then been completely sucked up with the blood.

A leech doesn't have to eat very often, because as it feeds the fluid part of the blood is drawn off through the kidneys and the solid matter stored in lateral pouches of the digestive tract as a sort of reserve food supply. Leeches have been kept in aquariums for as long as fifteen months with only a single feeding. So, if you are interesting in studying these animals, you can do so with a minimum of care. All you need is a bottle partially filled with water, and a piece of mosquito netting or similar material tied over the mouth to prevent the animals from crawling out. A meal of ground meat, beef liver, or earthworms will do them for several weeks. Be sure to change the water each day to provide them with a fresh supply of oxygen and to prevent the water from becoming polluted. In observing their habits I would suggest a reading glass, although for close observation a hand lens should be used. In olden times leeches were used in bloodletting, and I read lately that the practice is being revived; some drugstores again carry them.

ADVENTURE 27

We Identify Some Ferns

FERNS ARE NOT a particularly important form of plant life. However, it was not always so. At one time they and their allies were the dominant plants of the earth. They are generally supposed to be the oldest form of terrestrial vegetation now in existence, and the coal we now mine is said to have been formed from their remains many millions of years ago. At that time they grew to an enormous size, often attaining a height of fifty feet or more. Some of the ferns found in the tropical rain forests today grow to considerable heights, but the ferns with which most of us are familiar are low-growing species.

There are many kinds of ferns, and though, at a glance, they may appear to be much alike, they all differ from one another if only slightly. Sometimes only an expert can recognize certain species. Many of them can readily be recognized by their habits of growth, by the shapes of their fronds, or by the manner in which the fronds have been cut, so we need not be an expert to know at least a few of them. Once we have become familiar with such easily recognizable species as the bracken, the sensitive fern, and the common polypody, for example, we can go a little further and learn how to identify others by their fruit dots. These fruit dots appear as little brown or gray specks or dots on the lower surface of the frond; perhaps you have noticed them.

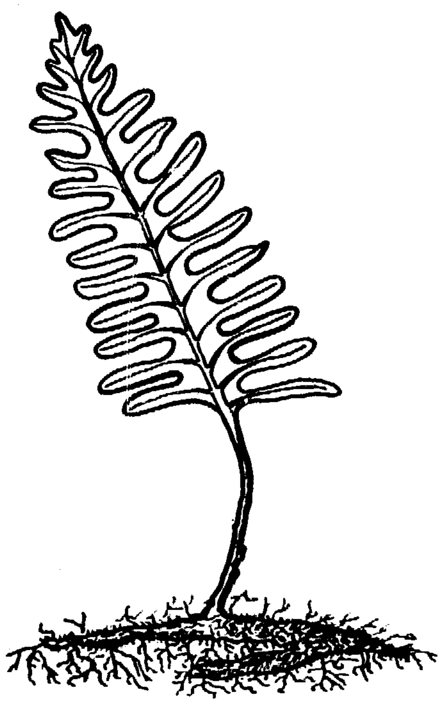

Figure 108A
COMMON POLYPODY

Before we continue, let me point out that a frond is merely a leaf. In most ferns the fronds have been cut into divisions or leaflets called pinnae, and in some species these divisions have been further subdivided into still smaller leaflets, or pinnules. Ferns reproduce by means of spores, which are produced in small structures called sporangia (singular sporangium). These sporangia are usually clustered in groups called sori (singular sorus), which occur in various shapes in the different species. Thus they may be linear, oblong, kidney-shaped, or curved. Their shape and position on the frond, or more accurately on the pinnae, serve as a means of identification.

Let us consider the common polypody (*Figure 108A*). This fern is one of the most abundant and ubiquitous of our fern species and may easily be recognized by its evergreen fronds, which are deeply divided into long, narrow, usually obtuse segments that almost reach the midrib, and by its general habit of growing among shaded rocks in the woods. Since the fruit dots are visible to the naked eye, we need only glance at the lower surface of the fronds to find whether they are there. Fruit dots are not always present on the ferns; since they are reproductive structures, they occur only at certain times. Should we look at the polypody frond at the right time of the year and examine the fruit dots with our lens, we would find them rather large, yellow-brown in color, roundish in form, and located midway between the mid-vein and margin of the pinnae (*Figure 109*). These features, namely color, form, and position, are peculiar to the polypody and thus serve as diagnostic characters that would enable us to identify this fern if we could not otherwise readily do so by the shape of its frond, habit of growing, or some other outstanding characteristic.

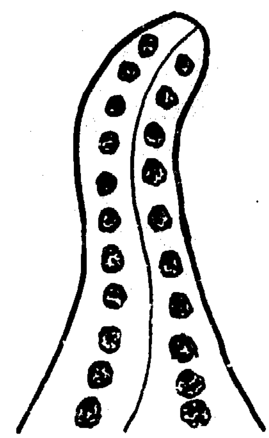

Figure 109
FRUIT DOTS OF COMMON POLYPODY

If we should next examine the fruit dots of the silvery spleenwort (*Figure 109A*), a

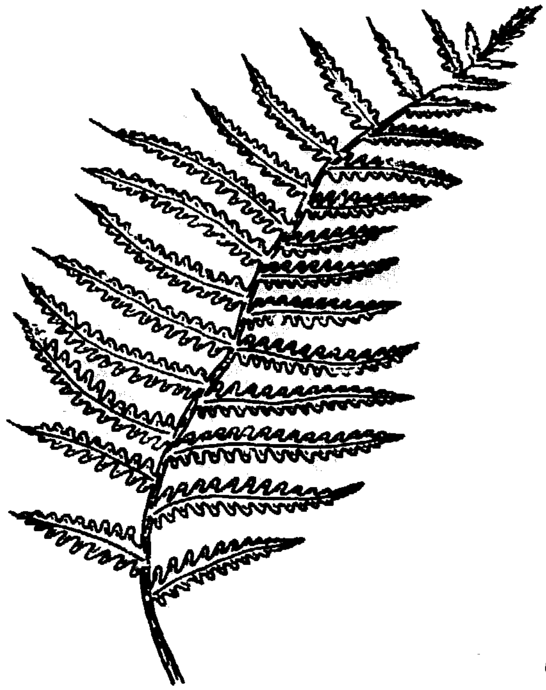

Figure 109A
SILVERY SPLEENWORT

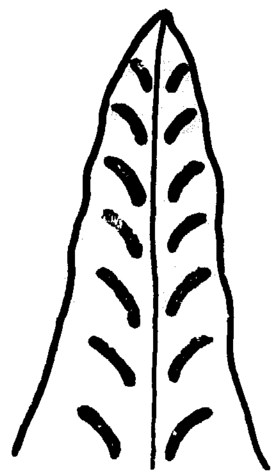

Figure 110
FRUIT-DOTS OF SILVERY SPLEENWORT

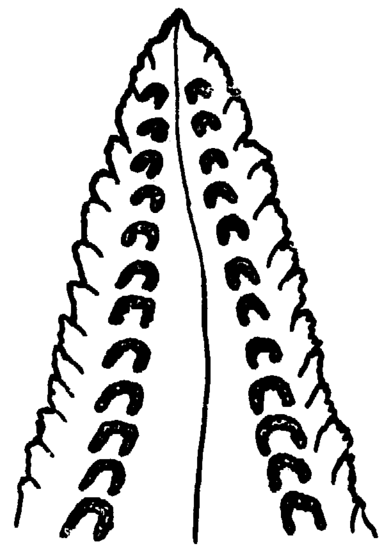

Figure 111
FRUIT DOTS OF UPLAND LADY FERN

fern with fronds two feet or more long and also found in the woods but usually in wet ground, we would find the fruit dots quite unlike those of the polypody. They are numerous, slightly curving, and oblong and are arranged in a double row at an angle to the midveins of the pinnules (*Figure 110*). So far we have seen how the fruit dots of these two ferns differ. Let us take a third species—the upland lady fern. Here the fruit dots are horseshoe-shaped and curve away from the midveins (*Figure 111*). There appear to be all sorts of variations in the ap-

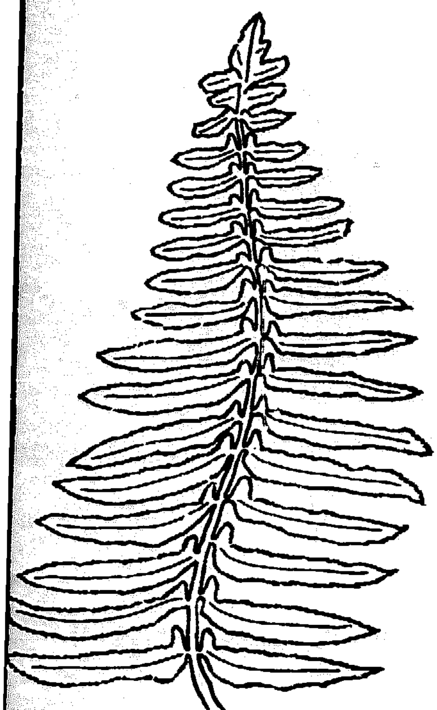

Figure 111A
CHRISTMAS FERN

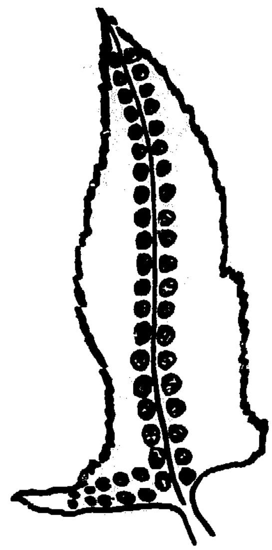

Figure 112
FRUIT DOTS OF CHRISTMAS FERN

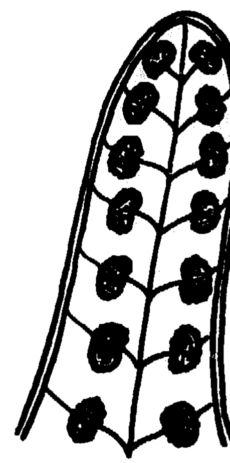

Figure 113
FRUIT DOTS OF MARSH FERN

pearance and position of the fruit dots as we examine one fern after another. Thus, in the Christmas fern (*Figure 111A*), they are round and arranged in two lengthwise rows near the midveins (*Figure 112*), and in the marsh fern they are small and kidney-shaped in two rows parallel to and near the midveins (*Figure 113*). There is no denying that the variations found in the fruit dots provide us with another facet of nature's working, but, what is perhaps more to the point, furnish us with an easy and interesting way of becoming acquainted with the ferns.

ADVENTURE 28

We View the Scale Insects

Sometimes we find pine needles covered with what appears to be a white powder. If we examined it with our lens, we would discover that it is not a powder but a mass of long and narrow snowy-white scales (*Figure 114*). If these scales further intrigued us and we pried one off with a fingernail and looked at it closely, we would find that it is some sort of an animal, possibly an insect. We would not be mistaken in our conclusion, for what we had observed on the pine needle is known as the pine-leaf scale, one of a large group of insects known as scale insects.

Figure 114
PINE-LEAF SCALE

There are many different species and as a group present a number of interesting and curious features. The males do not have a mouth and have only a single pair of wings, although in a few species they are entirely wingless or have only vestigial wings. As with the true flies (See Adventure 10), their hind wings have been replaced by a pair of club-like halteres. Unlike the males, the females are always wingless, and so are the young, and the females in some species are legless, too. The females have either a scale-like or gall-like form or they may be grublike and clothed with wax. The waxy covering may be in the form of powder, large tufts, plates, a continuous layer, or a thin scale beneath which the insect lives.

All scale insects suck plant juices, and though most of them occur on leaves and stems, a few infest the roots of their host plants. Some species are quite restricted in food habits, while others can feed on a variety of plants. Because they suck the plant juices, they are injurious and can cause considerable damage when they become abundant. Some scale insects, however, are not harmful; a few species, as the lac insect, which supplies us with shellac, are useful. At one time various dyes were obtained from certain species, but these dyes today are made from coal tar. Wax, too, was formerly obtained from these insects; candles were once made in China exclusively from such wax.

One of the commonest and most widely distributed of the scale insects in our country is the oyster-shell scale. It is usually found on fruit trees and various shrubs, but also occurs on other plants. Lilac branches are sometimes covered with it. The scales may be seen with the naked eye, but are better observed with the lens. They are curved like oystershells, are about one eighth of an inch long, and their brownish color matches the dark bark (*Figure 115*). If you examine these scales in winter, you will find upward of a hundred white eggs beneath each scale together with the dead body of the female. The winter is passed in the egg stage, and in the following spring minute yellowish young emerge, in-

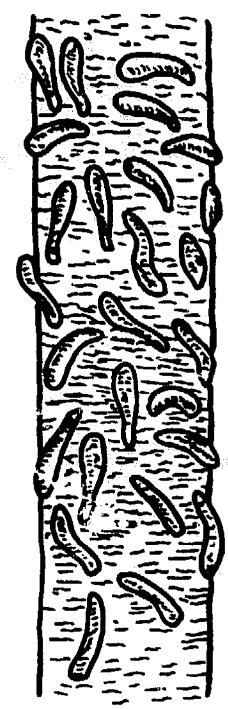

Figure 115
OYSTER-SHELL SCALE

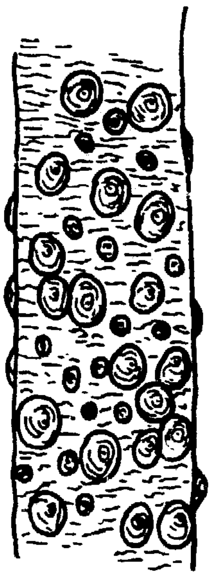

Figure 116
SAN JOSE SCALE

Figure 117
ROSE SCALE

sert their sucking tubes in the bark, and begin to feed.

Perhaps the best known of all our scale insects is the San Jose scale. It is also the most notorious because of the enormous losses it inflicted at one time upon fruit trees. It was the cause of considerable legislation leading to the development of comprehensive quarantine in this country. It infects many varieties of fruit trees and garden shrubs, and if you live in a region where the winters do not get too cold, you should have no trouble finding it. The female is yellowish in color, circular in form, without legs, and slightly smaller then the head of a pin. She is covered with a dark gray circular, waxy scale, one sixteenth of an inch in diameter, slightly elevated in the center into a nipple formed by cast-off skins and surrounded by a ring that varies from pale yellow to a reddish yellow (*Figure 116*). Smaller black scales somewhat elongate in form are the males.

Sometimes the stems of rosebushes present a whitish scurfy appearance, evidence of attack by the rose scale. The scales of the female are circular (*Figure 117*), snowy white, and if you were to examine them in winter, you would likely find masses of purplish eggs concealed beneath them. White scales that are irregularly oval, with a yellowish point and about a tenth of an inch long, denote the presence of the scurvy scale, a common pest of the apple but not particularly destructive. I can recall the first time I happened to come across the cottony maple scale. I was doing some collecting along a brookside when my eye was attracted to what appeared to be bits of cotton stuck on several twigs of a maple. Curious to know how they had gotten there, I went closer to investigate and found that they were actually tufts of a cottony material protruding from oval brown scales (*Figure 118*). The cottony maple scale is common on maple, Osage orange, and grape, and during the summer it is not unusual to find the twigs of these plants festooned with the cottony tufts.

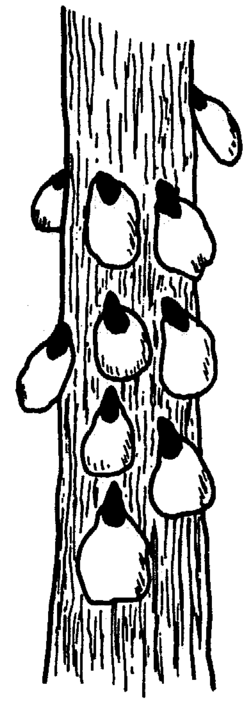

Figure 118
COTTONY MAPLE SCALE

ADVENTURE 29

We Undertake the Study of Minerals

THE DICTIONARY DEFINES a mineral as any chemical element or compound occurring naturally as a product of inorganic processes. It says further that it is usually a solid of a definite molecular composition and that it occurs, except in rare instances, in crystal form. The question now arises, what is meant by crystal form? Again referring to the dictionary, we find that crystal form refers to any solid form having plane surfaces symmetrically arranged. Let us go into the kitchen and dissolve some ordinary table salt

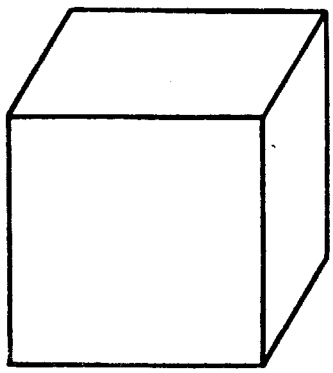

Figure 119
CRYSTAL OF SALT (HALITE)

in a little water. When it has completely dissolved, we place a drop of the solution on a piece of glass. We wait until the water has evaporated and then examine the residue with our lens. What do we find? Small, perfectly shaped cubes of salt—in other words, salt crystals (*Figure 119*).

By chemical analysis salt is shown to consist of one atom of sodium and one atom of chlorine. Since it is therefore of a definite molecular composition, it must be a compound. Thus it satisfies the above definition of a mineral. As a mineral it is known as halite (*Figure 119*).

Let us next examine another very common mineral, water. You might question my calling water a mineral. But it has a definite molecular composition, being formed of two atoms of hydrogen and one atom of oxygen and chemically known as hydrogen oxide; it is a solid (ice); and as a solid it crystallizes. You certainly have heard of snow crystals, which are simply crystals of solid water or ice. You can see them at any time of the year. Scrape some ice from the inside of your refrigerator onto a piece of glass and look at it with your lens. Water crystallizes as hexagonal, or six-sided, pyramids, but since several crystals are usually grouped together they may not be very sharply defined.

A third common mineral generally available is quartz, known chemically as silicon dioxide or silica. Everyone is so familiar with this mineral that it seems hardly necessary to say anything about it. In general appearance it resembles glass except that it is crystalline in form, whereas glass is amorphous, or without form. It occurs in many varieties. Amethyst, carnelian, opal, chalcedony, agate are all color varieties. But the quartz, as we mostly know it, is colorless and transparent. If you can locate a piece of pure quartz, you will observe that its usual form is a hexagonal prism (*Figure 120*). Quartz, however, also occurs in grains or masses. Ordinary sand is composed in part of quartz grains; they are actually the chief constituent of river and beach sands. Obtain some of this sand (the sand sold in stores for cage birds will do) and examine it with your lens. You should recognize the quartz grains easily. They are not crystalline but are rounded or irregularly shaped, due to the action of wind and water.

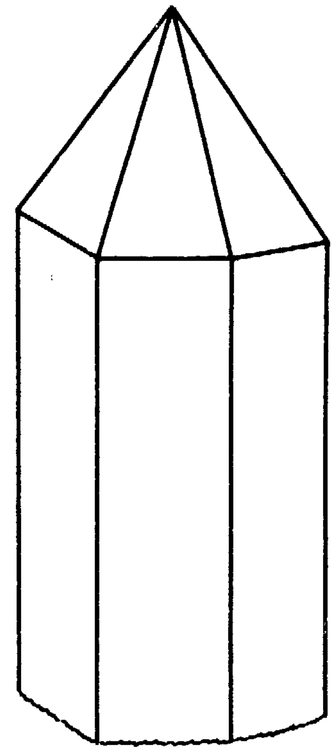

Figure 120
CRYSTAL OF QUARTZ

ADVENTURE 30

We Consider Some Diagnostic Characters

ALTHOUGH TREES are a familiar and conspicuous feature of the landscape, most of us can recognize only a few of them at a glance and only in a general sort of way. We know a pine, for instance, when we see one, or an oak or a maple or birch, but can we distin-

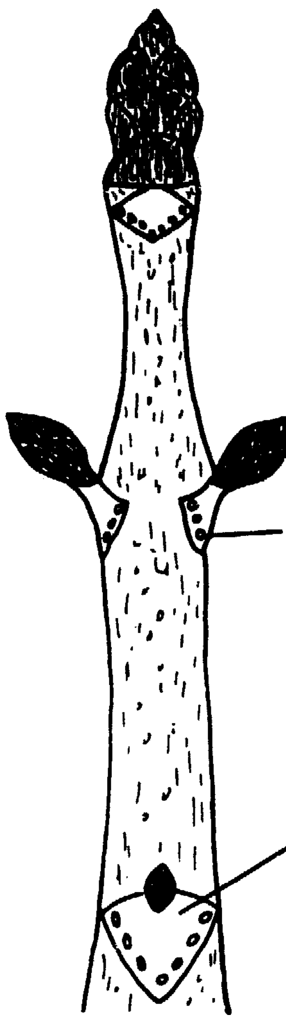

Figure 121
TWIG OF HORSE CHESTNUT

guish between a white pine and a pitch pine, between a white oak and a red oak, or between a silver maple and a sugar maple?

Most of our trees are easy to identify once you have learned how. It is much like getting to know people you meet. Once you have met them, you recognize them the next time by certain characteristics, as the color of the hair or eyes, the shape of the mouth or nose, or by other features. We can know our trees in much the same way.

The best time of the year to study them is in the winter. Most of our trees have a distinct shape or form that is more or less hidden in the foliage of summer, but when they stand naked and silhouetted against the sky, it is then that their architectural contours are most perfectly revealed and their natural grace and beauty most clearly defined. Once you have seen the umbrella or vaselike form of the American elm outlined against the winter's sky, you will never forget it. Nor will you forget the pin oak, with its tall straight trunk and pyramidal head, or the Lombardy poplar, which looks like a church steeple. All of our trees do not have such distinct or characteristic forms. All do, however, have twig structures we can use to identify them. These structures are called diagnostic characters.

Examine the twig of any tree after the

leaves have fallen, for instance the horse chestnut illustrated in *Figure 121*. Observe the smooth, light-colored areas that appear at first glance as scars. And that is exactly what they are—leaf scars, formed when the leaves fall off. The shedding of leaves when cold weather approaches is nature's way of protecting the trees against excessive loss of water during the winter, when the supply is at a minimum and it becomes necessary for every tree to conserve whatever it can obtain from the soil. Leaves function, in addition to their food-making activities, as an outlet for any excess water that the trees may absorb from the soil, at such times as when the water table is high, and that, if not eliminated, would drown them. Since the leaves would continue to function in this manner, were they permitted to remain on the twigs during the winter, it is quite possible that the outgo of water might exceed the intake, with resultant injury to the trees. The subject of leaf fall is physiologically an interesting one and more complicated than we can discuss here.

Most leaf scars are visible to the naked eye, but in some cases we need our lens to outline them clearly. Look at your leaf scars with the lens and you will see small raised dots. These dots, called bundle scars, indicate the ends of the conducting vessels that carried water in

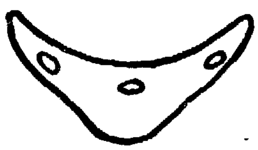

Figure 122
LEAF SCAR OF RED MAPLE

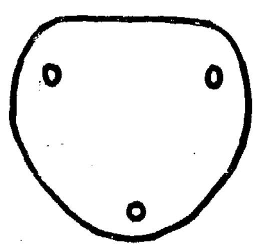

Figure 123
LEAF SCAR OF AMERICAN ELM

and out of the leaves. As you probably know, the water entering the leaves carries dissolved minerals for food-making, and on leaving the leaves carries dissolved food materials, which are carried to all parts of the plant and used or stored as the occasion may require. The shape of the leaf scars and the number and arrangement of the bundle scars vary in different trees, but are always constant for each species.

Let us consider the twig of the horse chestnut, a fairly common tree in our cities and towns. The leaf scars are very large and may easily be seen with the naked eye. Observe that they are inversely triangular (*Figure 121*) and that they are arranged opposite one another on the twig. Observe also that there are seven bundle scars also visible to the naked eye and that they are arranged in a simple curved line. Now let us compare this twig with one from the red maple. Observe, first of all, that the twigs differ markedly in size. The leaf scars and bundle scars, as might be expected, also differ in this respect. But not only do they differ in size; they differ in other respects. The leaf scars in the red maple are not triangular, as in the horse chestnut, but broad, U-shaped (*Figure 122*), and the bundle scars are only three in number. The leaf scars are arranged oppositely as in the horse chestnut.

We next examine a twig of the American elm and note first of all that the leaf scars are arranged alternately on the twig. Then that they are semicircular in outline. If we now look closely at them with our lens, we observe that they are slightly raised above the surface of the twig and that, though small, they are fairly conspicuous because of the contrast in color between the light, corky surface of the scar and the darker brown of the twig. The bundle scars are three in number and rather large and noticeable (*Figure 123*).

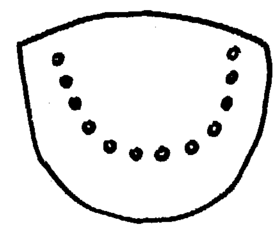

Figure 124
LEAF SCAR OF BLACK ASH

These three examples serve to illustrate the degree of variation we might expect to find in these characters. Leaf scars may have almost any form and in addition to those we have just discussed may be circular and crescent-shaped. They may be very narrow, as in the pear, and their upper margins may be flat, convex, as in the black ash (*Figure 124*), or deeply notched, as in the white ash (*Figure 125*). Sometimes they may form a band nearly surrounding the bud, as in the sycamore. In some cases they may be dingy and inconspicuous or be quite distinct by reason of a color contrast, as in the elm, which we have mentioned. They may be level with the twig or more or less raised, with their surface parallel with the twig or making various angles with it up to a right angle. Much the same can be said of the bundle scars in regard

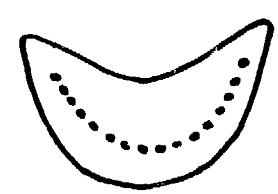

Figure 125
LEAF SCAR OF WHITE ASH

to their number, size, relation to the surface of the leaf scar, as sunken or projecting, and their arrangement.

Though there may be many variations in these structures, the structures themselves, as we have already remarked, are fairly constant for the species, and as you pursue this study and examine the twigs of our trees, you will gradually associate certain characters with certain species. Thus the large triangular leaf scar, with its seven bundle scars arranged in a single curved line, is characteristic of the horse chestnut; the U-shaped leaf scar, with its three bundle scars, we associate with the red maple; and so on. You might begin your study by collecting twigs from the trees in your neighborhood, and then, with the aid of a book on trees, identify, label, and keep them for ready reference.

ADVENTURE 31

We Inspect the Breathing Apparatus of Some Aquatic Insects

EVERY LIVING PLANT and animal needs air, or, more specifically, oxygen, to live. Oxygen is necessary for respiration, a word applied to a number of complex chemical processes whereby food materials are converted, among other products, into heat and energy. In many animals, as birds and mammals, oxygen as a component of air passes directly into the body, where the lungs effect a transfer of the oxygen from the air into the blood stream; in other animals, as fishes, the gills effect a transfer of oxygen from water into the blood stream.

Insects have neither lungs nor gills. Instead they have a network of tubes called tracheae and smaller tubes called tracheoles, which convey air to the remotest tissues of the body. The tracheae are provided with openings to the exterior through which air enters, as in our nostrils. These openings are called spiracles and, with a hand lens, are easily visible on the abdominal segments (of the grasshopper, for instance).

This kind of respiratory system does very well for terrestrial or land insects, but how about those that live in water? Would not the water enter through the spiracles and then course throughout the tracheal system and drown them, much as water would enter our nostrils and into our lungs if we submerged and remained beneath the surface for any length of time? Aquatic insects, however, have developed modifications of the tracheal system that enable them to live in water.

Between the terrestrial insects and those which are truly aquatic is a group of insects that can be referred to as semi-aquatic. They dwell, for the most part, on or near the surface of the water and, being air breathers, submerge for only rather short periods. All have tracheal systems with open spiracles. In this group belong such insects as the water striders, which we often see skimming over the surface of a pond, and the whirligig beetles, the little blue, oval-shaped, metallic-appearing beetles that swim about in circles in the quiet parts of a pond or stream. Also in the group are such insects as the diving beetles, watch boatmen, back swimmers, water scorpions, rat-tailed maggots, and mosquito larvae and pupae, which are found usually beneath the surface. But they are not truly aquatic forms, since they are air breathers. How, then, do they obtain air?

Some of them, as the diving beetles, water boatmen, and back swimmers, periodically rise to the surface to breathe in the normal manner, and when they dive carry down bubbles of air, which permit them to remain submerged for varying periods. When the air supply is exhausted they rise to the surface. The others, as the water scorpions, rat-tailed maggots, and the larvae and pupae of mosquitoes, are provided with special breathing tubes, which they extend above the surface of the water. The various adaptations exhibited by these and other semi-aquatic insects, not alone for respiration, but for living in an aquatic habitat, makes for the most interesting reading. We are not concerned with

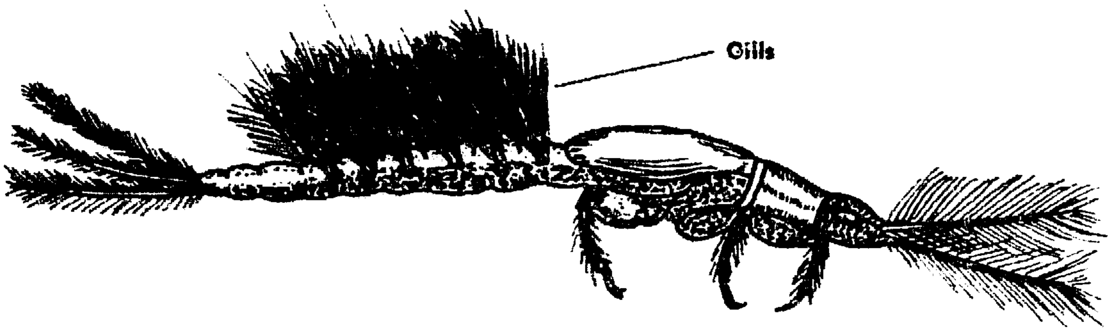

Figure 126
MAY-FLY NYMPH

these insects, however, except in passing, but rather with the truly aquatic species and the means they have developed for obtaining oxygen.

In the truly aquatic insects, which are essentially immature forms as nymphs and larvae and which live beneath the surface, the spiracles have become suppressed or functionless, and respiration is effected by means of gills. These gills are hairlike or platelike expansions of the body wall and are abundantly supplied with tracheae and tracheoles. Hence they are known as tracheal gills. They are so thin that oxygen can pass from water through their walls into the tracheae and thence into the body. Many May-fly nymphs (*Figure 126*) have leaflike gills in which the tracheal system is clearly visible with a hand lens. These nymphs live in clean fresh water, flowing rivulets or rivers, tumbling waterfalls or quiet pools, and usually we have no trouble collecting them. They may best be collected with a pan or some sort of scoop or a water net dragged slowly over the bottom along the shore of a pond, river, or pool where the water is shallow. May-fly nymphs vary in size and shape, but they all agree in having seven pairs of gills on the abdomen and two or three long slender tail filaments. The gills, when examined with a lens, appear as in *Figure 127*.

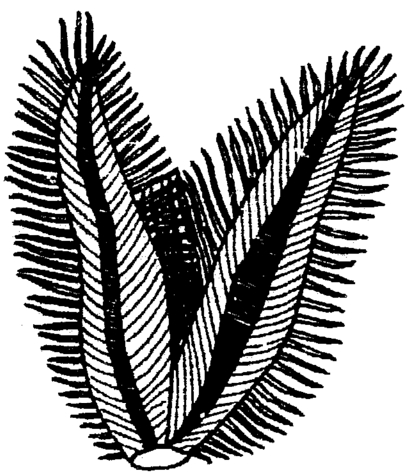

Figure 127
TRACHEAL GILLS OF MAY FLY

Although tracheal gills are usually located on the abdomen, as in the May flies, dobson flies, and caddis flies, they are sometimes located on the head and thorax, as in the stone flies. In the dragonflies they are found in the rectum at the posterior part of the body and are known as rectal gills, and in the related damsel flies they take the form of three flat plates at the posterior end of the body and hence are known as caudal gills (*Figure 128*). The gills of the damsel flies are bathed by water drawn into the rectum and expelled at rather irregular intervals. Should you place one of these damsel flies in a container of water, a pan, for instance, you may find that it will turn over on its back with its legs bent double, and while thus "playing dead" suddenly be propelled forward by the expulsion of a stream of water from the tracheal chamber.

Adult May flies usually appear in May and may be seen then in swarms in the vicinity of streams, ponds, and lakes. Frequently the banks are strewn with their dead bodies. They are attracted to lights and it is not uncommon to see hundreds of them about a street light. These insects are also known as ephemerids, a word derived from the Greek *ephemeros*, which means "lasting but a day." It has reference to the fact that the adult May flies are short-lived. They live usually only a single day or night or but a few hours, though sometimes they may live a few days. The name, however, is misleading, for though the adults live only a short time, the nymphs may live as long as three years before they transform. The insects are an interesting group and present some curious features. One of these is the complete absence of mouth parts in the adults, as you can readily see by examining them with your lens. This explains their short span of life as adults, since they cannot eat. Another curious sidelight is that, unlike other insects, the May flies molt after they have obtained functional wings.

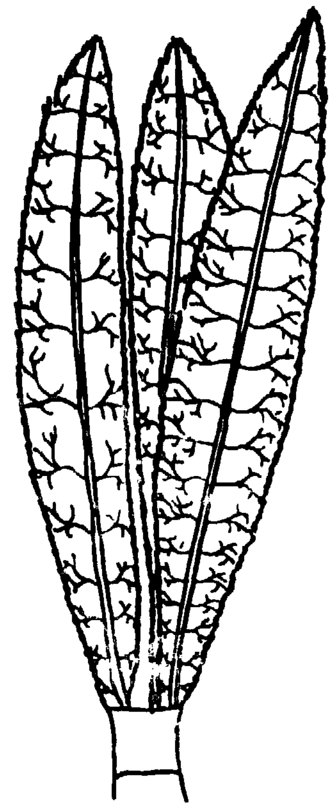

Figure 128
CAUDAL GILLS OF DAMSELFLY

ADVENTURE 32

We Do Some Fishing

LET US LOOK at a fish scale, or rather a few of them, for they are not all alike. Indeed, like other things we have already discussed in previous Adventures, they differ in ap-

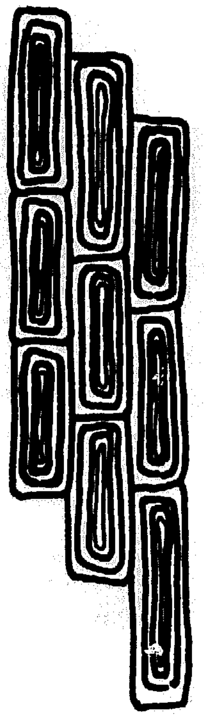

Figure 129
GANOID SCALE

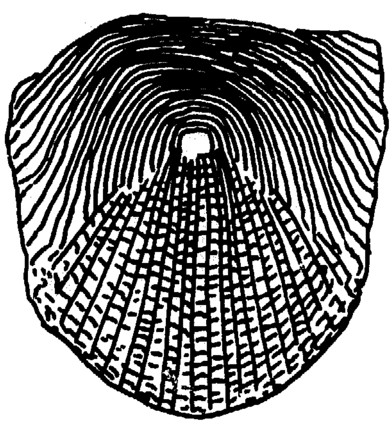

Figure 130
CYCLOID SCALE OF COMMON SHINER

pearance and form according to the species, and here again we have another illustration of variation so characteristic of nature's workings.

First of all, what purpose do they serve, and, second, what are they? They form the outer protective covering of the fish and are formed by certain scale-forming cells in the dermis. These cells lay down two layers of different substance, an outer layer, which is bony, and an inner layer, which is fibrillar or threadlike with calcareous deposits. As the fish grows the scales increase in thickness and size by successive additions of bony material, these additions being indicated by lines of growth. As periods of growth alternate with periods of comparative inactivity, due to seasonal variation in food, it is possible for us to estimate the relative age of a fish by examining these diary-like lines.

There are three principal types of scales: ganoid, cycloid, and ctenoid. Ganoid scales (*Figure 129*) are usually rhomboid or diamond shape, and occur in such fishes as the gars, pikes, and sturgeons. Cycloid scales (*Figure 130*) are usually circular, with concentric rings about a central point, and are found in the trout, minnows, and most other soft-rayed fishes. Ctenoid scales (*Figure 131*), which are characteristic of the perch, bass, sunfish, and most other spiny-rayed fishes are similar to cycloid scales except that the posterior margin bears small spines or teeth. Both of these two types of scales are arranged in overlapping rows like the shingles of a house.

Now examine some scales with our lens. The question arises, where to get them? We can get them at any fish market or catch our own fish. A scale may be removed from a fish with a knife or pair of forceps (tweezers), and it isn't necessary to kill the fish to do so. Indeed, after a scale has been removed the fish may be replaced in the water.

Everyone who has fished in our ponds and streams knows the sunfish, a beautiful and gamy little fish (*Figure 132*), an inhabitant of almost every pond throughout the Eastern and Central states. Another fish, equally well known and abundant in almost every pond and small stream east of the Rocky Mountains, is the common shiner (*Figure 130*). The yellow perch, too, is familiar (*Figure 131*). Lastly, the brook trout needs no introduction (*Figure 133*).

If you decide to get your scales from your fish market, ask your fish dealer to save some scales for you the next time he cleans fish. If he is a co-operative sort of fellow, perhaps you can get him to put the scales in small separate envelopes and mark each envelope with the name of the fish from which the enclosed scales were removed. You should, of

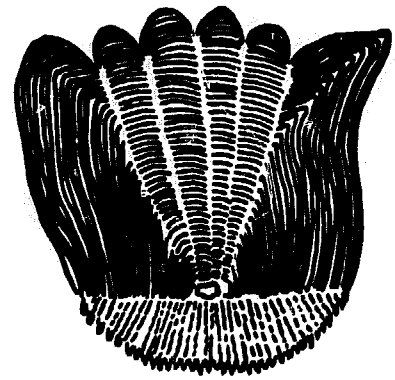

Figure 131
CTENOID SCALE OF YELLOW PERCH

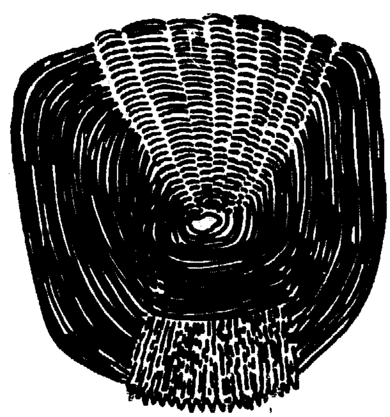

Figure 132
SCALE OF SUNFISH

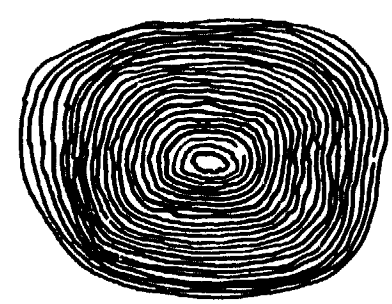

Figure 133
SCALE OF BROOK TROUT

course, supply him with the envelopes. Should you care to keep scales as a permanent collection, it is advisable to clean them. Be careful not to break the margin of the scales or to disrupt the soft inner surfaces. After they have been thoroughly cleaned, put them aside to dry, then mount them on small cards and label.

ADVENTURE 33

We Turn Our Attention to Buds

In Adventure 30 we became acquainted with leaf scars and bundle scars and found that they help us to identify trees and shrubs, especially in winter. Buds, too, serve the same purpose.

Most of us think of buds as unopened or unexpanded flowers, but this is only partially right, for there are buds that produce stem growth and leaves. The buds we find on twigs and branches of trees and shrubs are rudimentary stems and consist of a short length of partially developed stems with leaves in various stages of development. We can see this for ourselves if we cut a bud transversely and examine it with our lens. A bud of the cottonwood cut in this manner is shown in *Figure 134.*

Buds of trees and shrubs are usually protected by several layers of overlapping scales, called bud scales, which are really modified

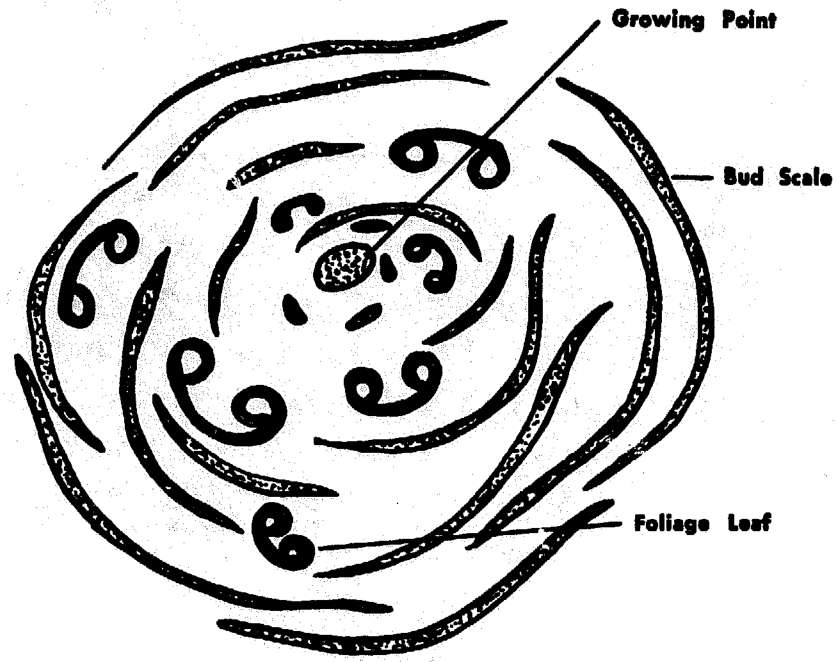

Figure 134
CROSS SECTION OF
COTTONWOOD LEAF BUD

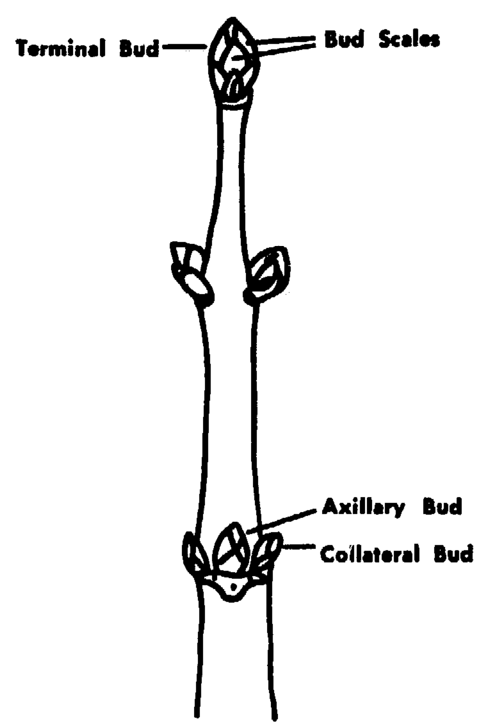

Figure 135
TWIG OF RED MAPLE

leaves (*Figure 135*). These bud scales are often covered with hair, as in the willow, and sometimes, as in the cottonwood, with a waxy secretion effective in protecting the enclosed tender structures from drying out and from mechanical injury. In the woody plants of the moist tropics and in herbaceous plants the buds are not protected by scales and are said to be naked.

Buds found on the twigs and branches of trees and shrubs are formed during the summer of the preceding year and are known as winter buds, since they live through this part

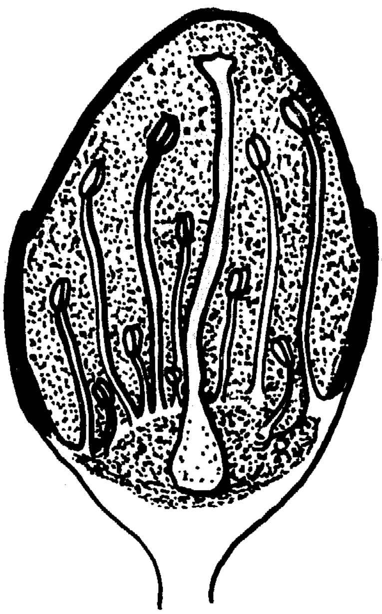

Figure 136
LONGITUDINAL SECTION OF FRUIT BUD

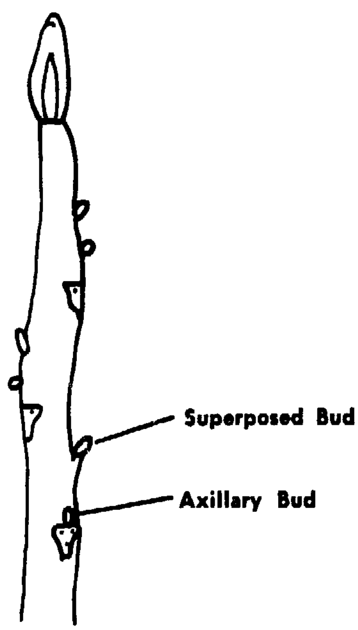

Figure 137
TWIG OF BUTTERNUT

of the year. Buds are known as leaf buds, flower buds, and mixed buds. Leaf buds contain a number of small or undeveloped leaves. Flower buds contain one or more miniature or undeveloped flowers but no foliage leaves. We find such buds on fruit trees, for instance, and if we open one lengthwise and examine it with our lens, it will appear as shown in *Figure 136*. Mixed buds contain both undeveloped leaves and flowers. As a rule it is not possible to distinguish leaf buds from flower buds by merely looking at them, although in some cases, as in the elm, the flower buds are larger.

In tree identification the position or arrangement of the buds on a twig is considered. Buds found on the end of stems are known as terminal buds (*Figure 135*). Axillary buds (*Figure 135*) develop in the leaf axils, which are places on the stem directly above where the leaves are attached. Frequently other buds are found in company with these axillary buds. They are called accessory buds and may be either superposed (*Figure 137*) or collateral (*Figure 135*). Lastly there are buds that are formed anywhere on the stem except at the tip and leaf axils. They are the so-called adventitious buds.

Variations occur among buds as in other plant structures. These variations, as shape, number of scales, presence or absence of hairs, etc., may seem insignificant, yet they are constant for the species. After a while you will associate certain kinds of buds with specific trees and shrubs, and tree identification will be almost a perfunctory habit.

We have discussed buds—now let us look at a few of them as a sort of practice exercise. We shall select first the Norway maple, which has been planted extensively as a shade tree and thus should be available. The buds, which are rather large for a maple, are commonly red or yellowish green toward the base, and sometimes the entire bud is strongly tinged with green. The terminal bud is larger than the lateral buds, oval or ovate in shape. In comparison the lateral buds are small and appressed, that is, they lie close against the twig (*Figure 138*). We can see all this with the naked eye. With our lens we now examine the bud scales and observe that they are more or less keeled, or with a ridge like the keel of a boat, and that the margins are covered with fine hairs. We next count the scales of the terminal bud. To find them all, we must lift up some of the scales with a pin. There are five pairs. The enclosed scales are covered with dark, rusty-brown hairs.

For our second choice we find ourselves in something of a dilemma. Since some of you live in the city and others in the country, the same trees may not be available to everyone,

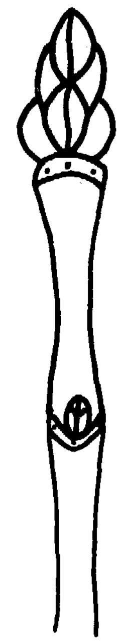

Figure 138
TWIG OF NORWAY MAPLE

Figure 139
TWIG OF SUGAR MAPLE

Figure 140
TWIG OF ASPEN

Figure 141
TWIG OF WHITE OAK

so let us take an imaginary walk. As we leave our house our attention is attracted to a rather stately tree growing by the roadside. We look at the buds and find that they are conical to ovate (egg-shaped) in form and sharply pointed. They are also reddish in color. Using our lens to examine them more closely, we also find that they are rather downy, especially toward the tip. If we next count the scales, we find four to eight overlapping pairs with margins finely hairy (*Figure 139*). The tree is the sugar maple.

We continue on and after we have gone a short distance we observe a tree with a light green bark. We pause and look at the buds, which we find to be of two shapes and sizes. Some are narrowly conical and very sharply pointed; others are ovate and larger. All lie close to the twig and are shining; indeed, they appear sticky, and when we touch them we find that they are. When we look at the scales with our lens, we note that they are reddish brown and rather thin and dry along the margins (*Figure 140*). The tree is the aspen, and the larger, ovate buds are flower buds.

Not far from the aspen is a tree whose light gray or nearly white bark appears broken by fissures into long, irregular, thin scales. Anxious to examine it more closely, we go over, and, looking at the twigs, we observe that the buds are clustered at the ends of the twigs (*Figure 141*). The buds themselves are broadly ovate and blunt, and when we look at them with our lens we observe that they are somewhat five-sided, with five rows of closely overlapping, reddish-brown scales. Buds clustered at the ends of the twigs are a characteristic of oaks, and from the color of the white bark we label this tree the white oak.

The next buds we examine are quite unlike anything we have seen thus far. They are stout, semi-spherical, rusty to dark brown, and a few are even black. Through the lens they are more or less downy. The scales of the terminal bud are in opposite pairs with sharply abrupt points (*Figure 142*). The buds identify the tree as the white ash.

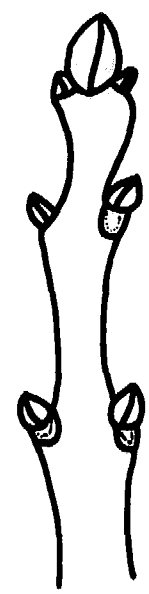

Figure 142
TWIG OF WHITE ASH

Leaving the white ash, we wander about and suddenly discover that we are in a wet field, and here we see a tree with slender yellowish buds that, beneath our lens, appear to be crowded with glandular dots. As we look carefully we observe that the buds are slightly hairy between the scales (*Figure 143*). We also observe that the scales, strangely, do not overlap. In botanical terminology they are said to be valvate. These odd-shaped buds belong to the bitternut, a member of the hickory family.

Figure 143
TWIG OF BITTERNUT

The wet field merges into a moist woodland, the natural habitat of the red maple, often called the swamp maple. This tree is very well named, for some part of it is red in every season of the year. The twigs and buds are red and prove a pleasant contrast to the white landscape of winter; the flowers are red in spring and so are the fruits that follow; and in the fall the leaves flash a brilliant red against the blue October sky. The buds are bluntly pointed and vary from oval-ovate to spherical, with four pairs of scales. As we study the twigs we see the presence of collateral buds (*Figure 135*). These buds, as you may remember, are buds that occur on either side of the axillary buds.

There are many other trees whose buds we can examine on our imaginary walk, but these examples should serve to illustrate the use of buds in tree identification. Whether you continue with this subject, which can be a very fascinating one, is for you to decide. But should you stop here, at least you will have discovered that buds are not necessarily the prosaic things most people consider them to be.

ADVENTURE 34

We Trace Some Tunnels

Unless you know something about entomology, you may wonder what leaf miners are. Go outdoors with your hand lens—into the garden or neighboring field—assuming it is summer, and look for a leaf with blotches (*Figure 144*) or twisting lines (*Figure 145*)—leaves with these disfigurements are common. Remove the leaf from its stem and hold it up so the light will pass through it. You should find the blotch or twisted line occupied by a small, wormlike creature, unless the little animal has reached maturity and been transformed into an adult insect, when it would have left its temporary home and taken up a different kind of existence.

The twisting lines and blotches are passages or tunnels that the larvae of certain insects excavate in the tissues of the leaves. The insects may be beetles, flies, moths, or sawflies, but despite their diversity as insects they all have one thing in common—small size. It seems incredible that some insects are so small that they are able to live between the upper and lower surfaces of a leaf that is almost of paper thinness. Not only can they live there, but they manage to grow and increase in size. This is indicated by the increasing width of the passageways. Follow one of these twisting passageways from the beginning. Note that it begins almost as a pinpoint, and here is where the egg hatched. You will see that it becomes progressively wider and wider.

There are two general types of mines, as the blotches and tunnels are known: the

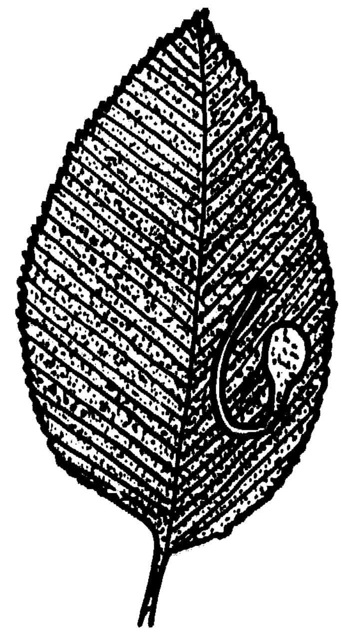

Figure 144
MINE OF ELM-LEAF MINER

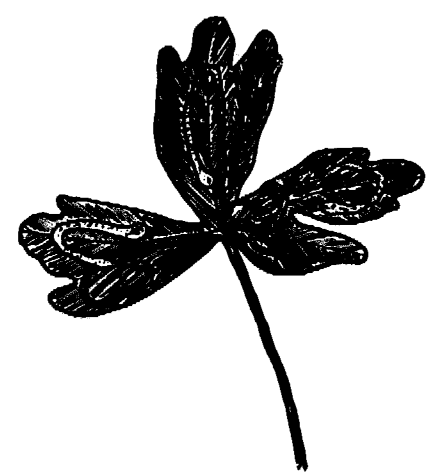

Figure 145
MINE OF COLUMBINE-LEAF MINER

twisting, or linear, mine made by the insect as it moved forward, and the round, or blotch, mine made by the insect as it moved around and around within the leaf. There are many modifications of these two types as the linear-blotch, the trumpet, the digitate, and the tentiform. Indeed, the patterns described by the insects as they eat their way through the plant tissues may be as varied as the insects themselves. But each species makes its own characteristic design, so that anyone familiar with these insects can usually identify the species merely by looking at the form of the mine. As one writer has put it, "they write their signatures on the leaves."

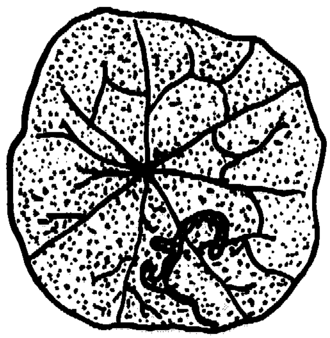

Figure 146
MINE OF NASTURTIUM-LEAF MINER

Even though the leaf miners are provided with shelter and plenty of food, they do not live an altogether carefree existence. Like anyone else, they too have their problems. Sometimes they find the veins of the leaves a barrier to further progress, and they must either eat through them or confine their operations to a limited area. They must be careful, too, not to cut the latex cells lest the secretions from these cells pour into their mines and drown them. But their gravest problem is waste disposal. Some miners distribute the wastes over the floor of the mine, as you can see with your lens, while others go to the trouble of excavating side chambers in which to dispose of their refuse. Still others have developed the habit of cutting holes in the surface of the leaf through which they push out their fecula, which is the accepted term for the waste material or excrement voided by insects.

A common leaf miner is a small fly whose larva makes a kind of twisting tunnel, called a serpentine mine, in the leaf of the columbine (*Figure 145*). The columbine is a favorite perennial of most gardeners, and you should have no difficulty finding it. Observe that the mine is a whitish tortuous or twisting trail that frequently crosses itself and finally ends in a spot about an eighth of an inch wide. Here is where the maggot pupated and transformed into the adult. The nasturtium is another garden plant frequently inhabited by a leaf miner (*Figure 146*). Even a pine needle may have its little inhabitant—the pine-leaf miner. If you can find a pine needle with its occupant and hold it up to the light, you may observe the little creature running up and down in its tunnel as if it were dismayed at being disturbed (*Figure 147*). Note a small hole near the lower end of the tunnel. This hole is where the larva entered the leaf and through which, after it has enlarged it slightly, it will emerge as an adult.

Leaf miners attack nearly all families of plants and some of them are quite destructive. Frequently an entire family may occupy

Figure 147
MINE OF PINE-LEAF MINER

a leaf, and if you hold such a leaf up to the light, you will find that each member makes its own little niche, all eventually joining together to make one large blotch or blister.

ADVENTURE 35

We Continue Our Study of Minerals

In Adventure 29 we learned something about minerals and we looked at several of the common ones. Let us go a little further afield and get acquainted with a few more.

Minerals are where you find them. There are localities where certain minerals occur in abundance, but we aren't all able to visit them, nor is it necessary to do so. As many minerals occur in rocks, we need only to look for rocks. Bare and exposed rocks, where fresh and unweathered surfaces are available, are often productive. Quarries and places where crushed stone is made are excellent sites. It is just a matter of grubbing around and examining them at random. It is advisable, however, and often necessary, to get permission from an authorized official of the company before you are allowed to explore their workings. Permission is usually granted with the warning not to get too close to the bottom of the cliffs.

Other likely sites are places where blasting has occurred in road construction. Fissures and cavities in cliffs or ledges or large boulders should be explored, for they frequently contain fine crystals. All you will need for equipment is your lens and a hammer, preferably a stonemason's hammer, for breaking up the rocks. A pair of thick-soled shoes will make walking among the rocks somewhat more comfortable, and unless you want to stuff your pockets, take a bag or box in which to carry home your specimens. I might add that if you are really interested in looking for minerals it would pay you to locate someone who is either an amateur or professional mineralogist and write for a list of localities in your state where specific minerals occur. Colleges and universities that have a mineralogy department have such lists and would be glad to give one to you.

You have doubtless heard of fool's gold. This is one of our commonest minerals and one you should have no trouble finding. It occurs in all kinds of rocks in the form of cubes, octahedrons, and pyritohedrons (*Figure 148*), terms that need not concern you too much. You will readily recognize it by its brassy color and metallic luster. As a mineral, it is known as pyrite. It is a compound of iron and sulphur and though very abundant is rarely used as a source of iron because the sulphur is difficult to remove and to leave it in the iron would make the latter brittle and useless for most purposes.

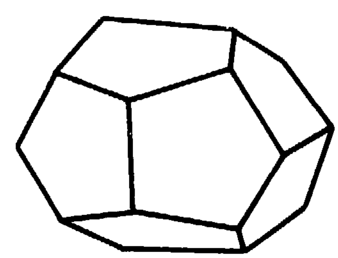

Figure 148
PYRITOHEDRON CRYSTAL OF PYRITE

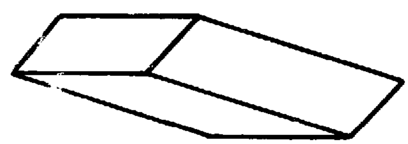

Figure 149
RHOMBOHEDRON CRYSTAL OF CALCITE

Calcite is another very common and abundant mineral and, since it is usually colorless or white, is easily found. It occurs in well-defined crystals, but the form of the crystals varies considerably. All the forms, however, are variations of the rhombohedron (*Figure 149*). Should you ever be in doubt as to the identity of a calcite specimen, place a drop of hydrochloric acid on it. If calcite it will effervesce, or fizz. Calcite is a carbonate of calcium and is soluble in water. This is the material that mollusks, corals, echinoderms, and other animals take from the water to make their shells and other more or less permanent structures in which they live.

As I write I have before me on my desk a rock about six inches in diameter which I found on one of my collecting trips. Embedded in it are a number of garnet crystals. Garnet occurs usually either in the form of a dodecahedron (*Figure 150*) or a trapezohedron and is found essentially in metamorphic rocks but is also present in other kinds of rocks. It occurs in various tints of red, brown, yellow, green, and occasionally black and in size ranges from that of a grain of sand to that of a marble; sometimes garnets may be found as large as four inches in diameter. The ones I have are yellowish and are found throughout New England and the

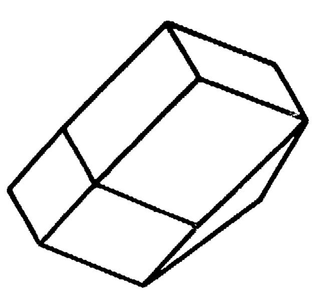

Figure 150
DODECAHEDRON CRYSTAL OF GARNET

Piedmont Plateau. Garnet is usually crushed and used as an abrasive, especially for finishing wood and leather, but pure and clear specimens are frequently used as gems. I also have a specimen of tourmaline on my desk. This is not a common mineral and may be found only in certain localities; hence the need for a list of localities. This mineral may easily be recognized by its black or brown color and its three-sided prismatic crystals (*Figure 151*).

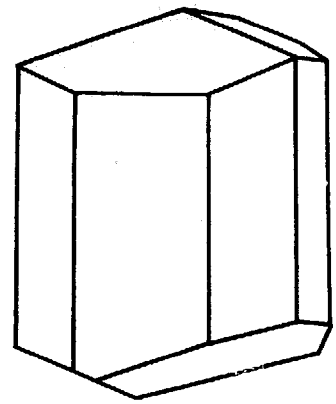

Figure 151
PRISMATIC CRYSTAL OF TOURMALINE

Galena, which is a compound of lead, is a mineral found in every state in the Union and is usually associated with pyrite and calcite. Be on the watch for it when you find specimens of these two minerals. It is lead gray in color, with a metallic luster, and occurs in well-formed cubic crystals. Beryl is another mineral that is fairly common in certain rocks. It is usually some tint of green and occurs in hexagonal crystals (*Figure 152*). A specimen free from cracks and inclosures and of gem quality is so rare that its value is greater than that of the diamond. We know it as the emerald.

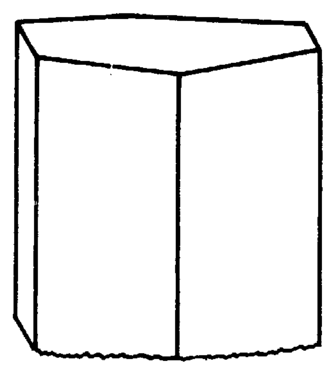

Figure 152
HEXAGONAL CRYSTAL OF BERYL

No matter where you look you are sure to find the mineral limonite, for it is nothing more than iron rust. It does not occur in the crystal form, but in masses and incrustations. A brown stain on a rock is sure to be limonite.

The mineral is not an important source of iron; its chief use is as a pigment (ocher yellow) for paints.

The chief source of iron is the mineral hematite, found everywhere, in some states in considerable deposits. Hematite occurs as small crystals and in masses. You will most likely find it in the non-crystalline form in rocks where its red color will call it to your attention.

ADVENTURE 36

We Scrutinize a Miniature Pepper Box

An individual moss plant is a rather inconspicuous form of vegetation, and yet when a number of them are found growing together they collectively provide a bit of greenery to places that would otherwise appear drab and barren. They cover the woodland floor with a soft green carpet and are the first plants to appear on the naked sides of ditches, clay banks, and other unsightly spots. As little cushions they fill in the crevices of pavements and relieve the harshness of rocks and boulders. A decaying log is never so attractive as when it is covered with mosses and lichens.

The leafy moss plant in itself may not be of much interest except to those who have discovered an interesting hobby in the study of the mosses. But the spore cases are another matter, since they are somewhat unique in themselves and provide a further illustration of variation, which we find so prevalent in all of nature's wonders.

For our purpose we shall select the spore case of the hairy-cap moss because this is one of the most abundant as well as one of the largest of the mosses. The hairy-cap grows in dry fields and meadows and on dry knolls and near the margins of damp woodlands. Like other mosses it is subject to great extremes of moisture and dryness and differs in appearance under varying conditions. During a period of dry weather the leaves fold up lengthwise and twist into the merest threads, so that the soft green surfaces will expose the least area to the air and thus prevent loss of water through evaporation. With a rain or return of moisture they straighten out and are again green and leaflike.

The spore cases of the hairy-cap may be found only during the months of June and July. We then find them perched at the tips of stiff, ruddy little stalks that rise into the air from among the leaves (*Figure 153*). When we look at one of these spore cases through our lens, we observe first of all that it is covered with a yellowish mohair cap, ending in a golden-brown peak at its tip (*Figure 153*). This cap, or calyptra, as it is called, was present from the very moment the

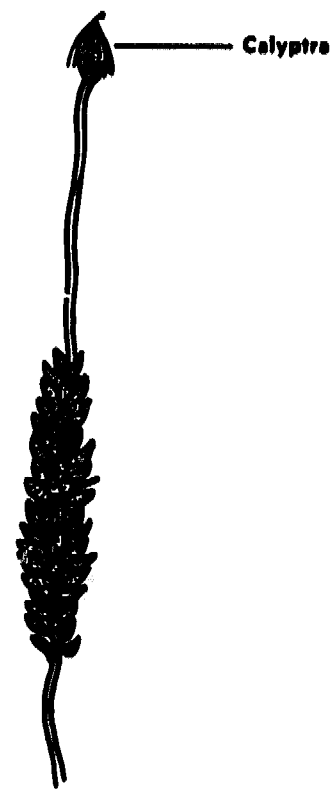

Figure 153
HAIRY CAP MOSS

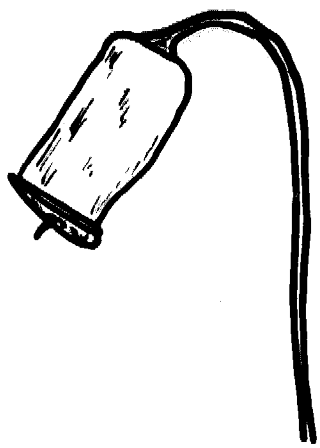

Figure 154
CAPSULE OF HAIRY CAP MOSS

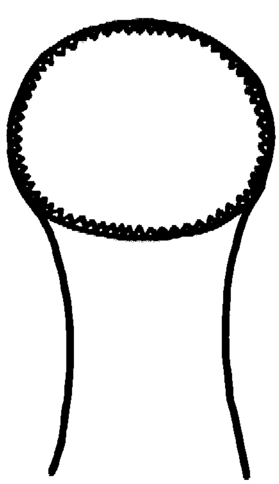

Figure 155
PERISTOME OF A MOSS

spore case started to form, and served as a protective covering for the delicate tissues throughout its development. We can lift it off very easily and expose the spore case, or capsule. It is a beautiful green object, four-sided or cubical in shape, with a lid (operculum) on top like a sugar-bowl cover except that it has a point instead of a knob at its center (*Figure 154*).

We next pry off the lid with a sharp knife and look at the uncovered end with our lens. We see a row of tiny teeth (peristome) around the margin (*Figure 155*) and if we count them carefully we find that there are sixty-four of them. Between the teeth we note small openings, and it is through these openings that the spores escape when ripe. The capsule is in fact a miniature pepper box, with a grating around its upper edge instead of holes in the cover.

As we look at a clump of hairy-caps we observe that some capsules are held in a vertical position, while others are held horizontally. Here we have an interesting provision. Until the spores are mature, the capsule is held vertically, but when the spores are ready to be released the capsule is moved through an angle of ninety degrees so that the spores may more easily be shaken out. The teeth also illustrate another interesting habit. They behave much like the leaves; when moist they swell and close up the openings between them. The reason for this is to prevent the spores from falling out in wet weather, when they would fall to the ground among the parent plants, where there is little room for them to develop into new plants. In dry weather the wind scatters them to places where they would likely find more favorable conditions.

Capsules of mosses may be found at almost any time of the year, since the many species do not all mature their spores at the same time. Examine them whenever you find them and you will discover that some are round, others are cylindrical, while still others are curved. You will also find that the number of teeth vary and that the teeth may be entire or split or irregular, and in some instances there is a double row of them. There are countless variations, and for those who are interested in these plants they help in identification.

ADVENTURE 37

We Invade the Privacy of Gall Makers

GALLS ARE the strange and eye-catching outgrowths or excrescences so common on plants. These odd structures, formed mostly by insects, occur in a variety of shapes and sizes. Some are only blister-like swellings on the leaves, while others are hairy or pile-like growths. Others are suggestive of bullets, and some take a spherical form as much as an inch or more in diameter. Then there are various deformations of stems and roots, often in grotesque shapes, and aborted flowers and flower clusters that appear as if ravaged by some terrible disease. The habit of gall formation is believed to have been the first insect habit observed by man, although it was not known for a long time that insects were responsible for these outgrowths. Pliny writes about them and Theophrastus refers to their medical and curative properties. Both of these men lived some two thousand years ago but it was not until 1686 that Malpighi, a physician and botanist, in a treatise called *De Gallis,* explained what causes them.

There are probably more than fifteen hundred different kinds of galls. The number is unimportant—of more interest is what they are, how they are produced, and their economic value. Strangely enough, in spite of their apparent worthlessness, many of them have found application in the arts and sciences. Tannic acid is one of the chief products. Various dyes are obtained from certain species. Permanent inks have for years been made from them. Some galls have been used in medicine and upon occasion as food—a gall found in the Near East has been an article of commerce, and in Missouri and Arkansas an oak gall is fed, when abundant, to cattle, hogs, and sheep, as well as to chickens and turkeys, with excellent results.

Galls occur on almost every form of plant life and may be found on any part of a plant —root, branch, leaf, blossom, fruit, and even seed—in fact, on any part that furnishes food to the gall maker. Some galls are very simple in structure; others are most complicated. Many are highly attractive and striking in form and coloration. There is no evidence that the form is of any adaptive importance, and the answer may be that the formation of any specific form is purely mechanical. But the remarkable feature about galls is that those made by the same species of insect are all of the same form, are all formed on the same species of plant, and are always on the same part of the plant, so that those versed in gall lore may know the identity of the gall maker by merely looking at the gall.

Although we know that galls are produced by insects—and in some instances also by mites and nematode worms—we still do not know what causes them or just how they are produced. It is generally believed that the formation of a gall is initiated, or that the plant tissues are stimulated in growing abnormally, by a secretion from the larva. Yet the fact remains that the physiology of gall formation is still obscure. The study of galls is a fascinating one, and the study of the insects that make them is, in some respects, difficult, for we cannot always be sure that the insect that emerges from the gall is the one that made it, since many insects do not make galls but lay their eggs in those made by others. Such insects are called "guests." Furthermore, both the makers and the guests are attacked by parasitic bees and wasps, which only adds to our confusion, for it is not always easy to determine the interrelations of these insects. Many galls are complicated communities. In one case as many as thirty different kinds of insects, belonging to almost all the orders, were reared from a single species of gall.

Galls are especially numerous on willows, oaks, roses, legumes, and composites, so we should have no difficulty finding them. One of the most common and abundant is the so-called oak apple. Occasionally oak apples are so numerous as to suggest a fair crop of fruit on an apple tree. They are globular in shape and the larger ones an inch or two in diameter. They appear in May or June, and as we first look at them they seem to grow directly from the bud, but on closer inspection we note that each oak apple is a deformed leaf. If we cut one open with a sharp knife or razor blade when it is still in the process of being formed and examine it with

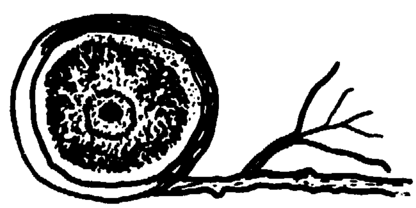

Figure 156
OAK APPLE

our lens, we shall probably find internally a juicy, spongy white substance and a large central larval cell containing a small grub or young gall wasp (*Figure 156*). There are different kinds of oak apples, and if we selected one that is green with red spots and opened it, we would find that instead of a spongy substance supporting the larval cell it is supported by radiating fibers (*Figure 157*). The occupant, as before, is also a gall wasp.

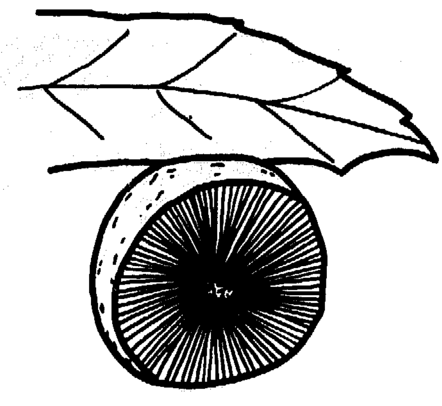

Figure 157
OAK APPLE

An extremely beautiful gall, indeed one of the most beautiful objects in nature, is the wool-sower (*Figure 158*). It occurs on the twigs of various oaks, is woolly creamy white, and is admirably set off with pinkish-red blotches, the woolly growth with seedlike grains. Here is really an object for your lens.

Figure 158
WOOL-SOWER

There are so many different kinds of galls that I find it difficult to know which to describe or which to suggest that you examine. Perhaps it is best you look for them yourself. Do not expect to find the gall maker in its dwelling once it has become an adult, for it then has no longer any need for a shelter and will have left it. You can always tell whether the occupant has left by a small exit hole. If you want to find the maker still within its little home, open only those galls that are still fresh-looking and not the brown dried ones, although in some cases such galls may contain the hibernating occupants, as there

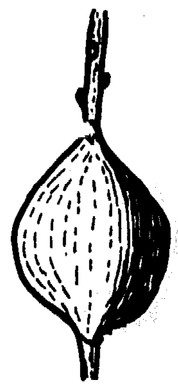

Figure 159
GOLDENROD GALL

Figure 160
GOLDENROD GALL SHOWING HIBERNATING LARVA

are some gall makers that use their shelters for winter retreats. Three such galls come to mind, two of which are found on goldenrod stems. One is oval (*Figure 159*) and provides a winter home for the larva of a moth, and the other is spherical (*Figure 160*) and serves as the hibernaculum for the larva of a fly. Both may be found in midwinter. The third is the pine cone willow gall (*Figure 161*), shaped like a pine cone and formed on the terminal buds of willow stems by the gall gnat. It is very common and there are often dozens of them on one willow. An interesting facet of this gall is that it often shelters a number of insect guests. As many as thirty-one dwellers have been listed as occupying one of these galls at one time, in addition to its maker. Open one and see how many insects you can find and how many different species they represent.

ADVENTURE 38

We Are Introduced to Some Queer Plants

In early spring we often notice queer, pale-colored plants that shoot up above the ground in sandy and gravelly places, as along the roadside, in a waste place, and along a railway embankment. These plants are called horsetails, possibly because of the fancied resemblance to a horse's tail of the green vegetative shoots that follow later. They are of no economic value today, but if we can judge from the fossil remains, which show a considerable number and variety of these plants, they probably were at one time an important element in the flora of the earth, like the ferns, and contributed their vegetative parts and spores to the formation of coal during the Carboniferous Period.

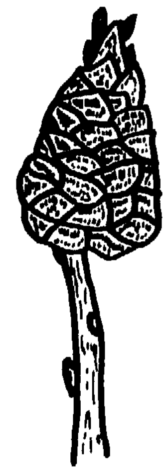

Figure 161
PINE CONE WILLOW GALL

As we look closely at one of these plants, we observe that the stalk is pale and rather weird in appearance (*Figure 162*). The stem, which is the same diameter from bottom to top, is ornamented at intervals with slender, black, pointed scales. These scales, which point upward, are united at the bottom and encircle the stalk in a slightly bulging ring which shows a ridge for every scale, extending down the stem. The scales are much-reduced leaves that long ago lost the ability to carry on photosynthesis, the process by which green plants manufacture their food materials from the water of the soil and carbon dioxide of the air.

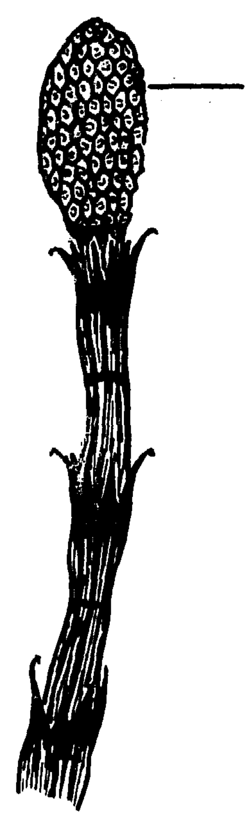

Figure 162
FERTILE UNCOLORED SHOOT OF HORSETAIL

Continuing our examination of the plant, we note further that the tip is surmounted by a cone-shaped whitish structure called a strobilus. If we look at it through our lens we find that it is made up of tiny disks that remind us of miniature toadstools. On the lower surface

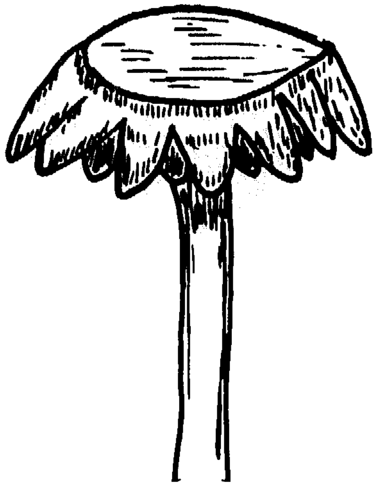

Figure 163
SPORANGIUM OF HORSETAIL

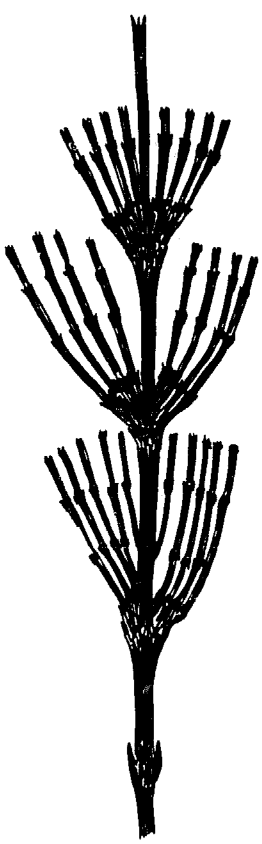

Figure 164
STERILE GREEN
SHOOT OF HORSETAIL

of each disk can be seen from five to ten sacs that are spore-producing structures, or sporangia (*Figure 163*). After the spores have been released, these sporangia hang around the disk in torn scallops.

The spore-producing shoot is only part of the horsetail plant. As soon as the spores have been released, the shoot dies down and is followed by a slender green shoot with numerous branches set in whorls at intervals, or nodes (*Figure 164*). At one time the plant probably had a whorl of leaves at each node, but since there are now so many green branches, the leaves have been reduced to mere points and appear to be merely a sort of trimming. Each little cup or socket of the joint or node, in branch or stem, has a row of points around its margin. If a branch is triangular in cross-section, it will have three points, if quadrangular, four points, and so on. Both the stem and branches are made up entirely of segments, each set at its lower end in the socket of the segment below it and each easily pulled out.

As you handle the horsetails you will find that they are rough and of harsh texture. The reason for this is that they are impregnated with silica, and on this account the plant was formerly used for cleaning and polishing metal utensils and was given the name "scouring rush."

ADVENTURE 39

We Stand Corrected that Eggs Are Not Always Egg-Shaped

In Adventure 21 we discussed the eggs of the lacewing. You may recall that each egg was placed at the tip of a stalk to prevent the other eggs from being eaten by an emerging aphis lion. I remarked at the time that this shows an interesting provision, and so it does, but it is a departure from the normal egg-laying habits of insects and should not be accepted as typical. Most insects need not be concerned that their eggs will be eaten by hatching young, so they lay their eggs either directly on some part of the food plant or in a convenient place near the food supply, although there are exceptions. In some respects insect eggs are much like seeds—they are sometimes produced in fairly large numbers and vary in size and shape and often have sculptured surfaces; indeed, when viewed through the lens some are very beautiful objects.

If we examine the recently developed leaves of the apple in early spring, we would likely find the eggs of the codling moth, since this insect is a common pest of the apple. We usually think of eggs as being oval or spherical in shape, but surprisingly those of the codling moth are scale-like and white in color and about half the size of a pinhead. If we look on cabbage leaves at about the same time, we would likely find conical, pale yellow eggs, and if we viewed them through our lens we would see that they are ribbed (*Fig-*

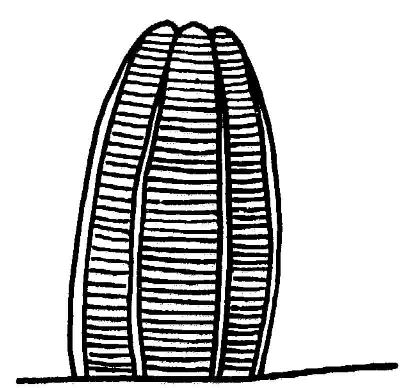

Figure 165
EGG OF CABBAGE BUTTERFLY

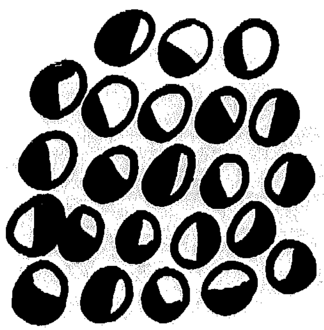

Figure 166
EGGS OF SQUASH BUG

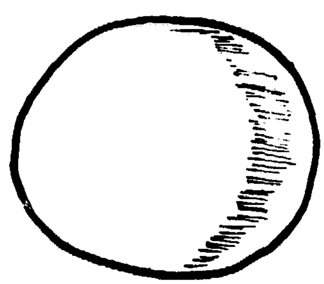

Figure 167
EGG OF BLACK SWALLOWTAIL BUTTERFLY

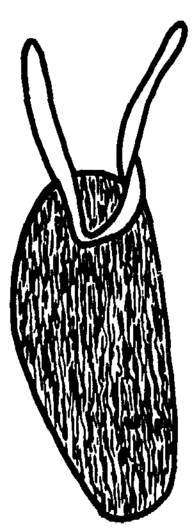

Figure 168
EGG OF FRUIT-FLY

ure 165). The eggs are those of the imported cabbage worm, a common and familiar insect we know more familiarly as the white butterfly we so often see flying about our gardens and fields in search of cabbage and related plants.

A little later, when squash leaves have developed, the squash bug, another common insect and rather injurious to squashes and other members of the squash family, appears and lays her eggs on the leaves. They are easy to find, for they are laid in clusters and are oval and pale yellow to brown (*Figure 166*).

After the carrot, parsnip, and celery have grown beyond the seedling stage, the leaves are frequently found with the pale yellowish eggs of the black swallowtail butterfly. The eggs are more or less spherical, as are all the eggs of the swallowtail tribe (*Figure 167*).

Not all insect eggs are laid in such exposed places; most of them are deposited in out-of-the-way places, as in the bark of trees and shrubs, in crevices and other hidden retreats, and within the tissues of plants, as in stems and leaves. The eggs of tree hoppers, leaf hoppers, and tree crickets are deposited in such places, and we do not ordinarily find them unless we actually are looking for them or if we inadvertently come upon them.

During the summer months when you are outdoors be sure to carry your lens with you and examine various plants, for you never know when or where you will find insect eggs. As you observe them through your lens, you will find that they may be smooth or variously sculptured, in some instances with small hexagonal areas; others may have ridges or show other forms of ornamentation. Though the ornamentation is often exquisitely beautiful, the patterns are probably of no particular use, being produced incidentally as impressions by the cells that secrete the eggshell.

Some eggs, strangely enough, are provided with appendages. This is true of certain species of fruit flies (*Figure 168*). The water scorpion, which lives in shallow water concealed in the mud or among dead leaves and twigs, lays eggs that have a crown of eight or more filaments (*Figure 169*). These eggs are laid in the tissues of decaying plants. The eggs of stinkbugs have a circle of spines around the upper edge (*Figure 170*). One member of this group lays white eggs in a double row on the leaves of cabbage and related plants that look like small barrels because of their two black bands and white spot (*Figure 171*). The insect that lays these eggs is known variously as the harlequin cabbage bug, or calico-back, the terrapin bug, or fire bug, and is shining black or deep blue profusely marked with red.

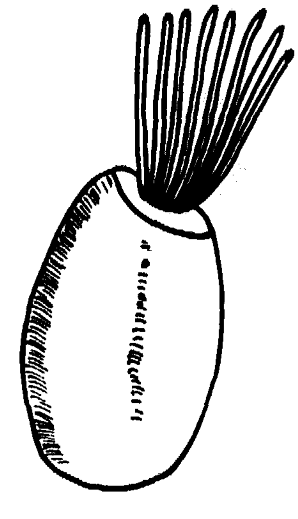

Figure 169
EGG OF WATER SCORPION

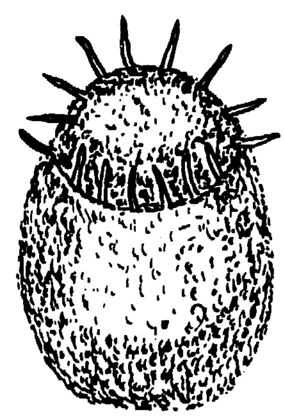

Figure 170
EGG OF STINKBUG

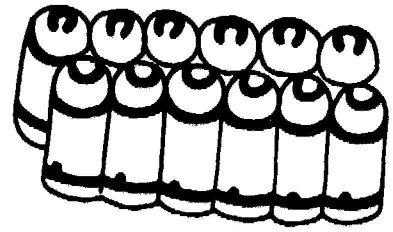

Figure 171
EGGS OF HARLEQUIN CABBAGE BUG

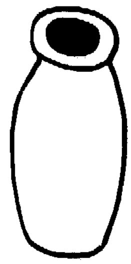

Figure 172
EGG OF WHEEL BUG

Figure 173
EGG OF POULTRY LOUSE

The assassin bugs include a number of different species, as the wheel bug, and are rather striking insects. They are all fairly large and some of them are gaily colored. Their eggs take various forms and may be cylindrical or elongate-oval (*Figure 172*). But it is not their shape that is of interest, rather the presence of a cap at one end which is pushed off in the hatching process and which is often decorated with raylike extensions. Of all the ornamental structures with which insect eggs may be furnished the most striking are undoubtedly those found on the eggs of the poultry louse. The eggs are white, elliptical, and are provided with white, glass-like spines (*Figure 173*). They are worth looking for and viewing through your lens if you are not averse to examining the feathers of chickens to which they are attached.

ADVENTURE 40

We Play Amateur Petrologists

IN TERMS OF GEOLOGY a rock is a mineral found in large quantities in the earth or is a mixture, or aggregate, of minerals. The familiar granite is chiefly a mixture of three minerals, quartz, feldspar, and mica, whereas the less familiar sandstone is composed usually of a single mineral, quartz.

According to their origin, position in the earth's crust, and location in respect to one another, rocks are divided into three main groups: igneous, made by the solidification of molten material; sedimentary, formed by the deposition of material by water, wind, and glacier; and metamorphic, produced by the action of heat and pressure on igneous and sedimentary rocks. Let us consider a common rock illustrative of each of these three groups.

We learned in Adventure 29 that certain substances will form crystals if dissolved in water and the water is allowed to evaporate. Similarly, if certain substances are heated, they will form crystals on cooling. Igneous rocks were formed in that way. So if we examine such a rock with our lens, we would expect to find crystals. View a fragment of granite through your lens and you will find that this is true. Some of the crystals you will probably recognize as quartz crystals. Present is another kind of crystal, which is monoclinic or needle-shaped, in form (*Figure 174*). This crystal is the mineral feldspar, which forms the whitish or pinkish portion of the rock. These two minerals are the essential constituents of granite, though there may be other minerals present, as hornblende, biotite, muscovite, and, to a lesser degree and only occasionally, epidote and tourmaline. Muscovite, more familiar to us as mica, is

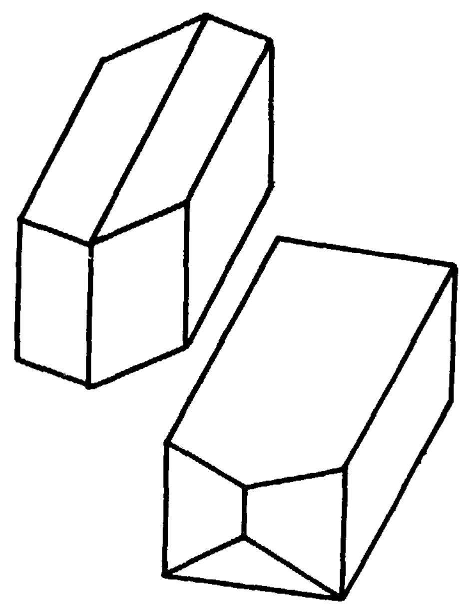

Figure 174
MONOCLINIC CRYSTALS OF FELDSPAR

extensively used in electrical insulations. It occurs as pearly scales that you can easily lift off with a knife. If black particles that are not easily separated into thin layers are present, they probably consist of the mineral hornblende.

Obviously sandstone is a rock formed from sand, but actually the word is used to describe any sedimentary rock whose particles are about the size of sand grains. When we view a fragment of sandstone through our lens, we find it composed of subangular to rounded grains we recognize as quartz. We may also observe that there are small spaces or pores between the grains,* although there are some sandstones without such pores. Some sandstones are composed entirely of grains held together by the compactness of the rock, but in others the grains are held together by a cementing material that then fills all the pores. Essentially a sandstone consists of quartz grains, but frequently other minerals may be present, such as feldspar, muscovite, and calcite. I said at the beginning of this paragraph that in a sandstone the particles are about the size of sand grains. If the particles are smaller, less than one five hundredth of an inch, the sandstone grades into

* In general there is a considerable amount of space between the grains of sand so that a sandstone will absorb large amounts of water—up to 25% of its bulk.

shale; when they are larger than that of a pea, it grades into conglomerate. If a sandstone has been subjected to heat and pressure, it is then known as quartzite, a metamorphic rock. Frequently one grades into another. Quartzite may be distinguished from sandstone by the almost complete lack of pore spaces, its greater hardness, and by its crystalline structure. It may be further distinguished by the fact that a sandstone, in breaking, separates between the grains of sand, while a quartzite breaks through the grains.

In Adventure 35 we said that the mineral calcite is removed from water by various animals that use it in building shells or other structures in which to live. When the animals die the shells sink to the bottom, where they are pulverized and accumulate in large deposits of mudlike consistency which eventually are compressed to form a sedimentary rock. We know this rock as limestone. Through the lens a fragment of limestone appears much like sandstone. Pure limestone is white, but it may be variously colored by impurities. As in sandstone, other minerals may also be present. As you will recall that we can determine the identity of calcite by adding a drop of hydrochloric acid to it. Since limestone is calcite, we can apply the same test to a rock we suspect to be limestone.

If limestone has been subjected to heat and pressure, it is then known as marble, also a metamorphic rock. Marble is a broad term. It is preferably used for any limestone that will take a polish and can be used commercially, whether it is sedimentary or metamorphic, but I am using it in connection with metamorphic limestone. Similarly, as in the case of quartzite, which is crystalline sandstone, marble is also crystalline, indeed, it has more crystalline structure than most metamorphic rocks. Pure marble is white but may be variously colored red, pink, green, and black by the presence of other minerals.

ADVENTURE 41

We Marvel at Nature's Ingenuity

WE KNOW THAT INSECTS are useful agents in the pollination of flowers—bees, for instance, are indispensable in the orchard—but few of us are aware of the intimate relationships that have been established between many flowers and their insect visitors. Many flowers have become structurally modified in such a way that the insects visiting them for their nectar cannot leave without carrying a number of pollen grains with them. The fantastic forms of orchids are really elaborate traps designed toward this end. So, too, are the flowers of the common milkweed.

Let us examine one of the latter. The milkweed is common everywhere—along the way-

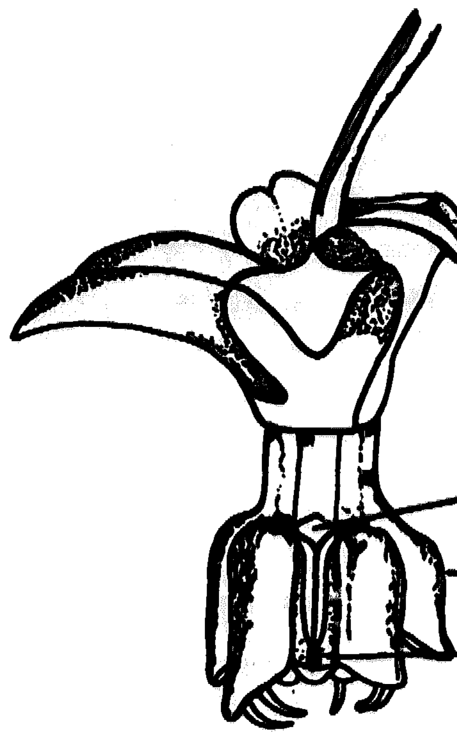

Figure 175
MILKWEED FLOWER

side, in fields and meadows, in waste places, along the woodland border—and its large, pendulous, cloyingly sweet flower clusters are conspicuous on the summer landscape. We need our lens and a needle. When we view one of the flowers we first observe the five hoods or nectar horns filled with nectar, located in front of each anther (*Figure 175*). We next look carefully between these hoods and find the white-bordered, V-shaped opening, or fissure, of a long pocket or slit, at the upper end of which is a black dot, or notched disk. We slip a needle into the pocket or fissure and extend it upward until it touches the black dot or disk, and if we then apply a slight pressure out pops a pair of yellow saddlebags, each attached to the disk. These yellow saddlebags are the pollen masses, or pollinia (*Figure 176*).

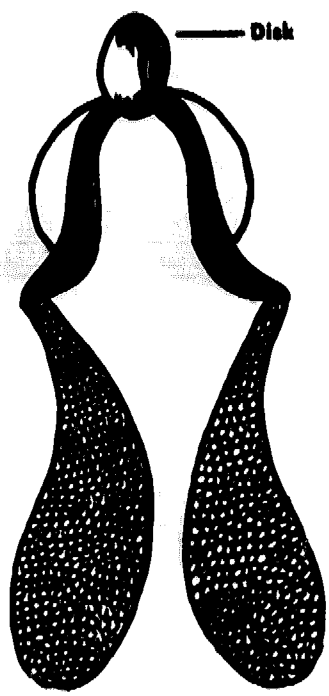

Figure 176
POLLINIA OF MILKWEED

When a honeybee or other insect visits the milkweed and crawls over the flowers to get the nectar, its legs slip in between the hoods, and as a leg is drawn up, a claw, hair, or spine invariably catches in the V-shaped fissure and is guided along the slit to the notched disk. The disk clings to the claw, hair, or spine, and when the insect leaves it carries away with it the two attached pollen masses. You can see this for yourself if you station yourself by a milkweed plant and observe the behavior of an insect visitor through a reading glass when it alights on the flower cluster. I should add that when first removed from their enclosing pockets or anthers the two pollen masses lie in the same plane, but in a few seconds they twist on their stalks and come face to face in such a way that one of them can easily be introduced into the stigmatic chamber of a new flower visited by the insect.

Another common flower, also modified to ensure pollination by insect visitors and one we can easily examine, is the iris, or blue flag.

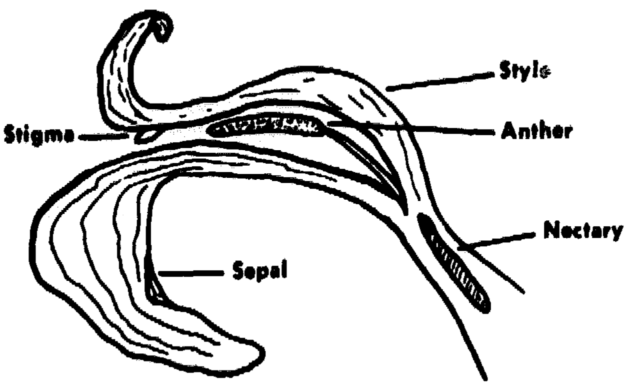

Figure 177
SECTION OF IRIS FLOWER

The iris is one of the more familiar spring flowers of swamps and marshes, and related members of the group are extensively cultivated in gardens. The blue flag, with its large showy blossoms, seems especially designed for bees, since blue is their favorite color, but other insects also visit it. Each of the three drooping sepals forms the floor of an arched passageway that leads to the nectary, the roof being formed by three straplike divisions of the style (the middle portion of the pistil). Over the entrance to the passageway and pointing outward is a movable lip, the stigma (*Figure 177*). In back of the stigma and beneath the roof is the stamen with its anther. When a bee visits the blossom, carrying pollen from another flower, it alights on the tip of the sepal, and then as it presses forward it hits and bends down the stigma, which scrapes the pollen from the back of the bee and then springs back into place. As the bee continues on its way toward the nectary, its hairy back rubs against the overhanging anther and becomes powdered with pollen grains. When it backs out of the passageway, after getting its fill of nectar, it again encounters the stigma, but this side of the stigma cannot receive pollen and so immediate close pollination is averted. Just how all this is accomplished may easily be observed through the reading glass by waiting for a bee to enter a blossom and then watching its actions.

The milkweed and iris are but two examples of structural modifications for insect pollination. There are countless others. The sage, nasturtium, and larkspur of our gardens come to mind. The butter-and-eggs, with its delightful two-lipped, spurred yellow and orange flowers and so common from July to October along roadsides and in waste places, and the jewelweed, blooming by the brookside, its bright flowers hanging like jewels from a lady's ears, also come to mind. Why not examine these and others, too, with your lens and discover, if you can, the various and often ingenious mechanisms that plants have developed to compel their insect visitors to carry their pollen to other flowers and thus ensure their survival as species.

ADVENTURE 42

We Breed Some Flies

HAVE YOU EVER NOTICED small flies about the fruit bowl or fruit basket especially in summer? Have you ever wondered what they were doing there? The larvae feed on ripe or overripe bananas and other fruit, and the flies we see about the fruit are either females preparing to lay their eggs in the fruit or newly developed adults recently emerged from their pupal state. The larvae also feed on vinegar, stale beer, and the like, hence the insects are variously called fruit flies, sour flies, vinegar flies, and pomace flies. They are, however, best known as fruit flies.

These flies are insects of distinction. Some years ago Thomas Hunt Morgan used them in studying heredity and sex, and because they lend themselves so readily to investigative work on such studies, they have been extensively used since then on both simple and complex cases of Mendelian inheritance and the relations between body characteristics and genes. There are several reasons why they are ideal experimental animals. One is that they reproduce quickly. The average duration of the egg period at ordinary room temperature is about two days; of the larval period about six days; and of the pupal period about five days. Another is that a bit of banana in a bottle is about all that is necessary to breed the insects.

We are not interested at present in inheritance or inherited characters, but in breeding a few generations. To do so, we need first of all a few flies, and the best time to get them is in the summertime. We can place some fruit in a dish and trust to luck that the flies will appear, or we can dip a piece of ripe banana in a suspension of yeast (which can easily be prepared by dissolving a quarter of a yeast cake in some water) and inserting the piece of banana along with a strip of paper toweling into a clean bottle. We can put the bottle aside or, better still, we can take it to our neighborhood fruit store and ask the owner if we can leave it there overnight. When we return to the store the following morning, there will be some flies in the bottle. We plug the bottle with some cotton wrapped in cheesecloth, take it home, and set it aside. We call this our culture bottle. Within two weeks we should have an ample supply of flies.

To breed the flies, we select a male and a female from our culture bottle and place them in another bottle, similar to the first, which we have meanwhile prepared. As the flies are small and active it will be almost impossible to transfer them unless we first render them unconscious. To do this, we must have an etherizer. We get a bottle having a mouth the same size as the mouth of the culture bottle. We insert a nail one inch long into a cork stopper that fits neatly into the mouth of the bottle and cover the nail with several layers of cotton, tying the cotton to the nail with thread or string. We then put a few drops of ether on the cotton, taking care not to use it near an open flame, since ether is highly inflammable.

We are now ready to transfer the flies from the culture bottle to the etherizer. We tap the culture bottle on the table so that the flies will drop to the bottom, quickly remove the cotton plug, and place the mouth of the etherizer closely against the mouth of the culture bottle. We next invert the two bottles and again tap the culture bottle so the flies will drop into the etherizer. To hasten the flies into the latter, we place an electric light near the etherizer because the flies are heliotropic and are attracted to light. When the flies have moved into the etherizer, we quickly separate the two bottles, replacing the cotton plug in the culture bottle and stopping the etherizer with the cork stopper containing the nail and cotton soaked with ether. The flies will be anesthetized in a few seconds.

When the flies are completely unconscious, we remove the stopper and spill them out on a piece of white paper. Since the flies will remain unconscious only a few minutes, we have to examine them quickly for our male and female. Frequently this may take a little

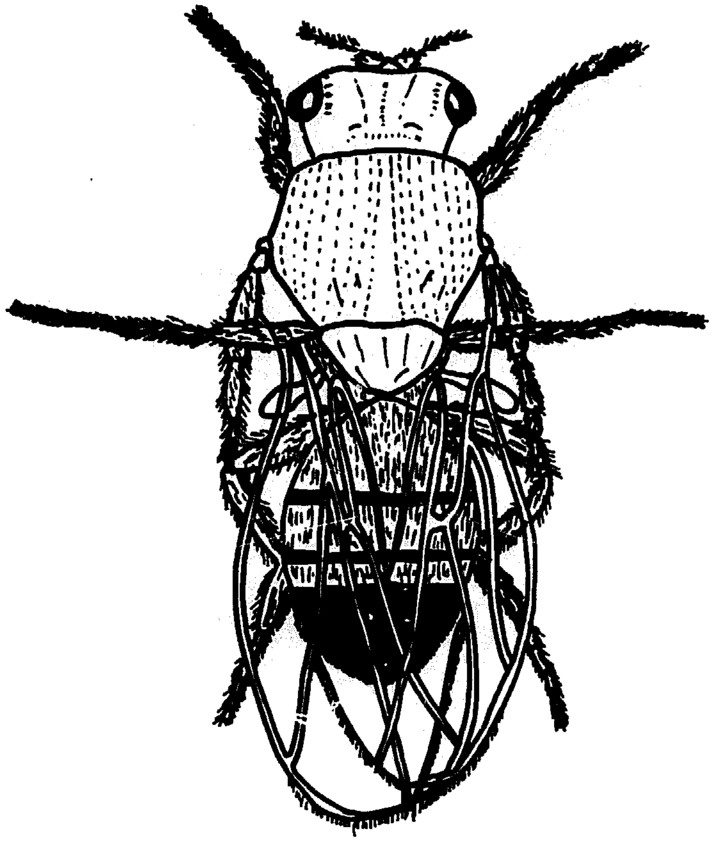

Figure 178
MALE FRUIT-FLY

longer than we anticipate, and the flies may begin to show signs of recovering consciousness before we have been able to obtain our mating pair. To guard against this, we have on hand a shallow dish with a piece of blotting paper attached to it with a piece of adhesive tape. If the flies show signs of recovering consciousness, we add a drop or two of ether to the paper and invert the dish over the flies for a few seconds. We may have to repeat this operation several times or until we have obtained our male and female. As the flies are fragile it is advisable to handle them or to transfer them with a camel's-hair brush.

We need our lens in order to distinguish the male and female. How can we tell them apart? First of all, the male is a trifle smaller than the female and has a bluntly rounded abdomen with a wide band of dark pigment (*Figure 178*). The female's abdomen is elongated, with narrower pigment bands. Secondly, the male has five abdominal segments, the female seven. And thirdly, the female has an ovipositor or egg-laying apparatus, while the male has "sex combs" on the end of the tarsal joint of the front legs (*Figure 179*). These "sex combs" are black bristles and may be for the purpose of appearing more attractive to the females when he performs his courtship dance. The male, however, can be deprived of them without apparently lessening his chances with normal males for the favor of some female. Perhaps, as someone once said, they are used for cleaning his antennae, but then how does the female clean hers?

When we have separated a male and a female from the others, we place them in a second prepared culture bottle and await results. We can raise a third generation from their offspring and continue this breeding indefinitely.

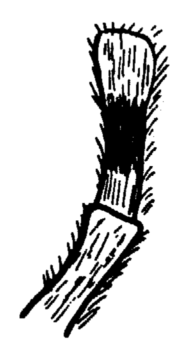

Figure 179
SEX COMB OF MALE FRUIT-FLY

ADVENTURE 43

We Explore the Subject of Variation

THE DANDELION is such a common flower and so familiar to us that there seems to be little more we can say about it that we don't already know. In the spring the yellow flower heads appear in the fields and on our lawns and are shortly followed by the white heads that contain hundreds of seeds each provided with a little parachute tuft of fine silky hairs. If we look at one of these seeds through our lens, we will find it to be somewhat spindle-shaped, with four to five rough ribs and one end prolonged into a very slender beak that bears the fine silky hairs we just mentioned. (*Figure 180*). These hairs, as we all know, catch in the wind, which carries the seed about until it is finally deposited on the ground. But what about the other end? Here, too, we find hairs, but these are stiff. What purpose do they serve? They help the seed to cling to the ground when it lands and thus keep it in place until it can germinate and send down roots for anchorage.

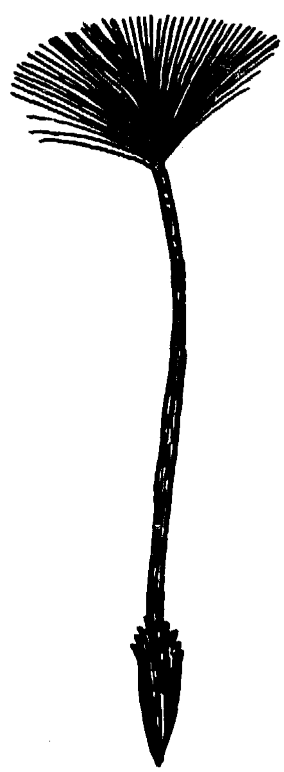

Figure 180
AKENE OF DANDELION

The seed of the dandelion is not actually a seed in the botanical sense, but a fruit—a one-seeded fruit called an akene. The akenes are a very common type of fruit, although we may not think so because most of us see so few of them, and are produced by a large number of different kinds of flowers. Since these flowers differ from one another, we might suspect that the akenes differ also, and

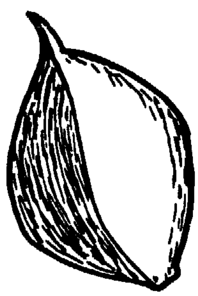

Figure 181
AKENE OF MEADOW BUTTERCUP

Figure 182
AKENE OF EARLY BUTTERCUP

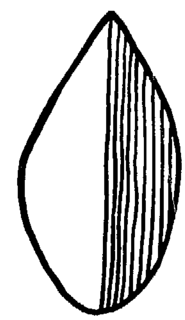

Figure 183
AKENE OF FIELD SORREL

this is so. Basically they are much alike, but variations occur, although sometimes they are minor, so that we can often tell by looking at an akene which plant produced it. The akene of the meadow buttercup, for instance, is compressed, with a short beak, and is pictured in *Figure 181*. The akene of the early buttercup, which is a woodland or hillside species, has an awl-like beak (*Figure 182*).

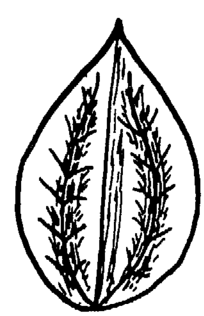

Figure 184
AKENE OF BUCKWHEAT

The field, or sheep, sorrel is a troublesome weed, with long, arrowhead leaves and inconspicuous green flowers. The flowers later turn brown red and eventually develop into akenes that are without a beak (*Figure 183*). The akene of the related buckwheat is somewhat similar in form but granular and marked with lines (*Figure 184*). Another relative, the

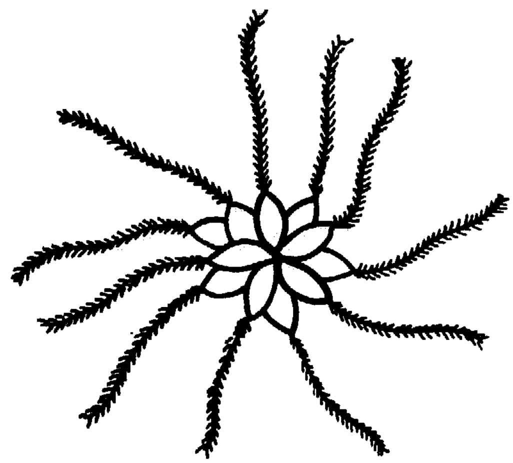

Figure 187
AKENE OF CLEMATIS

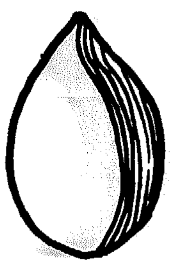

Figure 185
AKENE OF SMARTWEED

smartweed, or water pepper, has an akene that is three-angled and broadly oblong or ovoid (*Figure 185*). *Figure 186* shows an akene of the common cinquefoil, whose yellow flowers decorate meadow and pasture in early spring and are sometimes incorrectly called the wild strawberry. The little seeds of the strawberry, incidentally, are akenes. In some instances the akenes are furnished with plumose appendages (*Figure 187*) as in the clematis, or virgin's-bower, a beautiful trailing vine commonly found draped over bushes in copses and by moist roadsides. When viewed through the lens they appear like many tiny, twisted tails.

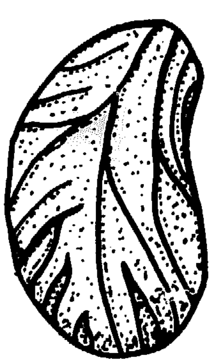

Figure 186
AKENE OF CINQUEFOIL

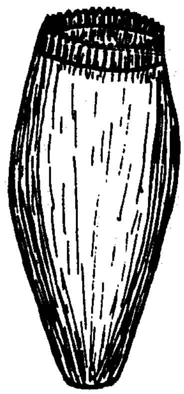

Figure 188
AKENE OF CHICORY

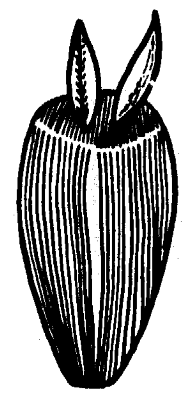

Figure 189
AKENE OF SUNFLOWER

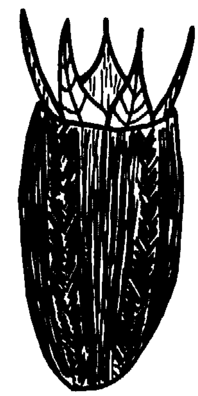

Figure 190
AKENE OF SNEEZEWEED

Speaking of appendages, the akenes of various composites are furnished with various appendages in the form of scales, hooks, barbs, and chaff. The appendage, no matter what its form, is called a pappus. In the chicory it is a shallow cup (*Figure 188*), in the sunflower it consists of two deciduous scales (*Figure 189*), in the sneezeweed of five scales (*Figure 190*), in the sow thistle of delicate, downy hairs (*Figure 191*), and in the dandelion it is made up of a number of silky hairs that are attached to the long, tapering beak of the akene (*Figure 180*) After you have examined these few akenes, you should be able to find many more.

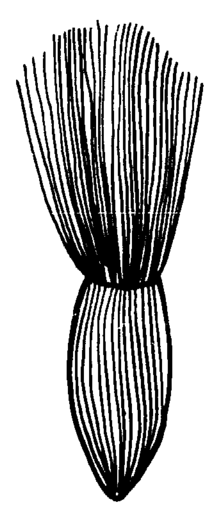

Figure 191
AKENE OF SOW THISTLE

ADVENTURE 44

We Get to Know the Barnacle

THOSE OF US WHO LIVE near the coast can find many things of interest along the sea beach, not the least of which are the barnacles. Barnacles are shrimplike animals that live within a calcareous shell. They are familiar objects along the rocky shore. Because of their shell they were at one time believed to be mollusks, but since they have jointed appendages they are now placed among the arthropods. The appendages are fringed like feathers and are drawn into or protruded from the shell at will. When the animal is covered with water the appendages are extended out of the shell and sweep through the water like a casting net, capturing small swimming creatures and organic fragments that serve as food.

The life history of the barnacle is most interesting. The young barnacle, which hatches from the egg, is free-swimming and in no way resembles the adult. After swimming about for a while it undergoes changes and then settles on some solid object, such as a rock, wharf pile, drifting timber, the bottom of a ship, and even on a whale, fastening itself, head foremost, by means of a cementlike secretion. (If you think barnacles are not securely attached just try to pry one off). After it has found a permanent location it undergoes further changes until it has attained its adult form.

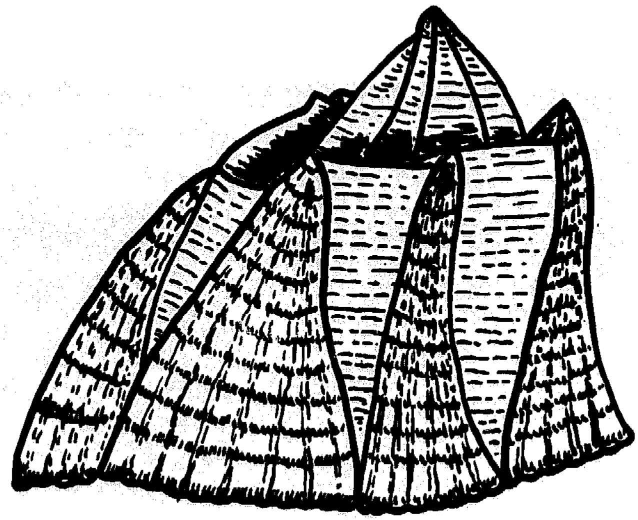

Figure 192
BARNACLE

There are several different kinds of barnacles, but the one familiar to most of us is the rock barnacle, which we find attached to rocks along the shore. Sometimes the rocks are so thickly covered with the barnacles that they appear white from a distance. If we look at the shell through our lens, we find it composed of a number of thick calcareous plates that fit together in a tentlike form (*Figure 192*). These plates, which are usually six in number, are rigidly attached to each other and to a fold of skin surrounding the body of the animal, but there are two pairs of hinged valves at the top which may open and close like double doors. It is said that if you tap a rock encrusted with barnacles and hold your ear near you can hear the closing of many doors.

If you visit the seashore when the rocks are covered with water and if the barnacles are unmolested, you will see thousands of tiny fringed feet waving to and fro. They are extended out through the open doors and serve as a sort of casting net. Their movements are perfectly regular and rapid and may beat back and forth as many as a hundred times a minute. As someone once remarked, a barnacle is a little shrimplike animal standing on its head within a limestone house and kicking its food into its mouth with its feet.

ADVENTURE 45

We Seek the Liverwort

If you look along the mossy bank of a brook or stream or among the mosses in damp woods, you should find flat, ribbonlike plants growing close to the ground. They are papery thin and may be either long and slender or repeatedly lobed and forked. In a way they resemble the lichens except that they are distinctly green in color. Called liverworts,* they are very simple plants without stem or leaves. Of no economic importance, they are of interest, however, because

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* The name "liverwort" is derived from the somewhat liver-shaped thallus and the belief at one time that they could cure diseases of the liver.

they represent the transition stage from a water living habit to a land living habit, in other words, they bridge the gap between the algae, which are fundamentally aquatic, and the higher flowering land plants.

There are some four thousand species of liverworts, but one of the most common and the one you are most apt to find is Marchantia, a name derived from a French botanist who lived about three hundred years ago. It has a peculiar dull-green color with a broad, ribbon-shaped thallus, which is simply a plant without true roots, stems or leaves, and generally forked once or twice. The upper surface is divided into angular areas in the center of which we can distinguish an air pore. If you will examine the lower surface with your lens, you will find numerous hairs, called rhizoids, that anchor it to the ground and that serve to some extent the same purpose as the roots of higher plants.

Note if umbrella-like structures extend into the air from the surface of the thallus. These upright growths are the reproductive organs. The umbrella part may be either flat, shield-shaped, radially lobed, or it may be a disk with deep, fingerlike lobes that usually curve downward. The former is the male organ, or antheridial disk (*Figure 193*), the latter the female, or archegonial disk (*Figure 194*), and you will not find them on

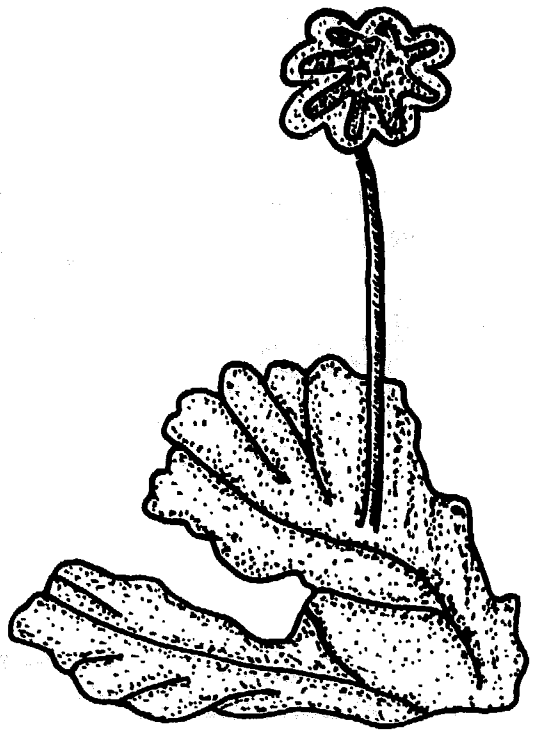


Figure 193
ANTHEREDIAL DISK OF MARCHANTIA

Figure 194
ARCHEGONIAL DISK OF MARCHANTIA

the same plant. Sperms are produced in the male organ and eggs in the female, and since these organs occur on separate plants, it is necessary for the sperms to swim to the eggs so that the latter may be fertilized. This explains why liverworts always grow in wet or damp places. At first there seems to be a considerable element of chance involved in this method of reproduction, for the question arises, how do the sperms locate the eggs? The probability of a sperm's locating an egg would appear to be one in a million, if the odds are not even greater. Actually the

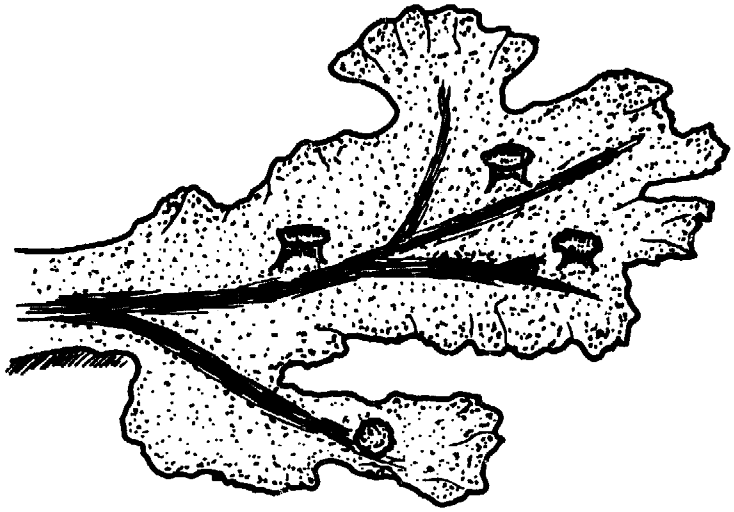


Figure 195
GEMMAE CUPS OF MARCHANTIA

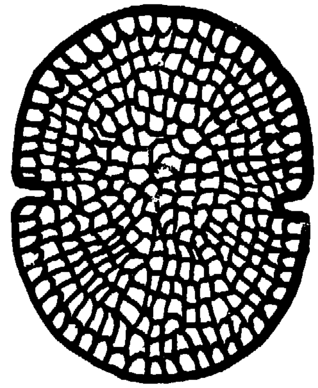


Figure 196
GEMMA OF MARCHANTIA

sperms have no difficulty finding the eggs because the female organ discharges substances that help to orient the sperms in the right direction. The phenomenon is called positive chemotaxis.

Instead of the umbrella-like structures you may find little cup-shaped or saucer-shaped structures with toothed margins on the upper surface of the thallus (*Figure 195*). These structures produce green disks called gemmae, or brood bodies (*Figure 196*). When washed out or blown to some distant place they grow into new plants.

ADVENTURE 46

We Set Some Traps

THE DICTIONARY TELLS US that a trap is a device that shuts suddenly with a springlike action for taking game and other animals. Man has devised many ingenious traps, but I doubt if he has improved upon those designed by nature or will ever do so. I am thinking specifically of the traps developed by certain plants for catching insects. Best known are the Venus-flytrap, the sundew, and the pitcher plant. Perhaps you are familiar with them.

The Bladderwort (*Figure 197*) is perhaps not quite so generally known, but it has designed a trap that, I think, is more ingenious than those developed by the plants mentioned above. It is a plant of ponds and sluggish streams, delicate and vinelike in appearance, and floats beneath the surface among the stems of water lilies and pondweeds. Without roots it has instead twiglike rhizoids that function as roots. The stem is slender and bears finely branched leaves arranged alternately but divided so closely to the base that each leaf appears to be two leaves growing opposite one another. The leaves are furnished with small bladders that at one time were believed to function entirely as floats but which also serve as traps for capturing small aquatic creatures. They deserve our attention, so let us examine them.

To do so, we need to lift the plant out of

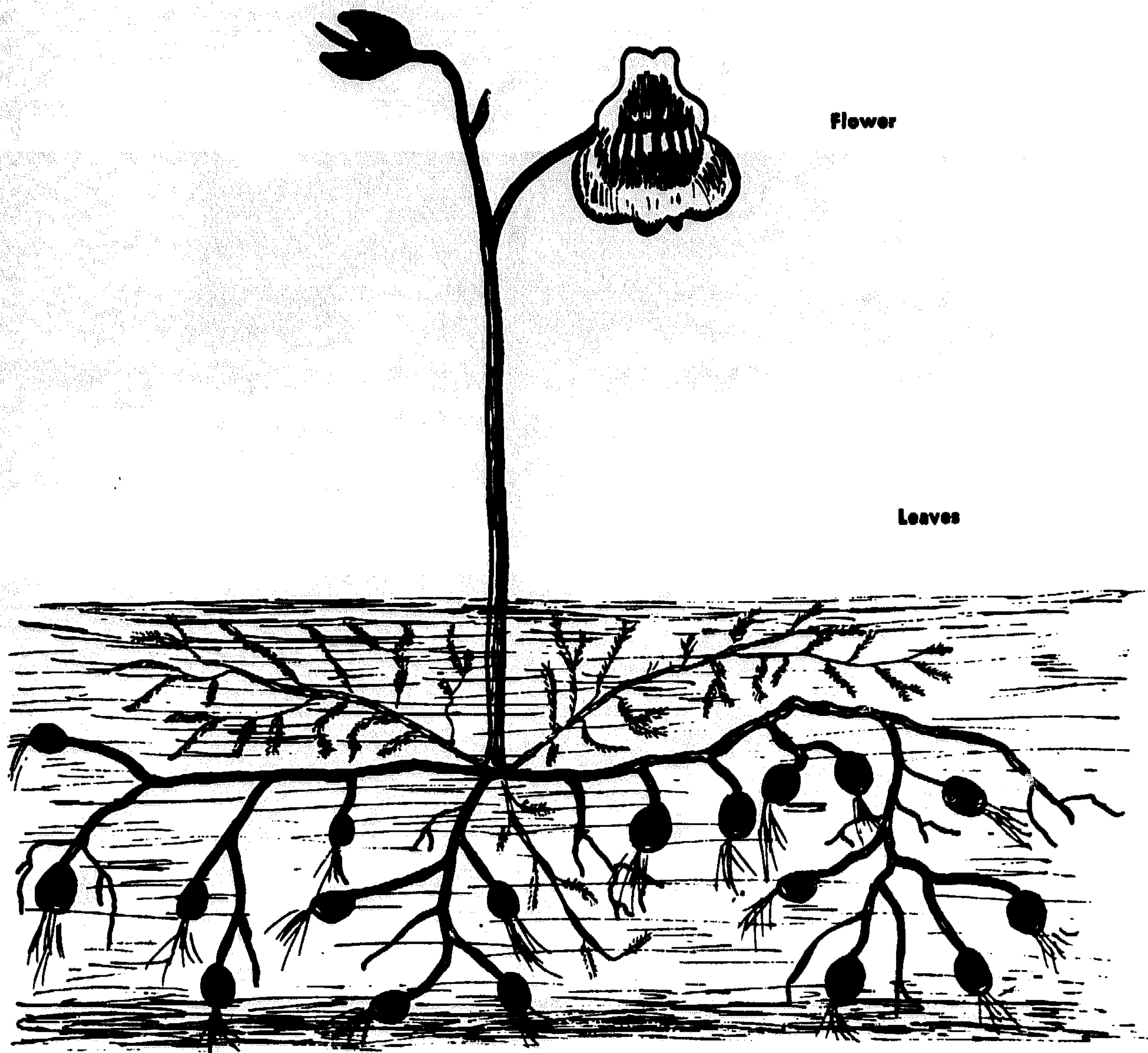


Figure 197
BLADDERWORT

the water, and when we look at one of them through our lens we find it a slightly compressed sac with a slit-shaped opening (*Figure 198*). The opening is guarded by a valve,

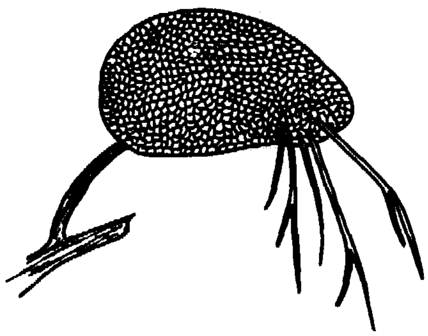


Figure 198
BLADDER OF BLADDERWORT

or trap door, that opens only inward, and the rim of the opening is armed with teeth and bristling hairs. Within the bladder are more hairs.

How does the trap door operate? When an unwary water animal swims into the opening, its movements stimulate the valve to open. As the sides of the bladder are ordinarily dented inward, the moment the valve opens water flows into the bladder and presses on the walls, which are then pushed outward. This inward flow of water creates a suction that results in the flowing of more water into the bladder. You have read how a sinking ship creates a suction and pulls down with it anything within the area of the suction, and why sailors, when they abandon a ship, are in a hurry to get away from it. The trap of the bladderwort functions in a similar manner. As the water flows into the trap, the animal responsible for starting the flow is carried into the trap, as well as others that may be caught in the suction. Once within the bladder there is no escape, because the valve is strongly elastic and snaps shut behind them. What is the fate of the imprisoned animals? They are digested by secretions produced by the walls of the bladder, and the digested material is then absorbed by the plant as food.

You can observe the operation of the traps if you take home a bladderwort and place it in an aquarium filled with clear water and well supplied with water fleas and other small aquatic creatures. For best results take a plant whose bladders are empty. The water fleas and other animals can be obtained from the same pond or stream where you found the plant by merely scooping out a pan full of water and transferring it to a bottle. Or you can submerge a large, widemouth bottle and allow the water to run into it. When observing the traps function it is advisable to use a reading glass rather than a small hand lens or pocket magnifier, since you probably can't get close enough with the latter to see what takes place.

I should add, as a final word, that the bladders, which at one time were believed to act as floats, actually function as such at the time of the flowering season. At that time they become filled with air and serve as pontoons to buoy up the plant so that the yellow flowers may be kept out of the water where insects can visit and pollinate them (*Figure 197*).

ADVENTURE 47

We Quest for Oil

AT ONE TIME herbs were used extensively in cooking to improve the taste and flavor of various foods, and in recent years they have again become very popular. Almost everyone

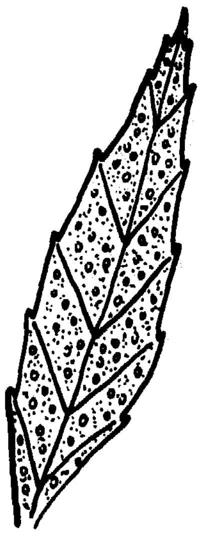


Figure 199
SPEARMINT LEAF WITH OIL GLANDS

who has a garden has a few herbs growing in it. They may be used throughout the growing season or harvested in the fall, dried, and placed in jars. Many roadside stands at this time of the year have attractive displays, and many stores carry them throughout the year.

The substances used in adding taste and flavor to foods, drinks, and confections are basically aromatic oils secreted by glands or similar structures in the stems, leaves, and fruits of certain plants. For instance, if we examined a spearmint leaf with our hand lens, we would find the surface dotted with numerous small glands (*Figure 199*). The spearmint is a member of the mint family, a group of plants that are essentially aromatic and include peppermint, thyme, and marjoram, savory and sage. Examine the leaves of any of these plants and you will find them dotted with glands.

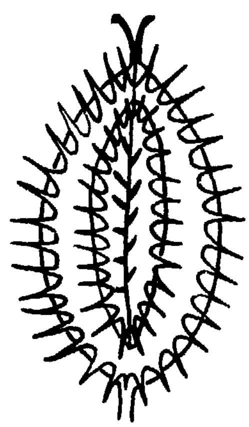


Figure 200
AKENE OF WILD CARROT

The aromatic oils that give such plants as dill and fennel, caraway and coriander their characteristic odors and tastes are produced not by glands in the leaves but by oil tubes located in the seeds or, more strictly speaking, in the fruits, which are akenes. All these plants are members of the parsley family, to which the wild carrot also belongs. As most of us may not have access to dill or fennel, caraway or coriander, we shall examine the akene of the wild carrot, which is common everywhere. Viewing it through our lens, we observe that it looks like a miniature green barrel beset with spines (*Figure 200*), which may lead some of you to think of the porcupine. We note also longitudinal ribs. Between these ribs are oil tubes, or vittae. Cut the akene transversely with a razor blade and you can see the ends of the tubes (*Figure 201*). Unlike other members of the family, the akene of the wild carrot produces oil that is not particularly pleasing to our taste. I might add that if you examine the akenes after they have matured you will find them brown instead of green.

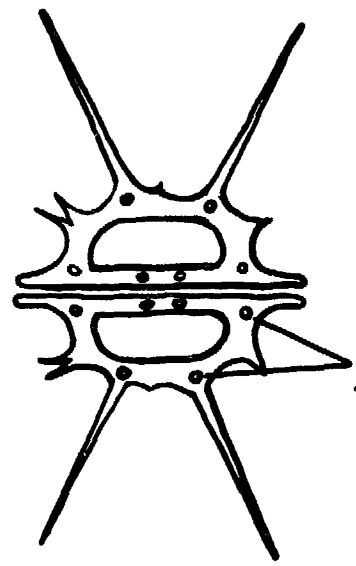


Figure 201
TRANSVERSE SECTION OF AKENE OF WILD CARROT

ADVENTURE 48

We Assume the Role of Farmers

TAKE A SLICE OF BREAD, soak it in water, place it in a saucer, set the saucer aside for an hour or so, then cover the bread with a tumbler, and place it in a warm, dark place. Within two or three days you should find a cottony or cobwebby-like growth on the bread.

Examine this growth with your lens and you will find it composed of long threads passing in and out among each other forming a web (*Figure 202*). This tangled mass of threads is called a mycelium and forms the vegetative part of a fungus plant familiar to us as bread mold. The threads, which collectively compose the mycelium, are called

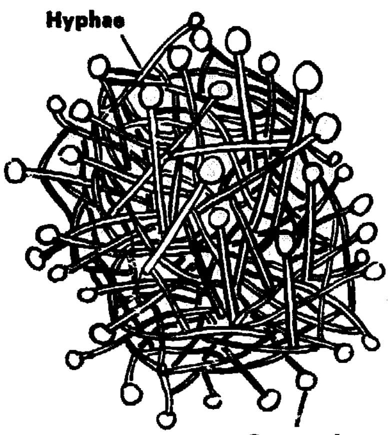


Figure 202
MYCELIUM OF BREAD MOLD

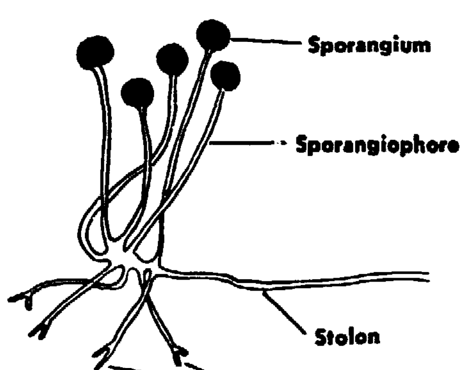


Figure 203
BREAD MOLD

hyphae. Some of the hyphae penetrate the bread and serve as absorptive structures called rhizoids; others grow over the surface of the bread and are called stolons. If you examine the latter carefully, you should see other hyphae extending upward from them and bearing at the tips small, pearl-like globules (*Figure 202*). These aerial hyphae are known as sporangiophores, and the globules as sporangia. Within the sporangia, spores are formed. As the spores ripen, the sporangia turn black and the entire mold plant acquires a black appearance (*Figure 203*). When the spores have fully matured the walls of the sporangia rupture, the spores are released and carried about by air currents. Upon encountering favorable conditions for growth a spore germinates, producing a hypha, which, by an extensive branching growth, forms a new mycelium and we have another mold plant.

On the same piece of bread may appear molds that are blue, green, or yellow in color, or if we should repeat the above procedure with a piece of cheese, a piece of orange rind, or some other food there should appear within a few days one of these colored molds. These molds are essentially like the bread mold except that the spores, instead of being borne within tiny globules, are borne in chains at the tip of certain hyphae. The

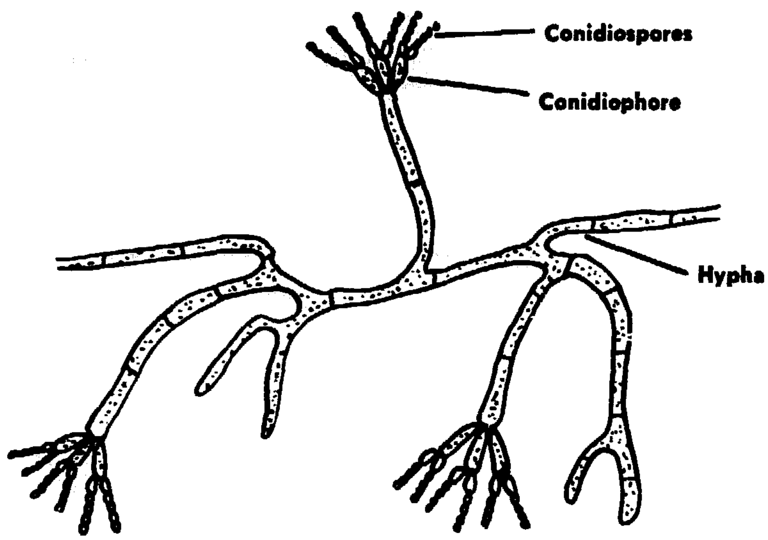


Figure 204
COMMON BLUE MOLD

spores are called conidiospores and the hyphae that bear them are called conidiophores and resemble tiny brooms (*Figure 204*). The conidiospores are produced in great numbers and are very small and light in weight. When mature they become detached and are carried about by air currents, and when they find favorable conditions quickly germinate and develop into new mold plants. Since the spores are variously colored, the characteristic color of the mold is due to the color of their conidial masses.

Since our experience with molds may be limited to those that appear on our foods, leather goods, fabrics, tobacco, and other organic materials, we may get the erroneous impression that all molds are harmful. It is true that many of them are destructive agents in the spoilage of foods, while others are responsible for several diseases, yet some species are quite useful, as those that are agents in the decay of dead plant and animal bodies and thus help in the maintenance of soil fertility. Others are used in the manufacture of alcohol from rice starch and in the commercial production of various organic acids. The characteristic odors and flavors of certain well-known types of cheese are due to their metabolic activities in the butterfat and casein of milk. One species has received considerable publicity in recent years as the source of a bactericial drug, penicillin, which is used to destroy certain pathogenic organisms responsible for a number of human diseases.

ADVENTURE 49

We Are Intrigued by an Ingenious Mechanism

IN SPITE OF ITS NAME a starfish is not a fish. Perhaps "sea star" would be a better name, since it is shaped like a star and lives in the sea. To many of us starfish are animals in name only, but to most of us who live near the coast they are actually living creatures we find in tide pools and among the rocks along the seashore. They are rather odd animals

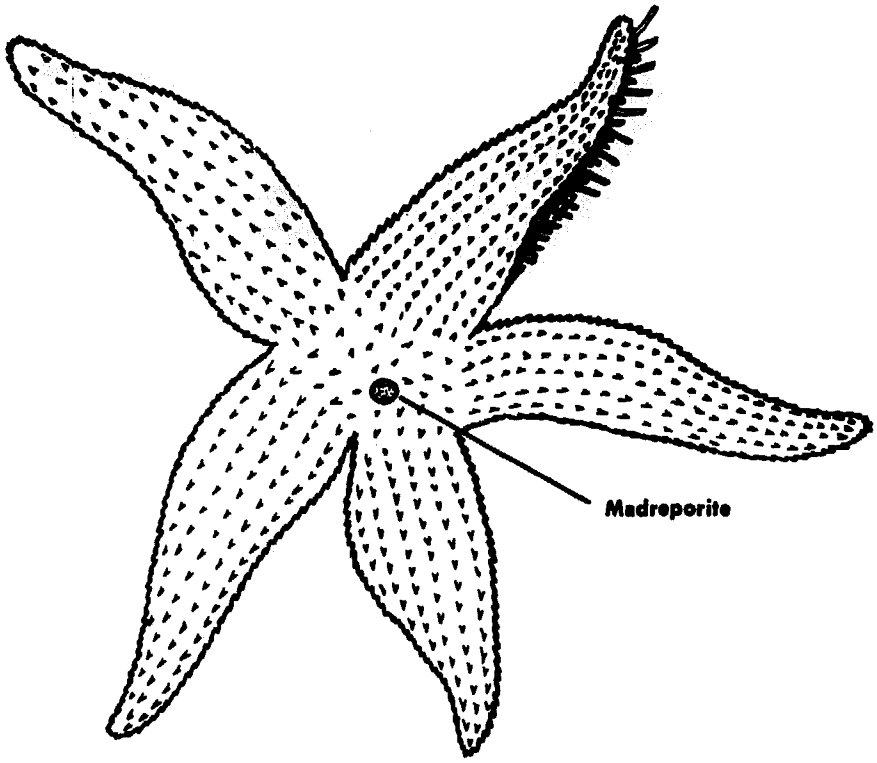


Figure 205
STARFISH

with a spiny skin and a body consisting of a central disk from which radiate a number of arms. In the common starfish there are five arms, but the number varies according to the species. Apart from their harmful tendencies of preying upon oysters, starfish are of no importance. Why, then, do we make them the subject of this Adventure?

Starfish have a peculiar way of moving around. Movement is effected by a number of structures called tube feet, which are operated by a sort of hydraulic-pressure mechanism. Viewed through a lens or reading glass, the manner in which these tube feet function is most interesting. So let us go to the seashore and look in the tide pools or among the rocks for them. The best time is when the tide is out, for they are usually found below the low-water mark. As we pick one up the first feature we notice is an orange disk on the upper surface and called the madreporite (*Figure 205*). Actually it is a sieve plate, and if we examine it with our lens we note that it is provided with minute openings. Water enters through these openings and passes down a tube called the stone canal, so-named because its wall is made rigid by calcareous rings. This canal opens into a circular tube that runs around the mouth, which we can locate by turning the animal over and looking at the lower surface. The circular tube, known as the ring canal, in turn connects with radial canals that run the length of the arms. There is a canal for each arm, so in a starfish with five arms there are five of these canals. The water upon flowing down the stone canal enters the ring canal and then flows along each of the radial canals. What happens to the water now? Again looking at the lower surface of the starfish and particularly at the lower surface of the arms, we observe a groove (ambulacral groove) that runs along the length of the arms. If we now place the fingers of one hand on one side of the groove and the fingers on the other hand on the other side and press gently, we can open the groove, and as we do so we find a number of odd-shaped structures that appear through a lens as cylinders ending in what seem like disks. These odd-shaped structures are hollow and thin-walled and are called tube feet. Each is connected by a short branch to the radial canal and further connects with a rounded muscular sac, the ampulla (*Figure 206*). The ampulla extends within the arm, and we cannot see it unless we dissect the animal.

And now to answer the question, what happens to the water when it flows along the radial canal? Since the tube feet are connected to the radial canal, the water enters the ampullae, and when the ampullae contract, through muscular action, the water is forced into the tube feet, which become distended, and the bottom of the foot, the sucker, becomes pressed against the substratum. But why doesn't the water flow back into the radial canal, you ask, when the ampullae are contracted? Simply because a valve prevents the water from doing so. To continue: After the tube feet have become distended, longitudinal muscles, with which they are provided, are brought into play,

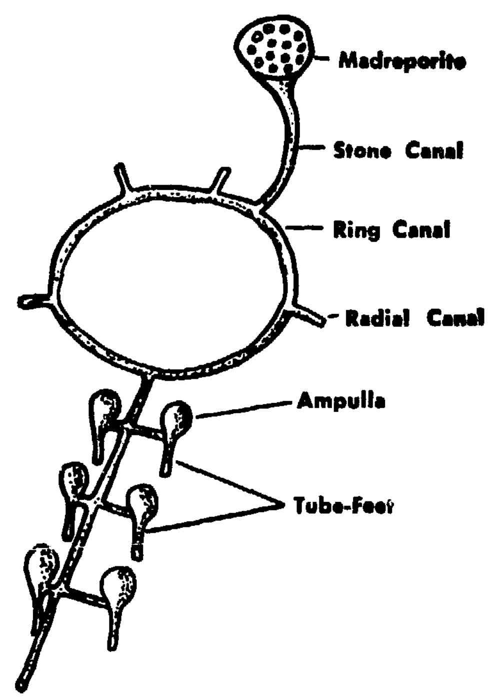


Figure 206

DIAGRAM OF WATER-VASCULAR SYSTEM

shortening the tube feet, forcing the water back into the ampullae, and drawing the animal forward. One tube foot, of course, is not particularly effective, but the combined efforts of hundreds of tube feet are capable of moving the animal.

If you are skeptical that the tube feet are able to exert enough force to move a starfish in this manner, try to open a live clam or oyster barehanded. You will find it almost impossible. But a starfish, which is not much larger then either of these animals, does it easily. The starfish mounts the clam or oyster in a humped-up position, attaches its tube feet to the two shells, and begins to pull. The clam or oyster reacts to the attack of the starfish by closing its two shells tightly. But the starfish continues to pull and by using its tube feet in relays is able to outlast the clam or oyster, whose muscles finally become fatigued and relax. When the shells gape the starfish turns the lower part of its stomach inside out, extends it through its mouth in between the two shells, and proceeds to digest the soft parts of the clam or oyster.

As you watch the movement of the tube feet through your reading glass, note the movable spines on either side of the ambulacral groove. These spines can be brought close together and thus protect the soft tube feet when the starfish is attacked.

ADVENTURE 50

We Probe into a Complicate[d] Life History

IN SPRING, about the time apple blossoms begin to show a touch of pink, we sometimes find on cedar trees brown swellings from which extend numerous long, thin, bright orange tendrils, or horns, that twist about like petals of a flower (*Figure 207*). Known as cedar apples, they excite our interest by their curious appearance. Perhaps you have seen them and wondered what they were.

Actually they are galls, but, unlike those we have already discussed (see Adventure 37), are produced by a fungus plant. There is more to it than this, however, for these galls produce spores that are one of several kinds involved in a rather complex life history. The plant is known as the apple rust and is in reality a disease of the apple. Why it is called a rust we shall see presently.

The tendrils, or horns, which are small at first but which grow longer with every spring shower, produce a certain kind of spores called teliospores. These teliospores develop within the tendrils, or horns, into a second kind, known as basidiospores. When fully ripe the basidiospores are released and carried by the wind. If they fall on apple or crab-apple leaves and the conditions are favorable, they germinate quickly, penetrate the leaves, and produce a mycelium that branches throughout the leaf tissues. Their presence in the leaves may be detected by the appear-

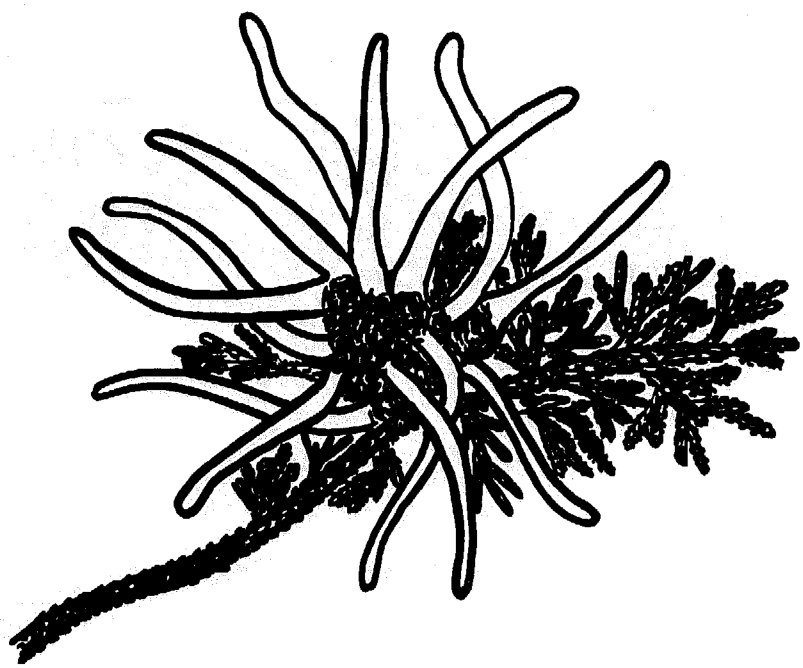


Figure 207
CEDAR APPLE

ance of yellow spots. The yellow spots resemble rust, whence the name, and if we examine them with our lens we find amber blisters. These blisters contain flask-shaped structures, pycnia (singular pycnium), which increase in size and exude a sticky substance. This exudation contains a third kind of spores called pycniospores.

The pycniospores are one of two sexes and a pycniospore of one sex must reach one of the other sex for fertilization to take place. This is effected by insects that are attracted to the exudation. After fertilization the pycnia change into black dots (*Figure 208*) surrounded by a reddish circle, and at the same time the fungus grows through the leaf, forming structures that appear through our lens as small cups with recurved and fringed or toothed margins (*Figure 209*). These cups, called aecia (singular aecium), produce still another kind of spores, called aeciospores. The spores mature in July and August and, like the basidiospores, are scattered by the wind. If they land on cedar leaves they germinate and produce by the following June small, greenish-brown swellings, or galls. The galls gradually increase in size until by autumn they have become chocolate brown and kidney-shaped, with small, circular depressions. They remain in this form until the following April, when, under the influence of spring showers, they begin to put forth the tendrils, or horns. After successive showers the horns grow longer and longer until the galls, covered with these horns, sometimes get to be the size of a small orange. Another crop of teliospores is now produced, thus completing the life cycle in something like two years. A point worth noting is that the rust cannot spread from cedar to cedar or from apple to apple, but must alternate between the two hosts.

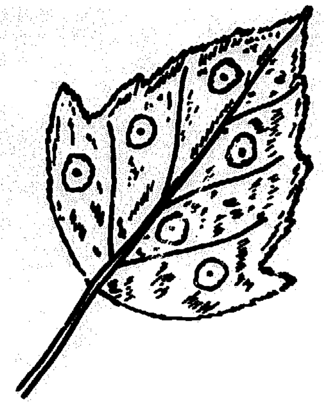


Figure 208
APPLE LEAF WITH PYCNIA

Figure 209
APPLE LEAF WITH AECIA

Chief injury is to the apple, the rust causing premature defoliation, dwarfing, and fruit of poor quality. Control methods, however, have reduced infection on orchard trees. Most damage, today, is to crab apples planted as ornamentals.

The Production of School Science Equipment

by Keith Warren and Norman Lowe

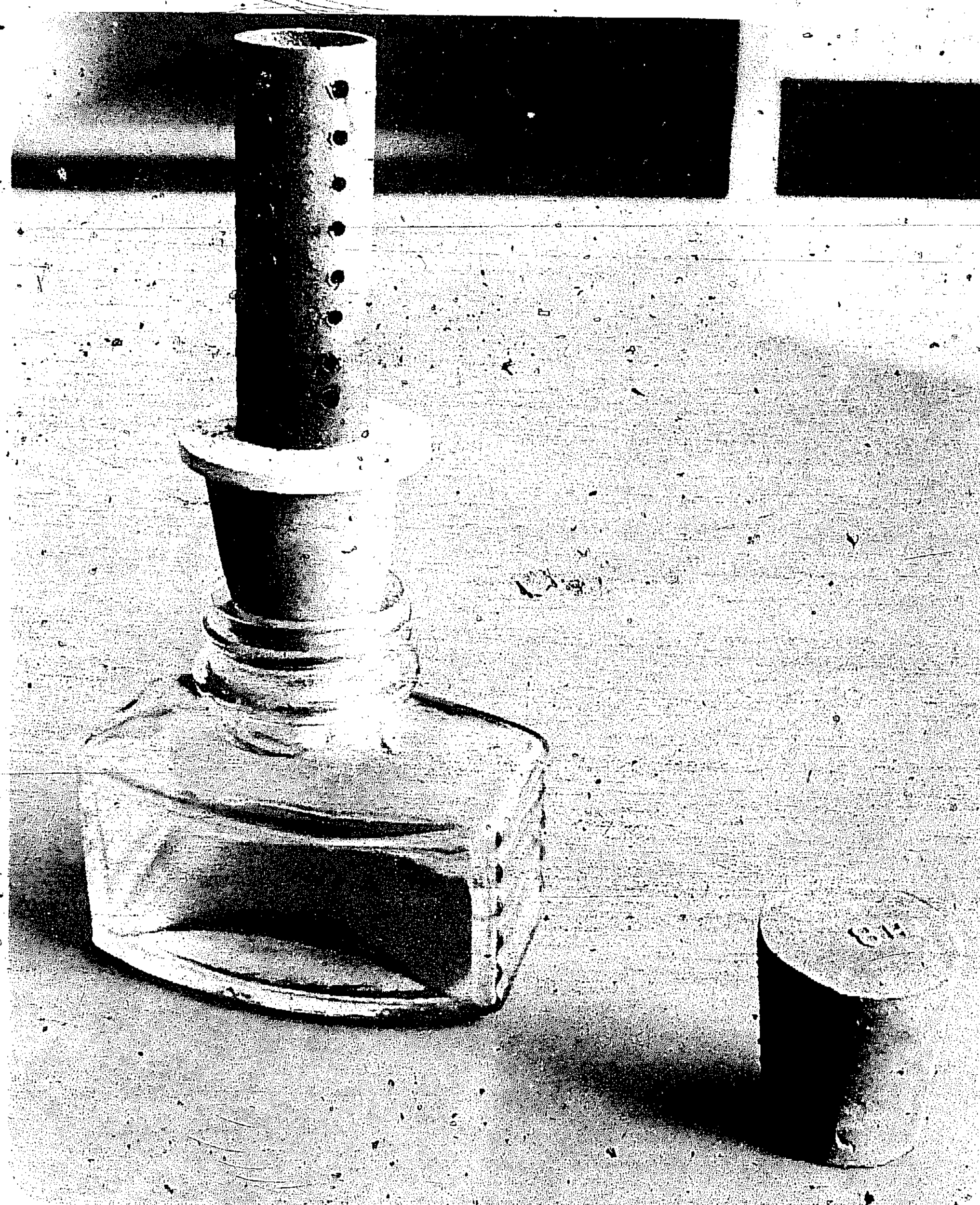
Published by:

Commonwealth Secretariat

Available from:

out of print

The production of school science equipment



Commonwealth Secretariat

COVER PICTURE

An inexpensive spirit burner made out of an old ink bottle

THE PRODUCTION OF SCHOOL SCIENCE EQUIPMENT

a review of developments

Keith Warren

and

Norman K. Lowe

Commonwealth Secretariat

COMMONWEALTH SECRETARIAT

Marlborough House Pall Mall London SW1Y 5HX

First published 1975

ISBN 0 85092 100 7

Published and Printed by the Commonwealth Secretariat

Contents

Intention

In this book we have tried to provide a review of the kinds of science teaching equipment that are likely to be of interest to organizations and school systems that are planning to make, or to select, apparatus for situations in which items from the main science equipment supply houses are unsuitable or unobtainable.

It is a great waste if people with similar problems and with usable solutions do not communicate with one another. The needs of the many schools struggling to teach science with inadequate apparatus are enormous - not only in the volume of the items required but also in the suitability of design. A sharing of ideas and a knowledge of how others are coping with similar problems can bring about considerable economies of time, effort and money.

Throughout the world there are some fifty to a hundred organizations working on the design of elementary science education apparatus for primary and lower secondary schooling. Some are fully commercial producers, others are state enterprises; some are curriculum centres, others are teachers' colleges. The intention of this book is to help spread some of their ideas for consideration by other organizations which may be able to use them to assist in the solution of some of their own problems. It is not, of course, an exhaustive collection; there are undoubtedly other projects and ideas that are not mentioned here. Good ideas often come from unexpected sources - for example from toy manufacturers, hippy communes or hardware stores. In fact, the field of ideas is so wide that this review provides little more than a taste of what is going on, together with some photographs, comments, and an indication of some sources of further information.

In order to provide continuing assistance to developing countries, the Commonwealth Secretariat will be very pleased to receive further details and up-to-date information about low cost, locally produced school science equipment and the organizations producing it.

Keith Warren

Norman K. Lowe

May 1975

Note: Anyone wishing to purchase any of the books listed in this publication is advised to order them direct from the publisher only if they cannot be obtained by a bookseller.

Section 1 Food for Thought

CONFERENCES ON THE PRODUCTION OF LOCAL APPARATUS

There have been several conferences on the production of teaching equipment - sometimes specifically on science but sometimes more general - and the subject is frequently discussed at other conferences. As can be seen from the reports, there is a great similarity about most of them. The impression one gets is that they are often seen by the organizers as lecture presentations by foreign specialists who indicate that they have identified the local problems and know how to implement the solutions. While this is valuable on technical matters of a certain sort, surely the job of a foreign specialist is to act more in a consultant capacity - that is, to lead his 'clients' to identify and to define the problems for themselves. In the case of providing science teaching apparatus for schools, the problems are not as obvious or as easy to solve as they have generally seemed to be - as the many failures witness.

Similarly, the resolutions passed by many conferences have a naive air. There are rarely any operational proposals - no timings, allocations, responsibilities, flows; nor is there any attempt at scheduling. Though the lecturers may have referred to 'objectives' in educational discussions during the conference, the final resolutions reveal that they know little of the way a system of objectives is written for the scheduling of activities in real life. They have borrowed a jargon but not understood it. Perhaps if a businessman from the locality were to be present at all conferences on the production of teaching equipment, a more practical result would be achieved.

It may be useful here to list some of the conferences, seminars, workshops and courses which have taken place and which were directly or indirectly concerned with the design and production of school science apparatus.

At RECSAM, Penang, there was 'Production of Low-cost Teaching Materials for Primary Level Science and Mathematics' in October 1973. This was jointly sponsored by the South-East Asian Ministers of Education Organization (SEAMEO) and the German Foundation for International Development (DSE).

There was a Regional Conference on 'Problems of the Promotion and Production of Teaching Materials in South-East Asia', also sponsored by SEAMEO and DSE, in October 1972 in Singapore. This was organized by the SEAMEO Regional Centre for Educational Innovation and Technology (INNOTECH).

Food for thought

Aspects of apparatus needs are covered in the book 'Science Education in Africa' (1), which is a report of the sixth Levershulme Inter-University Conference in Africa held at the University of Malawi in March 1968. There is a section on 'Science Teaching Equipment, Materials and Facilities' in 'Planning for Integrated Science Education in Africa' (2), which is the report of a Workshop for Science Education Programme Planners in English-speaking African countries held at Ibadan, Nigeria in September 1971. There was a Regional Seminar on School Science Equipment in New Delhi in December 1972. The final report is published by UNESCO Regional Office for Education in Asia, Bangkok, 1973.

There was a course at RECSAM in June 1973 on 'The Development of Primary Science Apparatus'. It was the second of its kind and it aimed at training some key educators in the theory and practice of apparatus production in their countries and at developing some prototypes. There is a report (August 1973) and a description of the prototypes, with photographs, in a 50-page booklet ('Collection of Assignments by Participants of RME-1 (1973) Course'). It would serve as a model for similar courses which other production units might like to consider.

(1) Science Education in Africa (Gilbert and Lovegrove). published by Heinemann Educational Books Limited, 48 Charles Street, London W1X 8AH, England.

(2) Planning for Integrated Science in Africa published by UNESCO, 7 place de Fontenoy, 75700 Paris, France.

EUROPEAN PRODUCTION FOR SCHOOLS IN AFRICA, ASIA AND LATIN AMERICA

A number of European firms are aiming at markets for school science apparatus in Africa, Latin America and Asia. Most, of course, hope to sell their home style of product but a few are attempting to design realistically for the situation, seeing their long-term advantage in doing so. Their very reasonable hope is that if they come to know the real needs of the market by struggling with it at first-hand during the development stages of such educational schemes as are now beginning to get under way, and if the market gets to know them in these early stages, they will be of greater commercial advantage and value to their customers than they will if they come in later.

It is a high-risk venture. International agencies with an interest in the presence of satisfactory equipment in new curricula could very helpfully collect and make available publicly a great deal of information and advice which could assist such firms. There are, of course, difficulties in this but probably they could be overcome.

Cornelsen, Velhagen and Klasing of Berlin have produced a number of kits of considerable interest to primary schools wanting a collection of items dealing with a single subject such as Weather or Heat. Photograph 1 shows one of the more complicated kits - a class kit for eighteen pairs of children. Educationists in New Delhi and teachers in Calcutta who were shown the CVK kits made certain criticisms: that they were bulkily packed; that though they incorporated some good points (like the mounting of thermometers for pupils in a particularly neat way in a metal angle) they were in some respects flimsy; that a kit needs an accompanying text in the appropriate language; and that the price was totally out of reach of most schools in a developing country.

The German Foundation for International Development (DSE) arranged a conference (Calcutta, September 1973) at which teachers, educationists, apparatus designers, and so on, from all over India, had a look at science and mathematics teaching kits produced in Germany. The intention was to see whether the kits themselves, or modifications or ideas from them, were useful in the Indian classroom. The conference members actually used the kits with school pupils from a local bustee (slum) in the mornings over two weeks, sitting on the floor, each with some half dozen children. The resulting reports, though not edited and published, are detailed and valuable. This real attempt at testing European materials in Asian classrooms had several aims: - to educate local teachers and designers as to what materials exist; to demonstrate to distant manufacturers how their products fit into the Indian context; and to indicate to the international organization whether they are on the track of a process to help Asian children, local production and European manufacturers. The impression at the conference was that this is an enormously valuable process which many international agencies should copy. What made this particular one successful was an informality which allowed truth to come out, properly-based analyses to be made (still unpublished possibly because of the informality) and the fact that people were actually influenced, not merely informed. The kits have since been sent around India as an exhibition.

During discussions about kits in New Delhi and Calcutta, one point arose that is of importance to designers of apparatus - the idea of kits rather than individual items was warmly welcomed. Indeed at Delhi UNICEF was urged to put its supplies into kits. A pre-selected collection is usually gratefully seized on by those who otherwise would have to make their own selection. Most people at the New Delhi conference averred that some dreadfully poor selections and omissions were commonly perpetrated by administrators or by sincere but inexpert or rushed officials. There was a strong feeling in favour of kits because of this great risk; the possibility that a ready-made kit might contain an inappropriate selection seemed to be less feared. Of course, in practice it is unlikely that anyone would consider attempting a totally international kit for a wide range of levels. Nevertheless, large manufacturers do need to bear in mind that a grade 8 level kit for a Bengal village is unlikely to be appropriate for, say, the same grade in a Mexican city school. How it would need to differ is a matter for research in the locality.

That some kind of warning is necessary, however, is evident from the proposal of a European firm to market, in countries poor in school apparatus, a large, expensive universal science teaching kit - photographs 2 and 3. Though handsome and excellently designed for Europe, several factors put it right out of consideration: for instance, the irreplaceability of its multi-use parts; the need for access to some repair skill and facilities; the fact that it does not fit a local syllabus and needs local-language software and an optimistically well trained-teacher; and its general air of sophistication. The international organizations can already blushingly tell us of the many European science kits standing unused on shelves in Nepal, Indonesia, Jamaica....

Food for thought

A further advantage of a kit is that it can have a box which serves as the store-cupboard for the items in the classroom. Most classrooms, certainly in primary schools, have no storage space at all. The NCERT kit has a metal case which can lock with a padlock - photographs 6 and 7. When making new designs, production units will need to bear in mind this lack of storage space or their apparatus will not last a year. (Though what they can do to cater for those schools in Vietnam without roof or walls, or those in Malaysia which are occasionally entirely submerged by water, is not so easy to decide.)

APPARATUS FOR THE FEW OR THE MANY

If ninety-nine per cent of the school population are not going to be academic scientists, it might be expected that only one per cent of the apparatus manufactured for school science (in a country where manufacture must not be wasted because of its difficulty) would be of the conventional standard type. Suprisingly the opposite is usually found to be more nearly the case. Consequently the majority of the children are starved of relevant practical scientific experience. This grossly undemocratic practice comes about for three reasons: a policy of elitism (usually not expressed); a tradition from the days when science teaching was given only in superior secondary schools (or, in the case of a country newly undertaking science teaching, by accepting advice from people in whom that tradition was ingrained); or a belief that low level science needs no apparatus.

This review does not contain much primary school science apparatus made outside Europe and the USA because there is good justification for supposing that in the early primary school very little manufactured apparatus (apart from scissors, containers, string, rulers, and a balance) is needed. It is actually better for the pupils to make simple things with their own hands. Such a policy remains a good one for the later primary and early secondary school, but in a much smaller part. Children cannot make flash lamp bulbs, or reasonably good weighing devices, or the 'clip together' blocks they need for number theory. Ten stones or a handful of maize seeds are just not suitable.

BAD DESIGN FOR THE SITUATION

If there were a record of attempts to get suitable science teaching apparatus used in schools, it would show a great proportion of failure and waste of money. Only too often dusty piles of unused apparatus at the backs of cupboards, bills at the headquarters of an international organization, perhaps a bland report or two written near the end of a project - and untaught children - make up the only sad record.

Yet most science teaching equipment has been excellently made. It is strong; its joints work freely; everything fits together properly; it does not leak; it is well finished. In proper hands it can demonstrate exactly what it has been made to demonstrate. Usually it is wellnigh perfect except in one very important respect - it is not usable in the situation into which it has been put. It lies totally ineffective on a shelf. Nobody checked whether the teachers could and would use it, and it was found too late that they could not or would not. It is irresponsible on the part of the designer to blame the teachers for this. The designer of a dam must first study the site on which the dam is to be built. Should the dam fail, the designer cannot escape responsibility by asserting that the design was good but the earth on which it was built was not suitable. It is in this sense that the failure of a science apparatus project can be attributed to poor design. The reasons are usually clear and discoverable.

Much of the apparatus in this review is excellent in many ways, though it may not be well-designed in its most important aspect - its real suitability for the teacher, the children and the classroom situation in which it is to be used (see photographs 4 and 5). The primary job of the apparatus designer is therefore to watch the operation of some examples of his proposed apparatus in a genuinely average class, undisturbed by his presence. To find a person with the necessary empathy and ability for this task is not easy, but the ability to do such research is essential. The natural choice, particularly for a primary school, is probably a woman. She must also have good mechanical design ability or work with someone who has.

These paragraphs are intended as a warning against an easy misuse of this review.

CONVENTIONAL VERSUS NEW DESIGNS

Some apparatus makers see their job as reproducing conventional American or European items; for example, the commercial manufacturers in Ambala, India. They are supplying the needs of schools which work from essentially pre-1960 texts.

In the 1960s however, school texts and apparatus began to change rapidly in countries with sophisticated school science systems. The change came first in secondary then in primary schools. At the same time countries without much tradition for teaching science with apparatus were changing to new curricula. Sometimes these demanded new styles of apparatus. For instance, UNESCO helped initiate curricula in Africa which needed the English 'Nuffield' equipment. The Nuffield system needed complete class sets of items, but countries found they could not afford the apparatus, particularly if it was to be purchased with foreign currency. They therefore considered local construction of one sort or another - such as teachers' do-it-yourself construction, science centered protoytpe making, and teachers' college small-scale production units. (Full-scale local manufacture has been talked of in several conferences but rarely undertaken.) In most cases the aim seems to have been to copy existing items. The result has been massive wooden ticker-tape timers and bamboo test-tube racks - simple copies in local material of new-style and old-style items - in batches of 100 or less. That teachers in general have little time or ability to construct these things has been a major problem.

The Science Education programme for Africa has had a different method for primary school teaching. It uses common objects such as grass, bamboo, automobile tyres, and cooking pots which the children manipulate for themselves and do their own construction as part of the lessons (see photographs 16, 17, 18). This method needs its own special texts. Other projects, for example FUNBEC in Brazil, have created entirely newly-designed apparatus and their own system. They manufacture (and seem to be commercially successful with) some fifty pocket-sized packs of very simple experimental kits with small accompanying books and a larger text (see photograph 58).

Most school systems in the world work with conventional apparatus and do not envisage much change within the next ten years. Their need, presumably, is for such equipment. Most of those secondary schools that teach science with apparatus in Britain, Thailand and Colombia, for example, use types of equipment hardly different from that used in a German secondary school in 1900. By far the largest proportion of the science apparatus manufactured in the USA, India, or in the newly-started production unit in Burma, is of the ordinary, standard, old-fashioned kind. In great part, this is quite natural. Standard academic physics is the same the world over and, if this is to be taught in the secondary schools, the same apparatus will be suitable, more or less, even if it is a bit pedestrian to the eyes of a technologically highly-developed country. Computers, quick-fit apparatus and photographic microscopy are not inherently superior for teaching: the academic stream of the secondary school in a less technically advanced country is as well provided for with slide rules, test tubes and magnifiers.

DESIGNING VERSUS COPYING

There is ample evidence that many so-called designers are merely copyists who have opened another manufacturer's catalogue and made what they saw there. This can be futile. Many educational analysts believe that though the introduction of a piece of machinery or a new technique into an educational system may seem straightforward, it can have deep social, religious and political effects (through an inevitable process of contingent texts, training and other influences). Thus the British have introduced intellectual elitism with their school apparatus into some countries, and the Americans have introduced a questioning of parental and religious authority as a concomitant of their approach to science.

In most countries mechanics are social engineers, whether they know it or not. They should therefore beware of copying Japanese, European or Brazilian items without due thought. When any of the items in this review are being considered this warning should be borne in mind. They are presented here not for copying, but as an encouragement to designers to be inventive and to make their own modifications to meet the needs of the teachers and children with whom they are specially concerned.

CURRICULUM/APPARATUS LIAISON

Collaboration between curriculum designers and apparatus designers should be very close. A sequence of experiments which an apparatus designer may have discovered to be possible, given the manufacturing capabilities which he knows of, might well be a useful suggestion to incorporate in the curriculum. On the other hand, an activity which an apparatus designer knows cannot be instrumented in the given situation will have to be modified if the curriculum designer wants it to be done practically. There are numerous similar situations where collaboration is necessary. A much larger general question which has to be settled between the two designers is which experiments are for demonstration by the teacher and which are to be done by the pupils.

Most of the apparatus in this review would not fit most textbooks: one or the other would need to be modified, for the text and its pictures must be compatible with the apparatus. Cases have been known of apparatus being manufactured without the makers knowing what text or curriculum it was to be used with. Frequently, too, textbooks are written without the required apparatus being available. Poor planning of this kind is particularly apparent in countries where there is no wide and varied supply of apparatus and texts. And the children suffer.

THE NEED FOR SYSTEMATIC OVERALL PLANNING

Rather distant from the task of this booklet, seen as a review of apparatus, are two important aspects of apparatus production: organization, and financing.

Many production units are conceived without a clear policy, particularly if they are set up by an international bilateral organization. The danger is that a project proposal is made out in rather general terms and is funded without an analysis of the 'market' being undertaken. The market is the school system whose needs (by reference to curriculum and ministry policy) are presumably fairly easily assessable. No estimation of production flow, costing, permitted amortization of capital, and so on, is undertaken. It is unclear what the long-term operational problems are, who the imported machinery belongs to, and who is responsible for servicing. No analysis is undertaken of the whole system into which the production unit fits. Items for production are selected ad hoc, and often the organizations concerned do not know whether they are making prototypes, pilot batches or are mass producing. Consequently things are likely to go wrong, and when they do it is difficult to see what the error was and how to avoid it next time. There may even be no contingency plans to meet the present difficulty. The international organization may be hoping that the unit will eventually become self-supporting, while local government - perhaps by failing to provide counterpart staff to take over from foreign experts - may not be contributing to this aim. The ministry may, by mere lack of understanding, permit the unit to be elitist in its production (in the sense described earlier) in opposition to the government's educational policy. As a result of this lack of systematic planning, enterprises may founder altogether.

As far as the workers and advisers are concerned, the reasons are understandable and forgivable. It is less easy to forgive the higher echelons. Planning is their reason for existence.

A further moral for the use of this booklet is obvious. The ideas to be found here are often in the nature of single bright ideas. They are useless unless they enter as part of a system.

PROFIT-MAKING AND NON PROFIT-MAKING PRODUCTION UNITS

Some economists divide all human enterprises into a mere two categories: those which make profits and those which educate. It is necessary for any organization which wishes to get science equipment used in schools to decide in which category its intentions lie.

If a producing factory is set up in a country which permits private enterprise, and if that factory makes a real profit for the owners, there is a strong likelihood that it will continue to exist and to supply science apparatus. The managers are likely to respond to market demands quite sensitively since their income depends on it. If, however, the factory is an educational enterprise making a financial loss, its continued existence depends on an external budget. In this case its educational effectiveness depends on planning according to external criteria, such as researched needs of the classroom. The educational effectiveness can be zero as easily as can financial profit. The physical existence of a unit in these circumstances is assured as far into the future as the certainty of a budget. If the unit is small and the funds are directly from ministry of education sources, the certainty may be one year or less. This is particularly likely when the unit is isolated from some kind of mother-body, but if it is within, say, a teachers' college, it is likely to have a much longer lasting budget.

If the funds are from some other agency, the intention will usually be to get the unit going and then for the government to take it over (assuming it is a non-profit making unit). This has happened in Burma. Alternatively the unit may be set up to demonstrate possibilities, processes, costing, and so on, to local (small-scale) industry. The intention to make it really profitable is rare; though this is intended for the unit in Sri Lanka and it has actually occurred with FUNBEC in Brazil.

INTEGRATION OF THE UNIT INTO THE COUNTRY'S SYSTEM

The risk, of course, with any size of production unit is that it may absorb funds over a long period while having only a small or insignificant effect on actual classroom practice. It may have excellent ideas and produce some useful items but unless it is well-designed as part of the system into which it must fit - that is, into the educational set-up of the ministry, the social reality of the classroom, the commercial environment, and so on - its effect will almost certainly be merely local.

Any relatively modest enterprise intended to help to get apparatus into schools would therefore be well advised to avoid any risk of isolation from the system. Quite apart from what this means in terms of planning, it probably means that the effort should go into an existing institution, such as a teachers' college or a science or curriculum centre. There is also a good chance that this will decrease certain overhead and capital costs. Space and skill will be at premium but almost certainly there will be the access to valuable informal knowledge and existing channels through which to feed out information and apparatus. Isolation and fragmentation are likely to be ineffective.

SUITING THE APPARATUS TO THE CHILDREN

There are other considerations besides those of management, organization and item design. A major one is curriculum, and as the apparatus designers and curriculum designers are both parts of the design system, they should work closely together. In doing so they should be aware of the profound effect their work will have on the whole society. There is a big move, particularly among the younger engineers of Britain and the USA, towards social responsibility for the use and potential of the equipment they make. In an equipment production unit in a poor country there should be (and increasingly these days, there is) someone who understands the arguments presented in such publications as: 'Pedagogy of the Oppressed' by Paulo Freire (1); 'One Hundred Countries, Two Billion People' by Robert McNamara (2); 'The Wretched of the Earth' by Franz Fanon (3); 'Education in Rural Areas' (4); Charles Silberman's 'Crisis in the Classroom' (5); 'Modernizing Peasant Societies' by Guy Hunter (6); 'The Age of Discontinuity' by Peter F. Drucker (7); and the monthly 'New Internationalist' (8).

A review of much relevant literature up to 1969 is 'Preparation of the Child for Modernization' (9), a very helpful working paper constituting a report on a study by the UN Research Institute for Social Development. It gives brief comments on original papers (which it lists) concerning developing countries, children's problems, abilities, experiences, intellectual development, traditions, and so on, under various headings. All are of great interest to a school science apparatus designer, being such matters as: childhood experiences in technological and non-technological environments; living and learning; conditions of children; skills and intellectual requirements of modern technological activity; the use of tools by children in what it calls 'traditional' environments; two-dimensional representations of reality; absence of technical words in a traditional environment; scientific thinking and development; transfer of traditional physical capacities to modern tasks; formal and informal training of the pre-school child; the penalization of children's questions by parents; the use of toys and games and household objects for play, and so on. Much of the bibliography is on Africa. The review points out how little is really known and how little research has been done. More may be available now that a number of child development institutes have been established, such as the one initiated by UNESCO beside Prasarnmitr College in Bangkok.

An unusual and valuable book which demonstrates how clever children are if they are allowed to solve problems in their own way, particularly when adults sympathetically attempt to understand the elements of what the child - lacking appropriate terminology and wide experience - is trying to say, is: 'Children Solve Problems' (10).

(1) Pedagogy of the Oppressed (Freire)
published by Sheed and Ward Limited, 33 Maiden Lane, London W.C.2., England.

(2) One Hundred Countries, Two Billion People: Dimensions of Development (McNamara)
published by Praeger Publications, 111 Fourth Avenue, New York, N.Y.10003, USA.

(3) The Wretched of the Earth (Fanon)
published by Penguin Books, Harmondsworth, Middlesex, England.

(4) Education in Rural Areas: Report of the Commonwealth Conference on Education, Ghana 1970
published by the Commonwealth Secretariat, Marlborough House, Pall Mall, London SW1Y 5HX, England.

(5) Crisis in the Classroom (Silberman)
published by Random House, 201 E. 50th Street, New York, N.Y.10022, USA.

(6) Modernizing Peasant Societies: Comparative Study in Asia and Africa
published for the Institute of Race Relations by Oxford University Press, Ely House, 37 Dover Street, London W1X 4AH, England.

(7) The Age of Discontinuity (Drucker)
published by Heinemann Educational Books Limited, 48 Charles Street, London W1X 8AH, England.

(8) New Internationalist (monthly)
published by Research Publications Services Limited, Victoria Hall, Greenwich, London SE10 0RF, England.

(9) Preparation of the Child for Modernization (Mandl)
published by UNRISD, UN Palais des Nations, Geneva, Switzerland.

(10) Children Solve Problems (de Bono)
published by Penguin Education, Harmondsworth, Middlesex, England.

THE USE OF TOYS AND DOMESTIC OBJECTS

Something which teachers have always done to some extent is to use common objects and toys to illustrate scientific principles. Several apparatus projects throughout the world have used this principle too. It is possible to avoid special manufacture if there is an object already available within the country which can illustrate a concept, or replace a chemistry beaker, and so on. Indeed, it may be an educational advantage to use an object which the children recognize rather than a foreign-looking object remote from their experience. Cheap plastic roller skates may replace a special dynamics trolley; a local flute may serve as a source of sound much better than a tuning fork; even a mouse-trap may serve to teach several ideas about mechanics. Of course, these will need testing by children and by teachers as well as from the economic point of view.

For teaching a whole range of projectile mechanics, a toy in England called a 'flikball' - which flings a pierced ball off a stick - is remarkably versatile. Many electrical items are obtainable, as wholes or as parts, from quite small hardware stores, radio shops or garages. Examples are torch bulbs, rectifiers, and power supplies bought as battery charges. Bicycles are a prolific source of material for experiment. (Photographs 8 - 12 illustrate some of the things mentioned so far.) Objects of use in teaching may not only be found but modified, or assembled from parts, or wholly constructed. These processes may be undertaken by pupils or teachers, local craftsmen or a central manufacturing concern. The practical limits are set by local conditions.

Toys which exist in many cultures may be more suitable pedagogically, culturally and mechanically for helping children to understand science than specifically manufactured educational apparatus. For example, the Indian

NCERT primary science kit contains a large plastic wind direction indicator. This is expensive to make, occupies a lot of space in the small cabinet, points upwind which confuses the children, and, to make things even more difficult, has a base to stand on a table instead of a hand-grip to suggest its being held high outside. In fact it is unnecessary to have a specially constructed wind vane in India since children there commonly fly flags, pennants and kites, all of which indicate wind direction. Moreover, before launching a kite the young boy usually throws up some dust to see which way it drifts. From this he gets not only an indication of the wind direction but an estimation of wind speed as well.

Thus it will be wise for apparatus production units to investigate local toys and games so as to avoid unnecessary manufacture.

GAMES AS TEACHING APPARATUS

The difference between games and toys is that games are competitive and operate with symbols while toys represent real things for individual play. Although a number of games are claimed by their makers to be educational, few of them really teach much of significance. However, there are some good ones, and production units might like to consider them. Invicta Plastics (1) make several which teach elements of logic and mathematics. One which develops children's sense of strategy and gives much enjoyment is called 'Master Mind'. This is a simply manufactured device (pegs and peg board) and a model of what can be done. Of course, such games should not be copied too closely; all countries have their own idiom in games and this should be incorporated in the design of educational games if they are to work effectively (see photograph 15).

Nowadays, management training in industry makes use of games to simulate real situations. There is no reason why this should not be done in schools, though there is always a risk that it will make a subject theoretical instead of practical. It is of obvious use in non-formal education to teach about social matters and it is also applicable to subjects such as health, family planning, agriculture and similar topics which involve both science and social matters. A very interesting project which approaches this area is the 'Ecuador non-formal education project', being aided by the Centre of International Education, Massachusetts (2). Photographs 13 and 14 show a game-board and some cards from a Monopoly-like game from the project. The games are not manufactured but are made by those who want to use them; they are made to simulate the local situation about which participants want to learn.

(1) Invicta Plastics, Oadby, Leicester, England.

(2) Centre of International Education (School of Education), University of Massachusetts, Amherst, Massachusetts 01002, USA.

DESIGNING FOR THE TEACHERS' ABILITIES - TEACHERS' GUIDES

To help the teacher and the children to use apparatus, a guide of some sort is necessary. Most textbooks assume that the teacher can assemble and use equipment, although in fact most teachers cannot. Teachers' courses may endeavour to provide the necessary training but it is as hard for the average teacher to learn to handle science teaching apparatus satisfactorily as it is for the average person to learn to play the piano. If the apparatus designer discovers - and it is an important part of his job to research this aspect - that not more than half the teaching population will be able to use his proposed new apparatus in the next ten years, he must realistically plan for that fact.

Probably no one knows how much or how well a teacher will use a guide book. Common sense suggests that a small book is more likely to be read than a big one and that pictures are better than words. In many countries photographs are much more understandable than diagrams. Some examples of guide pages have been included to show some of the 'software' that apparatus makers put out with certain kits. It is certainly more the task of the apparatus designer than the textbook writer to describe the practical use of his apparatus. Often it is quite small matters which puzzle a teacher who is unpractised at handling physical apparatus and, naturally, any unusual aspects of design need explaining fully.

TAKING ACCOUNT OF AVAILABLE MATERIALS AND OF PREJUDICES

This review attempts to search out new ideas in methods of production. An important one to consider is the use of readily available materials for production wherever possible. For instance, the use of common mild steel stock sizes, half-inch iron piping, and so on, instead of special materials, will bring great advantages to the producer who must otherwise import stock or use skilled operators on expensive milling machines. Though this kind of designing is now common in industry, it is unfortunately less widespread among science teaching apparatus production units. Allied to it is the art of not over-specifying (for instance, on accuracy or surface finish).

A disadvantage of modifying an engineering specification to suit available machinery and skills is that it does tend to give the manufactured item an unusual, simple or even crude appearance. Though this may make an item less acceptable in the eyes of a country's educational officials and secondary school teachers, it rarely influences primary teachers and never affects their pupils. However, if prejudice exists it must be discovered and taken into account in designing the system.

KITS AND STORAGE BOXES

Much locally-produced apparatus is conceived as a kit to suit a curriculum. It is a ready-made collection for presentation to a teacher and often fits in with a text. Sometimes it is a collection of items for a particular teaching topic of very limited extent - such as a clip-together style of microscope or electric motor, or a little set of chemicals and test tubes together with a booklet for discovering pollution in streams. It may even comprise a whole set of items for several years' experiments or a complete primary science course (for teacher demonstration) in one box. Since teachers' storage problems need to be thought of, ideas for solutions are worth noting. There are not many solutions in this review.

SAFETY

Production units and others concerned with putting into schools apparatus with which teachers and children could have accidents, might consider their responsibility for providing suitable advice on accident prevention. Useful booklets are 'Safeguards in the School Laboratory' (1), and 'Safety in Science Laboratories' (2).

(1) Safeguards in the School Laboratory published for the Association for Science Education by John Murray Limited, 50 Albemarle Street, London W1X 4BD, England.

(2) Safety in Science Laboratories - DES Safety Series No. 2 published by H.M.S.O., Head Office, Atlantic House, Holborn Viaduct, London E.C.1., England.

WORKSHOP STAFF SELECTION

Selecting the right workers for the various jobs in a workshop is very important, and production units may find some of the publications of the International Labour Office of help to them in undertaking the task (1). A review of available tests (which might suggest some equivalent home-made versions to the selection staff at production units) is 'Personnel Selection and Training' by R. Goldstein of the ILO (2).

The trained science laboratory technician is invaluable in the school equipment production and development unit. The appropriate course of study for science laboratory technicians is the City and Guilds of London Institute Course 735 Parts 1, 2 and 3. Advice on the availability and training of such personnel can be obtained from the Institute of Science Technology (3).

(1) ILO Publications, Sales Service, 1211 Geneva 22, Switzerland.

(2) Personnel Selection and Training (Goldstein) a mimeographed book produced for the Jamaica National Industrial Vocational Training Programme (Kingston 1973), available through the Ministry of Labour and Employment, 112 East Street, Kingston, Jamaica, West Indies.

(3) Institute of Science Technology, 345 Grays Inn Road, London WC1X 8PX, England.

LOCAL REPAIR

Apparatus should obviously be designed in such a way that it can be kept in working order. For primary schools which are mainly located in country areas and shanty towns and which lack funds for apparatus and skill in repair any possible breakage needs to be replaceable or repairable locally. There is plenty of glib reference to local repair but little realization of what is implied - such as a hammer and wire job by an itinerant tinker (see photograph 5). It is the designer's job to discover the realities here as well as in the classroom.

INFORMATION NEEDED BY COMMERCIAL FIRMS

The initiative towards producing sets of items, or indeed individual items, to fit curriculum developments need not come only from government ministries or educational agencies. In many countries it will seem appropriate for production to be undertaken by private enterprise. Even if they are not themselves the originators, it seems essential that (where the form of government permits) commercial firms should eventually undertake production and marketing. If a product is viable, they will undertake it and thereby provide an assurance that production is likely to continue. For this reason potential manufacturing firms should have early access to as complete a range of information as they need for their planning - from clear help with teachers' apparatus guide publication to firm offtake numbers for items over the next few years. This is especially necessary with kits - and it is largely with kits, in one form or another, that most production units will be concerned.

This is an area in which the international organizations could and should help. To what extent, at present, do production units who are contracting for production with other firms, let those firms know what is to happen in the future, or try to draw them into the marketing procedures in any way? If this is not done, an international organization that conceives and nourishes a new enterprise will find itself holding a baby that should long ago have grown up.

UNWISE RETICENCE OF AID RECIPIENTS

External aid, through bilateral or multi-lateral arrangements, is, of course, often given to production units: for example, UN aid to Sri Lanka and Nigeria; German aid to RECSAM; Japanese aid to South Vietnam. Naturally the organizations receiving this aid are grateful. At times, perhaps, their gratitude disinclines them to make useful criticisms lest they be misconstrued. This may be compounded by a somewhat insensitive donating agency which, without having really taken the trouble to understand the real needs of the situation, assumes that what it gives is certain to be useful. It may accept unsuitable advice; it may tie its funds to purchases from the donor country; or it may for other reasons provide unsuitable items, production machines or other facilities. The outcome may be worse than a waste of effort: there is a real likelihood that the effect will be negative, concreting the enterprise into the wrong path.

To avoid this it may be necessary for the donating agency to use people of exceptional sensibility to research the local situation; it will certainly be essential carefully and sympathetically to encourage local educators, administrators and others to reveal their needs, hopes and doubts. In any situation this is not an easy thing to do. In much of Asia for instance, people's natural courtesy, reticence towards foreign experts, and gratitude for foreign interest and funds, can lead to the setting up of poorly-based projects. I have heard a senior UNESCO expert say in a large conference that UNESCO has too often found that its pilot projects have ended in failure because of lack of maturity in the necessary supportive services of the country involved. It is clear that this is an indication of badly-designed projects, yet the same kind of mistakes are still being made. Aid recipients can help by striving to eliminate unwise reticence so that aid from donating agencies is never wasted but channelled into well-designed and fruitful schemes.

A SUCCESSION OF ADVISERS

A problem allied to that of bad advice is too much varying advice coming from a succession of visiting or short-term advisers, resulting in the lack of a single coherent policy. It is not at all unusual for this year's adviser to denigrate the work of last year's adviser, set it aside, and start almost anew. The unfortunate ministry or other authority concerned can recognize the evil of this in general terms but can hardly see what to do about it since the man is paid by the agency funding the project. It looks ungrateful to criticize him for many reasons, not least because the agency has approved him - even though it failed to vet his intentions and ascertain whether they were concordant with previous policy. A further difficulty is that the ministry usually cannot be sure which adviser's policy is the right one - or it would not have needed an adviser in the first place. A study of some projects which have failed for these reasons, and of others which have been successful in spite of them, would be valuable. Such a critical analysis could help subsequent designs.

A very small project, which is reported as successful, is a CEDO (now British Council) laboratory/workshop at Prasarnmitr, the principal teacher training college in Thailand. This gives teachers-in-training experience in the use and construction of science teaching apparatus and originates some new designs. A senior adviser went out to look at the needs, and advised funding after a country-wide inspection of schools and colleges. A second adviser did a feasibility study showing specifically how the project would fit the system and how the system would integrate it and run it as the aid phased out. A third adviser, who was sympathetic with the intentions of the feasibility study, then ran the project for two years. The courses - now part of the college's system - are being run by local staff; the new apparatus and the tools are in full use; there is a store of apparatus made by successive courses; and the course is now also established at the sister college of Bangsaan, 45 miles away, and is likely to spread further. This small success story is worth critical analysis as suggested in the foregoing paragraph. There is a report - full of insights - in the now defunct British Council publication 'Educational Development International' for January, 1974.

PROPOSAL FOR AN INFORMATION AND PLANNING SERVICE

A potentially valuable service, which could be offered by an organization wishing to help a school system to initiate or improve its production of apparatus for schools, would be the provision of a wide range of information, with ideas for designers and administrators on how to make the most successful use of it. This might be run at two linked levels: one concentrating on the design of apparatus, the other on the design of systems. The information could be presented, perhaps in an existing journal, in the form of reports, critical analyses and sources. It would be accompanied by courses in the theory and practice of all that pertains to design at these two levels. The scope might thus extend from bright ideas about teaching chemistry with plastic bags to how to amortize capital; from large-scale production of toys in Turkey to a one-man production unit in Colombia. There is a great deal of information available on such matters and equally evident need for its propagation. No less is there a need for its analysis, followed by some practical use of the results; potential apparatus producers and users could be helped to benefit their own societies by searching out some of the reasons behind the various successes and failures.

Section 2 Current Developments

Africa

AFRICAN STATES

The Science Education Project in Africa (SEPA) which began life as the African Primary Science Project (APSP) uses common materials from home and surroundings with which to teach. There are some thirty teachers' guides with titles like 'Chicks in the Classroom', 'Common Substances Around the Home' and 'Playground Equipment'. This latter is a delightful example of the use of cheap equipment on a large scale. Bamboo, rope, car tyres and other objects, are used to construct towers, slides, swings, roundabouts, large balances and a giant shadow calendar. As the book says: 'Without too much trouble and very little expense, teachers can make playground equipment which will fascinate and excite their pupils... they will be experiencing with their whole bodies some of the important laws of science'. See photographs 16, 17, and 18.

These materials were developed in the USAID programme by a large number of people in the countries of Ghana, Kenya, Nigeria, Sierra Leone, Tanzania and Uganda, with assistance from the Education Development Centre, Massachusetts (1).

(1) Science Education Project in Africa (SEPA) details of available materials from the Education Development Centre, Newton, Massachusetts, USA.

BOTSWANA, LESOTHO AND SWAZILAND

These three countries are concerned in the experimental teaching of a New Junior Certificate Integrated Science Scheme which has considerably involved in-service teacher training. The Francistown Teachers' Training College, Botswana, is an example of an approach to teacher training whereby the teachers actually construct apparatus themselves. (There is a similar approach in the Nigerian situation.) Most of the developments are based on the University of Botswana, Lesotho and Swaziland, but as yet no concentrated effort in apparatus production exists.

KENYA

The Production Unit of the Kenya Science Teachers' College has designed, and is currently producing, some equipment. This is how it describes itself:

'The unit is a non-profit making body run by the Production Board of KSTC. The workshops are equipped with the most modern metal and wood working machinery. It is capable of producing almost any teaching aid required by Kenyan Schools.

'One of the main projects of the unit is to produce scientific equipment to relieve one of the many problems facing Kenyan schools. A physics kit has been developed and is produced. In the near future chemistry and biology kits will be developed. The annual turnout is expected to be about 1,000 kits. This capacity can be increased if the demand grows.

'Learning by doing is the motto of the scientists today and the kit gives just that possibility without high costs.

'The kit also gives an excellent opportunity for the students to train their manipulative skills. Until recently very few students in the country really got an experimental background in science subjects. The kit gives the teacher the opportunity of teaching science experimentally. By spending just a small amount of money the student will be able to perform most of the basic experiments in physics.

'The kit, although small, can be used as a demonstration kit as well. A manual is supplied with the kit to guarantee a good layout of the experiments.'

There is a pupil's text accompanying this equipment, some of which can be seen in the Curriculum Information Service (Education Information and Research Department) of the British Council, 10 Spring Gardens, London S.W.1.

NIGERIA

Considerable activity in curriculum development is going on in Nigeria, and alongside it is equipment development and improvement.

In 1970, the Federal Ministry of Education with the assistance of UNESCO established a Science Equipment Centre in Lagos. The function of the Centre was to provide facilities and expertise for the design and production of prototypes of school science equipment; the repair and maintenance of existing school science equipment; in-service training courses for primary and secondary school teachers and training courses for laboratory personnel;

and an advisory service in science teaching equipment. The aim was for the Centre to provide a service throughout the Federation, which consists of 12 educationally-autonomous States. To achieve this aim, a network of centres was planned which would be linked by Mobile Repair Units.

Components of the in-service training courses include woodwork, metalwork and glasswork, and participants construct apparatus themselves. It is not intended that teachers should be bulk producers of apparatus, but the activity is designed to boost the practical expertise of the teacher so that he may become more confident in his ability to experiment and more innovative in his science teaching.

Apparatus so far constructed by the Centre has been based on designs from the 'Guidebook to Constructing Inexpensive Science Teaching Equipment', Volumes 1, 2 and 3 (1) - see photograph 41. In addition, apparatus has been constructed for the Nigerian Secondary Science Project pilot schools, and also for the Primary Science Project based in Ahmadu Bello University, Zaria. The Centre workshops have been able to cater for 50-100 pieces of a particular item at one time and development of the workshops currently being undertaken should increase this capacity. The financing of the Centre is by the Federal Ministry of Education with UNDP/UNESCO assistance until 1976.

(1) Guidebook to Constructing Inexpensive Science Teaching Equipment
published by the Science Teaching Centre, University of Maryland, College Park, Maryland 20742, USA.

Asia

REGIONAL CENTRE - RECSAM, PENANG

RECSAM is the Regional Centre for Education in Science and Mathematics, in Penang, Malaysia. It is part of the South East Asian Ministries of Education Organization (SEAMEO). It serves Thailand, Malaysia, Philippines, Indonesia, Singapore, Laos, Khmer and South Vietnam. It runs conferences and three-month courses for teachers, introducing them to science and mathematics teaching methods. It receives multi-lateral and bilateral assistance; for example, the German Foundation for International Development (DSE) is probably about to equip a prototype development workshop there, and the British Council has funded some lecturers. Mr Khoo Tiang Lim, the science training officer, has originated a lot of the interesting science apparatus prototypes which are on display, and there is a wide-ranging stock of examples of science and mathematics apparatus from many modern projects. There is a proposal to set up the prototype workshop (with DSE funds) quite soon to design equipment for the SEAMEO countries which, it is hoped, will thus be helped and encouraged by this regional effort to set up their own national centres, or to improve them where they already exist.

8

Current developments

As in most such centres, the work is seen as involving engineering and educational effort, but without systematic analysis of either the varied classroom situations into which the apparatus must fit or of the administrative and commercial networks upon which its effective use will depend. This important aspect of the design of apparatus production is often neglected. RECSAM, however, does at times hold high-level conferences for administrators and involves administrators in its courses. The extent to which institutes of education in the universities of the region concern themselves with such analysis is uncertain, but no contribution from them seems to have reached any of the conferences on apparatus production.

Clearly there are specific and local examples of such planning with some Ministries of Education and with various projects (such as those of the UN organizations) which have undertaken educational development work involving school apparatus. It would be valuable to collect information on some of these initiatives, with a view to analysing it and making it available to the planners of production units. The Regional Centre for Educational Innovation and Technology (INNOTECH) is, in fact, already undertaking aspects of this at quite a high level in a long-term project. It holds courses for key educators. However, its work seems never to be referred to in the ground planning of actual apparatus production - plans which are rapidly becoming concrete in the region.

PRODUCTION CENTRES IN SOUTH EAST ASIA

THE UNIT IN BURMA

The following account, taken from a UN Newsheet, will help to set the Indian NCERT production unit (see pages 22 - 23) in context and provide an indication of the history and the hopes that people in the region have with regard to such enterprises. It consists of an interview with Soren Hakansson of UNESCO, Bangkok, the originator of and adviser to many of the apparatus production schemes in the region.

> 'This production unit is one of several in Asia which owe their existence to the example of a small industry set up in 1964 at the Rangoon Arts and Science University to make science equipment for education. All Asian nations have expressed a commitment to mass education and many have made remarkable progress towards achieving it. This commitment, coupled with the wish that the pupils should experiment for themselves in their science learning, has brought home to them the need for vast quantities of science teaching equipment. Production in Rangoon began in 1965 and has risen to the point where by 1972 about 200,000 Kyat-worth of such equipment per year was being turned over to the Director of Education. To have imported this would have cost the equivalent of about 460,000 Kyat. A very important point, of course, in all this is the saving of local currency, which in this case is a saving of nearly 100,000 US dollars. (One dollar is worth about 4.8 Kyat at the official exchange rate.) By 1972 the Rangoon workshop had 52 full-time technicians plus up to 100 temporary workers during summer vacations - physics and chemistry students from the University who volunteer their services for no pay. The items currently being produced cover nearly all those needed for high school physics and chemistry: balance, glassware, galvanometers, magnets,

prisms, calorimeters, tuning forks, lenses, hydrometers, etc.

'This project is mentioned in some detail here both because it was the first of its kind in the region and because its success and the consequent spread of the idea is a pointer to the future. It has been given help by the UN through the provision of UNESCO experts in equipment production and building planning and by the contribution of some 290,000 US dollars-worth of assistance by UNICEF. Under the Colombo Plan, Australia has contributed some 40,000 US dollars-worth of machinery and supplies.

'From its Burmese place of origin the idea of local manufacturing of science teaching equipment has spread outward to other countries of the region. Experts from UNESCO and other international organizations, much impressed during visits to the country, have carried the message. The idea has been repeatedly promoted at the regional science-teaching and school science equipment seminars, which UNESCO sponsors.

'The success of the project has overcome some of the doubts of surrounding countries as to whether they could find the trained personnel, the machinery and the facilities. The doubt, of course, remains as to whether such an enterprise could be instituted and continue as an ordinary commercial, self-financing (if not profit-making) enterprise. This seems very unlikely over an initial period of ten years. The financial input to the Rangoon workshop has been of the order of half-a-million US dollars while the apparatus produced has been of value about one quarter of a million US dollars. The funding agencies would have been able to provide twice as much equipment to the schools over this period if they had merely imported the items. This, of course, is invalid as adverse criticism on several counts.

'It is a primary task of international agencies to help countries to help themselves even though long periods elapse before countries can support the work themselves. It would, of course, seem natural that the shorter this period is the better, provided that the burden that the country thereby imposes on itself is acceptable. Further, aid of the type considered here is fully intended as a free initial provision, not part of a profit and loss transaction. Of great importance too is the model it provides for subsequent developments in other areas - and in this the Burmese project has been particularly fertile.

'Today one form or another of a school science equipment facility exists or is about to be established in Bangladesh, India, Indonesia, the Republic of Korea, Nepal, Pakistan, the Philippines, and Sri Lanka. In some, the Burmese pattern prevails, with the manufacturing of the school science equipment done at the facility itself. In other countries, with an established tradition of small-scale manufacturing - for example Bangladesh, India and Pakistan - the facility merely does the design work, producing pilot models suited to the needs of both student and serial production, with actual production being carried out by private industry.

'In Burma, the Science Workshop Superintendent U Chit Khiang says: "We expect to see annual production volume, as well as the number of employees, multiply by 4 or 5 times over the next four years. Right now we're producing science kits for high schools. But we intend soon to produce science kits for use in primary and middle schools. We're already testing the pilot kits."

'The ultimate aim is to manufacture all the science teaching equipment needed at primary level (for use by teachers) as well as all that required at middle and high school levels. The anticipated expansion includes broadened production facilities. To their present machinery for metal-working and glass-working the Workshop directorate expects to add machinery for plastics working - injection moulding, blow moulding and vacuum forming.

'Dr Maung Maung Kha, Rector of the Rangoon Arts and Science University says,: "The advantages of setting up our own plant for producing school science equipment go beyond just a saving of foreign exchange. We have provided new jobs. We now have trained technicians, we have acquired technical know-how. Moreover, the school science kits we produce are better suited to the needs of our own science courses, that we have ourselves developed, than foreign-produced kits."

'The chemistry kit built at the Workshop, which was designed by a professor at the Rangoon Arts and Science University, demonstrates the point. A semi-micro kit, it not only consumes one-tenth the quantity of chemicals required by normal-scale lab kits, but makes ingenious use of discarded materials - empty penicillin bottles, for example, serve perfectly as semi-micro reagent bottles.

'The Burmese project has also introduced another change into the region. Many of the countries of Asia have had no small precision industry at all. They do not have the technicians such industry needs. Good craftsmen they have, men who can turn out one beautifully-made item of a kind; but precision technicians, who can turn out 500 units exactly the same, exactly meeting blueprint specifications, and completely interchangeable - these have not been available.'

Soren Hakansson, the UNESCO consultant principally associated with the workshop in Rangoon said recently: 'I look ahead ten or twenty years. I see the Asian science teaching equipment industry largely taking care of the needs of the countries here; but I see more. Because a large part of the total cost of school science equipment is skilled labour, and labour is much cheaper here than it is in the developed countries, it is quite possible that in the future Asia will become an exporter of school science equipment to the West. Instead of just saving foreign exchange the industry will be earning it.'

INDIA

The National Council for Educational Research and Training (NCERT), New Delhi, India, is undertaking a very large scheme of curriculum reform, textbook production and apparatus manufacture.

Some of the apparatus has been designed by UNESCO experts. It takes the form of kits for primary and secondary level. The primary science kit is for an integrated study, though most of the materials are for physics. The secondary kits are at a series of levels in physics, mathematics, chemistry and biology. The NCERT workshops produced the early prototypes and Soren Hakansson of UNESCO drew the blueprints. UNICEF is supporting early stages of the production of primary kits, some 20,000 of which have been produced by local industry. (This is, of course, only a small proportion of the need: there are 500,000 primary schools in India.) In fact, it is rare for UNICEF to purchase locally - usually it is cheaper to purchase in Europe to an easily checked good quality. In this case, they must feel that, provided the schools use the apparatus effectively, the project will prove worthwhile. At present, UNICEF is responsible for seeking out manufacturers of the items, quality controlling them and getting them assembled into the kits. Photographs 19-25 show examples from the primary science kit, mostly prototypes. The quality is now higher though quality control is still a serious problem.

CEDO (now British Council) did a feasibility study in 1970/71 for UNICEF and reassured them about the project into which they are putting some millions of dollars for at least the pilot phase. The CEDO recommendations included the following points:

The NCERT should not be left high and dry for funds with a partially complete project - there is a moral obligation upon the Indian Government and UNICEF to help see it through.

The planned staffing and physical facilities of key institutions should be strictly enforced before apparatus is supplied.

The supply of modern syllabuses and instructional materials in training colleges is an urgent necessity.

The kits must go to all colleges which train elementary and middle school teachers.

The project must be widely and realistically spread within the States of India in a properly phased manner and the release of kits and materials must be dependent on the maintenance of a good standard of training.

Teacher re-training courses should be six weeks or at the worst, four. It is no use aiming to train only one teacher per school.

The project should be tried in careful steps for three years before general implementation is considered.

The States should be responsible for their own curriculum and should be prepared to vary the written materials as they translate them.

There must be a proper repair service for the school kits.

Supervisors have a very important role in getting the materials used.

The ministry must have an officer concerned exclusively with the project.

There should be improved communications between States, between the Ministry and States, and between NCERT and UNICEF and the States.

Current developments

The NCERT has itself written a great deal about all aspects of this project, from simple explanatory books to detailed reports. There are, of course, school texts, apparatus lists, teacher's guides, many of these in several versions and various State languages. Although it does not concern this present review booklet, the NCERT is working in all the school subjects and similar materials for these subjects are being created.

Some States in India have their own science development projects with apparatus and written materials. That of Bombay is perhaps the most developed of these.

COMMERCIAL INDIAN MANUFACTURE

A certain amount of school science apparatus is made commercially in India. There are small industries for this in Bombay; there is the Dynam Company in Bangalore, and over one hundred factories (some very small) in Ambala, between Delhi and Chardigarh. Some of these are highly-sophisticated, producing, for example, some good microscope series. Ambala produces much industrial scientific equipment. It has a consortium or chamber of manufacturers and a government standards certification establishment. The school science apparatus produced is the standard, sturdy, old-fashioned stuff.

These Indian commercial manufacturers might possibly benefit greatly from some good advice on how to suit their production to the new educational needs of their country, the region, and the rest of the world. They have adequate potential, the needs exist, and the government could encourage export in material ways - such as tax rebates on materials purchased abroad and subsequently exported as manufactured goods. In many cases the government will provide loans to industry. A parallel could be drawn here with Pakistan, which manufactures and exports to Europe surgical operating equipment to a high standard. The factory at Sialkot was, apparently, set up with German assistance, and the equipment bought by UNICEF. UNICEF and other international agencies would consider the purchase of science teaching apparatus from India if they could be assured of a commercially satisfactory supply. Naturally there are many economic factors, such as currency availability, to be considered in such export hopes. As yet, Indian production is still in a seller's market within the country and is hardly export-conscious.

Information on Indian manufacture exists in various trade directories produced in the country. Organizations such as the National Small Industries Corporation can provide surveys of potential manufacturers, production capacity, quality standards, prices inspection and distribution. Many countries have similar potential for obtaining such necessary information. India has some 30,000 large industries and 9.8 million smaller ones, excluding those concerned principally with agriculture, so the need for making explanatory surveys before embarking on a commercial or quasi-commercial venture is obvious. In most countries it is equally wise if not so obvious.

INDONESIA

Indonesia has some 14 million primary school pupils. The schools rarely have more than a blackboard, some chalk and a few textbooks. The teachers, if they do any science at all, teach it by rote, knowing little of the subject or of the new approaches to teaching. There is almost no science apparatus in the schools. There are other formidable problems. Indonesia's population of some 116 million is spread over three thousand islands, and probably some 30 million children have never attended school.

Now that events connected with the rise in oil prices have made Indonesia richer, it proposes to spend some millions of US dollars on school science equipment. This is already going ahead at the secondary level although there are at present few schools and teachers satisfactorily prepared for using the equipment. The teacher problem is much worse in the primary schools. Over the years Indonesia has received quite a lot of apparatus from international aid schemes, though educationists there have reported that much of it is unused by teachers because they lack the necessary preparation to handle sophisticated equipment. This sort of waste has been perpetrated in many countries and will occur again unless designers look realistically at the whole system of countries into which apparatus is to be introduced.

The curriculum in science is aligned with environmental needs between grades 4 and 6 (72 per cent of the working population are in agriculture), but the teaching has been very rigid. New curricula in mathematics and science are now in existence and about 60 million textbooks have been published to date, with aid from UNICEF and the Canadian government.

Some prototypes of apparatus and kits are designed at the Science Teaching Centre in Bandung. There is one small manufacturer of school apparatus in Indonesia and some expensive foreign apparatus is available.

KHMER

In the Khmer Republic, the Division of Pedagogic Services attempts the supply of apparatus on a small scale. Some courses in simple apparatus construction are available for teachers. There are no teachers' centres but UNICEF has equipped workshops with hand tools and they make some use of these. With the intention of making some apparatus locally, they have imported some prototypes (from Western catalogues). There have been meetings concerned with modifying and simplifying these prototypes but no one there is expert in the matter.

Khmer has sent a lot of trainees to RECSAM over the years. Some prototypes, based on RECSAM and UNESCO designs, have been designed by the Primary Inspectorate for schools in Phnom Penh. These prototypes are to be tried out in selected classes and, if they are satisfactory, pupils' books and teachers' guides will be prepared to guide their use.

Photograph 26 shows examples of papier mache bas-relief models and lino-cut printing blocks made in Khmer. This is about the limit of what is made at present. Priority of interest is in the use of local material, and during 1973 some thirty teachers had a six-month training course in its construction. The thirteen small workshops, set up originally by UNICEF for developing skills of primary school children, are currently being used to produce teaching items. The raw material used is what the children can bring in, plus that bought with what funds the Educational Development Committee can provide. The hope is that eventually all the primary schools of Phnom Penh can be supplied. In-service training of district supervisors and principals will be organized in order to pass on the new ideas. Then the principals will train their staff. This training concentration on key personnel is insisted upon. (See also the section on Vietnam.)

In the long term, Khmer realizes something much bigger is needed. There are some general plans, and some help from RECSAM and INNOTECH and other international and regional agencies is hoped for in developing them. There is a strong realization that their educational system is irrelevant to the needs of the country and that training methods are outmoded. Any improvements have happened only in Phnom Penh but they feel that improvement in rural schools is becoming a priority. The war has, of course, prevented this.

KOREA

There is a small amount of science teaching apparatus manufactured in the Republic of Korea by commercial firms. In addition, the Kyongpook Student Science Centre, Taegu, and Hoeingsung Teaching Materials Warehouse, Kangwon-do, produce small quantities. Some small-scale industry which once produced science teaching apparatus has now turned over to other products - but the capability to produce it must still exist. There is commercial production of scientific equipment - such as ovens, thermometers, balances - not specifically intended for schools but usable by them.

Mr Hakansson, who prepared a report on design and production of school science equipment in Korea (UNESCO Regional Office for Education in Asia, Bangkok, August 1972), states that although there was a fair amount of apparatus in schools and colleges, much of it was traditional and not designed for the present curriculum and student use. The equipment in most of the colleges was supplied through UNICEF assistance.

There is a proposal to set up a School Science Equipment Centre to design for mass production, and this may well by now have made some progress. Details of this proposal are fully set out in Mr Hakansson's report.

LAOS

Laos trains its teachers, to some extent, to make science apparatus with local materials, and an in service training course on this, run by Dr Ponniah of RECSAM, took place in July 1973. The Laotian schools have few materials - particularly at primary level - and, of course, the country is terribly war-wracked. Most innovation is introduced through inspectoral visits to schools. The inspectors demand much initiative from the teachers, particularly in such matters as using local material, and assert that teachers can and will make things for themselves.

The Directorate of Materials and Educational Productions produces some very simple materials. The Ministry of Education has created the National Pedagogic Centre, within which the Department of Pedagogic Materials will produce materials for primary schools throughout the country.

They express the need for some short-term consultants in the development of science teaching material. They also wish to duplicate in large quantities some suitable materials developed by RECSAM. Thus here, as in most countries of the area, there is a need for help to set up a national science/mathematics workshop and get advisers to train counterparts. As with many other countries in a like situation in the area, their need would attract funds if an adviser would help them prepare and submit a project proposal.

MALAYSIA

Malaysia already manufactures more than half its secondary school needs for science teaching apparatus. It has recently instituted new curricula at this level. The Curriculum Development Centre in Kuala Lumpur is re-designing equipment for the teaching of integrated science in the classroom (as opposed to apparatus which needs to be used in laboratory rooms). Presumably it is hoped this will then be produced by local manufacturers, since there will be a large market.

Primary curricula remain as they were. Apparatus is being developed at the Centre to suit these curricula - apparatus prototypes for local component manufacture. These components will be assembled in schools.

A few items in course of development at the Curriculum Centre are shown in photograph 27. The full work on apparatus development will begin in 1975 when a permanent building is put up. This will:

Develop prototype equipment of physics, chemistry, biology and social science, for pre-school, primary and lower secondary level, for pupil use and teacher demonstration.

Investigate the use of local materials.

Give technical know-how to local manufacturers (in die and mould-making, for instance) and educational/curriculum advice.

Lend its machine facilities to other Ministry of Education departments - ETV, for example.

Effect quality control on manufacturers, vet samples and advise on the suitability of tenders.

On rare occasions, actually manufacture.

Exhibit.

Malaysia does not expect its teachers to improvise the necessary apparatus for teaching; there are too many difficulties. In any case, school science equipment manufacture is now a fast-developing local industry. Plenty of commercial production facilities exist, much of it in small workshop/cottage industry form, given to a single type of product - such as thermo-plastic articles. These are often in the nature of family affairs, often with rather crude machinery and ill-paid workers, but well-suited to science apparatus manufacture. There is also a rapidly-expanding sophisticated industry: this can be seen in the industrial estate beside Penang airport.

Malaysia would provide a very informative case-study for anyone wanting to examine how school science apparatus production is being successfully pursued. The Ministry of Education is obviously both keen and effective in getting the process going. RECSAM has provided advice and training, and the materials are available in the country. CEDO (British Council) has provided consultants for the new curricula and textbooks.

NEPAL

A Science Equipment Centre has been established in Kathmandu. It was initially set up as a distribution centre for imported school science equipment. Plans are now in hand for the Centre to be used to develop and produce equipment locally, alongside the development of curricula being carried out by the Curriculum Development Centre.

PAKISTAN

There has been for some time an Educational Equipment Centre in Lahore. This Centre has been attempting to construct apparatus suitable to local needs: generally such items have been copies of traditional apparatus. Plans exist to improve the facilities and activities of this Centre.

PAPUA NEW GUINEA

An example of an 'integrated science' primary school course which uses a mixture of standard and local resource material is the Papua New Guinea Primary Science project (1). It is an easy one for other projects to study because its 200 or so work-cards - produced in three handbooks for teachers - each carry a photograph of the materials being used. An example is shown in photograph 30.

UNICEF originally supplied the standard apparatus, consisting of sixteen types of item for the pupils to use and about two dozen types of item with which the teacher can demonstrate. The Education Department supplied some sixteen types of common or domestic item, available locally. Each kit caters for forty pupils and is housed in a lockable cabinet with pull-out trays. In addition, children collect and bring in materials from home and their surroundings. Thus there are similarities with the African Primary Science Programme but the PNG project has a more defined set of experiments and uses some school science apparatus of a standard type.

(1) Papua New Guinea Primary Science
published by the Jacaranda Press, Elizabeth Street, Brisbane, Australia.

THE PHILIPPINES

The Philippines school system is very active in curriculum development. In addition to the work of the Department of Education and Culture, the University of the Philippines, through its Science Education Centre, has produced curriculum guides, teachers' guides and pupils' texts, some still in a pilot stage and some in commercial publication.

There are private and public schools. Despite efforts by the Department and foreign and UN agencies, the problem of supplying science materials to the 38,000 primary and intermediate schools is almost insurmountable. Standard items of equipment are available locally (imported) at very high prices which means that only the richer schools can acquire them. Most other apparatus is of a home-made sort purchased out of petty cash or the teacher's own pocket. There are courses on the use of inexpensive apparatus or kits provided by international agencies. Teachers organize workshop courses based on the construction of UNESCO Source Book items. Some private technical schools make a small amount of apparatus but this cannot be widely spread and is little known about. One or two equipment firms have opened up in the last few years and some importers have begun manufacture to new curriculum specifications but the output is small at present.

UNESCO has done a study of science equipment in Philippine schools with a view to getting a pilot production unit in operation. Essentially, this unit would make prototypes and pursue their manufacture far enough to demonstrate to local industry the viability, costing, and technical processes involved; and, hopefully, convince local industry to undertake manufacture.

The UNESCO report itself is 'UNESCO-UNDP Feasibility Study on the Production of School Science Equipment in the Philippines' by Crunden, Hakansson and Crellin. (Manila, July 1972. Published, internal document, at Bangkok by UNESCO. BK/72/D291-200.) This very thorough study brings out many of the problems and possibilities faced by a school science apparatus production unit.

SINGAPORE

Singapore schools are relatively rich and there are few major problems in getting apparatus into the schools. The curricula are changing, however, so new apparatus has to be obtained. At present apparatus is bought locally from firms which either manufacture or import the items. Quasi-governmental industrial agencies have helped in the design and production of science apparatus for sale to schools.

SRI LANKA

Sri Lanka has a production unit at Pattalagedera, Veyangoda, set up and equipped with help from UNESCO and UNICEF. Unlike most production units, there is a proposal to mass-produce there. (Most other units are prototype makers; or they make small batches; or they set out to demonstrate possibilities and costings to encourage local industry to undertake production.) To this end, it is getting mass-production machines such as turret lathes, a foundry, and a glass-blowing unit. Mr Hakansson visited the unit in early 1974; there is a report (internal document with restricted circulation, UNESCO, Bangkok 1974, BKS/74/D/219-25). CEDO (now British Council) was earlier involved in this unit and has documentation on various aspects.

THAILAND

In Thailand, elementary schools desperately lack teachers capable of teaching any science. There is a general teacher shortage and many teachers have to do a second job in the evening to earn a living wage. Textbooks are, on the whole, unsatisfactory; some are very poor. Most elementary schools in Thailand are totally devoid of any sort of teaching material for science, or indeed other subjects.

A number of Elementary Science Supervisors have prepared some teachers' manuals, supplementary books, experiment books, and lists of apparatus, to help develop science education. Some of the supervisors have been to RECSAM for courses over the last three years, and since their return have been writing work-sheets in conjunction with a Ford Foundation research project. One supervisor has designed a sample science kit - photograph 29 - with the hope of getting it replicated and distributed to elementary schools. However, its cost is around 65 US dollars, and it therefore reflects rather badly on the realism of this and other supervisors' projects.

The Department of General Education run short courses for supervisors on modernizing elementary education which include apparatus use and improvization. UNICEF has started planning an elementary science centre in Phyathai School, Bangkok (a library, laboratory and workshop) to be equipped with apparatus, audio-visual aids and workshop tools.

In a very well-endowed programme for the improvement of secondary science teaching, the Institute for the Promotion of Teaching Science and Technology (a Thai government and UNDP project) in Bangkok designs and makes prototype and small-scale production runs of apparatus for its newly-designed curricula. Examples are shown in photographs 28 and 31. It expects to work on primary level equipment later. It has a fine display of this equipment - for mathematics, chemistry, physics and biology - in its huge new building behind the UNESCO office. The British Council Curriculum Information Service (Education Information and Research Department, 10 Spring Gardens, London S.W.1.) has a few of the materials and also some of the books of specifications and photographs of the IPTST apparatus.

Prior to the full IPTST programme, Keith Warren and Lars Rudstrom (UNESCO) designed some apparatus at Bangkok, largely for the training of technicians (see photograph 32). One of those technicians remains with the IPTST; the other two, attracted by wealthier employment, have left. This is a frequent problem: nationals in many countries may be paid only at national civil service rates if in a government project. The result is that once they are trained they realize they have a high market value and leave for industry.

The UNESCO Pilot Project for Chemistry Teaching in Asia 1964-1970, took place in Bangkok. It was a high-level chemistry project using high-level techniques and was mostly in English. A bland evaluation was prepared in January 1972 by UNESCO, Paris (SC/WS/505). In contrast, the IPTST has looked for locally-available chemicals and materials and has to some extent aligned its syllabus on these.

VIETNAM

The Republic of Vietnam has no spare space in its classrooms so there is little chance of science materials being used for years to come - at primary level, at least. Teachers use some flash-cards and wall-charts, locally produced by silk-screen printing, but with sixty or seventy pupils per class - and sometimes three such classes in one room - there is no other possibility in the public schools. Private schools have around 100 pupils per class.

In a recent conference, the Vietnamese delegate officially reported his country's difficulties in terms such as 'How can we get an overhead projector easily?' 'How can we buy a video recorder without tax?' Meanwhile, the morning's newspaper (which the conference delegates had just read) carried pathetic pictures of children taking home-made desks along to sit on the beach near Quang Tri. Formal reports at international conferences often do not show the truth, and this in no way helps donors to hit the right level of international aid. The USAID programme has supplied Vietnam with one hundred movie projectors: the Overseas Technical Agency of Japan has given projectors and video-tape recorders to set up an audio-visual centre. Yet, in most Vietnamese schools there is no electricity; only a few of the largest schools have a laboratory; and there are no repair facilities except in the central workshop in Saigon (Ho Chi Minh City).

There are divisional, provincial and regional centres through which apparatus innovation could be introduced - at present these are largely supervisory. In a conference in Penang in 1973, an officer remarked that in ex-French colonies no teacher would dare to introduce new ideas that were not first suggested by the inspectorate. This is therefore an organizational matter. Its positive side was also asserted; if an inspector passes on some new ideas and says that he will later check and see whether they have been implemented, they will be taken up. The officer asserted that RECSAM should 'go and thump the table and get this done'.

Latin America

BRAZIL

The UNESCO Pilot Project on the Teaching of Physics operated in Sao Paulo, Brazil from 1963-1964 at the Instituto Brasiliero de Educacao, Ciencia e Cultura (IBECC). It was conceived as being for the whole of Latin

America (as was the Chemistry Project in Bangkok for Asia, and the Biology Project for Africa).

The project limited itself to the topic of Light. The team was made up of three UNESCO experts, three consultants, and twenty-six teachers from universities and pedagogical institutes in eight Latin American countries. They developed, and physically made, 200 lots of eight kits. One of these is shown diagramatically in photograph 33. These experimental kits were accompanied by 50 hours of student instruction in mimeographed programmed-learning texts in Spanish and Portuguese. The team also produced twelve short silent (single-concept) 8mm. films, and prepared a 30 minute sound film and eight television programmes. This _tour de force_ took only one year.

The materials are still available (commercially, it is thought) and are probably now at least partly translated into English. Further details can be had from Dr Nahum Joel (who was assistant director of the project), UNESCO, Paris. The project is also described in a UNESCO booklet (reference SC/WS/160).

The FUNBEC kits, which have already been mentioned on pages 5 - 6 and which will be mentioned again on pages 43 and 44, are also of importance in Brazilian and Latin American context.

COSTA RICA

Apparatus for local construction has been designed in Costa Rica by the Programa Conjunto Gobierno-UNESCO-UNICEF, under the Ministry of Public Education, San Jose. Detailed drawings have been produced and some prototypes made, using wood, tinplate and metal strip. A few of these items are shown in photograph 36. Blueprints are shown in photographs 34 and 35. It was hoped that local workshops would be able to undertake the production but there was some doubt about the commercial viability of the enterprise, but this information is only up to 1972. At that stage, they were considering using instead the low-cost Japanese mini-science plastic kits.

Other Countries

ISRAEL

The Curriculum Centre of the Ministry of Education and Culture in Jerusalem, Israel, has created a non-vocational curriculum for a modern approach to agriculture and rural science. They have produced apparatus kits, books, work-sheets, blueprints for 'land laboratories' and so on. There is a general description of the project in a Ministry publication in English: 'Let's Grow Plants' (Ministry of Education and Culture, Jerusalem, 1971).

In Israel, a commercial firm, Or and Kol (1), produces science teaching apparatus of a simple, modern kind - some of which may be to Soren Hakansson's designs. It is mainly applicable to secondary level and most of it is for physics. Some samples are shown in photographs 37 and 38. The firm, which is half government owned, planned the apparatus partly under the sponsorship of UNESCO. The simplicity of form (and presumably the consequent relatively lower cost) of many of the items is a pleasing contrast with much of the commercial apparatus available elsewhere.

(1) Or and Kol, Israeli Corporation for Educational Materials Limited, 40 Eben Gvirel Street, Tel-Aviv, Israel.

TURKEY

The Ministry of Technical Education established, some eighteen years ago, a Trade School to construct apparatus and equipment for the school system. This 'Trade School' employs some 1,400 people, and produces approximately 80% of the country's educational equipment needs.

Approximately five years ago an Audio-Visual Aids Unit was separately established to meet the educational requirements in this field.

Section 3 Sources of Reference

DESIGNS, DRAWINGS AND SPECIFICATIONS OF APPARATUS

A source for specifications, descriptions, suggestions and names of English manufacturers of primary level mathematics apparatus is 'Mathematics Apparatus for Primary Schools' (1). This also gives guidance on the use of the items. A similar source for primary science is 'Science for Primary Schools Part 4 - Materials and Equipment' (2). Guidance on this material is given in Part 1 in the same series and sources of 'software' are listed in Parts 2 and 3.

For designs of modern apparatus for teaching secondary level science, a good source is 'Nuffield Secondary Science - Apparatus Guide' (3). This contains 120 pages of very clear line drawings in accurate plan or isometric projection showing important dimensions, with descriptive notes beside each of them. Another section of the book gives guidance on where it all fits into the Nuffield Secondary Science curriculum with further notes on design, quantities needed, etc. A typical drawing is shown as photograph 39.

Some texts are good sources of designs. One with a lot of new ideas is 'Physics is Fun' by J. Jardine (4). Another, with peg-board mounting apparatus is 'Introductory Physical Science: Laboratory Equipment and Apparatus' (5).

Blueprints and dimensional engineering drawings have already been mentioned as produced by several production units. The largest series of these (outside the presumably unavailable designs of US, European and Japanese firms) is that of the NCERT, India. They have produced five large folders of 'Specifications and Manufacturing Drawings': Primary Science, Chemistry for middle stage, Biology for middle stage, and two Physics kits. (There may now be more.) An example is shown as photograph 25.

(1) Mathematics Apparatus for Primary Schools (Howson) published for CEDO (now British Council) by Heinemann Educational Books Limited, 48 Charles Street, London W1X 8AH, England.

(2) Science for Primary Schools Part 4 - Materials and Equipment published for the Association for Science Education by John Murray, 50 Albemarle Street, London W1X 4BD, England.

(3) Nuffield Secondary Science - Apparatus Guide
published by Longman Group Limited, Burnt Mill, Harlow, Essex, England.

(4) Physics is Fun series by J. Jardine
published by Heinemann Educational Books Limited, 48 Charles Street, London W1X 8AH, England.

(5) Introductory Physical Science: Laboratory Equipment and Apparatus
published by Prentice Hall Incorporated, Englewood Cliffs, New Jersey 07632, USA.

APPARATUS ASSESSMENT AND CRITIQUE

An important source of critiques of schools science apparatus along with much associated information of a helpful and practical kind is in the monthly bulletins of the Scottish School Science Equipment Research Centre (1). These have been produced since 1966 and the back copies constitute a mine of information.

(1) School Science Equipment Centre, 103 Broughton Street, Edinburgh EH1 3RZ, Scotland.

POTENTIALLY USEFUL BOOKS

Conferences, other than some of those arranged by INNOTECH, rarely look at the needs and problems of educational aid production as a system or part of a system - at least not in an analytical and realistic way. There are, however, books which do this, and although some of them are oblique to the purpose of this review, they throw light on pertinent but neglected aspects of the design and provision of school teaching aids.

The principles of designing any kind of equipment for satisfactory use by human beings are covered in 'Ergonomics' by K. F. H. Murrell (1). Although this is nominally about man in his working environment, much of it can be transferred with a little imagination to children working with apparatus at school. This study not only concerns itself with a worker handling a piece of equipment but with the design of working environments to encourage motivation, good working attitudes, and so on. It is enlightening because it reveals that many problems in school parallel those in industry. Though many of the problems have been solved or partially solved in industry little thought seems to have been given to applying these analyses and techniques to schools, whose problems grow daily.

An introductory book about which much of the foregoing also applies is 'Organization Theory' edited by D. S. Pugh (2). Again, although concerned with industrial organization, its approach suggests powerful techniques for helping children to work in school. It covers many basic considerations that apply to designing an organization for introducing teaching apparatus into schools. It is sad that errors long ago recognized and corrected in industrial management organization, and recounted as history in this book, are still current in the administration of many of the projects described in this review.

Sources of reference

Very relevant and specific to such problems is 'The Emerging Dimensions of Indian Management' (3) by Professor A. N. Agarwala of the University of Allahabad, especially the chapter 'The Management of Small Businesses in India'. One paragraph in particular makes a point which production units with foreign advisers should consider seriously: as many small Indian businesses are badly managed, is it not part of the duty of production unit designers, who in some way or another make use of such local businesses, to help to educate them effectively in the techniques of good management? If a school equipment production unit, aided by foreign funds and having valuable expertise, merely makes use of cottage industries and the like for its main purpose (however valuable) but fails to aid their management (which it often could do relatively easily) it lays itself open to the same charge. Moreover, this is truly short-sighted, for its main purpose will not be served if the small industries on which the continuance of the project will depend, remain inefficient or go out of business. The disappearance rate in India is high but the principle applies to all countries. Professor Agarwala says:

> 'It is, therefore, important to determine the specific methods in which the management of small and tiny business units of various categories can be improved, and to make constructive endeavours to get these methods inserted into their working practices. India has not had time or resources to do much in this direction. It has nevertheless made, and is making, some efforts, though they are frankly of a casual or coincidental nature. Even in the case of small-scale industries, which are the proud and much-courted queens of this kingdom, such consideration as is given to management aspects is often a by-product of the thought devoted to administrative, technological or some other type of problems. Questions like the following have to be directly faced and answered: How can a small-scale industrial entrepreneur manage his enterprise better? How can the village artisan or urban handicrafts-man manage his cottage unit more satisfactorily? How can a small money-lender or road-transportation operator manage his affairs more efficiently? In all such cases, the immediate criterion of efficiency will have to be the profit made from the business pursuit. Answers to such questions can only be given after careful case studies, empirical surveys, a priori deductions, discriminatory consultancy projects, and trans-disciplinary researches, in which respect foreign experiences and research techniques should be most useful.'

Thus a school science apparatus production unit is, or should be, more deeply concerned in the wider educational processes of the country than it may, at first sight, realize.

(1) Ergonomics: Man in his Working Environment (Murrell) published by Chapman and Hall Limited, 11 New Fetter Lane, London EC4P 4EE, England.

(2) Organization Theory (editor Pugh) published by Penguin Books Limited, Harmondsworth, Middlesex, England.

(3) The Emerging Dimensions of Indian Management published by Asia Publishing House, 447 Strand, London WC2R 0QU, England.

REFERENCE BOOKS ON THE USE OF SIMPLE APPARATUS

There are many books which describe the use of common objects for teaching science. The classic is the original UNESCO 'Source Book for Science Teaching' (1). (The new version uses less common material and is at a rather higher level of sophistication. See photograph 40.) Such books usually include a lot of apparatus for teachers to construct for themselves. From such sources, production units can get innumerable ideas. The best such construction book series is the 'Guidebook to Constructing Inexpensive Science Teaching Equipment' (2), with separate volumes for chemistry, physics and biology. Photograph 41 shows a page from this. UNICEF's apparatus catalogue (Guide List EVE Science Revision (3)) includes a resource materials kit (photograph 42) to help teachers do such construction.

Other similar books are: 'Making Elementary Science Apparatus' (4); 'Experiments with Heat' (5) and others in the mimeographed series by the Don Bosco technical school in the Philippines; a series of leaflets from the Dryad Press on techniques such as 'Making Papier Mache' (6); the cyclostyled 'Elementary Economic Experiments in Physics' (7), which contains dimensioned line drawings for secondary level modern science apparatus; books from the 'Science 5/13' project in England, such as 'Working with Wood' (8); the Nuffield Junior Science Book on 'Apparatus' (9); the 'Elementary Science Study Series' (10), shown in photographs 44 and 47; books from the project on Elementary School Mathematics and Science of the University of Illinois, such as 'A Conglomeration of Gadgets and Gizmos' (11).

Some other useful sources are: 'The Book of Experiments' (12) by Leonard de Vries and 'After-dinner Science' (13) by K. M. Swezey - these both use domestic items for science demonstration; the 'Junior Science Source Book' (14); the publications of Project Technology, which describe constructions and children's investigations of them, mainly at secondary level, such as 'School Technology Volume 1' (15). Both the old 'Demonstration Experiments in Physics', which may be difficult to obtain, and its huge recent two volume replacement 'Teaching Science with Everyday Things' (16) by Schmidt and Rockcastle, are valuable.

Some textbooks and teachers' guide books for older or new science courses are full of ideas for apparatus. In biology: 'Simple Experiments in Biology' (17) by C. Bibby; in chemistry: 'Gas Syringe Experiments' (18) by M. Rogers; and in integrated science: 'Teaching Science to the Ordinary Pupil' (19) by Laybourn and Bailey. The new English and US curriculum books in science also have useful ideas on new apparatus.

More unusual sources for designers looking for simple ideas, particularly those appropriate to situations needing low-level technology, are the hippie manuals for communes and the books which have grown from the simplified-life movement: 'The Foxfire Book' (20); 'The Last Complete Whole Earth Catalogue' (21); the 'Survival Scrapbook' (22) volumes on Tools and Energy - volume 3, 'Access to Tools', is particularly good for a design workshop. There are many books of similar intent; a good collection may be seen in the library of the Intermediate Technology Development Group, 9 King Street, London W.C.2., whose own books and pamphlets are likely to be valuable both for ideas for items and for their background philosophy of design.

Sources of reference

Books for home experiments by children sometimes provide model approaches which would be of interest to production unit designers and curriculum writers. Sometimes they also contain ideas for making or improvizing simple apparatus. The recently published 'Technicians Manuals' associated with the Schools Council Integrated Science Project 'Patterns' (23) scheme, provide a guide for the laboratory technician on what apparatus is required and what can be made. A very useful small book on apparatus storage in schools is 'Storage of Apparatus' by O. M. Stepan (24).

(1) Source Book for Science Teaching
published by UNESCO, 7 place de Fontenoy, 75700 Paris, France.

(2) Guidebook to Constructing Inexpensive Science Teaching Equipment
prepared by the Science Teaching Centre, University of Maryland, College Park, Maryland 20742, USA.

(3) EVE Science Revision
published by UNICEF, 866 United Nations Plaza, New York, N.Y. 10017, USA.

(4) Making Elementary Science Apparatus (Bowker and Hunt)
published by Thomas Nelson and Sons Limited, 36 Park Street, London W1Y 4DE, England.

(5) Experiments with Heat
series prepared and mimeographed by the Don Bosco Technical School, Philippines.

(6) Making Papier-Mâché
series published by the Dryad Press Limited, Northgates, Leicester, England.

(7) Elementary Economic Experiments in Physics (Melton)
available from the British Council, E.P.D., 10 Spring Gardens, London SW1A 2BN, England.

(8) Working with Wood
published by Macdonald Educational Limited, St Giles House, 49-50 Poland Street, London W1A 2LG, England.

(9) Nuffield Junior Science - Apparatus
published by Wm. Collins Limited, 144 Cathedral Street, Glasgow G4 0NB, Scotland.

(10) Elementary Science Study Series
published by McGraw Hill, 1221 Avenue of the Americas, New York, N.Y. 10036, USA.

(11) Project on Elementary School Mathematics and Science
available from Booker T. Washington School, 606 East Grove Street, Champaign, Illinois 61820, USA.

(12) The Book of Experiments (de Vries)
published by John Murray Limited, 50 Albemarle Street, London W1X 4BD, England.

(13) After-dinner Science (Swezey)
published by Kaye and Ward Limited, 21 New Street, London EC2M 4NT, England.

(14) Junior Science Source Book (Wastnedge)
published by Wm. Collins Limited, 144 Cathedral Street, Glasgow G4 0NB, Scotland.

(15) School Technology Volume 1
published by English Universities Press Limited, St Paul's House, Warwick Lane, London EC4P 4AH, England.

(16) Demonstration Experiments in Physics (Sutton) and Teaching Science with Everyday Things (Schmidt and Rockcastle)
published by McGraw Hill, 1221 Avenue of the Americas, New York, N.Y. 10036, USA.

(17) Simple Experiments in Biology (Bibby) and

(18) Gas Syringe Experiments (Rogers, Martin)
both published by Heinemann Educational Books Limited, 48 Charles Street, London W1X 8AH, England.

(19) Teaching Science to the Ordinary Pupil (Laybourn and Bailey)
published by the University of London Press Limited, St Paul's House, Warwick Lane, London EC4P 4AH, England.

(20) The Foxfire Book
published by Doubleday and Company Incorporated, Garden City, New York 11530, USA.

(21) The Last Complete Whole Earth Catalogue
published by Penguin Books Limited, Harmondsworth, Middlesex, England.

(22) Survival Scrapbook (Szczelkun)
published by the Unicorn Bookshop, Brighton, Sussex, England.

(23) Patterns Technicians' Manuals
published by the Longman Group, Burnt Mill, Harlow, Essex, England.

(24) Storage of Apparatus (Stepan)
published by the Association for Science Education, College Lane, Hatfield, Hertfordshire, England.

WIDE-RANGE REFERENCE BOOKS

There are, of course, many written sources of information about apparatus production. A world-wide listing of almost everything that is going on is: 'Report of the Clearing-house on Science and Mathematics Curricular Developments' (free to interested institutions from the Science Teaching Centre, University of Maryland, College Park, Maryland 20742, USA). This centre in Maryland contains most of the materials and many examples of apparatus from the projects listed. There is a great deal of information in the Briefing Room, Divison of Pre-University Science and Technology Education, UNESCO, Paris and in the libraries of UNESCO major field offices. The British Council has a display area at its Curriculum Information Service (Education, Information and Research Department, 10 Spring Gardens, London S.W.1.) where a wide range of apparatus and materials from projects all over the world can be seen. It has, for example, many of the NCERT Indian kits. The British Council's 'Science Education Newsletter' (free to overseas institutions from local British Council offices) lists and describes world-wide educational projects, including apparatus production information.

An excellent critical review and appraisal of the provision of teaching equipment to schools is 'Problems of the Promotion and Production of Teaching Materials in Developing countries' edited by Edda Eisenlohr et al, and published by the German Foundation for International Development (DSE., 53 Bonn, Simrockstrasse, West Germany). It is the report of an international conference in Berlin in October 1971. There is a brief but good analysis of production problems facing apparatus makers and book publishers, and a perceptive outline plan for the production of teaching materials by Mats G. Hultin of the World Bank (IBRD). The report covers a wide range of world projects.

REFERENCE PEOPLE

There are a number of more or less single-person initiatives in apparatus design all over the world. These range from inidividual teachers working in their own school whose productions are not seen by a wider public unless perhaps in the pages of a local teachers' journal, to people who have published their designs in a book. The journals of the Association for Science Education (1) in the UK, and the publications of the National Science Teachers Association (2) of the USA are sources of the first type. An example of the second type is R. F. Simpson's 'Simple Physics Apparatus' (3) which shows a wide range of science teaching items made up from common hardware store goods, such as pencils, magnifying glasses, electric iron elements and bottles. The items - some of which are shown in photograph 48 - make up a kit which can be packed in a small case. A similar example which uses simpler apparatus for an elementary level is Bowker and Hunt's 'Making Elementary Science Apparatus' (4).

In a small scheme supported by the British Council and the Ministry of Overseas Development, R. M. Garratt in Colombia was (in 1972) developing materials and apparatus for schools of Latin American type. Its aims were to use local resources to create adaptable materials which could be gradually built up in range as the needs became better understood. There are 'modules' of apparatus and appropriate work-sheets.

Other people who are creators, or repositories of information, in respect of apparatus ideas exist all over the world. Just a few are: Mrs Dora Whittaker (108 Parkside, Wollaton, Nottingham, England), chairman of the Schools Council committee on mathematics, who has until recently run a mathematics centre in Nottingham and is in touch with a wide range of sources for mathematics teaching apparatus. She herself is a creator, and a good source for US mathematics projects, with which she often works. Dr Ken Magnus (Chemistry Department, University of the West Indies, Kingston 7, Jamaica) is a source for Caribbean project information. Mr Brian Steven of City College, Leeds, England, is an inventor of apparatus from domestic materials. Many people in the Nuffield Science Teaching Project (Chelsea College of Science and Technology, Bridges Place, London S.W.6.) know about new apparatus for British schemes. Mr Norman Lowe, (97 Constance Road, Whitton, Twickenham, Middlesex, TW2 7HX, England) is a source of for information on African science schemes. The Division of Pre-University Science and Technology Education, UNESCO, Paris, is another source of information, with two individuals in particular being Dr Nahum Joel and Mrs S. Haggis. Keith Warren (The Grange, Ripley, Derby, DE5 3FT, England) has undertaken several studies of apparatus use and production, from reviews and critiques to design studies and inventions for village school science (unpublished). The best source for practical experience and design of production units is Mr Soren Hakansson (sometime Asia Regional UNESCO Adviser on School Science Equipment, and now at UNESCO headquarters in Paris).

(1) Association for Science Education, College Lane, Hatfield, Hertfordshire, England.

(2) National Science Teachers Association, 1201 16 Street, N.W., Washington, D.C., 20036, USA.

(3) Simple Physics Apparatus (Simpson) published by the Hong Kong University Book Store, Hong Kong.

(4) Making Elementary Science Apparatus (Bowker and Hunt) published by Thomas Nelson Limited, 36 Park Street, London W1Y 4DE, England.

TOYS AS TEACHING APPARATUS

For young children, especially pre-school, play apparatus may be desirable for helping them to understand aspects of science through body movement and through acting-out their 'experiments'. A collection of such play apparatus and materials is in UNICEF's Guide List 'Pandora' (1) which gives guidance on the choice and use of such material and its place in the child's development. There are lists and guide lines applicable to children in four age ranges: under 1 year, 1 to 3 years, 3 to 6 years and 6 to 9 years old. Local resource material is stocked by UNICEF for supply to group programmes.

Production units wishing to know what materials are used in pre-school and early primary school education in European countries and the USA can consult catalogues of supply houses or of shops which deal in these. A two-page list of basic items (such as paper, paint, scissors, paste) which may be used for early mathematics experience is available from Childsplay, 112 Tooting High Street, London S.W.17., England.

(1) Pandora Guide List published by UNICEF, 866 United Nations Plaza, New York, N.Y. 10017, USA.

KITS OF PLASTIC COMPONENTS

Kits come in many forms. They can be many-item collections - like the complete primary science kit of the NCERT - for teacher demonstrations. The CVK kit is for class use and is for a limited subject. Other types of collection, but still referred to as 'kits' are more limited: they may be, for instance, parts of a single device which is to be assembled; or a collection of simple things for use by an individual child; or even a set of blocks for pre-school or primary school experience.

The sets of 'new maths' equipment for primary level are fairly simple to manufacture, because they are plain designs. They can be conceived in plastic, as can many of the components of science kits. Once machines are obtained, the facility with which many items may be made rapidly by plastic injection or vacuum-forming techniques should almost make their use obligatory in teaching apparatus production units. However, making moulds and dies is skilled work, and technicians need proper training; only a skilled machinist could make the brass and steel injection dies for the plastic nuts and bolts kit shown in photograph 46. A high degree of skill is also needed to achieve the necessary accuracy to make the Centicubes in photograph 45 clip together properly - a skill probably beyond the range of most production units outside Europe, Japan and the USA.

It is quite possible that European firms would be willing to give advice, training or other aid. A helpful and informative source of advice on such matters is the Educational Division of Invicta Plastics (Oadby, Leicester, England). This firm, the largest of its type in Europe, markets in all continents and has a philosophy concerning local production, apparatus input from foreign sources, and aspects of bilateral aid, which makes it important for any production unit proposing to use plastics to get in touch with them.

Mr Hakansson, who has helped production units in South-East Asia to get plastics production of science teaching apparatus started, has written 'Use of Plastics and Other Techniques for Production of Low-cost Science and Mathematics Equipment for Schools'. This was a document at the RECSAM workshop of October 3 - 12, 1973, reference: SEAMEO/DSE/PLCTM/7.

KITS OF SCIENCE APPARATUS

Macalaster Scientific Company, (Route 111 and Everett Turnpike, Nashua, New Hampshire, USA) have produced kits of physics items for student assembly. The materials are unpainted and unfinished where 'finish' is unimportant; for example, the bases of items are often raw chipboard. Nuts and bolts, and so on, are supplied in envelopes and there are assembly plans. There may have been some consumer-reaction against their somewhat crude appearance, but the items generally worked well and covered some very sophisiticated physics. Many of the items were designed for the PSSC course of the USA. They are worth study as a possible model for a production unit which can make and pack the items but has to leave their assembly, with its intricate processes, to teachers or even to pupils.

Some Japanese firms make small kits of parts for assembly into physics apparatus - such as electric motors and bells, balances and pumps. There are similar kits of lenses, rulers, screens, for a range of experiments on the topic of Light, and other experimental assemblies. These kits were easily available in England and the US until a short while ago, but seem to have disappeared from toy shops. (UNICEF headquarters in New York know the Japanese manufacturer). They are well worth study and possibly some kind of imitation. Some are shown, with instruction sheets, in photographs

49 - 55. Much of the material is injection-moulded plastic or stamped tin-plate. They are flimsy and look like toys, but they are astonishingly well-dimensioned for exact fit and were astonishingly cheap. Despite the recent rises in plastic prices, plastic construction is still an attractive consideration for production units, since the quantity of plastic involved is very small (for example the weight of all the plastic parts of the pump shown in photograph 54 is less than 50 grammes) - though it would be much chepaer to buy than to produce them.

Kits of this sort are often not created to serve a particular curriculum. Probably kits can be designed which will be pleasurable as a kind of informative toy, game or hobby, and also serve a teaching purpose in schools. A production unit making small kits might consider this dual role for their product. As well as increasing the education of middle-class children by providing a kind of homework which can be presented as a gift, it can also be a way of widening the market and perhaps subsidizing other aspects of the unit's production.

The importance of having adequate guidance (for teacher or pupils) in the form of 'software' accompanying science apparatus was urged at a RECSAM conference in October 1973. It was pointed out that it is much easier to provide software for kits than for individual items because the writers know the total set of materials with which the teacher will be working. Booklets accompanying kits are also usually fairly small, and this is in itself attractive to teachers who often feel daunted by a bulky book. UNICEF's EVE catalogue (see photograph 43), for example, presents many problems to teachers selecting apparatus for themselves. It is arranged in alphabetical order in English. (In French and in Spanish the order remains the same, which makes the list un-alphabetical.) In any case, an alphabetical arrangement makes selection of items for a particular science topic rather difficult, despite the guidance and notes provided for the items. UNICEF is publishing a teacher's guide 'Using Science Apparatus', which attempts to meet this difficulty by describing a typical use of each of the EVE items, collected under topics - but this makes a very large book.

Software should be in the appropriate local language. In the case of a single large book, translation becomes a long-term job. If, however, it can be produced in sections, these can be written, translated, published and printed in stages, allowing gradual correction and improvement as faults of style and presentation become apparent. This is important because any production unit or curriculum project has to feel its way, and a facility for the incorporation of improvements must be included. Any large, 'one shot' approach militates against this possibility.

As a model for software, the FUNBEC booklets are very good, and the sheets accompanying the other kits reviewed here are useful. The NCERT software (of which there are several versions and types) is more an example of the single-book type, since the kits are large and extensive. One reason for this - which will be of interest to other production units - is that distribution in India is a major problem, so kits produced in a timed series would present additional difficulties.

The American 'Elementary Science Study' series consists of a wide range of pupils' kits, teachers' kits, pupils' books, teachers' guides, work-sheets, problem cards, and film loops, for elementary school use. There are about

60 main unit titles, such as: Bones, Gases and Airs, Growing Seeds, Whistles and Strings, Clay Boats, Match and Measure, Primary Balancing, and Pond Water. A unit is designed to be used for an average of six weeks. Some examples of these kits in use are shown in photographs 44 and 47. The principle might well be imitated by production units.

There are several somewhat similar mini-science kits around the world. In England the Precision Jigs Company Limited, (79 Caterham Avenue, Ilford, Essex) make nine types of kit for electricity experiments (with instructional leaflets). They use simple materials and are easily built up and used by English 12-year-olds. Photographs 56 and 57 show examples. Also in England, the Advisory Centre for Education (ACE) of 32 Trumpington Street, Cambridge, produces kits and packs called 'Things of Science'. Some are as simple as an instruction sheet for a game, with a little pack of nuts or seeds for play (photograph 15). Others may be as complex as a 20-piece geological collection with plastic magnifier and some equipment for testing samples, or a 'research pack' for investigating the pollution of streams (photographs 59 and 60). All of them contain interesting instructional material well-designed for children.

One of the most extensive range of kits is that produced in Brazil, (in Portuguese) designed by FUNBEC (Fundacao Brasiliera paro o Desenvolvimento do Ensino de Ciencias, Caixa Postal 2921, San Paulo, Brazil) and marketed by Abril S.A. Cultural e Industrial (Caixa Postal 2372, Sao Paulo). There are fifty kits, each in a pocket-sized box containing apparatus, usually fairly simple but often capable of being used in quite an advanced way (photograph 58). Each kit is associated with the work of a scientist, for example 'Newton and the Laws of Movement', 'Benjamin Franklin and Static Electricity', 'W. H. Carothers and Nylon'. Each has a booklet of some 20 pages containing constructional information and questions. There are plenty of photographs, small but clear, and several diagrams. There are three volumes of text, provided separately. Not only each kit with its text, but the whole system, evidences a creative imagination allied to careful design. It is all interesting and lively, and deserves widespread popularity.

KITS FOR TECHNICAL STUDIES

Kits of apparatus for secondary level technical studies are produced by Griffin and George Limited, in England. In the form in which this firm markets them they are extensive, and therefore costly relative to the budget of schools in poor countries. However, the concept and the specific ideas are well worth study by any production unit concerned with designing apparatus, and possibly kits, for a country which wants some of its school leavers to have had some practical technological experience. There are kits on Homecraft, Detergents, Human Mechanics, Dyeing, Cosmetics, and similar topics useful to home-makers; and there are science kits such as those on Microscopy, Crystals and Colour in Nature.

Production units supplying not only the conventional type of academic school but also those with technical biases, or even vocational schools, will also find the Griffin technical studies kits very valuable as examplars in various ways. Some of these are: Adhesives Kit, Metallurgy Kit, Plastics Casting Kit, Paper Kit, Fibres Kit, Glassmaking Kit, Photographic Kit, Flow Kit, Surfaces Kit, Corrosion Kit and Computer Games.

(1) Griffin and George Limited, Ealing Road, Alperton, Wembley, Middlesex, England.

MINI-SCIENCE AND OVERHEAD PROJECTORS

There are not many schools in the world with overhead projectors - at least not at primary and lower secondary level. However, production units might find much of interest (because the techniques are suggestive for different applications) in the 'Tested Overhead Projection Series' of small-scale chemistry experiments for overhead projection, using small quantities of chemicals and reagents in small square-section transparent tubes. There is a kit and a guide full of diagrams and experiments. The address is TOPS, Hubert N. Alyea, 337 Harrison Street, Princeton 08540, Massachusetts, USA.

UNICEF SCHOOL SCIENCE SUPPLIES

The United Nations Children's Fund (UNICEF) stocks and supplies a wide range of materials within the fields of education, agriculture, health and child care. The items are available to UN agencies. They are catalogued in some seventeen lists, including vocational training materials and tools, audio-visual equipment, school subject items, and agricultural implements.

A revision of the science teaching sections of one of the Guide Lists (EVE Science Revision: OSU-6000) has been undertaken in conjunction with UNESCO. This provides a wide range of apparatus consisting of:

(1) Primary Science and Mathematics (93 items)
(2) Tools for the Primary Science Workshop (15 items)
(3) Secondary Science: Biology, Chemistry and Physics (327 items)
(4) Tools for the Secondary Science Workshop (32 items)
(5) Chemicals and Reagents for Secondary Science (160 items)
(6) Curriculum Development Equipment for Teacher Training Institutions: Biology, Chemistry and Physics (76 items)

The items are listed as fairly detailed specifications, generally in a form suitable for commercial tendering purposes. Thus they form a good reference list of basic standard items and chemicals, with detailed notes on many aspects of their selection for schools.

A supplement ('Illustrations of Science Teaching Apparatus and Equipment', available from UNICEF as OSU-6000 Supplement 1) provides line diagrams of all items except tools. Examples from the EVE catalogue are shown in photographs 42 and 43.

The items have been carefully selected to cover most science teaching requirements except those that are highly sophisticated and very expensive. Items shown by previous experience to be too breakable in transit have also been omitted.

The main lists: (a) show suggested quantities per school stream at the various levels; (b) indicate an 'economy' selection of the most essential items; (c) show which laboratory (biology, etc.) each item is needed for;

(d) indicate by notes beside entries ancillary apparatus which will be needed, what the item is for and similar helpful information; and (e) give the UNICEF price.

Introductory pages provide guidance to field officers on estimating requirements, new attitudes in science teaching, the use of local resource materials and tools, curricular developments, and so on.

UNICEF's practice of buying for the Copenhagen Warehouse (UNIPAC) in large quantities from actual manufacturers is reflected in appreciably lower prices for a given quality than those of commercial apparatus supply houses. Other advantages are the UNESCO surveillance of the items, single-source supply of wide range, easy control of delivery dates, ready access to spares and replacements, and suitability of the items to the situation in developing countries.

A Teacher's Guide to the EVE items, 'Using Science Apparatus' is being published by UNICEF, covering use of the items, maintenance, repair and the supplementing of them from local resources.

UNICEF SUPPORT FOR WRITING AND PUBLICATION OF BOOKS

Requests may be made for the support of local schemes to write or to translate textbooks, and to publish, print, and obtain supplies of paper in connection with such schemes.

USEFUL ADDRESSES

United Nations Children's Fund (UNICEF)
United Nations Plaza, New York, N.Y.10017, USA.

Regional Centre for Education in Science and Mathematics (RECSAM)
c/o Malayan Teachers' College, Penang, Malaysia. - (established under the South-East Asian Ministers of Education Organization).

Regional Centre for Educational Innovation and Technology (INNOTECH)
P. O. Box 3049, Saigon, Republic of Vietnam. - (established under the South-East Asian Ministers of Education Organization).

Science Education Programme of Africa (SEPA)
c/o P. O. Box M-188, Accra, Ghana.

National Council for Educational Research and Training (NCERT)
Sri Aurobindo Marg, New Delhi-16, India.

Institute for the Promotion of Teaching of Science and Technology (IPTST)
c/o Physics Building, Chulalongkorn University, Bangkok, Thailand.

German Foundation for International Development (DSE)
53, Bonn, Simrockstrassel, West Germany.

UNESCO, 7 place de Fontenoy, 75700 Paris, France.

UNESCO Regional Offices

UNESCO Regional Office for Education in Latin America and the Caribbean, P. O. Box 3187, Santiago, Chile.

UNESCO Regional Office for Education in Asia, P. O. Box 1425, Bangkok 11, Thailand.

UNESCO Regional Office for Education in Africa, B.P. 3311, Dakar, Senegal.

UNESCO Regional Office for Education in the Arab States, B.P. 5244, Beirut, Lebanon.

UNESCO Regional Office for Science and Technology in Africa, P. O. Box 30592, Nairobi, Kenya.

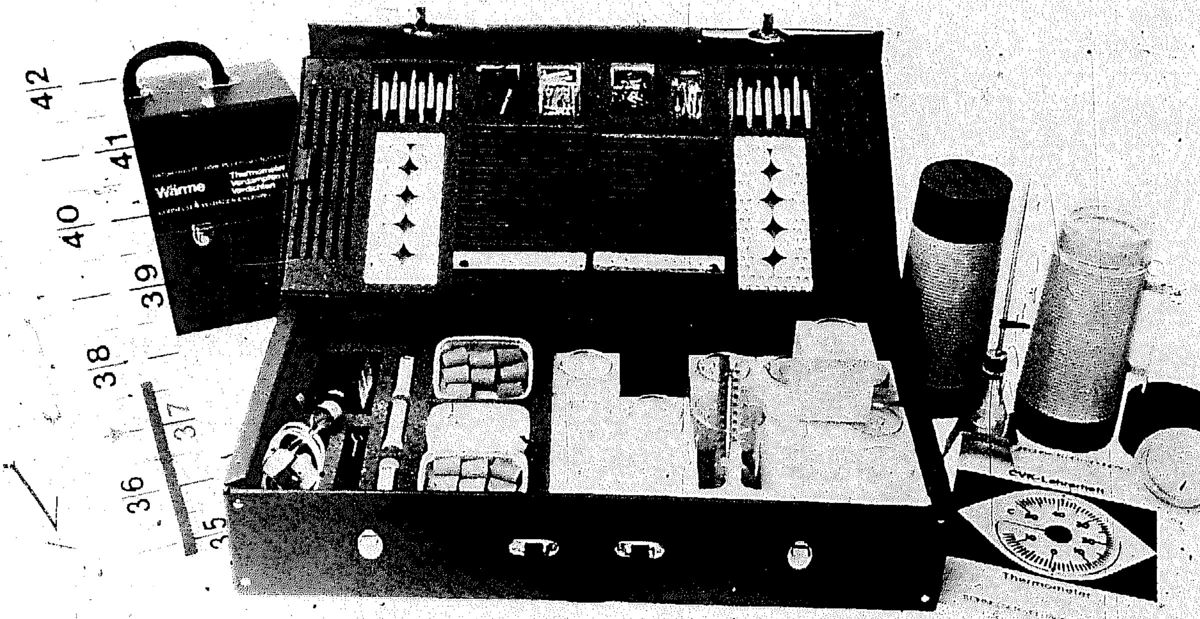
UNESCO Regional Office for Science and Technology in Latin America, 1320 Bulevar Artigas, P. O. Box 859, Montevideo, Uruguay.

UNESCO Regional Office for Science and Technology in the Arab States, 8 Sh. El Salamlik, Gardent City, Cairo, Arab Republic of Egypt.

UNESCO Regional Office for Science and Technology in South and Central Asia, UNESCO House, 40B Lodhi Estate, New Delhi 3, India.

UNESCO Regional Office for Science and Technology in South-East Asia, U.N. Building, 2nd Floor, Jalam Thamrin 14, 273/JKT Tromolpos, Jakarta, Indonesia.

The British Council, 10 Spring Gardens, London, SW1A 2BN. (Addresses of Overseas offices can be obtained from the British Council's Information Department at 10 Spring Gardens.)



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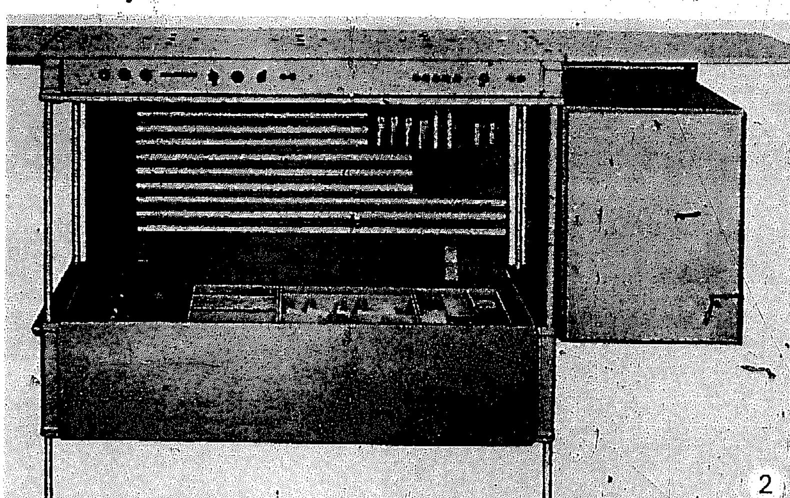
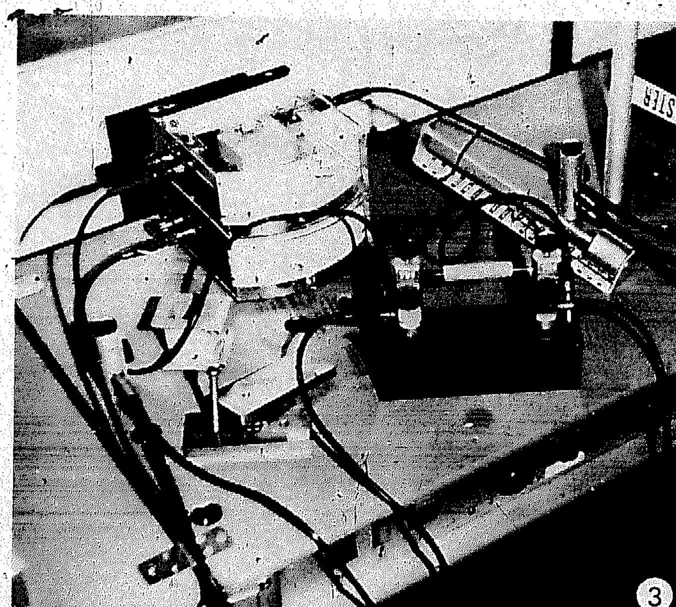




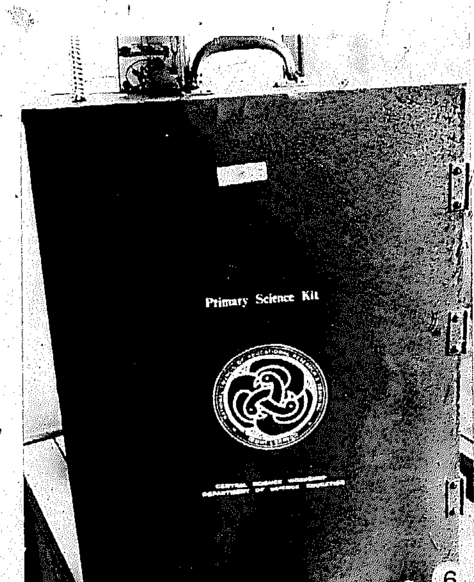
1 Primary school kit produced by Cornelsen, Velhagen and Klasing of Berlin

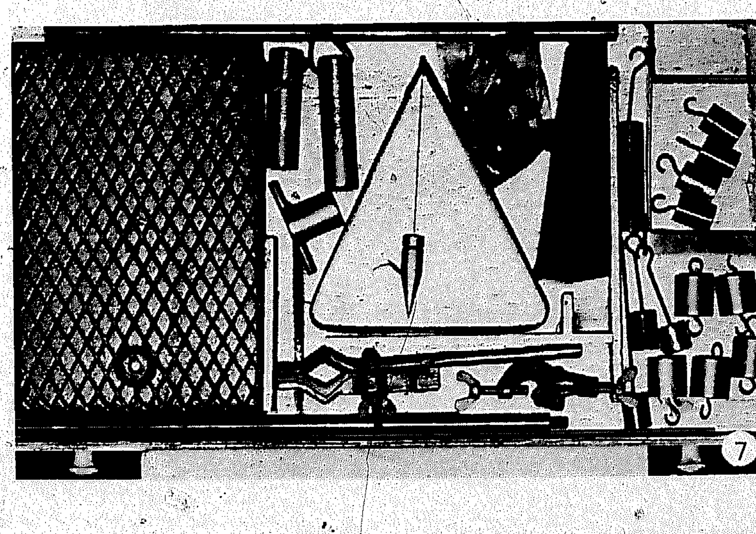
2 & 3 A 'universal' science teaching kit, made in Europe

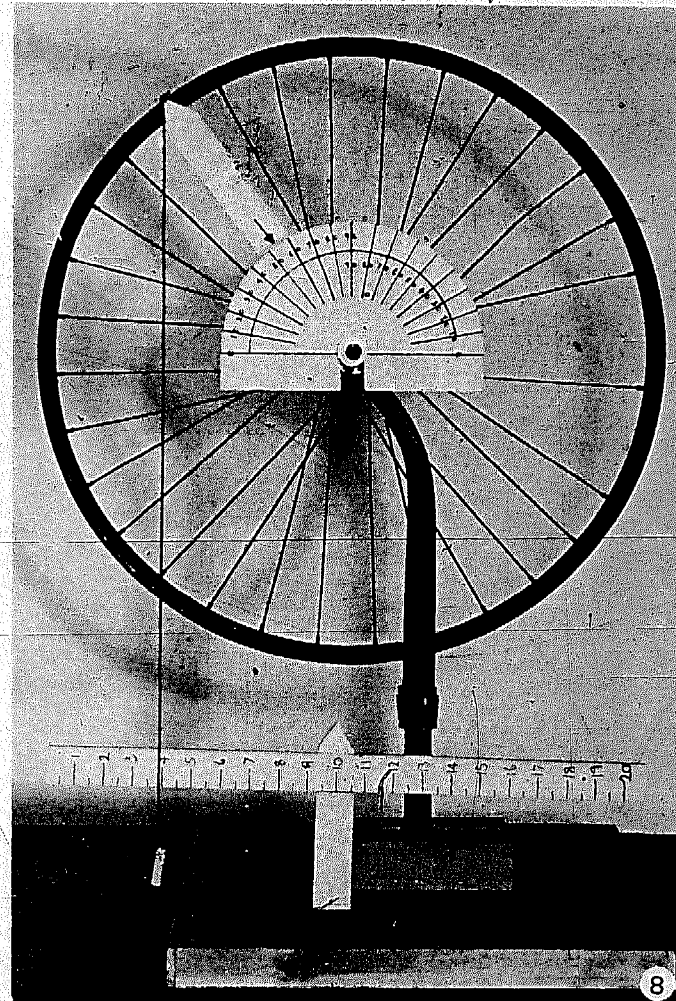
4 A Bengal village school—typical of situation in which many children in the world are taught, and into which teaching apparatus must fit

5 An itinerant tinker's tools—an example of local repair facilities in a Bengal village

6 & 7 A kit can be in a box which serves as a storecupboard for the items in the classroom







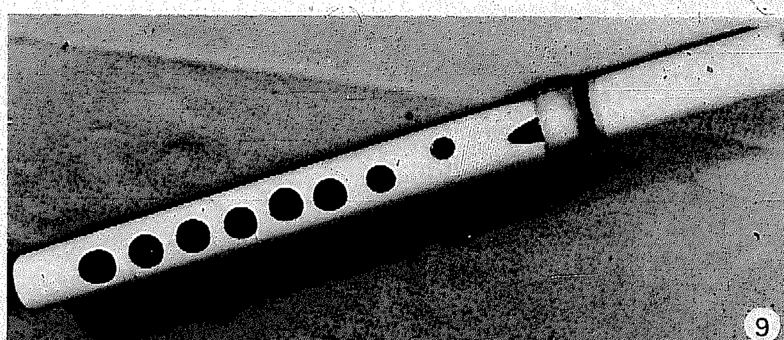
8 Bicycle wheels can be used to teach mathematics

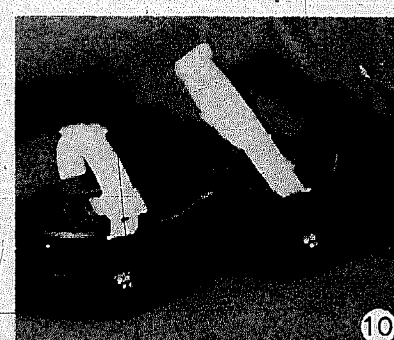
9 A Burmese flute—a local source of sound to replace a tuning fork

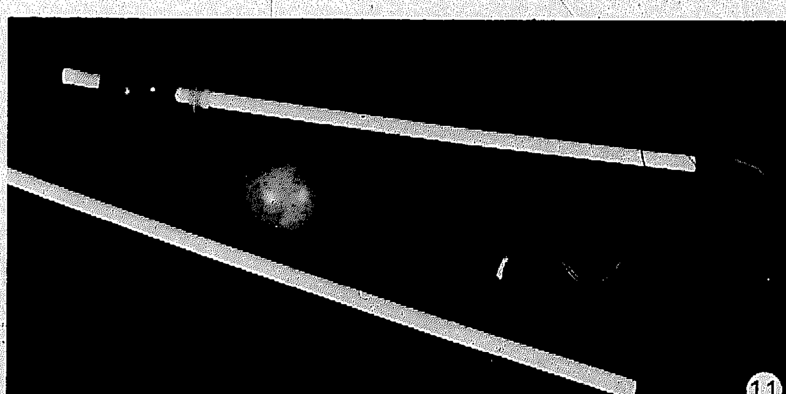
10 A plastic roller skate can, for some purposes, replace a dynamics trolley

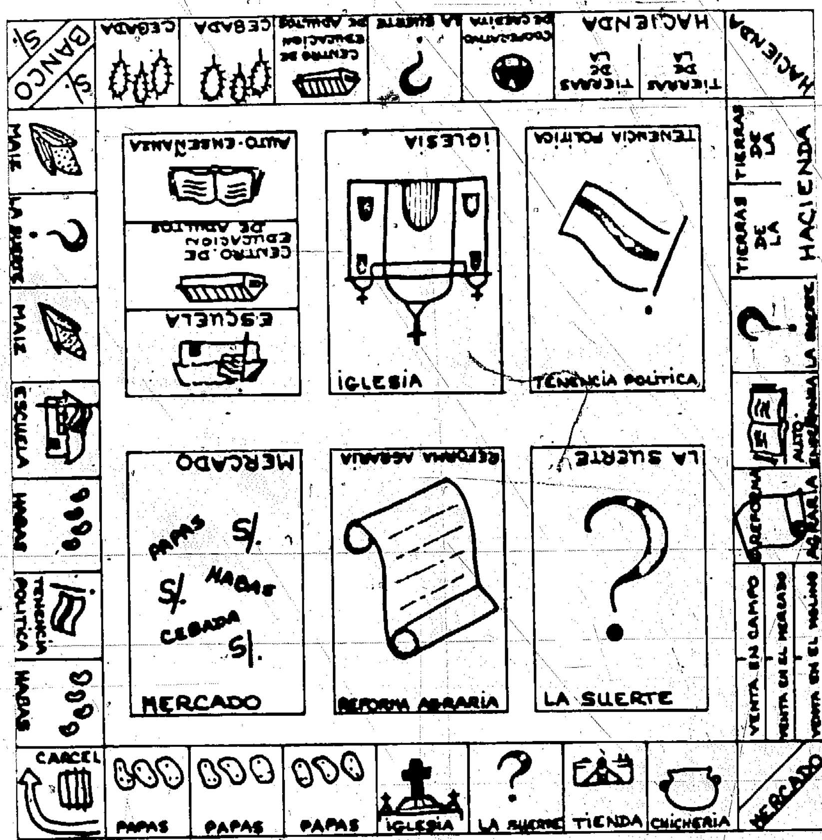
11 'Flikball'—a toy which can be used to teach

12 Simple objects such as a mousetrap may be used to teach



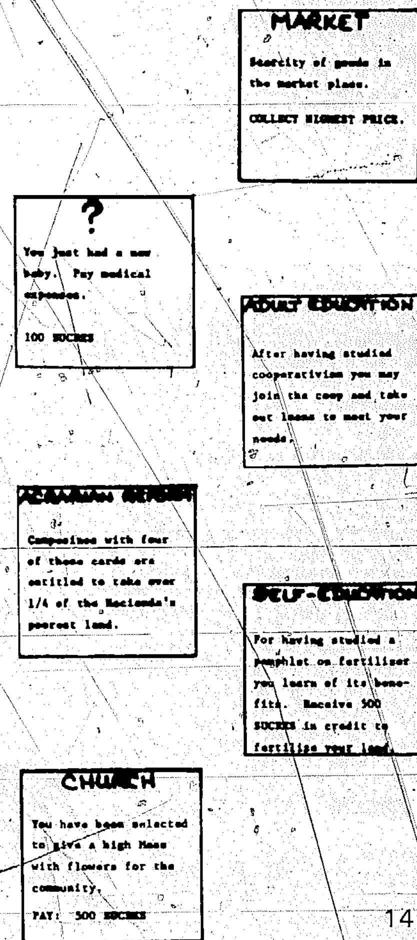






HACIENDA

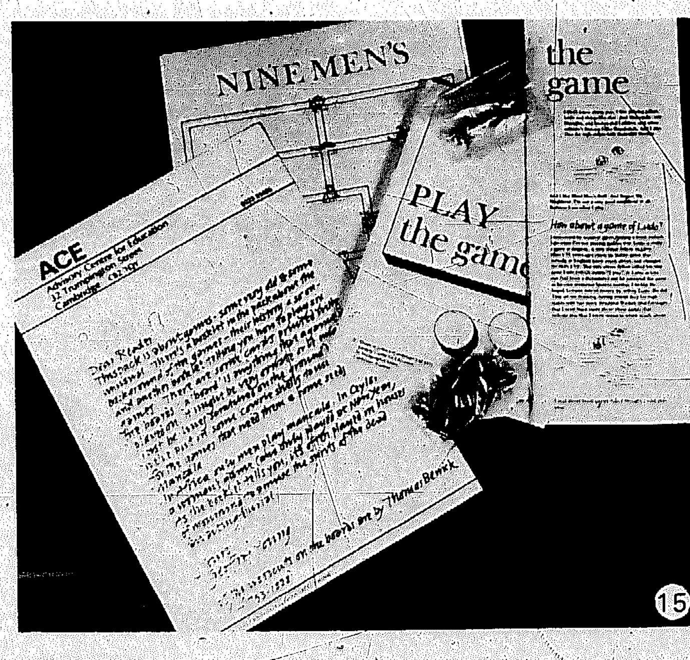
13



14

13 & 14 Gameboard and sample cards from 'Hacienda', a teaching game simulating the economic and social realities of the Ecuadorian sierra

15 The Advisory Centre for Education makes use of games based on 'Ludo' and others well-known to English children



15

Science Education Project in Africa

16 Bamboo and rope make an exciting tower

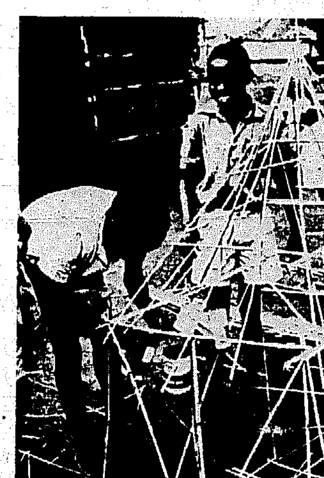
17 Seeing the world from a moving system

18 Sample page from the Teachers' Guide

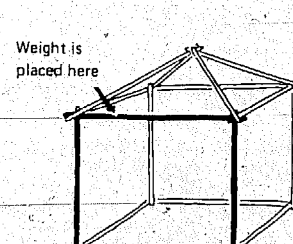
16

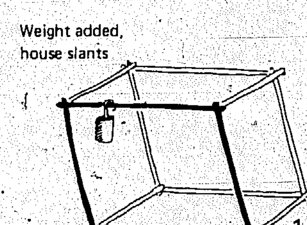
17

Or they put several tins in one spot.



As your pupils place the tins of sand at different parts of their houses, they may not pay much attention to what is happening. Each time they put a tin on one of the grasses, the grass will bend in a certain way. To prevent it from breaking, children usually add many more pieces of grass. Encourage them to be more methodical. For instance, sometimes when pupils hang a tin on their house, it bends in certain places, slants in one direction, or even tips the whole house over. In the following illustration, consider the solid lines only.





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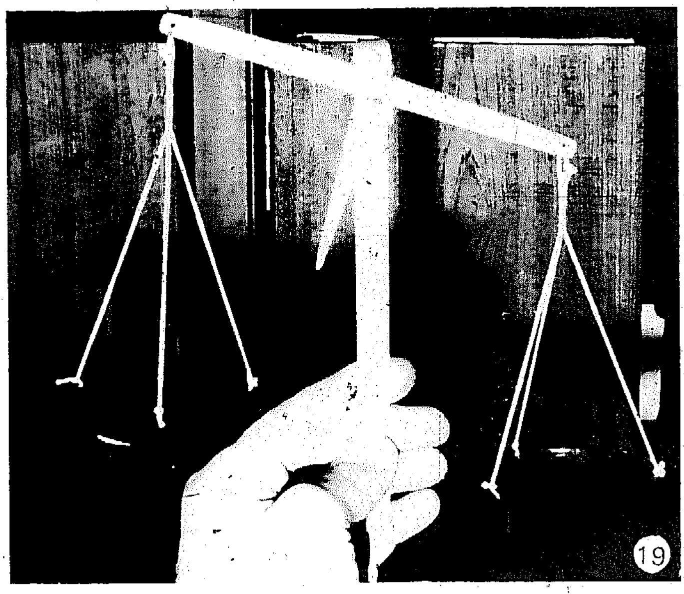
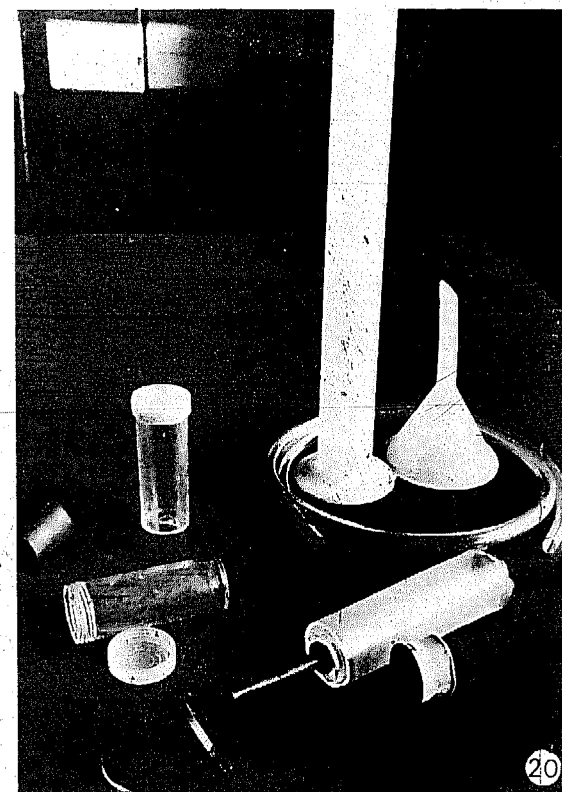
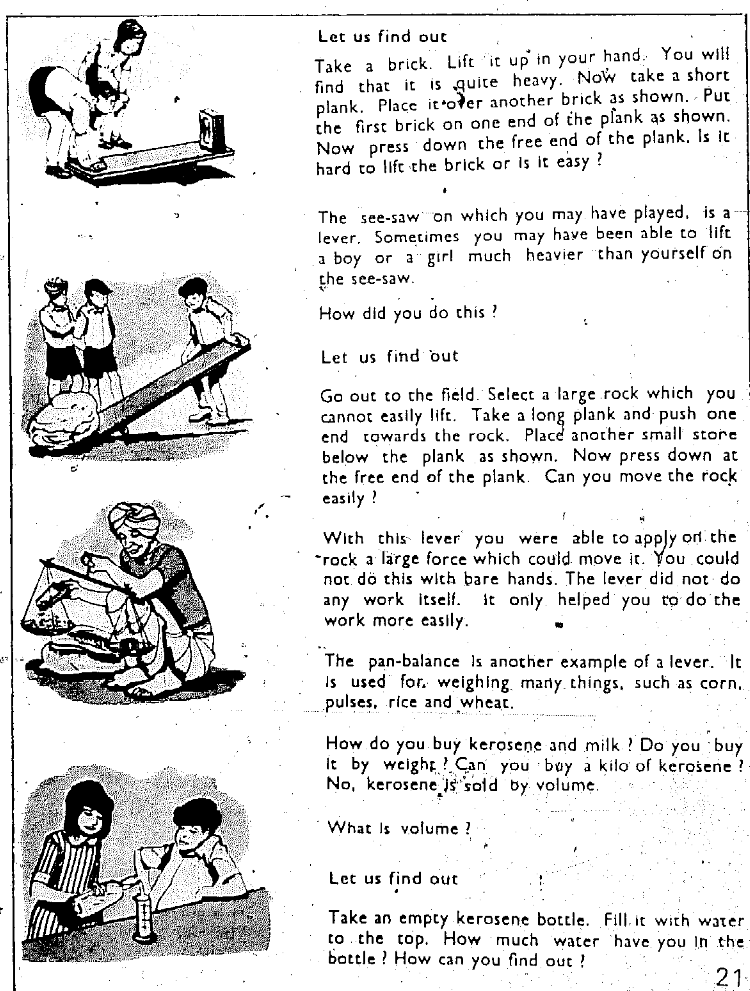






Let us find out

Take a brick. Lift it up in your hand. You will find that it is quite heavy. Now take a short plank. Place it over another brick as shown. Put the first brick on one end of the plank as shown. Now press down the free end of the plank. Is it hard to lift the brick or is it easy ?

The see-saw on which you may have played, is a lever. Sometimes you may have been able to lift a boy or a girl much heavier than yourself on the see-saw.

How did you do this ?

Let us find out

Go out to the field. Select a large rock which you cannot easily lift. Take a long plank and push one end towards the rock. Place another small stone below the plank as shown. Now press down at the free end of the plank. Can you move the rock easily ?

With this lever you were able to apply on the rock a large force which could move it. You could not do this with bare hands. The lever did not do any work itself. It only helped you to do the work more easily.

The pan-balance is another example of a lever. It is used for weighing many things, such as corn, pulses, rice and wheat.

How do you buy kerosene and milk ? Do you buy it by weight ? Can you buy a kilo of kerosene ? No, kerosene is sold by volume.

What is volume ?

Let us find out

Take an empty kerosene bottle. Fill it with water to the top. How much water have you in the bottle ? How can you find out ?

21

NCERT, India.

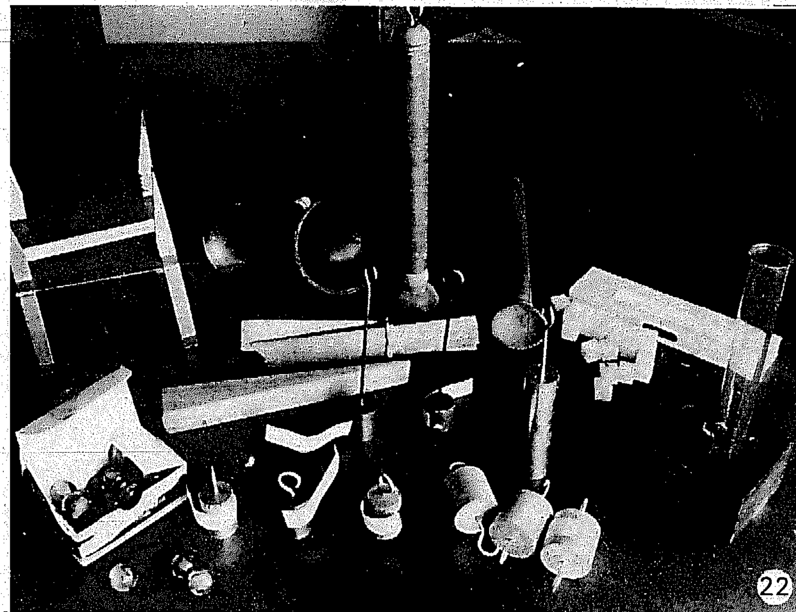
19 & 20 Items from the primary science kit

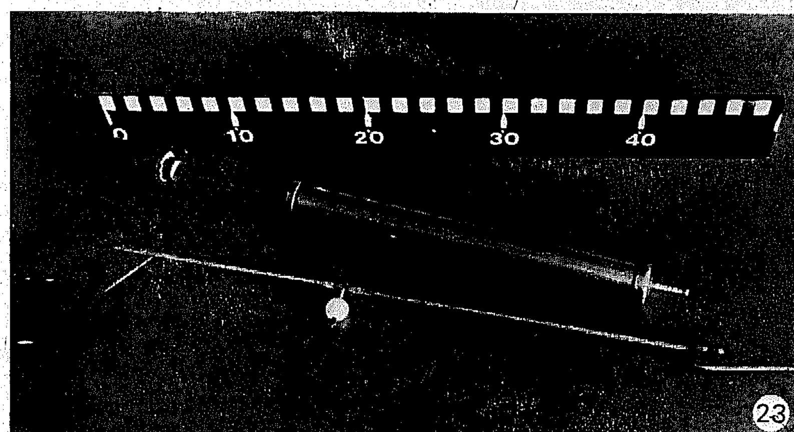
21 A page of pupil's text

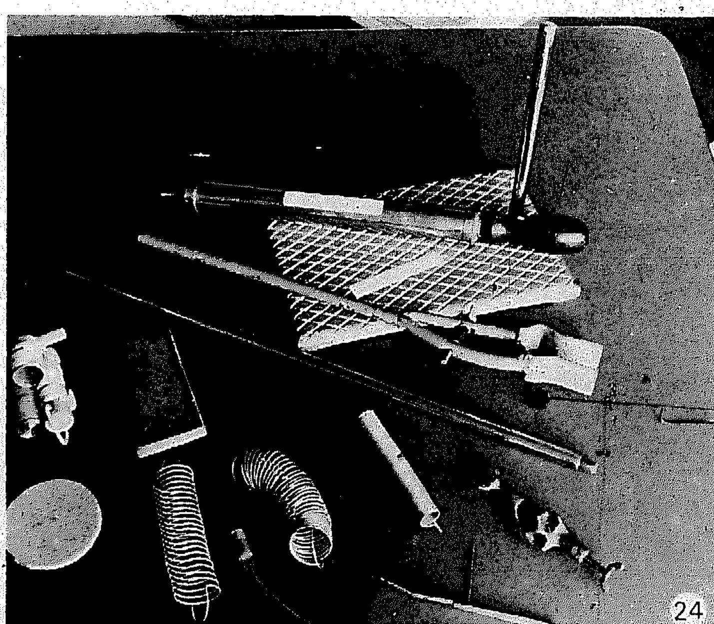
NCERT, India

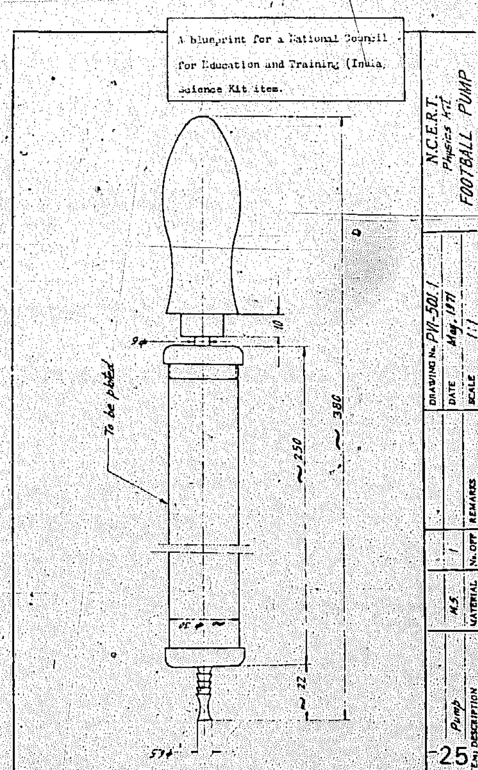
22, 23 & 24 Items from the primary science kit

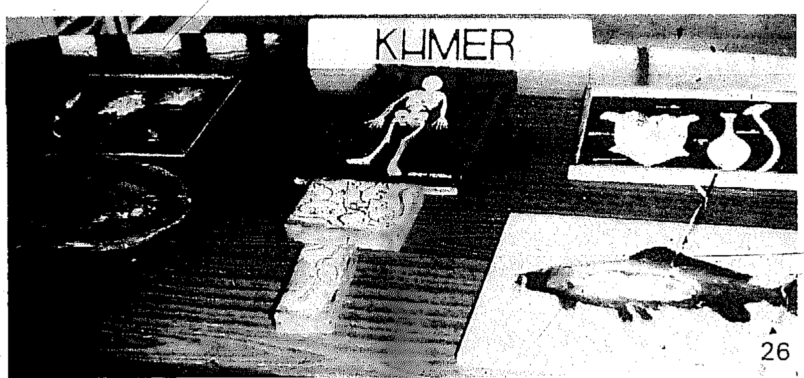
25 Dimensional drawing for the kit











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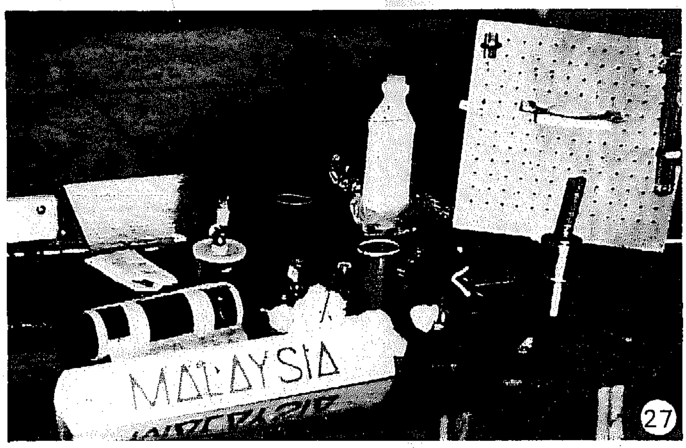


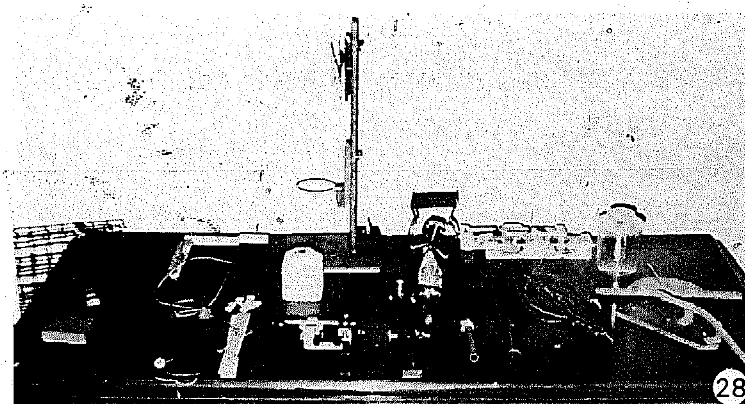
27

26 Some papier-mâché models and lino-cut blocks from Khmer

27 Examples of science teaching apparatus from Malaysia

28 Some secondary apparatus, IPTST Programme, Bangkok

29 Elementary science kit designed for Thailand



28

29

FORCES

PHASE IIIA
NO. 19

ORGANIZATION

Groups

LET'S FIND OUT HOW TO USE A PULLEY

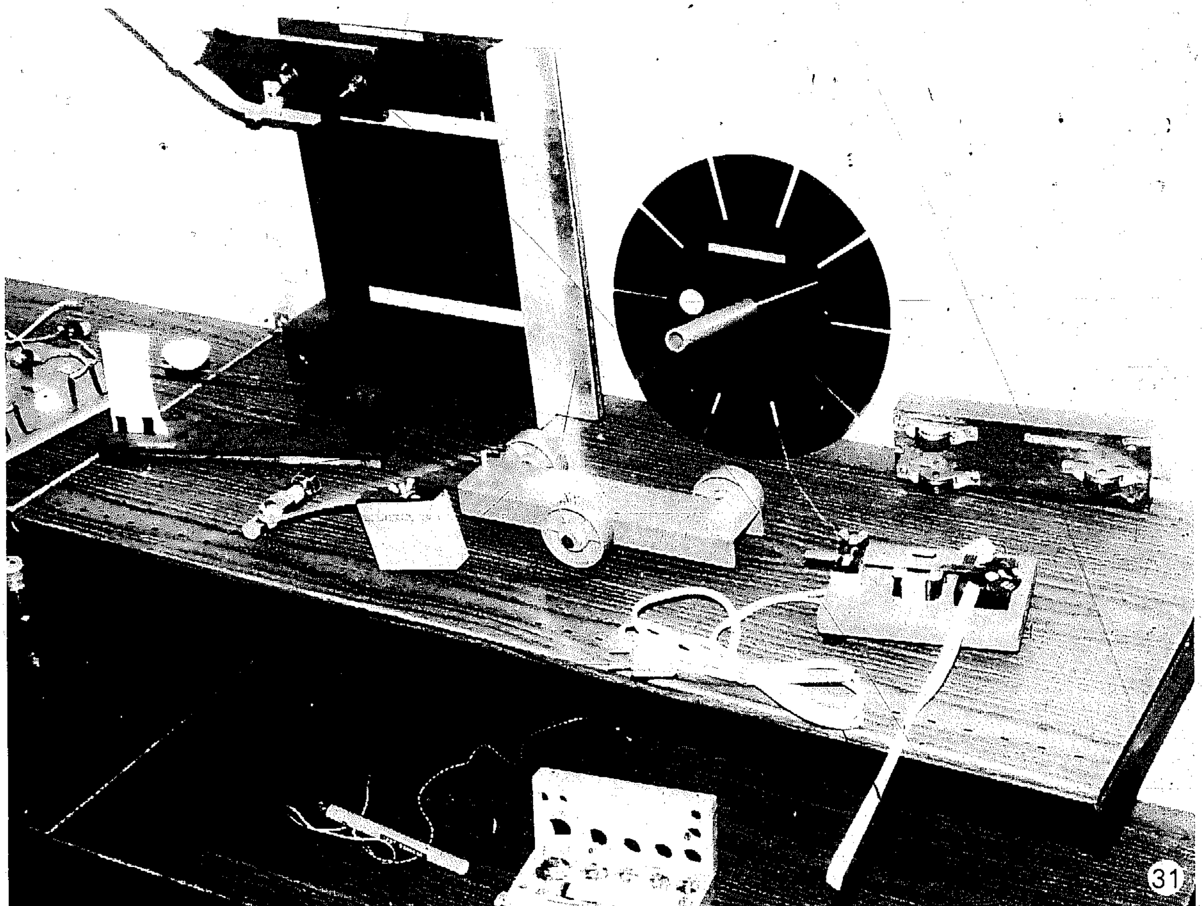
You will need:

- 1 ball of string.
- 10 *small* cartons, chalk boxes or plastic bags of sand (loads).
- 10 pulleys.

Do this:

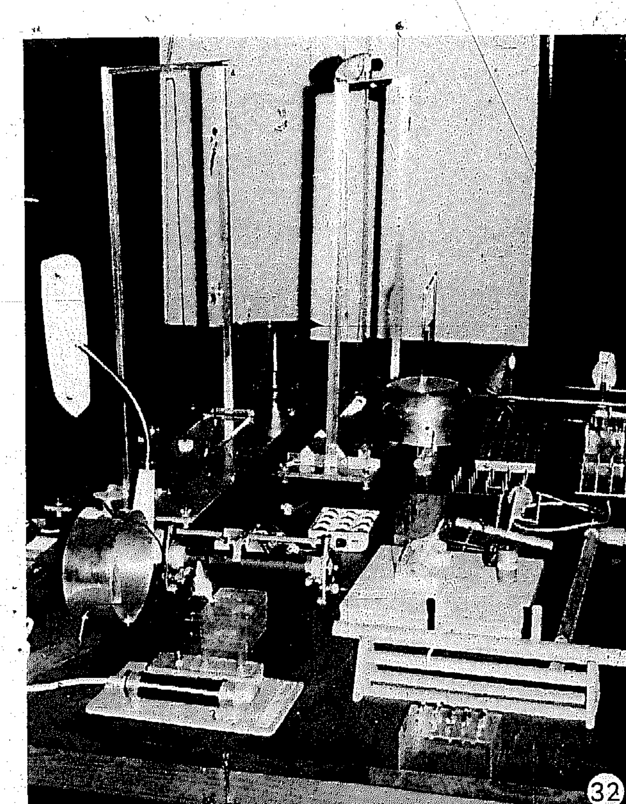
1. Group leaders collect 3 metres (10ft) of string and bag or carton of sand.
2. Tell the children to tie the load to the string and pull the load to a new position on their desks.
3. Give the children this problem. "See if you can find a way to move the load *away* from you by pulling the string". (This can be done if a pencil is held by another child at one end of the desk and the string passed around the pencil.)
4. Ask successful groups to show how they managed.
5. Give out a pulley to each group. Tell the children to use the pulley instead of the pencil and try again.
6. See if the children can suggest a way of lifting the load above their heads using the string and pulley.
7. Tie the pulleys to a beam across the classroom, and tell the children to pull up their loads using these.
8. Tell the children to make a record of what they have done in their note books. A drawing will be sufficient.

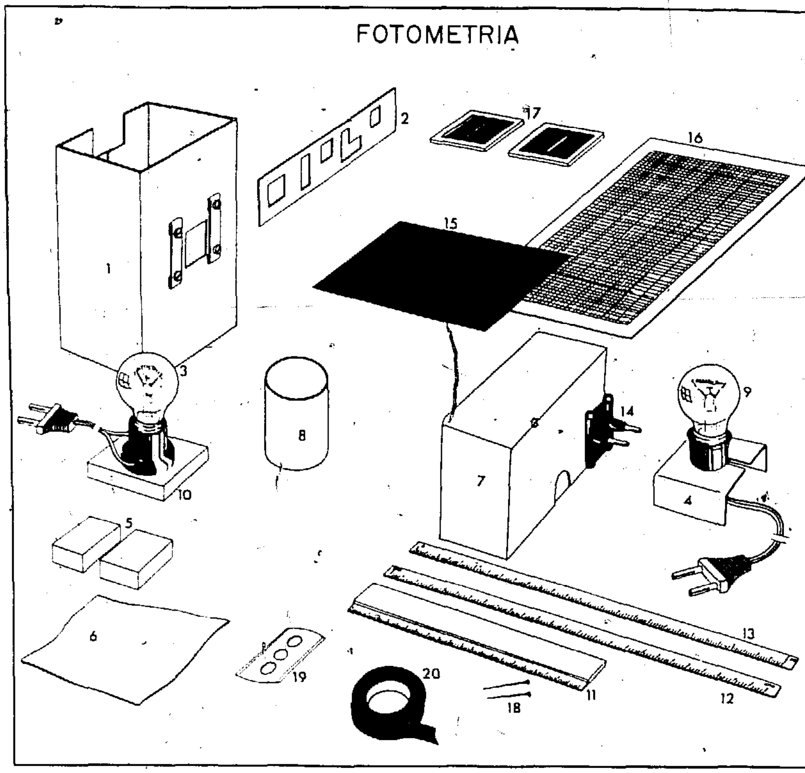
30 A sample workcard from the Papua New Guinea Primary Science project



31 Some secondary apparatus, IPTST programme, Bangkok

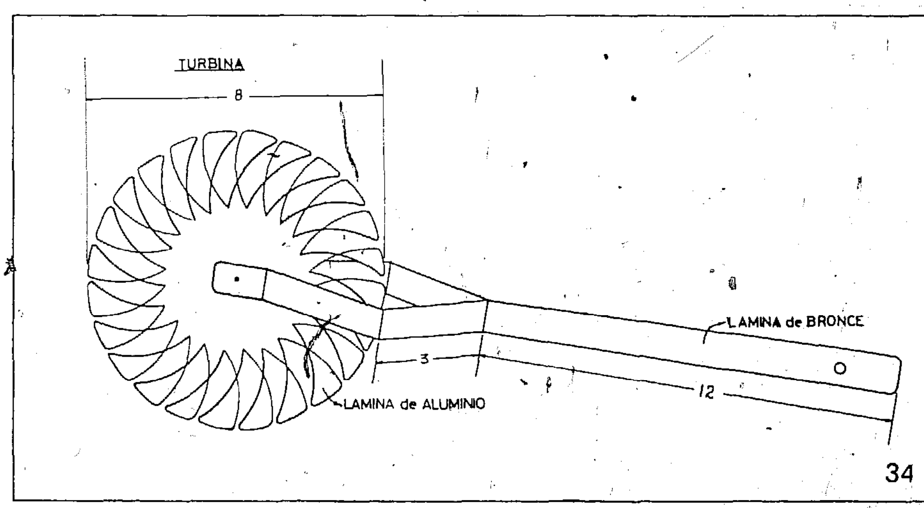
32 Equipment largely for the training of technicians, Bangkok – prior to IPTST





Nº	MATERIALES	Cant.
1	PROYECTOR DE ALUMINIO	1
2	LAMINA CON ORIFICIOS	1
3	LAMPARA 60W	1
4	BASE PORTALAMPARAS	1
5	BLOQUES DE PARAFINA	2
6	HOJA DE ALUMINIO	1
7	CAJA DE CARTON	1
8	TUBO DE CARTON	1
9	LAMPARA DE FILAMENTO RECTO	1
10	PORTALAMPARAS MADERA	1
11	REGLA	1
12	REGLILLA DE 50cm	1
13	REGLILLA DE 50 cm	1
14	ENCHUFE TRES VÍAS	1
15	CARTULINA NEGRA	1
16	PAPEL MILIMETRADO	3
17	DIAPOSITIVAS	2
18	ALFILERES	5
19	HOJA DE AFEITAR	1
20	ROLLO DE CINTA NEGRA	1

33



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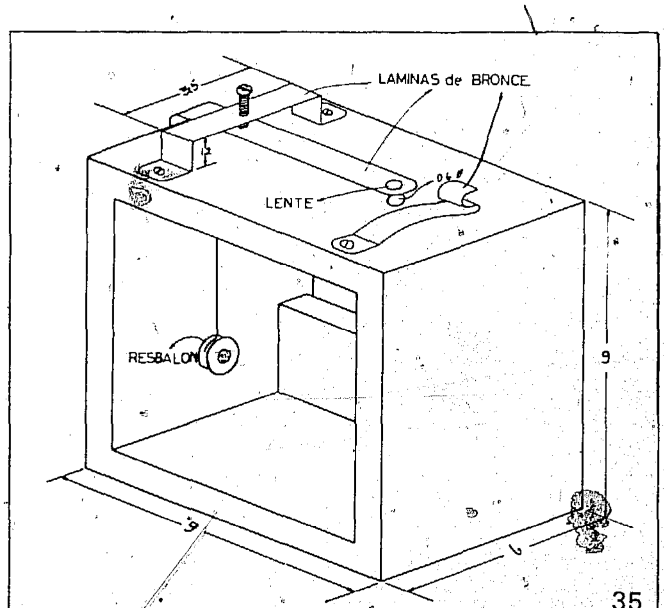
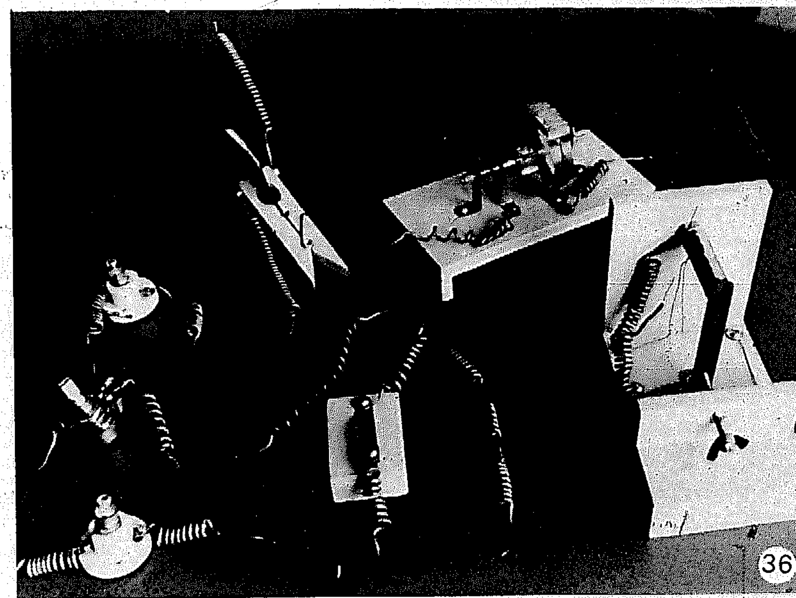
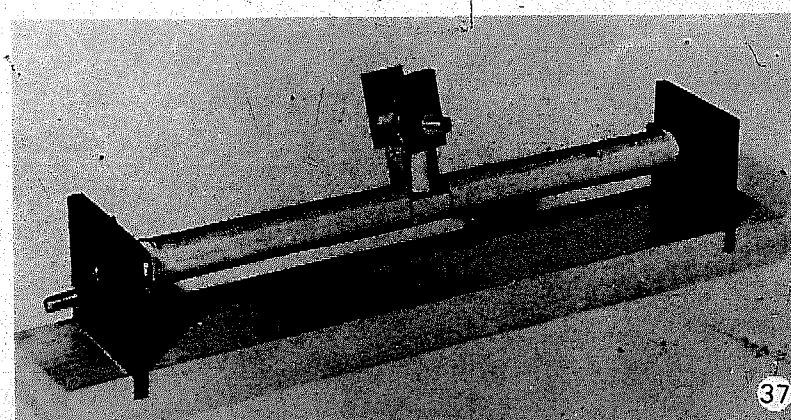


35

33 A Sao Paulo project kit

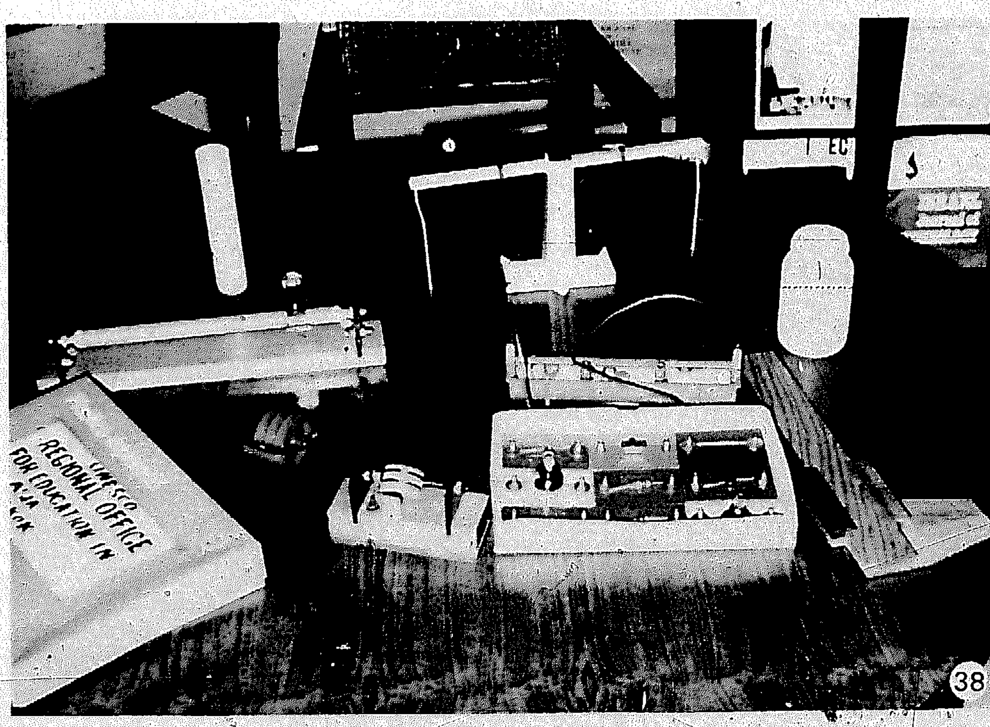
34 & 35 Dimensional drawings from Costa Rica





36 Some prototypes of science teaching equipment from Costa Rica

37 & 38 Items manufactured by Or & Kol, Israel



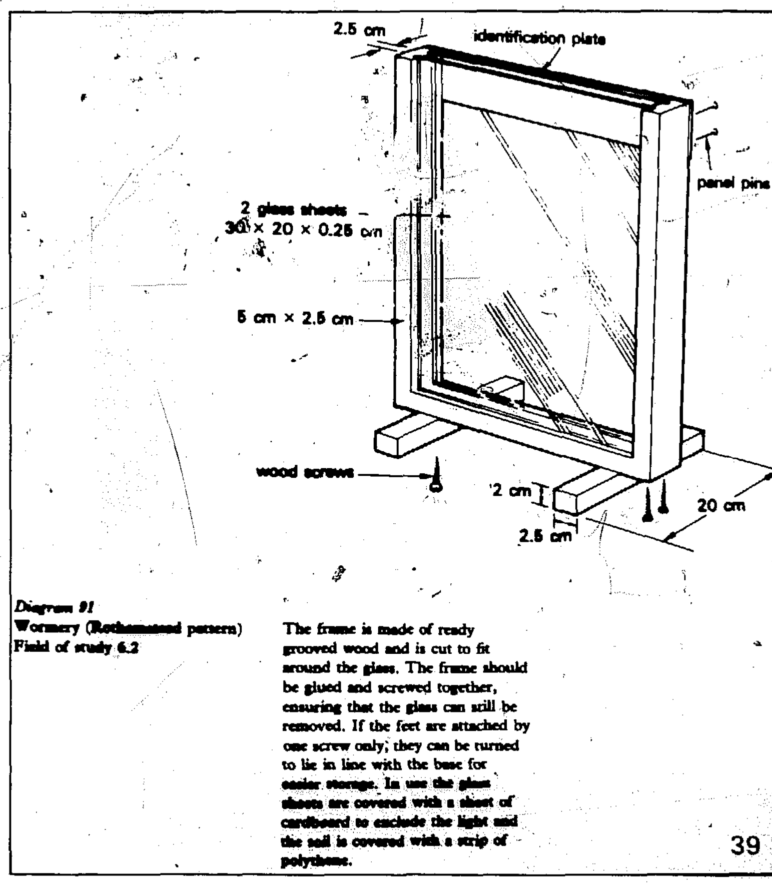


Diagram 91
Wormery (Rothamsted pattern)
Field of study 6.2

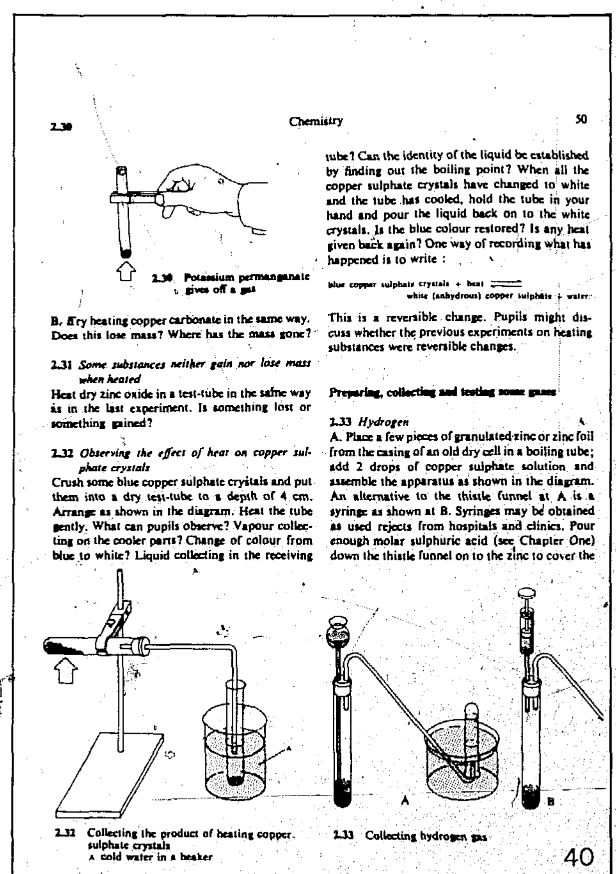
The frame is made of ready grooved wood and is cut to fit around the glass. The frame should be glued and screwed together, ensuring that the glass can still be removed. If the feet are attached by one screw only, they can be turned to lie in line with the base for easier storage. In use the glass sheets are covered with a sheet of cardboard to exclude the light and the soil is covered with a strip of polythene.

39

39 Dimensional drawing from 'Nuffield Apparatus Guide'

40 Example from the UNESCO 'Source Book'

41 Example from 'Guidebook to constructing inexpensive science teaching equipment'


2.30 Chemistry 50

2.30 Potassium permanganate gives off a gas

B. Try heating copper carbonate in the same way. Does this lose mass? Where has the mass gone?

2.31 *Some substances neither gain nor lose mass when heated*
Heat dry zinc oxide in a test-tube in the same way as in the last experiment. Is something lost or something gained?

2.32 *Observing the effect of heat on copper sulphate crystals*
Crush some blue copper sulphate crystals and put them into a dry test-tube to a depth of 4 cm. Arrange as shown in the diagram. Heat the tube gently. What can pupils observe? Vapour collecting on the cooler parts? Change of colour from blue to white? Liquid collecting in the receiving tube? Can the identity of the liquid be established by finding out the boiling point? When all the copper sulphate crystals have changed to white and the tube has cooled, hold the tube in your hand and pour the liquid back on to the white crystals. Is the blue colour restored? Is any heat given back again? One way of recording what has happened is to write :

blue copper sulphate crystals + heat ⇌ white (anhydrous) copper sulphate + water

This is a reversible change. Pupils might discuss whether the previous experiments on heating substances were reversible changes.

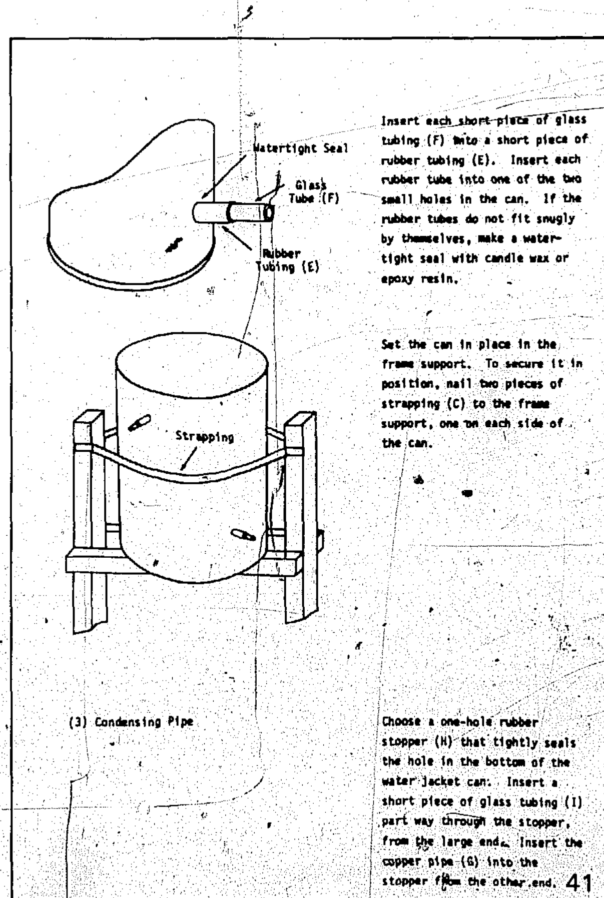
Preparing, collecting and testing some gases

2.33 *Hydrogen*
A. Place a few pieces of granulated zinc or zinc foil from the casing of an old dry cell in a boiling tube; add 2 drops of copper sulphate solution and assemble the apparatus as shown in the diagram. An alternative to the thistle funnel at A is a syringe as shown at B. Syringes may be obtained as used rejects from hospitals and clinics. Pour enough molar sulphuric acid (see Chapter One) down the thistle funnel on to the zinc to cover the

2.32 Collecting the product of heating copper sulphate crystals
A cold water in a beaker

2.33 Collecting hydrogen gas

40



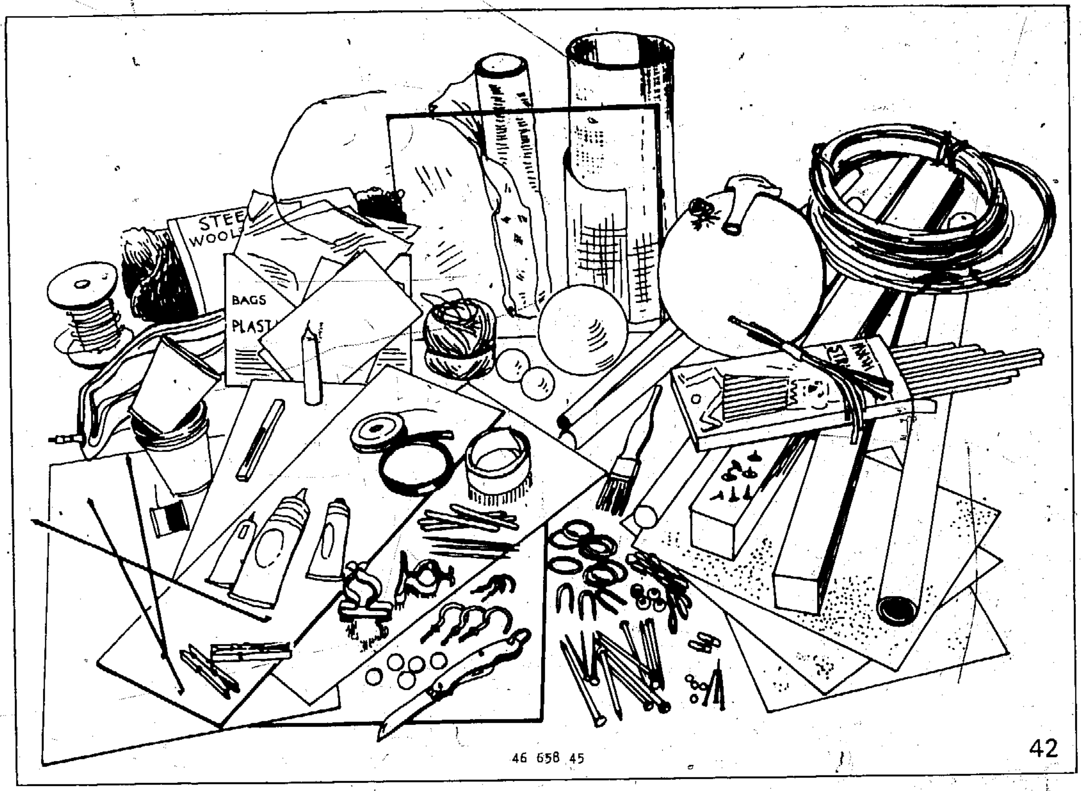
Insert each short piece of glass tubing (F) into a short piece of rubber tubing (E). Insert each rubber tube into one of the two small holes in the can. If the rubber tubes do not fit snugly by themselves, make a water-tight seal with candle wax or epoxy resin.

Set the can in place in the frame support. To secure it in position, nail two pieces of strapping (C) to the frame support, one on each side of the can.

(3) Condensing Pipe

Choose a one-hole rubber stopper (H) that tightly seals the hole in the bottom of the water jacket can. Insert a short piece of glass tubing (I) part way through the stopper, from the large end. Insert the copper pipe (G) into the stopper from the other end.

41



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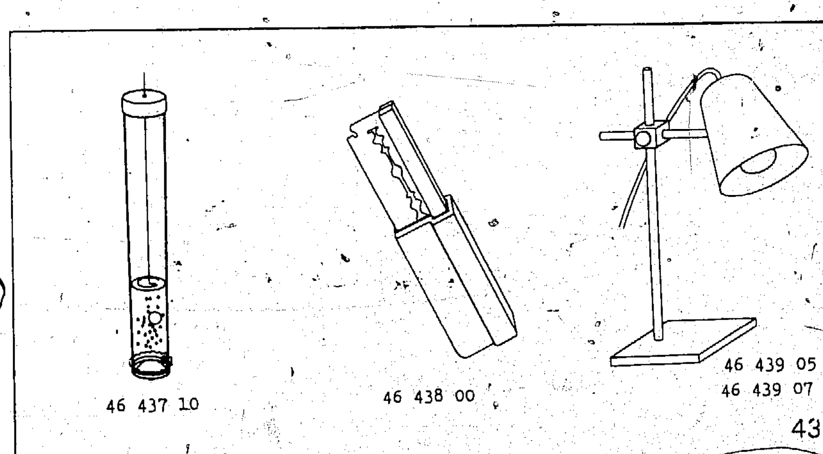
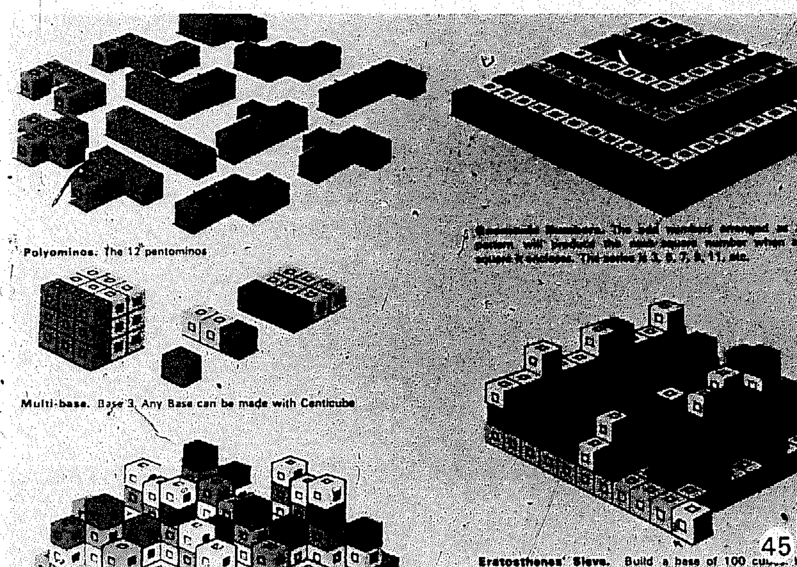
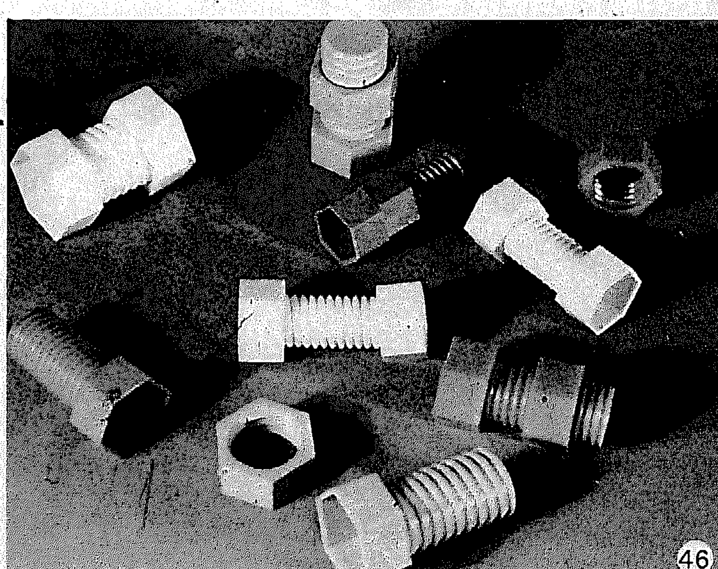


43

42 Resource materials kit, 'EVE' catalogue

43 Other items in 'EVE' catalogue are shown and listed separately

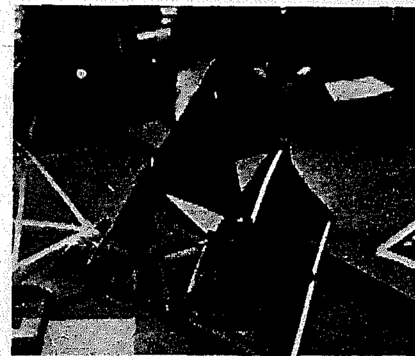




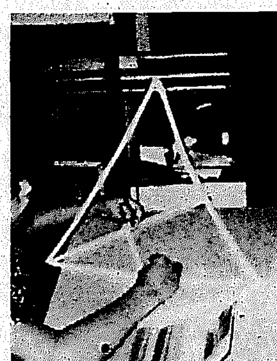
44 Practical work from 'Elementary Science Study' series

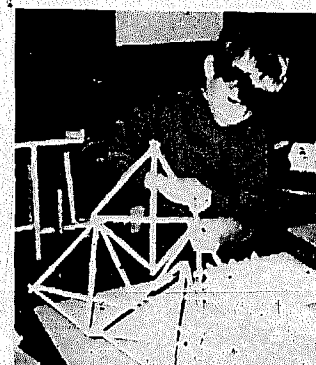
45 Centicubes

46 Plastic nuts and bolts kit



This is a model of Bell's structure which was presented to the students as their single source of information. With no assistance, each student was to reconstruct the model using 8-inch straws, pins, and paper.



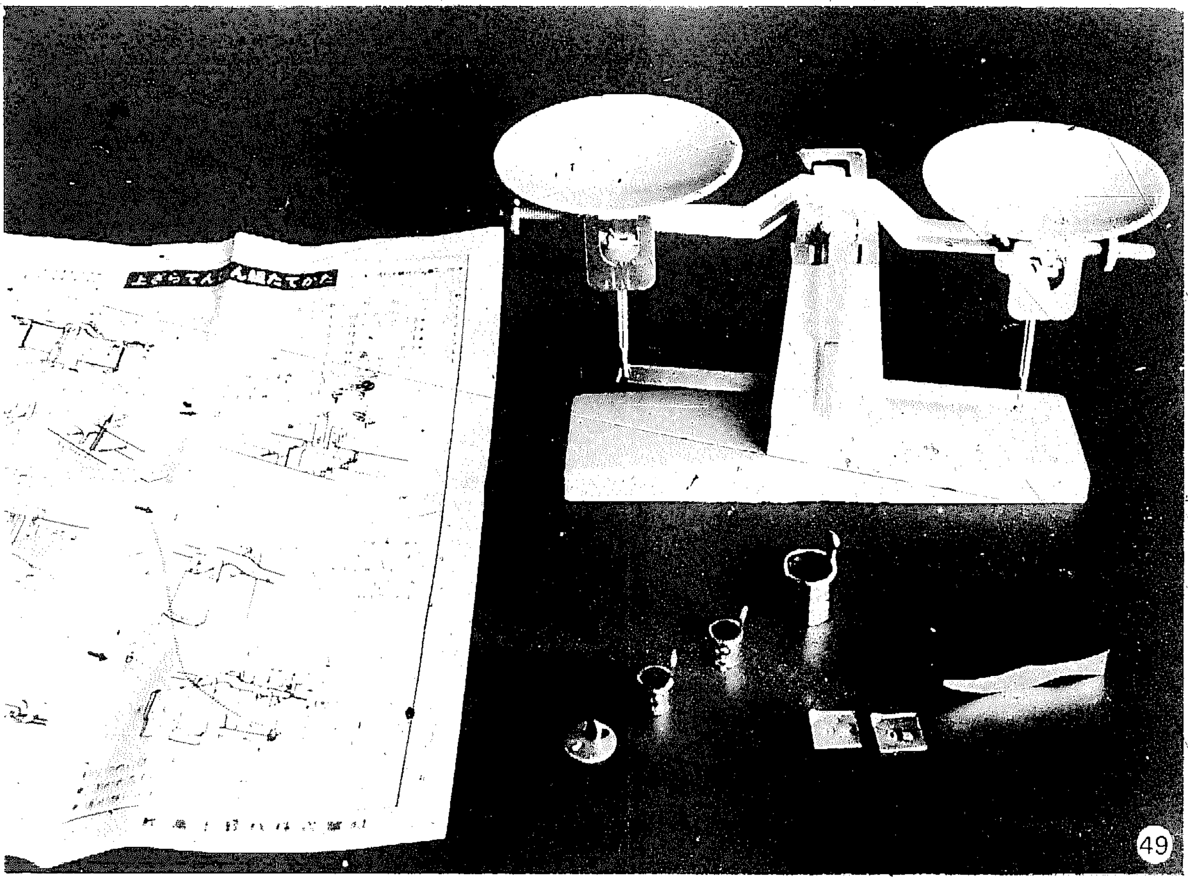


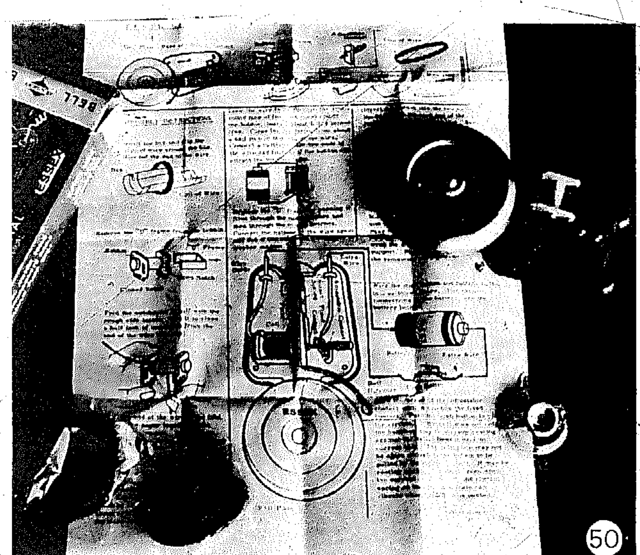
And so they did.

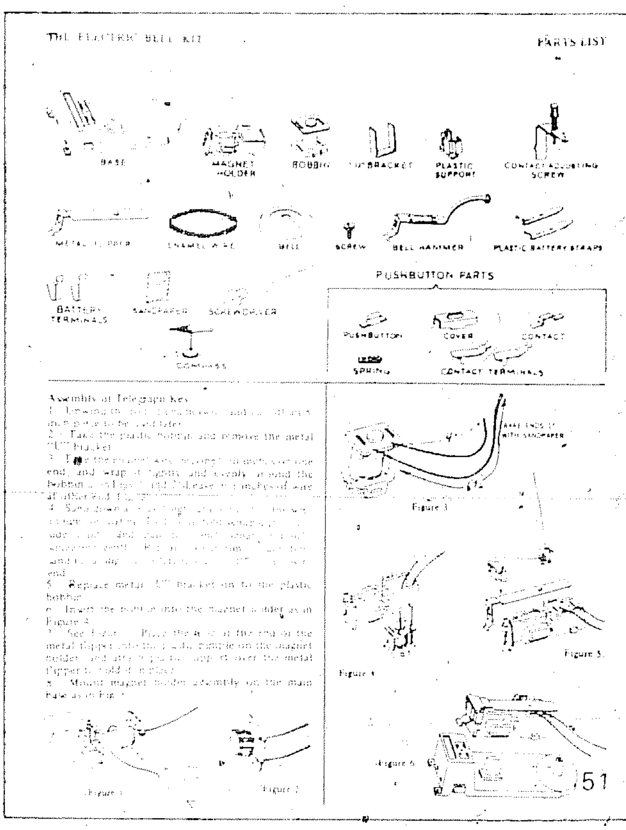
47

47 An example from 'Elementary Science Study' series

48 Some items from the kit compiled by Dr Simpson of Hong Kong







Japanese plastic mini science kits

49 Scales

50 Electric bell kit

51 Parts lists for electric bell kit

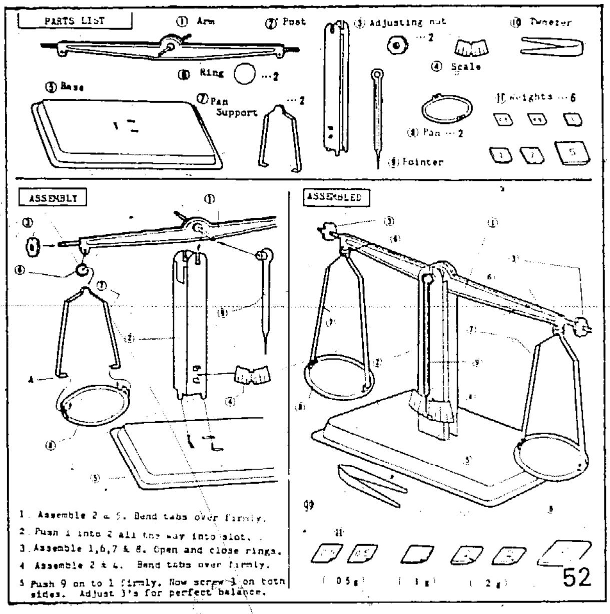
Japanese plastic mini science kits

52 Parts list for balance

53 Kits for pump, balance and electro-magnet

54 Parts list for hydraulic pump

55 Parts list for electro-magnet



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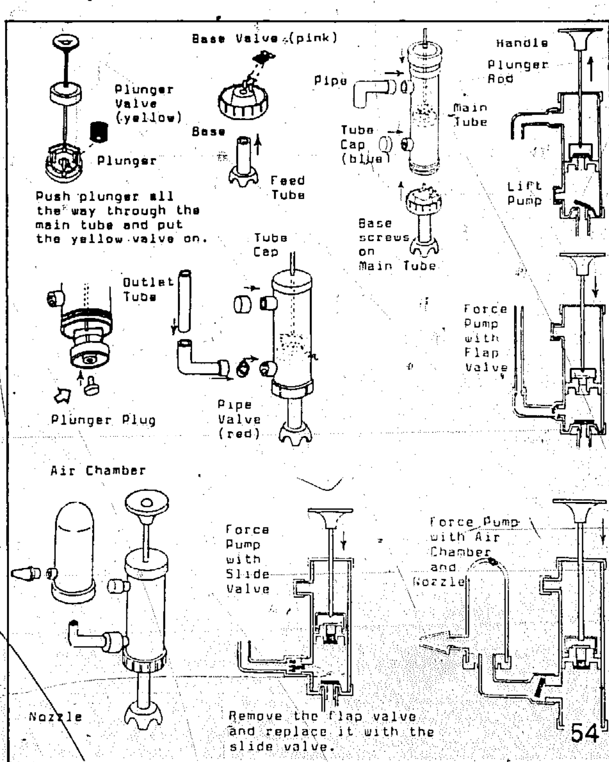

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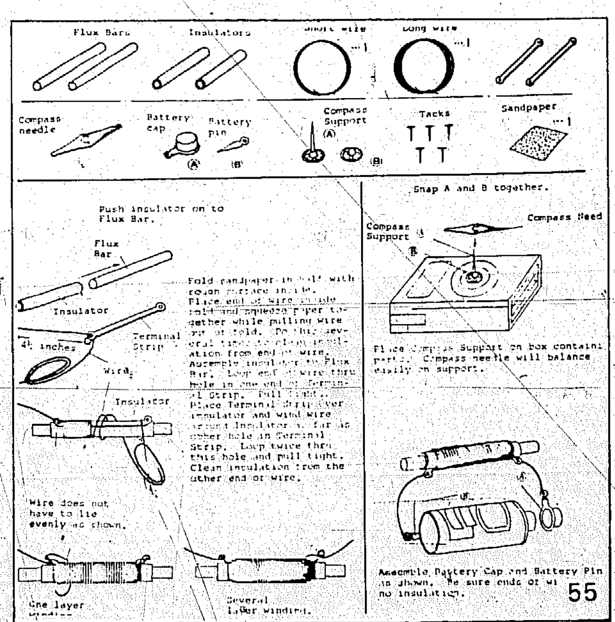

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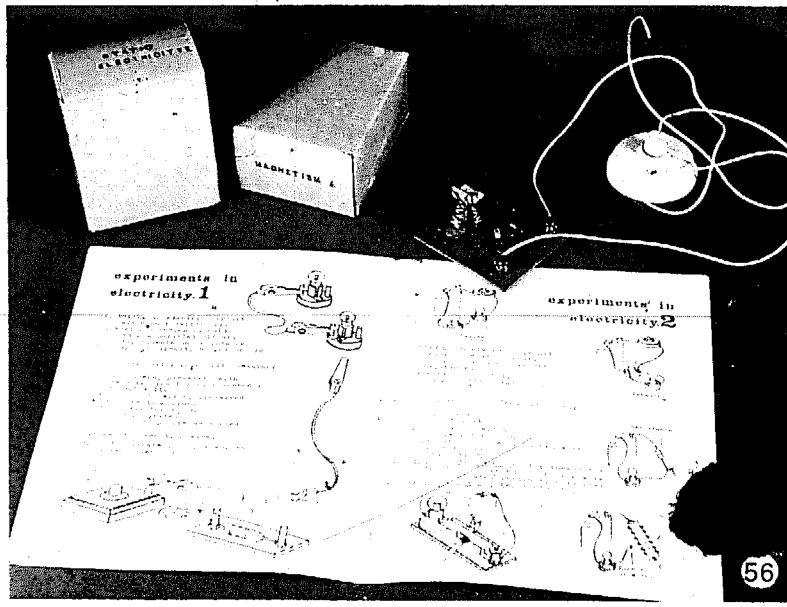
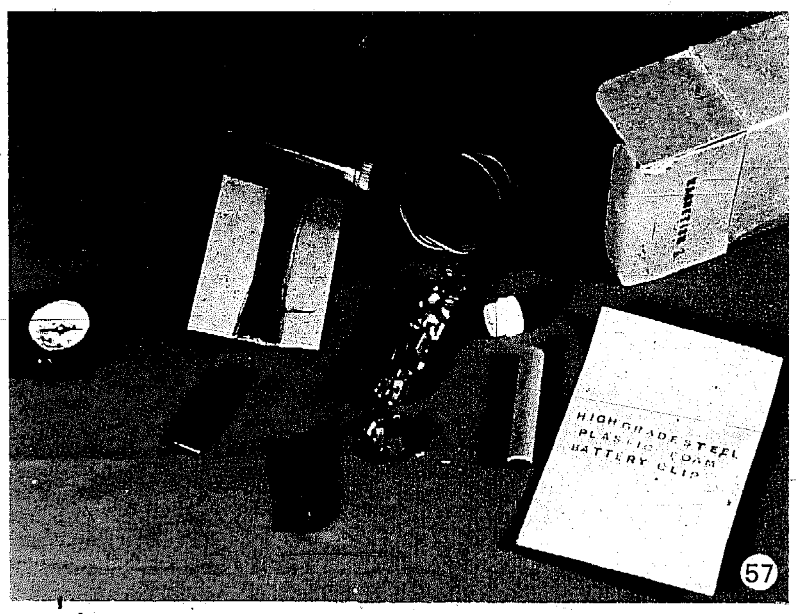
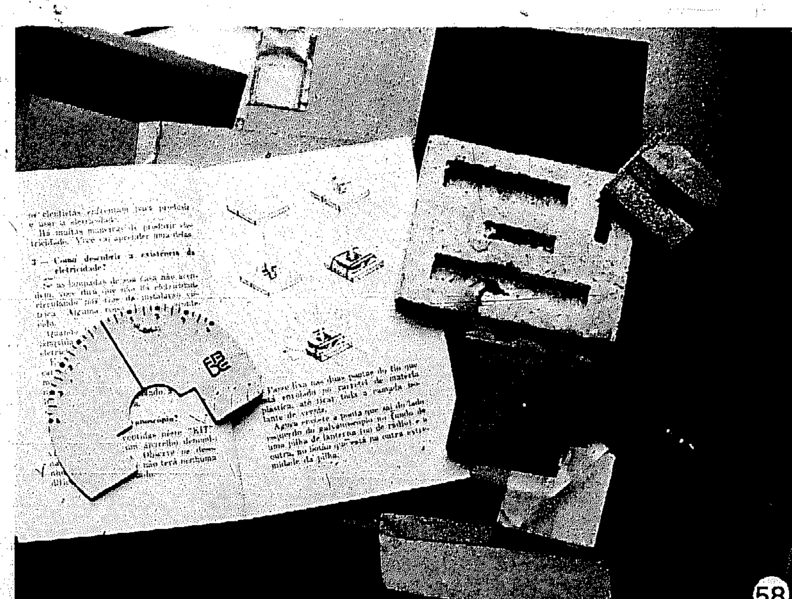
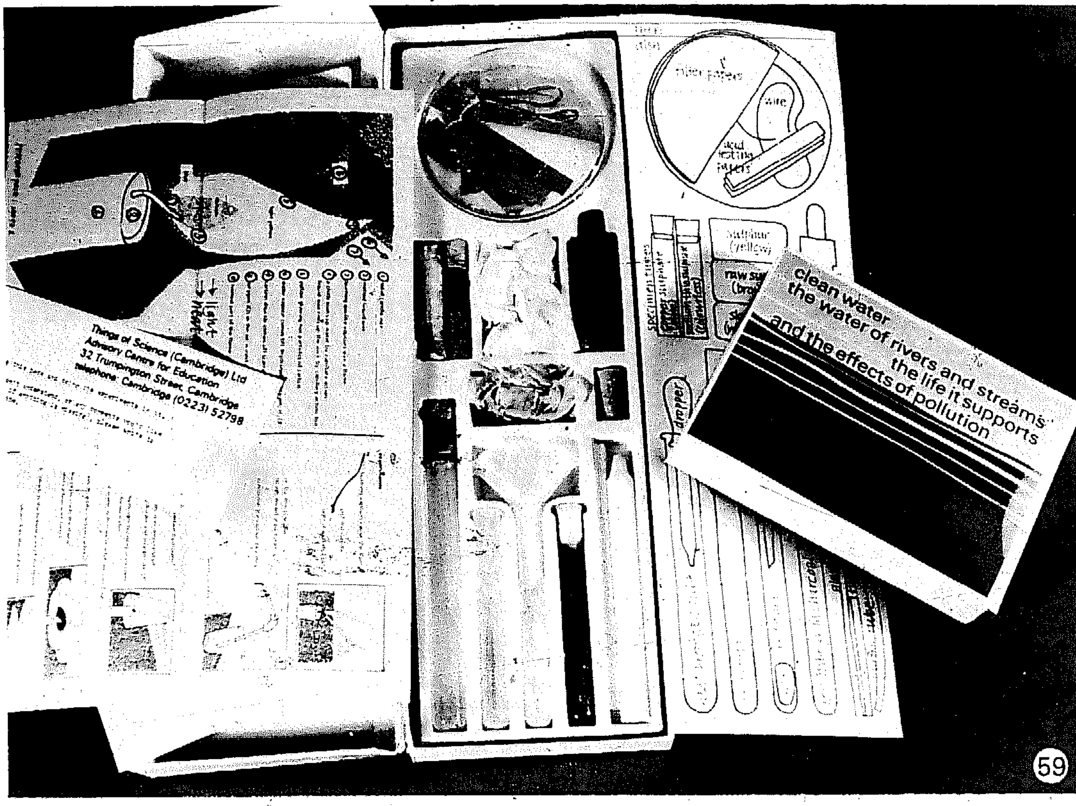




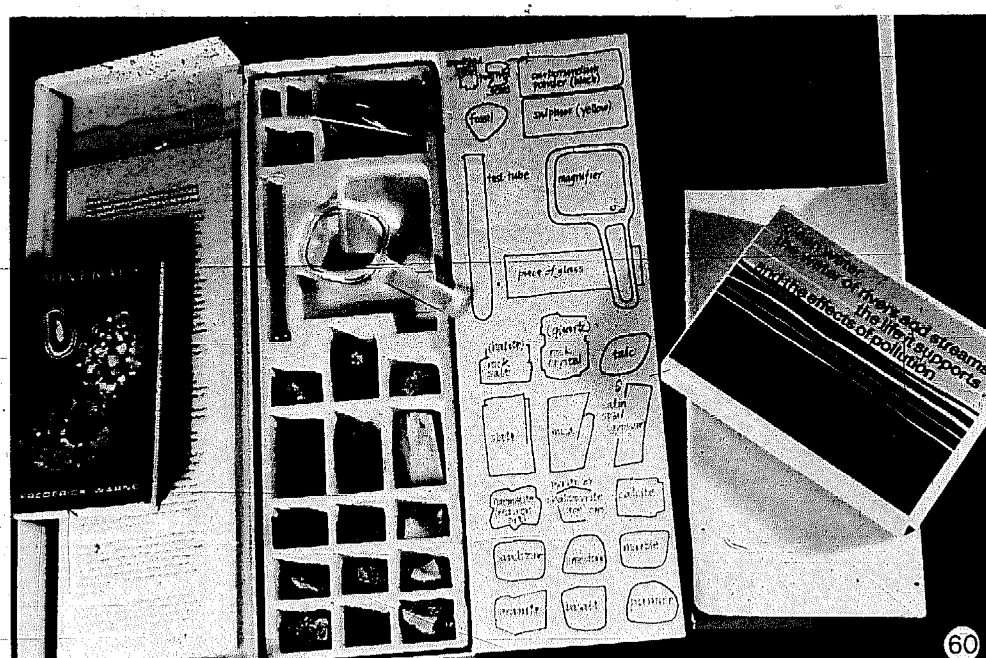
56 & 57 Kits from Precision Jigs Co. Ltd.

58 A sample kit from FUNBEC





59 & 60 Kits from the Advisory Centre for Education (ACE)



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Marlborough House Pall Mall London SW1Y 5HX

ISBN 0 85092 163 5

Copies may also be purchased from the Publications Section of the Commonwealth Secretariat.

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Printed and Published by the Commonwealth Secretariat

Contents

Introduction

In 1975 the Commonwealth Secretariat, acting on the recommendations of member states, initiated a programme of investigation and assistance in the field of low-cost production of school science equipment. The programme started with the publication in 1975 of The Production of School Science Equipment - a review of developments (1), and plans were then made to hold three regional seminars to consider the provision of relevant science teaching equipment from local and other sources.

To provide background material for the first of those meetings it was felt that studies of some of the existing centres, would be useful resource material. Four centres, each concerned in one way or another with getting science teaching apparatus into the classroom, were selected for the study. These studies were used at the first regional seminar held in Nassau, Bahamas in November 1976(2), and again at the second, held in Dar es Salaam, Tanzania in September 1977(3).

Subsequent feedback and requests have indicated that it would be useful to have the studies published as a separate publication, even though they were summarized and printed in the report of the first regional meeting.

The studies were originally carried out early in 1976 through funds provided by the Commonwealth Fund for Technical Co-operation. A further section has now been added to draw attention to some of the similarities and differences in the modes of operation and organization of the centres. It is not intended that any of the centres should be considered as models to be faithfully copied since they have to reflect the national goals and environmental realities they have been established to serve. Instead, each study focuses attention on problems and considerations which have to be accounted for when the establishment of some form of local production of school science teaching equipment is being considered.

Because the two regional seminars have deliberated on these factors, it is recommended that the seminar reports should be read in conjunction with this publication. The final seminar in the current programme will be held in Papua New Guinea in March 1979. It is expected that this meeting will draw together the work of the previous seminars and provide strong guidelines which can be used by a country wishing to start producing some of its own teaching materials.

---

1. The Production of School Science Equipment - a review of developments. Commonwealth Secretariat publication, 1975.

2. Low-Cost Science Teaching Equipment
Report of a Commonwealth Regional Seminar/Workshop
Nassau, Bahamas, 16-26 November 1976.

3. Low-Cost Science Teaching Equipment:2
Report of a Commonwealth Regional Seminar/Workshop
Dar es Salaam, Tanzania, 20-30 September 1977.

Section 1

THE NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING: INDIA

Background

The predominant pattern of education in India comprises eight years of integrated elementary education, three years of secondary education with diversified courses to give it a vocational bias and make it a terminal point for entry into a trade or higher education, and three years of university education leading to a first degree. Some of the states have adopted a pattern of seven years of elementary education. However, in 1966 the Education Commission suggested a uniform pattern of 15 years' duration leading to the first degree (10 years of general education, two years of general or vocational education at the higher secondary level and three years for the first degree).

This pattern, referred to as the 10 + 2 system, has already been introduced in over half the states and will shortly be introduced in several more.

Statistics of Education

The First All-India Educational Survey was conducted in 1957 by the Ministry of Education. In 1965-66 the Second All-India Educational Survey was carried out by the National Council of Educational Research and Training (NCERT) for the Ministry of Education and Social Welfare and the Planning Commission. In 1973 the Ministry of Education decided to have the Third All-India Educational Survey. Though the full results of the survey have not been finally presented, some provisional data on school education have been released. These show that in 1973 there were 461,864 primary schools, 87,702 middle schools, 32,779 secondary schools, 6,805 higher secondary schools and 2,938 intermediate and junior colleges in the country. Altogether there were over 82 million pupils in school, of whom over 60 million were in classes I to V (primary).

National Curriculum Development

Traditionally, each state in India was free to decide its own policy for education and its own structure. But with a view to improving school education in the country as a whole, the National Council of Educational Research and Training (NCERT) was set up in 1961 by the Government of India. The NCERT is an autonomous body wholly financed by the Government. It functions as the academic adviser to the Ministry of Education and Social Welfare.

In the field of curriculum development the Council is involved in devising standard curricula in all the school subjects and in producing model syllabuses and teaching materials which are then offered to the states for adoption or adaptation to their requirements. Few other curriculum projects are in existence or have existed in recent times. The largest separate project was the Bombay Municipal Project, an activity developed by the All-India Science Teachers'

Association and assisted by the British Council with a Nuffield-based approach. As its name implies, this project was operative in the Municipality of Bombay. British Council assistance ceased in 1975. Another small project is in existence in Hoshangabad in Uttar Pradesh. This project is a rural education project based on an Institute for Rural Development. The project has been in existence for some three years, and is a science teaching project operating in 16 trial schools. The Physics Department of Delhi University is assisting with this project, particularly in its evaluation.

Both of these projects have incorporated material developed by the All-India Science Teachers' Association Study Groups.

The National Council of Educational Research and Training

The NCERT was established on 1 September 1961 with its headquarters in New Delhi. It undertakes, aids, promotes and co-ordinates research in all branches of education. It organizes extension services, and pre-service and in-service training mainly at advanced level. It undertakes and organizes studies, investigations and surveys relating to educational matters or the appraisal of educational programmes. It disseminates improved techniques and practices, and it acts as a clearing house for ideas and information on all matters relating to school education. It has its own publishing house, producing textbooks, supplementary readers, research monographs, educational journals and a variety of educational materials on a "no profit no loss" basis. It also has a large purpose-built workshop where science kits are designed and developed. Details of this workshop are given later.

The NCERT functions through six constituent units as shown in Diagram 1. These are the National Institute of Education (NIE) and

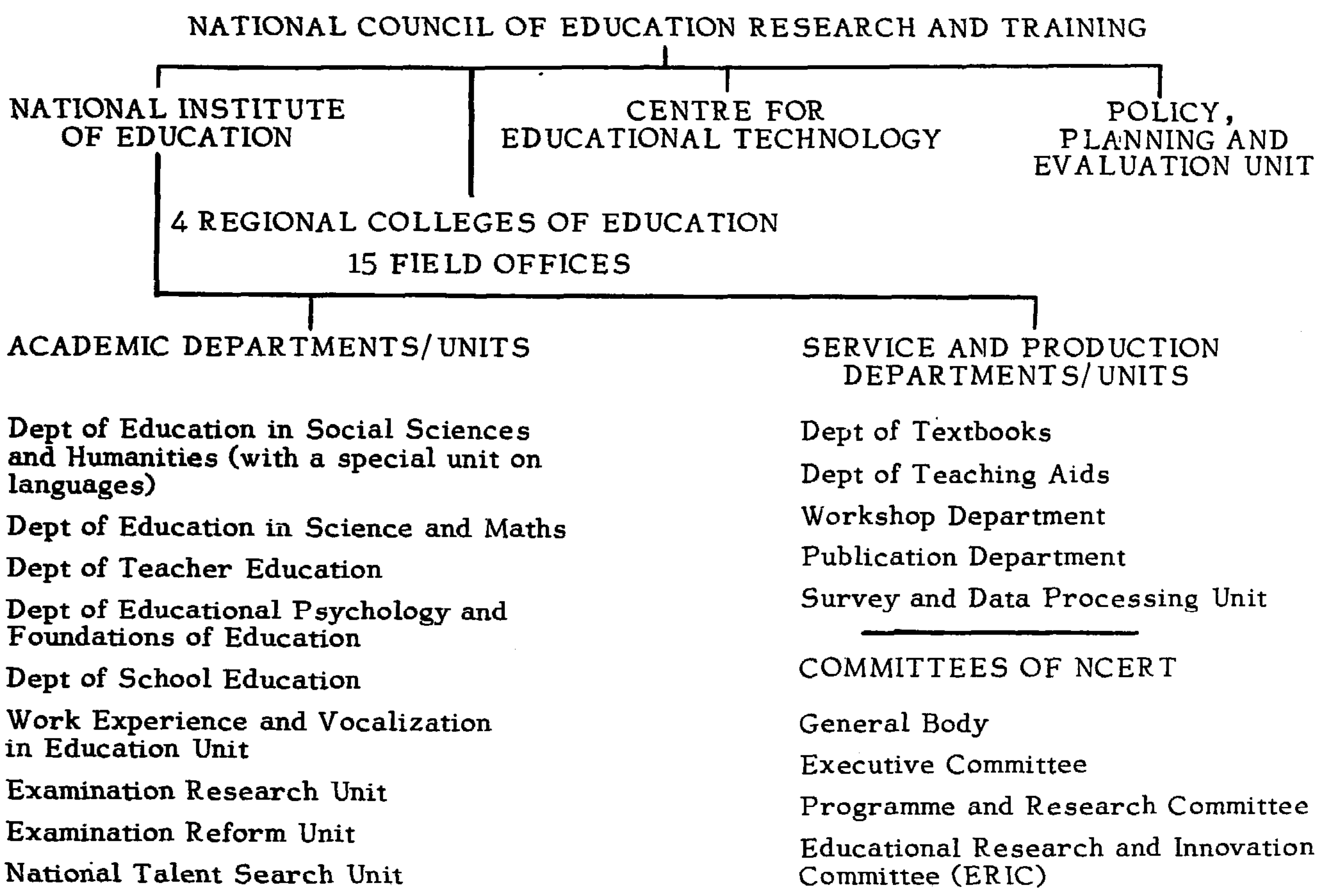

Diagram 1. The Structure of the NCERT

the Centre for Educational Technology (CET) at New Delhi, and the four Regional Colleges of Education (RCEs) at Ajmer, Bhopal, Bhubaneswar and Mysore. It maintains liaison with all relevant institutions furthering the aims of school education, and also with State Ministries of Education through a network of 15 field offices.

The National Institute of Education

The National Institute of Education (NIE) is concerned mainly with conducting research on problems of school education. As the diagram shows, it works through a number of academic departments (e.g. education in science and mathematics) and service and production departments and units (e.g. the teaching aids department, and the survey and data processing unit).

The National Talent Search Unit conducts an annual competition for final-year secondary students and provides scholarships in the basic sciences and mathematics to successful participants. The NIE also organizes several training programmes, seminars and workshops for teachers, teacher educators, educational administrators, and others.

The Centre for Educational Technology

The Centre for Educational Technology (CET) was set up by NCERT in 1973. It is concerned with the development of innovation in education using the various communication media. At present CET is operating a Satellite Instructional Television Experiment (SITE) using the Applied Technology Satellite No.6 loaned by the U.S.A. for one year (August 1975 to July 1976). This experiment involves 2,400 villages located in six states, and is a two-fold programme of primary teacher re-orientation and adult education. For the first of these programmes, by developing a multi-media package for training science teachers at the primary level (with SITE as one component of the package), it is hoped that a twelve-day training course for 96,000 primary school teachers will be possible. Since upwards of a million primary teachers will need retraining to meet the demands of the NCERT primary science curriculum, the project is of high importance.

The Policy, Planning and Evaluation Unit

The Policy, Planning and Evaluation Unit of NCERT acts as a clearing house for ideas and information on educational research and training, and an Educational Research and Innovation Committee (ERIC) was constituted to promote research and finance suitable research projects outside of NCERT.

Department of Education in Science and Mathematics

In 1963 the Government of India asked a UNESCO mission to report upon a desirable form of science and mathematics education for the country. The mission recommended a complete reform of the curriculum, and the provision of printed material and kits of equipment. The pattern of education for science and mathematics was suggested as being: Stage 1, Classes I-V; Stage 2, Classes VI-VIII; and Stage 3, Classes IX-XI.

At the first stage stress should be laid on obtaining information about the non-living nature, and arithmetic with some geometry. At the second stage a disciplinary approach to teaching Physics, Chemistry and Biology should be adopted. Biology and Physics should be introduced in Class IV, through to Class VI, whilst Chemistry should be introduced at Class V thereby allowing the basic Physics knowledge to allow a fuller development of the studies of the properties of matter in Chemistry. In the third stage a number of streams should be provided such as science, humanities, and technology. Only in the science stream would physics, chemistry and biology be taught.

Under the new twelve-year pattern of schooling (1975) the stages become: Stage 1, Classes I-V; Stage 2, Classes VI-VIII; Stage 3, Classes IX and X; and Stage 4, Classes XI and XII.

Science and mathematics will be taught to all up to the end of Stage 3, with streaming starting in Stage 4, thereby ensuring a general science background for all pupils.

Further recommendations made by the mission related to equipping schools for teaching science and mathematics. It was recommended that, since it would not be financially possible to provide science laboratories and equipment in all schools, at least a small demonstration bench should be provided. In addition a Central Science Workshop should be established which could carry out work along four major lines:

(a) Studying the equipment for teaching science that is manufactured by industry, and exploring how its quality could be improved.

(b) Designing, manufacturing and experimental testing of new teaching equipment.

(c) Utilization of the best Indian and foreign experience for designing and producing teaching equipment.

(d) Producing new designs for manufacture by industry.

Other recommendations included the training of science and mathematics teachers, and research in science and mathematics education.

Following these recommendations, a project for curriculum development materialized, and in September 1965 work began in the Department of Education in Science and Mathematics. UNESCO experts were made available to assist with the implementation of the curriculum development project, which was to develop not only the relevant syllabus but also textbooks, teachers' guides and kits of equipment related to the different subjects and levels of education. It was intended that the material should be as flexible as possible so that each state could adapt it to its own special needs without losing the spirit of the approach which was to be based upon experimentation and enquiry. To facilitate as widespread a representation as possible in the curriculum development work, 20 study groups were established in various university centres. They consisted not only of teachers but also of scientists. The tasks assigned to these study groups were to develop instructional material for the entire school stage in mathematics, and for the secondary stage from class V/VI upwards for physics, chemistry and biology.

These study groups appeared to have varying degrees of success, and a great deal of centralized co-ordination occurred to finalize the materials; for example the physics groups prepared separate materials and the final official version after some difficulties. (One set of materials developed by a study group is apparently the basis of the Bombay Municipality Project.)

The Central Science Workshop (now the Workshop Department) began designing and developing kits in 1968. The first were Physics 1, and a small chemistry kit for the middle schools. In 1969 a few prototypes of the primary science kit were developed, leading eventually to the comprehensive primary science kit which was contained in a box and had its own in-built demonstration table (flap) and chalkboard. The kit also contained a set of hand tools to enable the teacher to improvise some items for himself. The kit was developed for the village primary school which would only have the minimum of classroom fittings.

Physics Kit 2 and Chemistry Kit, followed by Biology were next developed, with the Physics Kit 3 the last to be developed. These kits were of two types, one for demonstration to class sizes of 35 to 40 and pupils' kits for groups of four to six students.

Implementation of the Science Education Project

The government prepared a plan of operation in conjunction with UNICEF/UNESCO for the pilot project on a national basis for the improvement of science teaching. Under this plan, UNICEF agreed to provide funds for (a) translating and printing the syllabus and instructional materials, (b) science laboratory equipment for training institutions, (c) teacher training, (d) the supply of kits to schools, and (d) a limited supply of paper for printing the instructional materials.

To implement the Science Education Project the states were encouraged to set up State Institutes of Science Education (SISEs) or science wings to their State Institutes of Education (SIEs). Some states already had such institutes. It was envisaged that these institutes would provide in-service training and orientation programmes for teachers. In addition, a number of key teacher training institutions were identified to assist in the project implementation. The basis of selection was made upon the suitability of staff and facilities. Initially 579 institutions were identified and received science equipment provided by UNICEF. It consisted of imported kits of traditional apparatus intended to equip the laboratories to a given standard. A later evaluation revealed that some of the institutions were not suitable to utilize the equipment effectively, and it was decided that any future institutions would be selected only after inspection by NCERT field staff.

It was decided to try out the NCERT material in a number of experimental schools. Consequently some 1,200 primary and 700 middle schools were selected throughout the country representing 30 states of the union.

Responsibility for providing the science kits needed for the pilot project was taken by the Workshop Department of NCERT. As only limited funds were available for the project, it was decided to concentrate on the demonstration kits rather than the pupils' kits. The workshop was strengthened in various sections to meet the demands to be made on it, and the toal number of kits provided up to the middle of 1975 was:

	69/70	70/71	71/72	72/73	73/74	74/75	75/76
Primary Science	-	760	188	155	61	110	47*
Physics 1	69	426	130	116	40	68	25
" 2	-	-	351	213	57	124	67
" 3	-	-	-	175	437	44	35
Biology 1	-	468	129	108	4	-	-
Biology Dem.	-	-	350	211	56	129	65
Chemistry Dem.	-	-	350	214	57	129	65
Physics Class	-	-	467	1,571	-	480	-

* 1,500 Primary Science Kits have been produced for the Republic of Afghanistan, and a further 800 for direct purchase by two states.

It is anticipated that some 8,000 primary kits will be produced for UNICEF during 1976.

The project plan was envisaged as having three phases - the pilot phase, the wider introduction phase, and universalization. The degree of progress through these phases has varied from state to state. UNICEF assistance at the wider introduction phase has been limited to primary education only, which in turn has affected its implementation in some states.

Workshop Department

The Workshop Department is in a purpose-built building in close proximity to the Science and Mathematics Department and is a single-storey building for the most part with a small first-floor area over part of the building.

The components of the Workshop Department are: main workshop; prototype design workshop; dies and sheet metal workshop; optics glass workshop; wood workshop; plastic workshop; foundry; electroplating shop; paint shop; welding bay; electrical repair/maintenance shop; design/development office; display laboratory; main stores (material); stores (spares, stock and inspection); completed kit stores; assembly area; reproduction/duplicating area; general office and administration section.

The Department has approximately 100 members of staff and, depending on demand, it also employs a daily labour force. Diagram 2 outlines the staff structure, but it should be noted that a particular title does not necessarily reflect the actual duties of an individual. For example, of the Technical Officers, one is responsible for office administration, and, in the Fine Mechanic grade, two are in the packaging section.

Diagram 3 on page 9 indicates the layout of the Workshop Department (not to scale).

Staff are recruited through national advertising, and the successful applicants are appointed to their appropriate grade. A system exists whereby any individual who shows aptitude can apply for the relevant trade test and be up-graded. (Such a system promotes staff improvement and encourages harmonious working relationships.)

The policy of the workshop has apparently been towards flexibility of staffing. Besides each individual having his specific duties, personnel can also be co-opted to other duties as the demand necessitates. This enables the NCERT to supplement demand areas and remove bottlenecks when they look like occurring. Such a policy, although often written into civil service conditions of employment, is not always effectively enforceable and often rests on good employer/staff relations.

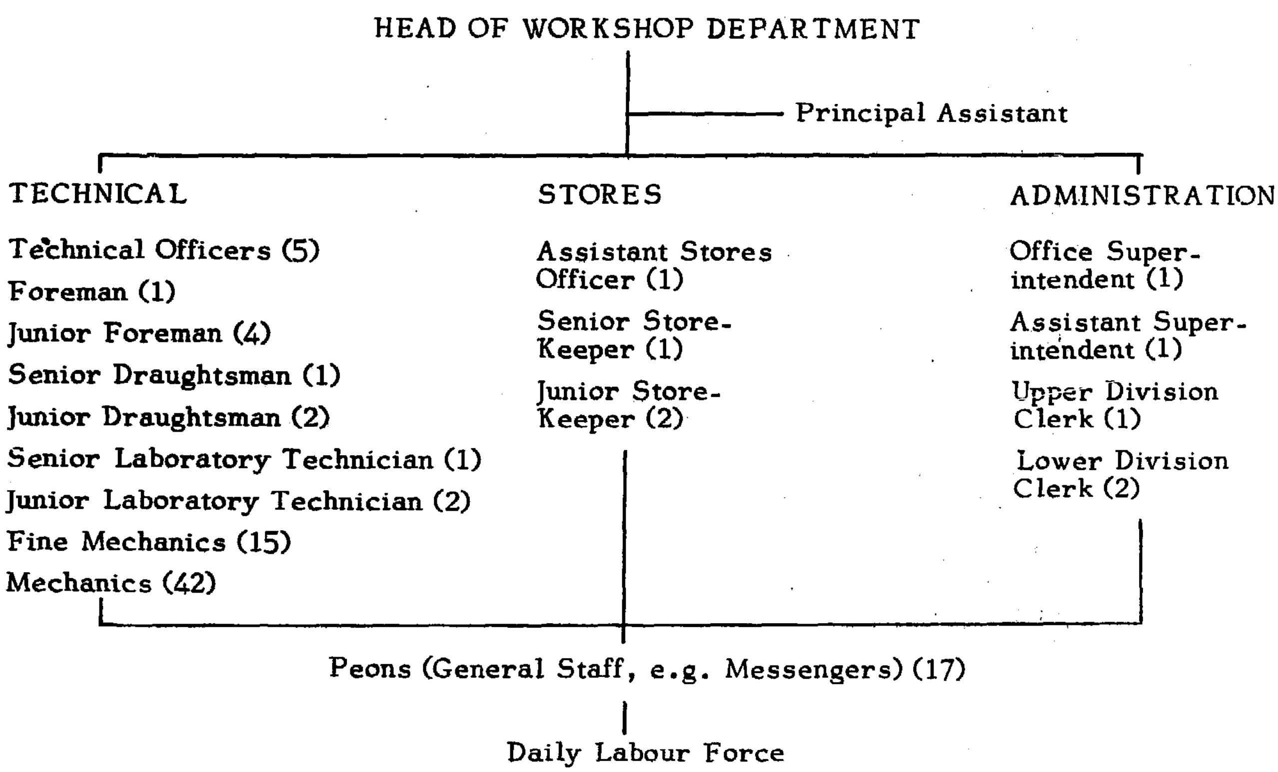

Diagram 2. Staff Structure of the Workshop Department

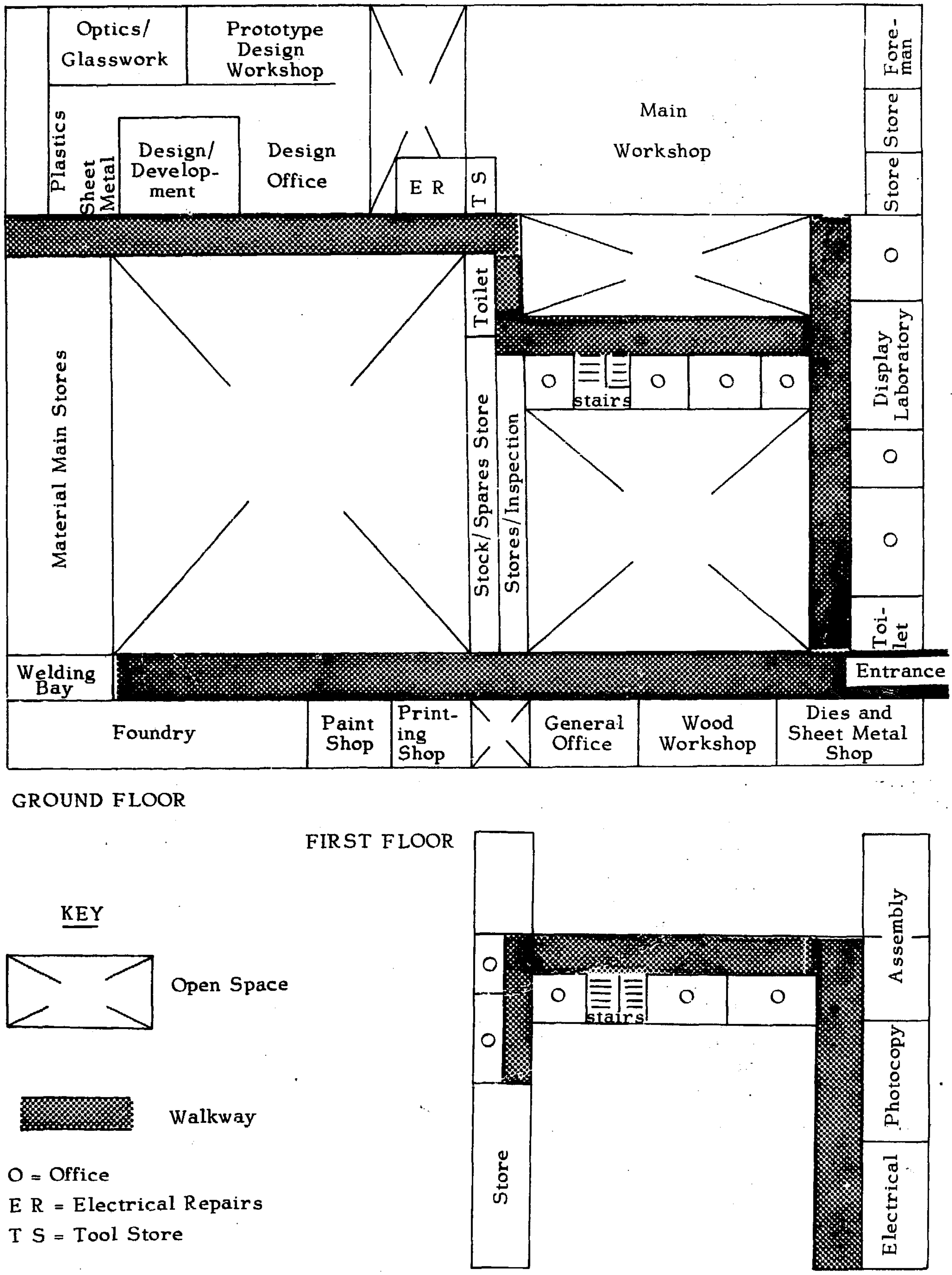

Diagram 3. Sketch of the Workshop Department (not to scale)

Financing

The NCERT is wholly financed by the Government of India. From the budget the workshop has been allocated 500,000 rupees for 1975/76 fiscal year, with a further 50,000 rupees for research and development. Of the 500,000 rupees, 60% is spent on the purchasing of raw materials, and the sale of the kits is normally expected to replace this expenditure. It is expected that the workshop will eventually be self-supporting financially, selling its products on a no-profit no-loss basis, which is not the case at present. A 'labour cost' figure is included in the price of the kits and this amount is reckoned at 60% of the staff costs. (Full staff costs are not included since the workshop also undertakes maintenance for the whole of the NCERT.)

Kits are purchased through each State Ministry of Education. Direct purchases cannot be made by schools, nor is it possible for them to obtain spare parts or replacement items at the moment.

The cost in rupees of the kit was quoted as being :

Primary Science Kit	210
Physics Kit 1	206
Physics Kit 2	250
Physics Kit 3	350
Chemistry Kit	420
" " (pupils)	224
Biology Kit	350

(Pupils' Kits have been discontinued due to the emphasis on primary work.)

(January 1976, £1 = 17.9 rupees.)

Development of Science Kits

In general the kits were developed by close liaison with the staff groups of the Science and Mathematics Department, as well as with the UNESCO specialists supplied under the UNDP/UNESCO assistance to the NCERT. From the workshop design staff's point of view, interchange of staff took place when developing a piece of apparatus, thereby allowing more than one individual to participate in the design at various stages. Materials were tried out in a local school, and, where necessary, modified prior to inclusion in the kits.

During the process of development, the production aspect of the apparatus was kept in mind, thereby facilitating a minimum of change between the form of the prototype and the form of the finished production item. On completion of development of the item, workshop production drawings were produced. They are available for anyone wishing to construct the apparatus.

Production of Kits

In addition to the facilities for constructing apparatus provided in the Workshop Department, a number of items are constructed by local manufacturers. Currently there are some twelve commercial manufacturers who tender for the batch requirements of the kits. The system is to request tenders for a fixed number of items with the suppliers working to the strict requirements of the Department. Poor quality control has been experienced in the past, and all items submitted to the workshop are inspected by selected members of the workshop staff prior to acceptance.

By maintaining their own quality control standards, the reliability of the manufacturers has improved, particularly since each manufacturer's tender rests heavily on the quality of his past product. New tender companies have to supply sample products prior to approval for tender. In addition to supplying the needs of the Department, these companies also offer their products on the open market for purchase by schools, etc. The Department supplies a list of such suppliers to all schools who write to the NCERT for information on the availability of the kits (see page 13).

Under the course work activities of the Science and Mathematics Department the workshop has held two courses on quality control. These have been for members of state Ministries of Education who have provided Quality Control Officers to specifically monitor the quality of products when purchased from commercial suppliers. The participants have been instructed in the requirements of their duties and have been provided with a kit of instruments and with samples purchased out of UNICEF funds.

AN EXAMPLE OF MATERIAL RELATED TO PRIMARY SCIENCE

REFERENCE BOOKS PUBLISHED (NCERT)

Textbooks

"Science is Doing" for Class III
"Science is Doing" for Class IV
"Science is Doing" for Class V

Teacher's Guides

Teacher's Guide to "Science is Doing" for Class III
Teacher's Guide to "Science is Doing" for Class IV
Teacher's Guide to "Science is Doing" for Class V

Teacher's Handbooks of Activities

General Science - A Handbook of Activities for Primary Schools Vol. 1
General Science - A Handbook of Activities for Primary Schools Vol. 2
General Science - A Handbook of Activities for Primary Schools Vol. 3

Kit Guide

SCIENTIFIC TOPICS COVERED UNDER NEW CURRICULUM

1. Our Universe. 2. Air, Water and Weather. 3. Rocks, Soils and Minerals. 4. Forces and Work. 5. Matter and Materials. 6. Housing and Clothing. 7. Living Things. 8. Plant Life. 9. Animal Life, including a separate chapter on Birds in Class III. 10. Man and His World (In Class V only). 11. Human Body Health and Hygiene.

LIST OF THE KIT CONTENTS

General Items

1. Aluminium Katori (a cup without handle) 100 mm. dia. - 2
2. Balls (rubber) 80 mm. and 50 mm. dia. - 1 each
3. Beaker 150 ml. and 100 ml. - 1 each
4. Hard glass test tube - 1
5. Compass needle - 1
6. Electric circuit-board with battery, bulb and switch - 1
7. Enamelled copper wire 24 gauge - 2 metres
8. Football pump - 1
9. Glass marbles - 50
10. Glass jar or empty jam bottle - 1
11. Glass rod 15 mm. dia. x 150 mm. long - 1
12. Hand fan - 1
13. Hand lens (mag. 4X) with plastic frame - 1

14. Hard board 200 x 200 x 3 mm. with rectangular slot of 80 x 80 mm. in centre - 1

15. Hollow polythene rectangular containers of same capacity but different sizes - 1 each

(a) 120 x 60 x 30 mm. height (red)
(b) 90 x 30 x 80 mm. height (blue)

16. Kitchen strainer (wire-net) - 1

17. Bar magnet - 1 pair

18. Measuring cylinder 100 ml. - 1

19. Aluminium tube 60 mm. dia. x 125 mm. long - 3

20. Soft iron nails 6 mm. dia. x 130 mm. long - 2

21. Mountirg needles - 2

22. Plane mirror mounted on wooden base 100 mm. x 61 mm. - 1

23. Plastic comb - 1

24. Plastic funnel 75 mm. dia. - 1

25. Tubing 7.5 mm. dia. (Polytene) - 1 metre

26. Plastic tumbler 100 mm. high - 2

27. Plastic syringe - 1

28. Polythene bags assorted - 6

29. Pulley - 1

30. Rubber stoppers assorted for item number 4 - 2

31. Rubber stoppers assorted for item number 36 - 3

32. Scale half-metre with five holes - 1

33. Sieve 125 mm. dia. - 1

34. Lamp (kerosene) - 1

35. Spring balance - 1

36. Test tubes 15 mm. dia. x 125 mm. long - 6

37. Thermometer 0-110° C on wooden base - 1

38. Thermometer clinical - 1

39. Torch with 2 cells - 1

40. Tripod stand with wire gauze - 1 each

41. Water wheel - 1

42. Wedge - 1

43. Wind-vane - 1

44. 1 kg. weight - 1

45. M. S. Wire 3 mm. dia. 200 mm. long - 1

46. Glider - 1

47. Top pan spring balance 2 kg. - 1

48. Model of lift pump - 1

49. Toy electric motor - 1

50. Kit box

Hand Tools

1. File triangular (100 mm.) - 1
2. Hammer with claw (250 gms.) - 1
3. Hand drill (6 mm. dia. capacity) with drill bits - 1

COMMERCIAL SUPPLIERS OF SCIENCE KITS

M/s. Delta Laboratory Equipments, 6438 Bagichi Ishwari Pershad, Bara Hindu Rao, Delhi 110006	Primary Science	III to V
M/s. Gaupad Chemicals, Kaithal Gate, Chandausi, UP	Primary Science	III to V
M/s. Optika & Chemico, 28-B Industrial Estate, Gwalior, MP	Physics I/Physics III	VI/VIII
M/s. Hargolal & Sons, Hargolal Building, Hargolal Road, Ambala Cantt.	Physics II/Physics III	VII/VIII
M/s. Metro Scientific Industries, Mori Gate, Delhi 110006	Physics I	VI
M/s. Dynam Engineering Corporation, 6 Haudin Road, Bangalore 560042	Physics I	VI
M/s. Arun Chemicals & Scientific Industries, 11/5495 Basti Harphool Singh, Sadar Thana Road, Delhi 110006	Chemistry	VII to VIII
M/s. Sisbro Scientific Industries, (New) 47, UA Lawahar Magar, Delhi 110006	Biology Composite/ Biology Non-Composite	VI to VIII/ VII to VIII
M/s. Mittal Sales Corporation, Chand Tara Building, G. T. Road, Shahdara	Biology Composite/ Biology Non-Composite	VI to VIII/ VII to VIII
M/s. Gadget House, Bhagat Ki Kothi, Jodhpur, Rajasthan	Biology Composite	VI to VIII
M/s. The Haryana State Small Industries & Export Corporation Ltd., Bank of India Building, (2nd Floor) Sector 17-B, Chandigarh	Biology I	VI
M/s. Educational Kit Manufactuer, 255/300 Mangal Pass Building, Kitchen Garden Lane, Bombay 400002	Biology Non-Composite	VII to VIII

Section 2

THE SCIENCE EQUIPMENT PRODUCTION UNIT: KENYA

Background

Primary education in Kenya is of seven years duration (standard one to standard seven) with the first four years being free. Education at this level covers a wide range of subjects including science and mathematics. Successful completion of primary education is marked by the award of a Certificate of Primary Education (CPE).

Secondary education takes place in Government-maintained schools, Harambee (self-help community) schools, or private schools. The private schools which are run by a person or organization (including religious societies) receive no assistance from the Government. Some Harambee schools receive Government help in the form of one or two teachers, and they may also obtain grants to help in the construction of classrooms, laboratories, and other school buildings. It is of interest to note that Harambee schools are gradually being phased out or being taken over as maintained schools by the Ministry of Education.

Entry into secondary schools is based on the performance of children at the CPE Examination. Entrants are generally those pupils with good marks who are at the same time able to pay fees, but scholarships and bursaries are available for very able pupils.

Secondary education is divided into two phases of four and two years' duration. At the end of the second year of the first phase of the basic secondary school course, there is an optional external examination which is normally taken by students in Harambee and private schools. This leads to the awards of the Kenya Junior Secondary Education Certificate. Students who successfully complete the four years of secondary schooling obtain the East African Certificate of Education (EACE)* which provides a basis for entry to the second phase of secondary education. The successful completion of these two years is marked by the award of the East African Advanced Certificate in Education (EAACE). This provides the basis for university selection.

Pre-service teacher education takes place in primary teacher training colleges, Kenya Science Teachers College (KSTC) and universities. There are three classes of teachers at the primary school level. Grade 3 teachers have pursued a two-year teacher training course after primary standard 7; Grade 2 teachers have completed a two-year teacher training course after secondary form

*To obtain a division 1 or 2 EACE, a candidate must obtain credit pass in maths and science.

2 or 4; and Grade 1 teachers have completed a two-year teacher training course after secondary form 4*. S1 teachers are lower secondary school teachers who after obtaining an EACE have pursued a three-year course at KSTC or who after obtaining an EAACE have completed a one-year course at KSTC. Senior secondary level teachers are normally expected to possess a university degree.

Table 1 gives some relevant educational statistics for the period 1972-76.

TABLE 1: SELECTED EDUCATIONAL STATISTICS: KENYA

	1972	1973	1974	1975	1976
Number of Primary Schools	6,657	6,932	8,000	8,049	8,500
Total Primary School Population	1,675,919	1,816,017	2,734,398	3,016,000	3,476,000
Number of Primary Teachers Colleges	17	17	17	17	17
Kenya Science Teachers College	1	1	1	1	1
Number of Polytechnics	2	2	2	2	2
Kenya Technical Teachers College	-	-	-	-	-
Number of Maintained and Assisted Secondary Schools	363	380	404	404	407
Number of Harambee and Private Secondary Schools	585	650	796	796	796
Number of Universities	1	1	2	2	2

Source: Ministry of Education Annual Report for 1972, 1973 and 1974
Unpublished data for 1975 and 1976

The Kenya Institute of Education (KIE)

As a result of a conference on educational institutes held under the aegis of the University of East Africa and the Ministries of Education in Kenya, Uganda and Tanzania, the KIE was established in April 1964. It was originally set up to administer a scheme of examinations on the behalf of the Kenya Ministry of Education and to act as a centre of professional activity for teachers. However, in 1968 it absorbed the former Curriculum Development and Research Centre (an amalgamation of the English Special Centre, the Mathematics Centre and the Nairobi Science Training Centre) and added to its list of duties the function of preparing educational materials.

*As from the 1976/77 academic year, all entrants to primary teacher training colleges must possess credit pass in maths and science in the EACE.

The work of the various sections of KIE is done through a system of subject panels. These panels consist of personnel drawn from the KIE, the Inspectorate Division of the Ministry of Education, the Kenya Science Teachers College (KSTC), the Education Department of the University of Nairobi and practising teachers.

The science panel played a central role in the development of the East African School Science Project, and has, since the early days of the Science Equipment Unit, provided professional advice to the work in the field of local production of equipment. Also, in addition to organizing in-service courses for teachers, the panel, from time to time, produces information sheets for schools, giving advice on science teaching materials. By mid-1975, over 500 publications had been produced by the KIE in conjunction with the Jomo Kenyatta Foundation, a non-profit making publishing organization.

The progress and evaluation of the materials produced are monitored by KIE. The necessary information is gathered through questionnaires, visits to schools, correspondence with the staff of teacher training colleges and at teachers' in-service courses.

All sections of the KIE are either broadcasting programmes to teachers and pupils or are planning to do so. The programmes in use and those envisaged are of three types: background materials for teachers, demonstration of how specific lessons should be taught, and specific help to teachers on how to teach individual lessons. It is hoped that increasing use of radio will be required as new materials are produced.

THE KENYA PRIMARY SCIENCE PROGRAMME

Overview

The Programme was initiated in the mid sixties. Aided by funds and personnel from the African Primary Science Programme (APSP), its first emphasis lay in the production of films and written materials. These materials were primarily in the form of guides for teachers, though a smaller number of science readers for children were also produced. Some 50 to 60 booklets, and five films, were produced, all of which received extensive fields trials in typical classroom situations.

Early on in the programme two subcentres for development were established, one at Kagumo Teachers College, and the other at Siriba Teachers College. Their basic purpose was to explore mechanisms for supporting teachers professionallly in primary schools. Both have subsequently been incorporated into the programme of Teachers Advisory Centres (TACs).

Recently the programme has produced a new set of Guidelines For Teaching Science in Primary Schools which will replace the former syllabus. These Guidelines outline the goals to be achieved through science education at each level in the primary school. The APSP booklets, as well as other materials, are referred to as resource materials to accompany the Guidelines. Research is being carried out to find suitable ways of evaluating the progress of children using the Guidelines. This includes consideration of the problem of writing questions for the primary school leaving examination which are both relevant to the new course and fair to the pupils and teachers in the schools.

Work is also going on which seeks to identify the most effective ways of giving professional support to personnel working in the field. In this connection KIE staff have co-operated closely with the Inspectorate in organizing workshops for Primary School Inspectors, TAC tutors and Assistant Education Officers. KIE staff also assist with in-service courses at the district level in an attempt to help to build up a core of local resource personnnel who can in turn assist in the task of in-service training. Curriculum materials are being developed for use by students and tutors in teachers colleges. Finally, the staff of the Primary Science Section of KIE are from time to time making professional contribution to the primary science education programme at the University of Nairobi.

Aims and Approach

The Programme has three basic aims: namely to encourage and assist children to: (a) develop the manual and intellectual skills that are necessary to solve problems in a scientific way; (b) preserve and acquire the attitudes that are necessary to apply those skills effectively; and (c) acquire a deep understanding of the natural phenomena that take place in their environment. In order to achieve these aims, activities in the classroom are made to relate directly to the pupils' environment. This is accomplished by helping children first to acquire problem-solving skills and than to apply the skills in solving problems based on their immediate environment.

In recognition of some of the complexities of the intellectual and emotional development of chilren, three stages in the programme are given special attention in the development of programme materials. In the first stage - that is for the first three years of schooling - children are presented with a variety of opportunities to preserve, strengthen and develop those attitudes and skills which will enable them to approach and solve problems rationally and effectively. They are encouraged to continue to develop their natural curiosity and their willingness to explore and ask questions, and to gain as much direct experience as possible of their natural surroundings. During the two years that follow, children are introduced to the process of solving specific problems. However, the application of the process of scientific problem solving is at this stage restricted to relatively simple and concrete situations. Finally, in the last two years of primary school, the children carry out a series of investigations, each of which covers a range of scientific topics, concepts and skills that were previously treated as separate entities.

This attempt to integrate the various scientific disciplines and use them to solve problems represents a significant change from the former approach which mainly consisted of learning unrelated pieces of information and repeating them in an examination. Moreover, this unified approach tends to bring the pupils' classroom experiences closer in line with real-life situations they will meet in the future.

Materials Available

No equipment is provided specifically for teaching science in primary schools. Teachers therefore make much use of ordinary things around them in the environment. In addition, some general equipment provided to schools can be used for science teaching. This equipment is purchased through the Ministry of Education Kenya School Equipment Scheme. Purchase is via the tender system, and deliveries take place to a central warehouse in Nairobi. Distribution is then to divisional warehouses located in 39 districts and seven municipalities, where Divisional Education Officers arrange distribution to the individual schools. Equipment lists are supplied by the Ministry, and schools make out their own requirements which are sent to the appropriate District Education Officer who submits lists to the Ministry for action.

Written material for the whole seven years of primary school and for teachers colleges can be summarized as follows:

Lower primary (standards I, II, III). About a dozen booklets have been produced which give suggestions to teachers on how to create opportunities for young children to gain the kinds of experience envisaged in the programme. The titles of some of these booklets reflect the close relationship of the suggested activities with the natural surroundings of the children: Plants in The Classroom; Water; Dry Sand; Woodwork; Exploring The Local Community; Construction. In all these booklets suggestions are given about using local materials that are available around typical primary schools. The use of locally available materials is important, not only in the name of economy and feasibility, but to help to prevent young children becoming alienated from their home community and background. Currently a group is at work preparing a guide to help teachers to use these booklets and other resource material in as integrated a style as possible. Additional materials are planned specifically for the transition period for children in standard three.

Middle primary (standards IV and V). The Guidelines Programme is introduced in Standard IV. Guidelines for standards IV and V have been prepared, and several reference units are being printed by the Jomo Kenyatta Foundation in 1976.

Upper primary (standards VI and VII). The first draft version of the Guidelines for Standard VI has been tested. The Guidelines and supporting resource books are being prepared to help teachers with such topics as people around us; the shamba; ourselves; and metals.

It is intended that the materials for Standard VII will follow a similar approach. However, the topics for investigation will be concerned with applied science and technology with the expectation that pupils will identify and solve problems of real and practical significance in areas such as agriculture, health and village technology.

Teachers Colleges are supplied with all the materials undergoing trial within the programme. In addition to the Guidelines and associated reference materials, a document called "Handbook for Teacher" has been developed as part of an international effort, sponsored by the Science Education programme for Africa. This Handbook has been designed specifically for use in teachers colleges to help prepare teachers in the effective implementation of new approach to primary science education. A further document "A Sourcebook For Tutors" is also being developed.

A number of films have been produced as part of APSP, both from Kenyan primary schools and from other African countries. These films have been found to be extremely useful when introducing the programme to teachers and other educators who have not yet experienced this kind of approach to science education.

SECONDARY SCHOOL SCIENCE

Science is taught in secondary schools either as general science or as physics, chemistry and biology. Because the separate subjects are generally regarded as bing academically superior, they tend to be more popular than general science.

In 1965, a move for reforms in secondary school science curricula in East Africa was initiated in Tanzania. Subsequently a series of conferences, held in Nairobi, Dar es Salaam and Kampala, led to the inauguration of the East Africa School Science Project (SSP) in 1966.

Originally the SSP aimed at adapting the Nuffield science materials for use in East Africa. Later, however, a more imaginative approach was adopted "to produce the right courses for the first four years of the secondary school programme".* By drawing upon the Nuffield project material as well as material from the UNESCO Pilot Project for Africa, subject panels in chemistry, physics, and biology were able to develop the required courses. Membership of these panels included university professors and lecturers, practising school

*SSP Physics Panel, SSP Physics: Introductory Statement, Dar es Salaam, April, 1970, p.3.

teachers, and representatives of the various Ministries of Education and the UNESCO Science Teaching Project for Africa.

The courses were first tested at the East African Certificate of Education level in 1970 (chemistry) and 1971 (biology and physics). They seek to promote in pupils, understanding, lively enquiry, and interest in science. Emphasis is placed on scientific concepts and principles, and on course content that has obvious relevance and interest to East African countries.

Materials developed for the SSP course include pupils' books, teachers' guides, background readers, filmstrips, film data book, photographs and other teaching and learning aids. It is noteworthy that the teachers' guides include, for the many teachers with limited qualifications and experience, advice on ways of introducing certain individual topics, on getting apparatus to work, on making-do with local resources when equipment fails to arrive on time, and on how to keep a whole class mentally active.

KENYA SCIENCE EQUIPMENT PRODUCTION UNIT (SEPU)

Background

In the early 60s almost all the science equipment used in schools in Kenya was imported from overseas. The high cost of apparatus precluded all but a small number of schools from buying the necessary quantity. Other problems were that imported equipment often failed to arrive on time, and that many items tended to be inappropriate to the conditions in Kenya.

With the growing interest in Kenya of science programmes such as Nuffield, SSP, and PSSC that emphasised individual student experimentation, the shortage of equipment became increasingly acute. Efforts therefore got underway to make cheap, readily-available equipment.

Two of these were unfortunately unsuccessful. The first of these was undertaken at a technically-biased secondary school - Starehe Boys Centre. Simple items of equipment suitable for the first year of the SSP course were produced. However, neither development work nor large-scale production was envisaged. The other was undertaken by the Engineering Faculty of the University of Nairobi where a few school science equipment items made from wood and metal were produced during a period of two summer vacations. The summer courses were aimed primarily at giving technical skills to the university's first year engineering students and to giving students in the faculty experience of production problems and planning.

Though efforts at these two production centres lapsed, it is hoped that in the near future the Faculty of Engineering will set up an Industrial Consultancy Unit similar to that based in the Engineering Faculty at the Universtiy of Science and Technology, Kumasi, Ghana.

Another venture, however, proved very successful. In establishing the Swedish-financed KSTC in 1965, the Agreement between the Kenyan and Swedish Governments made provision for setting up facilities for the production of science teaching materials and for running workshop courses. Three years later, KSTC accepted a Kenyan Government request to set up an Industrial Arts Department, and in March 1968 this Department began to run workshop courses for students. A small beginning was also made in the design and production of low-cost teaching materials for secondary schools. This early production effort was pioneered by the senior technical physicist, and the kit was therefore essentially a physics one. A special characteristic of this physics kit was that it was not linked with any particular teaching philosophy. In other words, the kit system was as such that it could be adapted easily to any of the "learning by doing" programmes mentioned above.

To make the efforts more successful, a production unit was set up within the College. It aimed at being both independent and economically self-supporting. A workshop occupying an area of 265m^2 was completed in 1970. Since then it has been expanded and it now occupies an area of 960m^2.

The principal machine tools supplied for the KSTC Production Unit are:

Metal Work: three lathes, one milling machine, one pillar drill, one band saw, one hack saw, two grinders, one oxyacetylene welding set, one arc welding set, one sheet metal roller, one manual guillotine, one bending machine.

Wood work: one circular saw, one band saw, one planer (3m), one thicknesser, one large belt sander, one spindle moulder, one bench mounted drill.

General: Compressor (a recent addition).

Science Equipment Production Unit Subscribers

Towards the end of 1971 a KSTC Policy decision led to the expansion of staff and the appointment of a full-time head of the Production Unit.

In 1972, a production unit Executive Committee was formed to help the understaffed unit in its management and design work. The five man committee comprised of the principal and administrative secretary of KSTC, the head of the unit (the SEPU Manager), a representative of the Kenya Institute of Education (KIE) and a representative of the Ministry of Education. The head of the unit left in July 1973, and due to difficulties with recruiting staff, the unit did not start functioning again until December 1973. During the period of closure, the unit was run as part of the Industrial Arts Department. In January 1975, SEPU became fully staffed and consequently the Committee was dissolved.

Currently SEPU is run as a company under a seven-man trusteeship. The trustees are the Director of Education, Ministry of Education; the Permanent Secretary, Ministry of Finance and Planning; the Kenya Science Teachers College; the Kenya Institute of Education; the National Council for Science and Technology, the Jomo Kenyatta Foundation; and the Kenya Technical Teachers College.

According to a Kenya/Sweden agreement signed in June 1976, the Swedish government will continue to provide financial aid and technical know-how to the company until 30 June 1979 when it is hoped that SEPU will be completely self-supporting.

Production Strategy

In developing the various items in the physics kit, no special strategy was adopted. However, to ensure economic viability and efficiency of the project the following approach has been followed, as far as possible, in the production of the chemistry and biology kits. To begin with, a list of the most acute apparatus needs of schools was produced by the Manager and the Designer in consultation with the chemistry and biology panels of the KIE. A questionnaire was used to probe the apparatus market prior to embarking on the development of the kits. It appears as Appendix 1 on page 26. The needs were then matched to the availability of raw materials, the amount of design work needed and the difficulty of production. At this stage an order of production priorities was agreed.

For each item the Designer produced one or more prototypes and calculated an order of magnitude cost. The costing procedure adopted was as follows: Cost of materials + 10%; cost of labour + 20%; running cost of machines + 40%. (The additions to the raw costs were to account for the cost of materials lying on shelf awaiting use or of finished items awaiting sale, the higher salaries paid to supervising and development staff, sales costs, and the wear and tear of machines.)

When the prototype was ready, it was vetted by the Manager who then determined the size of the batch, taking into account the relevance of the item to current syllabuses and likely sales. The Designer prepared the jigs needed for production with the help of the Manager, and arranged the sequence in which operations should occur. Once production started, continuity and quality remained in the hands of the Manager. At various stages in the production of a batch, items were subjected to tests devised by the Manager and the Designer. Any items failing these tests were either reworked or thrown away. In the early stages of 1972, the initial failure rate was sometimes as high as 80% although the final wastage in a batch, after reworking, was usually of the order of 7%.*

Prices: Local versus imported items

Table 2 below shows the prices in K.Sh. of some of the SEPU physics items and those of imported equivalents as of August 1973:

TABLE 2: COMPARATIVE PRICES

Item	Local Price	Imported Price	Type of Design
A. C. tuner	45	160	Local
Dynamics trolley	90 (per pair)	165 (per pair)	Local
Wheatstone bridge	80	202	Conventional
3-d Kinetic model	85	430	Local
Ray optics kit (including cylindrical lenses)	53	110	Local
Optics lamps	30	84	Local

SEPU Science Kits

Kits have been developed to allow students to have experience in as much individual practical work as possible in physics, chemistry and biology.

The items contained in each kit are accompanied by materials for students and teachers written by teachers with teaching experience in Kenyan Schools. Recently these have been strengthened by slides and tapes supported by leaflets. Still more recently radio programmes have been prepared to support the biology kit.

Whereas formerly most items (including electrical meters and lenses) were imported and assembled as part of the kit system, now the majority of the items in the kits have been developed locally. Since the three spearate kits have certain items in common, schools are able to cut down costs by buying a box containing, say, a physics/chemistry kit.

The chemistry kit can be used to illustrate the usefulness of the kits in teaching. The basis of the kit is the pegboard stand. This is a board drilled with small holes at regular intervals and supported

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*These details were obtained from J.M.S. Whittell's article "Local Production: Principles and Practice", in The School Science Review, June 1975, pp. 675-76.

stand by means of a special stainless steel clip. The clip has a base which can be fastened on a stand with a screw and nut, and its diameter can be adjusted to hold all the pieces of glassware from the thermometer up to the beaker. Compared to the more conventional retort stand, the pegboard is stable and light. Moreover it possesses many features which allow flexibility. For instance it is possible to mount apparatus anywhere on the stand and at the same time see where one piece of apparatus is in relation to one another. More important for work in chemistry, the apparatus can be mounted away from the stand when heating is required.

About 50% of the kit consists of items of glassware. These are bought mainly from local companies, most of which represent foreign firms. The Ministry of Education lists local companies in the Inspectorate Circular Letter No. INS/76/3 of 10 January 1976 as: Instrumentation Limited, Nairobi; Westco Limited, Nairobi; Howse and McGeorge Limited, Nairobi; E.T.: Monks & Company Limited, Nairobi; Anant Limited, Nairobi; Philip Harris Limited, Nairobi; Sciex (East Africa) Limited, Nairobi; Achelis Limited, Nairobi; Cross Chemist Limited, Kisumu; and Anpi Pharma, Nairobi.

A notable characteristic of the kit is that there is no bent glass tubing. When collecting a gas over water (an exercise that is done frequently) the gas is led into the collecting test-tube through flexible plastic tubing. This type of arrangement does away with the rather cumbersome process involving the use of beehive shelves, gas jars, and thistle funnels. Further, despite the standard nature of the glassware involved, each component of the kit has been designated to be compatible with as many other items in the kit as possible. Thus the rigid plastic tube used as the electrolysis cell can be converted into a drying chamber for gases. With many other items fulfilling more than one function, it is estimated that at least 100 simple experiments can be performed with the set of apparatus contained in the kit.

When not in use the apparatus can be stored in a plastic mould or inside a cardboard box but there is also a wooden box designed to store the apparatus of several kits.

In terms of the cost and approach, the kit has considerable advantages. However, a few problems have been noted in connection with its use. One of these is that the kit is relatively small and therefore not suitable for demonstration purposes. Another is that because many of the items in the kit are small, they are easily lost. Practical work has therefore to be carefully organized. A further problem is that although the chemicals required for the experiments are listed, they are not provided. It is hoped, however, that in the near future a "chemical kit" will be developed containing all the chemicals required for the experiments in the EACE Course. Finally, the pupils' sheets do not contain any reading materials other than that directly related to the experiments. Consequently pupils need additional support in the form of a text or other suitable background reading materials.

Production Figures and Sales

As early as 1972, it was found that sales promotion based on distribution leaflets alone was unlikely to prove successful. So a KSTC graduate who was then teaching in a secondary school was seconded by the Ministry of Education to SEPU and given responsibility for promoting sales and arranging demonstrations to schools. The result was immediate: during the first six months of this new appointment, sales were six times the estimated figure.*

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*J.M.S. Whittell, op. cit. p.677.

Table 3 below shows numbers of kits that had been delivered to schools in Kenya up to April 1976.

TABLE 3: KITS DELIVERED TO SCHOOLS

Period	Physics	Chemistry	Biology
1969-1972	547		
Jan-Dec 1973	443		
Jan-Dec 1974	381	162	
Jan-Dec 1975	436	353	13
Jan-April 1976	159	152	112
TOTAL	1,966	667	125

Prices of kits as at 1 May 1976 are as shown in Appendix 2.

Future Plans

With the completion of the new building, plans are under way to make use of the increased storage facilities to buy chemicals in bulk and repack them in smaller packages for distribution to schools. Lecture room facilities in the new building will also allow SEPU to hold in-service courses for teachers in the use of the kits.

SEPU is considering the possibility of designing a special kit in science for primary schools, and hopes to begin exporting equipment in the near future. A detailed evaluation of the kits is expected to be carried out soon. It is hoped that, among other things, this evaluation will find out the extent to which the SEPU project has affected student attitudes to science and the style of science teaching in secondary schools in Kenya.

TEACHER ADVISORY CENTRES (TACs) IN KENYA

Following the establishment of the Primary School Inspectorate Service in 1969, it became clear that local centres were needed in various parts of the country where short courses could be provided for groups of teachers or individual teachers seeking advice or help. Thus in 1970, 20 Teacher Advisory Centres (TACs) were established and equipped with basic constructional tools for making audio-visual teaching aids, books and other printed materials for reference purposes.

There are at present 43 TACs of which eleven are situated in primary teacher training colleges, (these tend to be better equipped), 15 in primary schools, four in secondary schools, and twelve in other community centres. These TACs are distributed throughout the country with at least one in each of the 39 districts in the country. In addition there are sub-centres situated among a cluster of schools in an area where teachers can easily get together for a meeting.

Siting of TACs in teachers colleges allows college tutors and tutors of Centres to interact in pre-service and in-service courses. Again when residential in-service courses are held for practising teachers, existing college facilities are an asset.

The Centres are currently manned by tutors who also work closely with a number of "example schools", usually to be found within a radious of 8 km of the Centre. In these schools the TAC tutor acts as a supervisor, encouraging teachers, assisting them to improve their competence, keeping a progress report of each teacher, and informing KIE of work in the field.

Teachers for the position of TAC tutor are carefully selected. Once appointed they collaborate with the area assistant primary school inspectors and principals of the primary teachers colleges where the Centres are situated. These personnel provide the Ministry of Education with a record and an evaluation of the tutors' work.

KENYA SCIENCE TEACHERS ASSOCIATION

The Kenya Science Teachers Association (KSTA) was inaugurated in Nairobi on 7 April 1952. The idea to establish a professional body of science teachers was conceived by a group of expatriate teachers who, being scattered all over the country, hoped that such a body would help promote communication among them.

The Association which is exempt from registration by the Registrar of Societies, exists (a) to promote good teaching of science at all levels of the educational system, and (b) to afford means of communication among members and also between the Association and other bodies. Membership is open to all teachers and any person interested in the teaching of science. Thus it includes primary and secondary school teachers, science student teachers, tutors of teacher training colleges, inspectors of science, and university lecturers and professors.

The Association enjoys good working relations with the Ministry of Education, the Kenya Institute of Education, Science Equipment Production Unit and other bodies. Its activities are restricted to matters concerning the teaching of science. These include organizing conferences, seminars, workshops and student science congresses, and publishing a journal. The student science congresses have been held at the national level since 1964 and continue to be popular. Of the many conferences dealing with various themes, one which deserves particular mention is the School Science Apparatus Conference held at the University of Nairobi in August 1973. The conference looked critically at the problems of equipping school science laboratories in Kenyan schools and explored ways of easing some of the frustration experienced by science teachers.

APPENDIX 1: QUESTIONNAIRE FOR PROBE OF APPARATUS MARKET

Part 1

1. Name of school:
2. Name of person to whom correspondence should be addressed:
3. Telephone number:
4. Type of school:
5. Number of pupils in school:
6. Level to which pupils are taught:
7. Number of parallel streams:
8. Are the following subjects taught separately? physics; chemistry; biology:
9. Is general science taught as well as, or instead of, above separate subjects?
10. Average number of pupils per class:

Part 2

11. How much money, if any, is spent at present on apparatus annually for (a) physical sciences? (separate into physics and chemistry, if possible) (b) biology sciences? (c) general science?
12. Are you interested in the samples of apparatus shown?
13. At the prices aksed, how much would you buy?
14. How much would you spend annually if told/shown what was available?
15. Is there any particular time of year when it is easier to buy apparatus because of availability of funds?
16. If there were an apparatus fair at some accessible centre once a year, would you (a) find it useful? (b) attend?
17. Could you, under any conditions, pay cash on delivery? If not, what period would be needed for payment?
18. Would you welcome, and use, a periodical pamphlet saying what apparatus is available and outlining its uses, and giving prices and availabilities?
19. For expensive apparatus which is beyond your financial reach, would you welcome the establishment of a pool of apparatus at some local centre from which you could borrow?
20. For the use of the pool outlined in 19, would you be willing to pay a small annual charge to cover the cost of maintenance?

Part 3

Comments and additional information:

APPENDIX 2: PRICE LIST

Kits	Shs.
1. One physics kit in one box	395.00

2.	Two physics kit in one box	745.00
3.	One chemistry kit in one box	295.00
4.	Two chemistry kit in one box	545.00
5.	One supplementary chemistry kit in one box	235.00
6.	One physics and one supplementary chemistry kit in one box	585.00
7.	One empty box	45.00
8.	Biology kit	210.00

Manuals

9.	Science kit manual	5.00
10.	Mechanics and general physics	5.50
11.	Heat	5.50
12.	Chemistry kit pupils sheet yr. I & II	10.00
13.	Chemistry kit pupils sheet yr. III & IV	8.00
14.	Chemistry kit teachers guide yr. I & II	10.00
15.	Chemistry kit teachers guide yr. III & IV	8.00
16.	Biology manual	8.00

Physics Slides

17.	High voltage electric fields	66.50
18.	Difference between sounds	66.50
19.	Electric charge and electrons	66.50
20.	Cassette tape for the physics slides	16.00

Chemistry Slides

21.	Making soap in Kenya	47.50
22.	Soda ash from Lake Magadi	47.50
23.	Making salt in Kenya	47.50

Biology Slides

24.	Sorting out living organisms	66.50
25.	Savannah ecosystem	47.50
26.	Man and nature	47.50

Geography Slides

27.	Physical geography slides	167.50

Others

28.	Friction drums	250.00
29.	Min-Max thermometer	40.00
30.	3-D Model	120.00
31.	Ammeter	110.00
32.	Voltmeter	110.00
33.	Galvanometer	110.00

34.	Meter bridge	120.00
35.	Trolley	80.00
36.	Timer	80.00
37.	Ticker tape	1.20
38.	Stroboscope	15.00
39.	Optic lamp	35.00
40.	Statistics board	25.00
41.	Wall thermometer	15.00
42.	Test-tube racks	13.00
43.	20 ml syringes	10.00
44.	50 ml syringes	15.00

*£1 = Shs. 14.50

Section 3

CENTRE FOR THE MANUFACTURE OF TEACHING AIDS AND EQUIPMENT : TURKEY

Background

Primary education in Turkey is free and compulsory for a period of five years in the six to 14 age-bracket. Three-year regional primary boarding schools exist in addition to the usual day schools, especially in rural areas. Turkish is the medium of instruction. Class sizes average about 45.

Up to the end of the 1974/75 academic year, successful completion of primary education was marked with the award of a certificate. This practice has ceased with the coming into effect in 1976 of the new eight-year minimum basic education.

Secondary education lasts for six years, three of which are spent in middle school (orta) and three in high school (lycee). There are no specialized courses in middle schools: the programmes offered are career-oriented. Middle schools are either independent or are attached to high schools.

The high school prepares students for higher education, for the professions, and for the necessities of life. In the first year, termed a career-selection grade, general education, professional and technical courses are offered. At this grade, students sample different kinds of courses to find out the type of career that suits their aptitudes and inclinations. In different sections of the second year of high schooling, two kinds of programmes - literature and science - are offered to prepare students for higher education. There are four different kinds of programme in the third year of high school; literature, social science/economics, math/physics, and natural science. In each of these programmes, there are common, compulsory, special and elective courses. Turkish is the medium of instruction, but foreign languages like English, French and German are taught. The normal class size in middle and high schools is 40, though class sizes of 75 and 80 are not unknown.

A few experimental schools (nine as at present) exist. These make the introduction of innovations into the school system relatively easy.

Table 4 of educational statistics for Turkey, showing the number of pupils in the country who attend state, private and minority schools at the primary, middle, and high-school levels, appears at the foot of page 28. It should be noted that the private schools in Turkey usually exist to serve the need of foreigners.

The Science Lycee

In 1964, the Ministry of Education established, with assistance from the Ford Foundation, a high school called the Science Lycee to provide a three-year course with a bias towards science and mathematics. The school began with very well-equipped laboratories, high staff-student ratio, and highly qualified staff. Its highly selective nature was evident from the fact that out of at least 10,000 applicants only about 300 were admitted. Its science programmes were adaptations of current American materials in the separate subjects of biology, chemistry and physics (i.e. the BSCS for biology, CHEM study for chemistry, and PSSC for physics). However, the Science Lycee is no longer the model school it was proposed to be. R.H. Maybury in his book Technical Assistance and Innovation in Science Education (John Wiley & Sons, New York, 1975) describes it as being now "an ordinary secondary school, struggling against the same problems of niggardly budgets, inadequate equipment, and indifference among teachers that afflict most secondary schools in most economically-deprived countries".

The Science Project (Fen Projesi)

In 1966, the Ministry of Education decided that the Science Lycee materials should be placed into other schools in Turkey. The first pilot effort began in Behceliever School during the 1966/67 academic year. In this exercise the Science Lycee staff assisted the Behceliever School teachers to use the course materials in all their science materials. This experience at Behceliever School led to the initial outlines of the framework for the large-scale extension of the Science Lycee materials that is described next.

In March 1967, the Ministry of Education set up a body called the Science Education Development Commission (SEDC) whose members were drawn from the Ministry of Education and Turkey's scientific community. The Commission gave priority attention to a pilot programme for extending the Science Lycee materials into other schools

TABLE 4: SCHOOLS AND PUPILS IN TURKEY

	1971/72		1972/73	
	No. of Schools	No. of Pupils	No. of Schools	No. of Pupils
State Primary School	39,100	5,076,166	40,154	5,268,811
Private Primary School	79	15,990	78	16,842
Minority Primary School	76	7,272	72	6,734
State Middle School	1,734	786,486	1,909	906,187
Private Middle School	87	18,031	67	15,856
Minority Middle School	17	2,231	17	1,945
State High School	423	235,525	490	257,068
Private High School	78	13,816	61	15,856
Minority High School	12	1,044	12	969

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in Turkey. Schools drawn from Ankara, Istanbul, Aydiu, Erzurum and Izmir cities were designated as lycees participating in this pilot project. TUBITAK (Turkey's Scientific and Technical Research Council) agreed to act as sponsor of this pilot programme under a project entitled: "Research on the possibility of conducting Science Education at other Turkish Lycees using the courses developed by the Science Lycee Project."

The original project involved nine lycees including Bahceliever School and about 100 teachers and 8,000 students. It consisted of trying out the Turkish adaptations of the American materials in use in the Science Lycee.

In June 1970 a SEDC-commissioned evaluation study of the performance of teachers and students of the nine pilot lycees in this project over the three-year period 1968 to 1970, showed that the materials were not as successful in other Turkish lycees as they had been in the Science Lycee. However, with the recorded positive attitude of the pilot lycee teachers, apparent failure was attributed to a number of causes including such factors as insufficient time to complete the ccurses, heavy workload on both students and teachers, lack of motivation of some of the students, and teachers' lack of experience in taking full advantage of modern teaching methods.

According to the new school system, the curriculum at first year high school was to be a general diagnostic one. It was then to be followed by a system of specialized options in which students chose to pursue literature or science stream courses.

With the first year general science course based on a Turkish adaptation of the American Introductory Physical Science (IPS) programme, the SEDC enlarged the scope of its outreach by launching a three-year experiment at the beginning of the 1971/72 academic year. This new project, in which all the existing American adapted texts were revised, involved 100 regular lycees and 89 lycee-level teacher training colleges. (The latter offer a four-year course including education and the general curriculum.)

The 100 high schools were selected from all over the country according to the following criteria: (a) the number of students in classes should not exceed 40; (b) there should be sufficient laboratory and classroom space for the teaching of science classes; (c) classroom-laboratories should be equipped with chairs and flat-top tables on which groups of four students could work; and (d) in case of an increase in the number of students, there must be a suitable place around the school building for construction of new buildings.

With this experiment over, the SEDC has begun introducing the following revised materials printed at the Science Project Centre into all state high schools in Turkey:

(a) Textbooks prepared by the Commission and printed by the Ministry of Education. These books are normally sold to students at cost but are generally given to poor students without charge.

(b) Teachers' guide books. These are distributed free to teachers who need to use them.

(c) Translations of a variety of source books for teachers and students.

(d) Tests and evaluation materials.

(e) "News Bulletin of Modern Science Education" published by the Scientific Commission.

In addition to these printed materials, films and film strips related to the modern science programmes are being procured. Reproducing these films for use in schools is the task of the Film Centre of the Ministry of Education, but purchasing them and meeting their costs in foreign currency are the responsibility of the Centre for Science Project.

Science Project Staff

The six professional staff, with supporting administrative and clerical staff, are housed in the new building of the Ministry of Education headquarters. These professional staff are all former teachers in lycees, and most have already been on training courses in the U.S.A. The current head of the team is Mr. Nihat Gurpinar. The SEDC is an advisory body to this team.

In-service Training of Teachers

The teacher training implications for the Lycee Science Projects have been met in part, at least by a series of summer institutes. A considerable budget from TUBITAK has been made available to these institutes which have been staffed by university professors and members of the Project. These summer courses are being conducted all over Turkey. It is worth noting that in the early years of the Lycee Science Project, a number of American tutors participated in these courses, and it is no surprise that the institutes seem to have been modelled on the extensive National Science Foundation summer institutes that were a feature of the U.S. curriculum science during the 1960s.

SCHOOL MATERIALS MANUFACTURING CENTRE (DAYM)

Establishment and Functions

With the aid of expert assistance and cash for machinery and equipment from the Organization for Economic Co-operation and Development (OECD), the Ministry of Education set up the School Materials Manufacturing Centre (DAYM) in Ankara in 1961.

The main function of DAYM is to provide teaching materials for schools in Turkey. This it does by producing the bulk of the equipment and aids and by purchasing the remainder for distribution from local or foreign markets.

The Centre also serves two other functions. The first of these is to hold in-service courses during summer months for science teachers in order to train them to use and to repair laboratory equipment. For this purpose, mobile units are used. They are based in a few centres, and generally consist of a van, science equipment, tools and small machines for repair work, and audio-visual aids. They are staffed by able science teachers who travel around a province (particularly in deprived areas) helping science teachers with their teaching problems, introducing them to new mehtods and techniques in science education, repairing broken equipment, and giving demonstrations in practical lessons in rural schools where adequate facilities for such work are at present non-existent.

The second function of the Centre is to run day and/or evening courses for apprentices as well as evening courses for people who intend to learn a trade. The students involved are adults and out-of-school youths. The courses include machine tool operation, metal turning, die making, electricity, electronics, glassblowing, technical drawing and woodworking. Over 2,300 workers have received satisfactory training through this scheme over the past ten years.

Structure

Though the Center started with only 25 workers and four teachers in what was originally a day technical school, the DAYM now has a new building in addition to the old one, 580 workers and 18 workshops (soon to be increased to 30), manned by 34 teachers. The administrative staff are all ex-classroom teachers and still belong to the teaching service. Of the 34 teachers, four are qualified engineers and four are Higher Education Technicians. The administrative set up includes: chiefs of various workshops (at present 18), a director, a deputy director, the head of the research development unit, the laboratory chief, five assistant directors responsible for personnel, education, public relations, commercial matters, and production, and 18 workshop chiefs.

Finance and Methods

DAYM is regarded as a Department and it is therefore financed as such by the Central Ministry of Education. Each year the Department of Education Aids within the Ministry of Education receives lists of schools' requirements from the Secondary and Elementary Education Departments. These requests are processed and passed on to the DAYM which then produces and sends the equipment to schools through private transport companies. A school's responsibility is simply to report receipt of equipment by writing to the Centre and to the particular Department under which it functions. If schools need supplementary equipment, they are expected to make direct contact with DAYM or local companies for supplies and pay out of their own school science vote. Records reveal that school requests are dealt with promptly by the Centre.

School Science Equipment

Science equipment for primary, secondary and teacher training levels in all types of materials (wood, plastics, steel and glass) are produced. In fact, apart from certain sophisticated equipment like microscopes and thermometers which are imported from Germany, the U.S.A., Israel and Japan, most of the school science equipment is produced by DAYM. It is estimated, for instance, that over 80% of the equipment required for teaching the Turkish PSSC-Physics is produced at the Centre.

To produce these instructional tools, the main raw materials that have to be imported are optical glasses; chemicals for metal plating; resistance wires (chrome oxide); magnets (horse shoe and bar types); Fe, Ni, A, Cu, components; and semi-manufactured musical instruments components.

The machines available at the DAYM for producing the instrumental tools are shown in the following table 5.

TABLE 5 : DAYM MACHINES

Machines	Quantity	Machines	Quantity
Automatic coil winding machine	4	Spring winding machine	2
Diffusion pump (for glass blowing)	1	Plastic injection press (for 2 kg. capacity)	1
Machines for optical workshops	1 set		
Checking and control devices for optics shop	1 set	Plastic injection press (for 1 kg. capacity)	1
Work dies for optics shop	1 set	Plastic injection press (for $\frac{1}{2}$ kg. capacity)	1
Checking and control instruments for electric and electronic workshops	1 set	Plastic blowing press (for bottle making - 2 litres capacity)	1
		Lathe	3
Special machines for the production of musical instruments	1 set	Polyester spraying machine	1

Table 6 on page 34 indicates the number of sets of equipment and aids produced and supplied to schools by DAYM during the period 1970 to 1973.

TABLE 6: INSTRUCTIONAL TOOLS GIVEN TO SCHOOLS IN THE YEARS 1970-73

Type of Instructional Tool	Number of Sets Given				
	1970	1971	1972	1973	Total
Lycee Modern Physics	88	94	105	100	387
Lycee Modern Chemistry	88	94	105	100	387
Lycee Modern Biology	70	76	90	100	336
Lycee Mathematics	125	126	150	100	501
Lycee Social Studies	115	445	200	100	860
General Science (Lycee + middle school)	60	670	220	500	1,450
Middle School Physics	100	40	340	-	480
Middle School Chemistry	120	40	340	-	500
Middle School Natural Science	100	40	340	-	480
Middle School Social Studies	100	210	350	500	1,160
Middle School Mathematics	125	152	300	500	1,007
Middle School Handicrafts	-	50	-	200	250
Primary School General Science and Natural Science	3,000	3,600	4,000	4,000	14,600
Primary School Social Studies	-	3,500	4,000	4,000	11,500
Primary School Handicrafts	350	-	400	400	1,150
Pre-School Education Instructional Tools	100	100	100	100	400
Middle School-Lycee, Lycee Level College Language Laboratory	-	9	10	10	29
Vocational - Technical Schools General Science	-	75	50	-	125
Grand Total	4,541	9,321	11,100	10,710	35,672

Section 4

REGIONAL CENTRE FOR EDUCATION IN SCIENCE AND MATHEMATICS (Malaysia)

Background

The Southeast Asian Ministers of Education Organization (SEAMEO) was established in 1965 to foster regional co-operation in education, science and culture. The eight member countries are Indonesia, the Khmer Republic, Laos, Malaysia, the Philippines, Singapore, Thailand, and the Republic of Vietnam. In addition there are three associate member countries, namely Australia, France and New Zealand.

The policy-making body of the Organization is the Southeast Asian Ministers of Education Council (SEAMEC) composed of the Ministers of Education of the member countries. The executive arm of the Council is the Southeast Asian Ministers of Education Secretariat (SEAMES), located in Bangkok, Thailand. Programme activities are mainly carried out through a series of Regional Centres/Projects located in various member countries. The Regional Centres/Projects are:

1. The Regional Centre for Tropical Biology (BIOTROP) located in Bogor, Indonesia.

2. Regional Centre for Educational Innovation and Technology (INNOTECH), temporarily located in Bangkok, Thailand (previously in Saigon, Vietnam).

3. Regional Centre for Education in Science and Mathematics (RECSAM) located in Penang, Malaysia.

4. Regional English Language Centre (RELC) located in Singapore.

5. Regional Centre for Graduate Study and Research in Agriculture (SEARCA) located in Los Banos, Philippines.

6. Central Office of the Governing Board of the Regional Tropical Medicine and Public Health Project (TROPMED) located in Bangkok, Thailand.

A further Centre, the Applied Research Centre for Archaelogy and Fine Arts (ARCAFA) is under consideration, and was originally planned to be located in Phnom Penh, Khmer Republic.

The Regional centres conduct a wide range of training courses. BIOTROP, INNOTECH, RECSAM and RELC award certificates and diplomas to their participants on completion of the courses, whilst SEARCA and TROPMED award master's and doctorate degrees and postgraduate diplomas.

Structure of RECSAM

RECSAM was established by SEAMEO as an autonomous institution in May 1967, with the main purpose of assisting member states in the improvement of science and mathematics teaching and thereby providing the firm foundation necessary for meeting the scientific and technical manpower requirements of Southeast Asian countries in the future. The Centre is hosted by the Government of Malaysia as her contribution to regional co-operation, and administered by a Director under the guiding policy of SEAMEC which channels its policy decisions through a governing board. The Director is guided by an International Advisory Council in the development of the Centre's programme.

The Centre is organized under four broad headings, namely Training, Research, Information and Special Services, and Administration.

The Training Division operates courses aimed at training key personnel in modern techniques of teaching and evaluation in science and mathematics.

The Research Division operates courses aimed at developing complete prototype units or modules in science and mathematics as well as conducting some pilot studies on child learning. The two most important projects are the Southeast Asian Science and Mathematics Experiment (SEASAME) and the Science and Mathematics Concept Learning of Southeast Asian Children.

The Information and Special Services Division produces and disseminates the various reports and other RECSAM publications, as well as maintaining contact with appropriate institutions and bodies both within and external to the SEAMEO region.

The Administration Division handles the organization and running of the Centre.

Location of RECSAM

RECSAM is located on the Malayan Teachers' College campus, near Georgetown, Penang. It began limited operations in 1968 in borrowed accommodation from the college, and occupied its own premises on the completion of the first building phase in 1972. This phase involved the construction of hostel accommodation and the recreational block (the latter being temporarily used as the teaching/administrative block pending the completion of phase two). The phase two building will contain two laboratory/workshop blocks, a library/information block, a conference hall and an administrative/teaching block. Details are shown in the drawing on page 37.

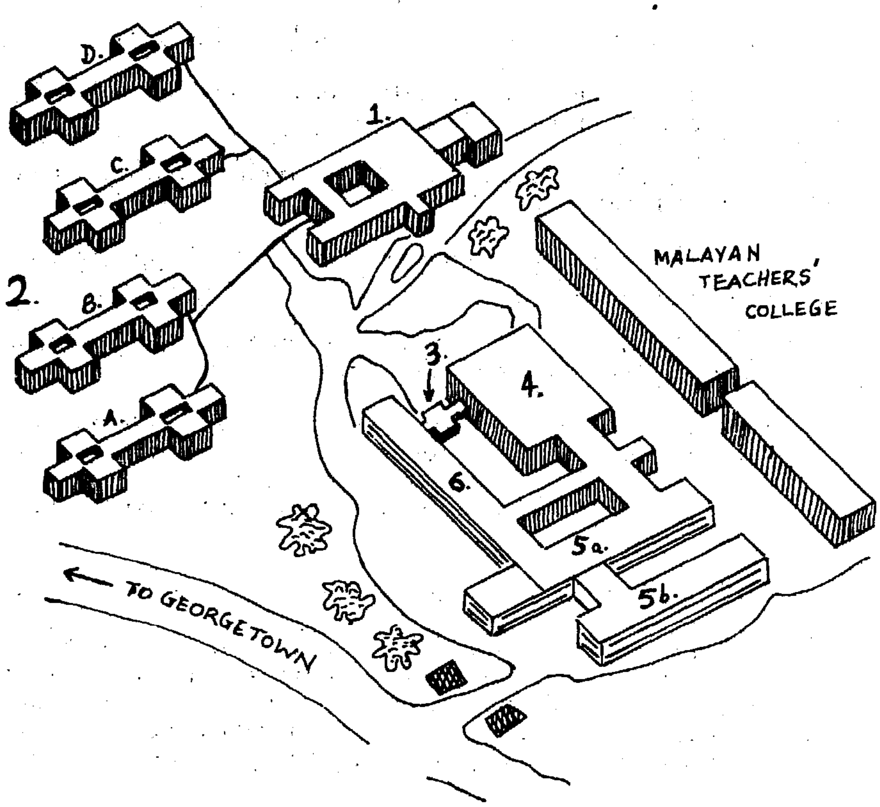
The building priorities were based on the provision of satisfactory accommodation for the course participants together with adequate teaching facilities, followed by purpose-built teaching facilities. By using such a plan, course participants suffered minimum interference to their work. (Accommodation is often a source of discontent on residential courses.)

Facilities

The building currently being used to house the activities of RECSAM is the recreational block, which will revert to this function when phase 2 is completed. The block contains classroom/laboratory space, a small workshop, stores, printing/duplication space, a small resource area (the main library is located in the Malayan Teachers' College building) and a small darkroom for photographic work. In addition, office space for staff, the administrative offices and the dining room are located in the building.

The new building is scheduled to have an administrative and teaching wing, two wings containing science laboratories and workshops, a library and information block, and a conference block. It is envisaged that the workshop facilities will be able to cater for course work by the participants, whilst a separate workshop will be concerned with prototype production of science and mathematics apparatus.

SKETCH PLAN OF THE RECSAM SITE



KEY

1. Recreational Block
2. Hostel Blocks (A, B, C, D)
3. Conference Room
4. Library and Information Block
5a. Science Laboratory/Workshop Block
5b. Science Laboratory/Workshop Block
6. Administration and Teaching Block

At present these two functions are carried out with some difficulty in the one small workshop in the recreational block. Basic hand tools are used for the construction of apparatus: machine tools are not used.

The hostel accommodation is located near the teaching area and consists of some 100 units of single/double accommodation, some of which are air conditioned. There are common rooms and laundry facilities in each of the four hostel blocks. A large dining room/recreation room is located in the recreational block, which at the moment is also used as a general purpose hall.

Functions of RECSAM

To achieve the purpose for which it was established, RECSAM undertakes the following activities:

1. Training programmes for key educators in modern methods of teaching science and mathematics.

2. Development of action-research techniques.

3. Critical study of selected pilot project materials.

4. Development of specific studies and instructional materials to be carried out as pilot projects.

5. Critical examination of research on curriculum materials and methodology.

6. Development of simple techniques in apparatus-making using low-cost materials.

7. Organization and conduct of professional seminars and workshops for educators in the region.

8. Gathering information and acting as a clearing house for science and mathematics education.

9. Consultation and special services for SEAMEO member countries.

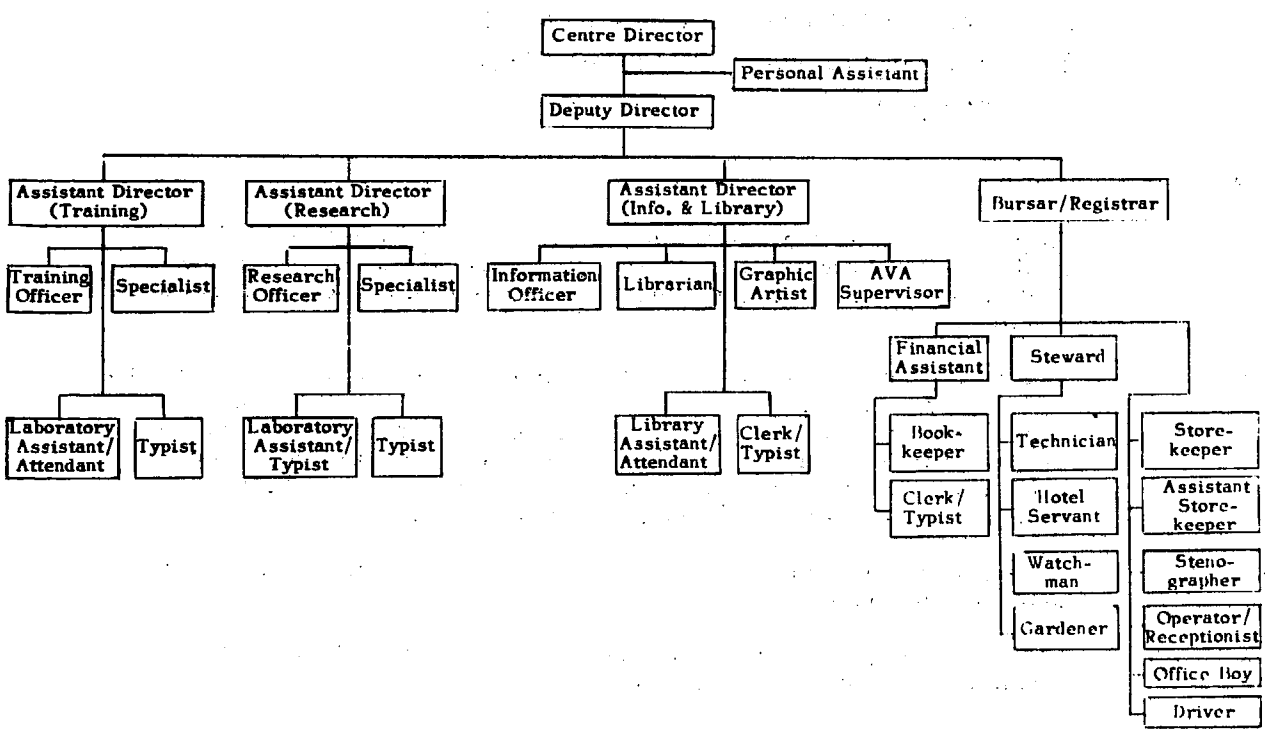
10. Promotion of indigenous efforts in curriculum development.

Formal relations have been established with UNESCO, thereby providing mutual-co-operation in matters and activities related to science and mathematics education in Southeast Asian countries. This link will also enable the Centre to benefit from the provision of specialists, consultants, etc. when required.

Staffing of RECSAM

RECSAM is staffed by tutors recruited from within the SEAMEO region and by specialists from elsewhere. In addition, the services of short-term consultants are utilized when required. Often these are generously provided by governments throughout the world. The organizational structure of RECSAM is shown in this diagram:

RECSAM ORGANIZATIONAL CHART



The actual staff and posts for 1975-76 are as follows.

ADMINISTRATION.

Academic Staff

Centre Director (1)
Deputy Centre Director (1)

Non-Academic Staff

Registrar/Bursar (1)
Financial Assistant (1)
Personal Assistant to Director (1)
Stenographers (2)
Book-keeper (1)
Clerical Officers (4)
Clerical Assitants (2)
Typists (2)
Store-Keeper (1)
Assistant Store-Keeper (1)
Van Driver (2)
Office Boys (3)
Maintenance Technician (1)
House Servants (10)
Gardners (6)
Watchmen (4)
Steward (1)
Security Officer (1)
Receptionist/Telephone Operator (1)

TRAINING DIVISION

Academic Staff

Assistant Director (1)
Training Officer (Science) (1)
Biology Officer (1)
Chemistry Officer (1)
Mathematics Officer (1)
Physics Officer (1)

Non-Academic Staff

Laboratory Assistant (1)
Laboratory Attendants (4)
Typists (2)

RESEARCH, DEVELOPMENT AND EVALUATION DIVISIONS

Academic Staff

Assistant Director (1)
Biology Officer (1)
Mathematics Officer (1)

Non-Academic Staff

Laboratory Assistant (1)
Workshop Technician (2)
Laboratory Attendants (2)
Typists (2)

INFORMATION/SPECIAL SERVICES DIVISION

Academic Staff

Assistant Director (1)
Information Officer (1)
Librarian (1)
Library Assistants (2)
A.V.A. Supervisor (1)
Graphic Artist (1)

Non-Academic Staff

Clerical Officer (1)
Clerical Assistant (1)
Typists (2)
Library Attendants (2)

Financing of RECSAM

In mid 1970, RECSAM became semi-operational with the first phase of its building programme, and this commenced the first five-year operational plan for the Centre. The total cost of the plan was projected as being US $ 8.7 million, of which the U.S.A. contributed 50%. The Government of Malaysia, as the host country, assumed responsibility for the capital and operating costs of the Centre whilst

SEAMES had the responsibility for raising the funds required for the Centre's activities. The latter are generally raised from grants and donations, in either cash or kind, from interested governments and other organizations and institutions. The second phase of the building programme is being financed jointly by the U.S.A. and the Malaysian Government. Work on this phase commenced in 1975, and occupation of the premises is expected in late 1976.

The second five-year development plan commenced in July 1975, and for this RECSAM is completely responsible for obtaining its own finances.

The responsibility for the total operational costs for the second five-year development plan was taken over by the Government of Malaysia in June 1975. The amount allocated was about M$ 4.6 million, with an additional M$ 3,150,000 for the construction of additional facilities in the building programme and for awarding scholarships and fellowships.

The breakdown of financing for the second five-year plan is as follows:

SECOND FIVE-YEAR FUNDING PLAN (1975-1980)

OPERATIONAL COST ESTIMATES

		Total for 5 years
Personnel emoluments for SEAMEO staff, including other personnel costs and benefits		M$ 4,092,500
Services and Supplies		1,655,900
Grants and Subsidies		145,000
	Total	M$ 5,893,400

SPECIAL FUND ESTIMATES

		Total for 5 years
Training and Research Scholarships		M$ 2,516,800
Seminars/Conferences/Workshops		137,500
Governing Board Meetings		96,250
Personnel Exchange		15,000
	Total	M$ 2,765,550

(M$ 1.00 = £S 0.20 approx. in January 1976)

ACTIVITIES

The Training Division and the Research Division are responsible for the courses conducted at the Centre and work closely together. The courses run by the Training Division aim at training key personnel in modern techniques of teaching and evaluation, whereas those run by the Research Division deal with the development of complete prototype units or modules and with conducting pilot studies on child learning. The range comprises elementary science, elementary and secondary mathematics, integrated science, biology, physics, chemistry, and elementary and secondary science apparatus. Up to June 1975 some 900 participants had attended training courses at the Centre. Depending on the nature of the course/seminar/workshop, participants spent from two weeks to twelve weeks there.

In the second five-year plan, some streamlining of courses has been introduced to reflect more clearly the intentions of the activity and distinguish more clearly the expected outcomes. Table 7 indicates the types of courses and the numbers of participants for the second five-year plan 1975-1980.

TABLE 7: PROPOSED PROGRAMMES FOR 2½ MONTHS EACH

	NUMBER OF SCHOLARS				
TRAINING COURSES	1975/6	1976/7	1977/8	1978/9	1979/80
TC-S1 Modern Methods of Teaching Primary Science	16	16	16	16	16
TC-M1 Modern Methods of Teaching Primary Maths	16	16	16	16	16
TC-C Modern Methods of Teaching Chemistry	16		8		8
TC-B Modern Methods of Teaching Biology	8		16		16
TC-P Modern Methods of Teaching Physics	16		8		8
TC-M2 Modern Methods of Teaching Secondary Maths	16		8		8
TC-E1 Modern Methods of Primary Science and Maths Evaluation/DP-SM	16	16	16	16	16
TC-E2 Modern Methods of Secondary Science and Mathematics Evaluation		8		8	
TC-1 Modern Methods of Teaching Integrated Science	16		16		16
TC-Q1 Training in Development of Primary Science/Mathematics Apparatus	8	8	8	8	8
DEVELOPMENT					
DP-SM Development of Teaching Modules for SEASAME Project	16	16	16	16	16
DW-02 Development of Secondary Science/Maths Apparatus (Production and Design)					
DW-LM Manual of Laboratory Management and Techniques	16	16			
DP-1 Development of Teaching Units in Integrated Science		8		8	
RESEARCH					
RP-SL Studies in Concept Learning - Primary Science	8	8	8	8	8
RR-M1 Studies in Concept Learning - Primary Maths	8	8	8	8	8
DEVELOPMENT					
DW-SIN Development of Pre-Service Teacher Training Modules in Primary Science		16		16	

Development (continued)

DW-MIN Development of Pre-Service Teacher Training Modules in Primary Maths		16		16	
DW-SMR Development of In-Service Packaged Units in Primary Science and Maths		16		16	
DW-M2G Development of Maths Teaching Units for Secondary Students (General Curriculum)		16		16	
DW-S2V Development of Science Teaching Modules for Vocational Studies			8		8
DW-M2V Development of Mathematics Teaching Modules for Vocational Students			8		8
TOTAL	176	176	176	176	176

N.B. If more scholarship funds were available more courses per year could be mounted or more scholars could be accepted for any course approved for any year.

Some idea of the range of the courses listed in Table 7 may be obtained from the following outline of three of them.

1. MODERN METHODS OF TEACHING BIOLOGY (TC-B)

Objectives

To train key educators from participating countries in the principles of curriculum development, their implementation and evaluation.

To acquaint participants with modern curricular projects in Biology (e.g. BSCS and Nuffield Biology).

To introduce participants to modern methods employed in teaching Population Biology with emphasis in field exercises and laboratory studies relevant to Population Education Studies.

To make use of readily-available resources in SEAMEO countries to introduce Population Education into their Secondary School Biology Curriculum.

To produce prototype instructional units in Population Education consisting of Pupils' Texts or Teachers' Guides.

Description

Under the guidance of specialist-consultants the participants will engage in the analysis of modern Biology curriculum projects from outside the SEAMEO Region (BSCS & Nuffield Biology). The course will also involve the participants in actual laboratory experiences as well as field exercises which have been planned to develop concepts which could then be presented to and understood by secondary students.

The participants will be acquainted with basic skills in: (a) planning and writing their units; (b) teaching techniques; (c) examination techniques; and (d) evaluation techniques. At the end of their term at RECSAM they will be required to produce prototype instructional units in Population Education. These units may be in the form of a teachers' guide or pupils' text. Participants will also evaluate their product in the classroom situation when they return to their home countries and send some feedback to RECSAM.

Participants Two or three educators who are involved in or are likely to be involved in curriculum development and/or teacher training programmes on returning to their own countries.

Duration A ten- to eleven-week course offered annually.

2. SECONDARY SCIENCE/MATHEMATICS APPARATUS (DW-02)

Objectives These workshops are aimed at the variety of problems of design and production of secondary science/mathematics equipment in SEAMEO countries.

Given the various national priorities for secondary level equipment, participants will:

(a) Design and produce industrial prototype (hand-made) for selected priority items of equipment.

(b) Produce small quantities of selected items for tryout in their countries' curricula.

(c) Produce plans for in-country testing and evaluation of these items.

(d) Produce a set of guidelines for co-operation (liaison) between curriculum development centres (educationists) and equipment design and production units (engineering personnel).

Description These workshops will be product-oriented, but on a small scale in order to ensure that the work of the participants will provide them realistic exposure and training in the techniques of mass production in the light of the equipment situation in their own countries. To some degree the workshops will be future-oriented.

Participants' work and training will include the following concerns: designing for small-scale mass-production from a tested educational prototype; making industrial prototypes; making inexpensive dies; properties of raw materials; manufacturing methods (small-scale); quality control (educational and industrial specifications); evaluating equipment in the classroom; and the nature of working relationships in the development of educational equipment.

Participants Two to four (depending on details of workshop's structure and duration).

Duration Ten to 20 weeks. The length of the workshop will depend on its implementation. If design and production are separated into two sequential workshops, both could extend for ten weeks. If design and production are not separated, but run simultaneously, the duration could be ten weeks.

3. STUDIES IN CONCEPT LEARNING - PRIMARY SCIENCE (RP-SL)

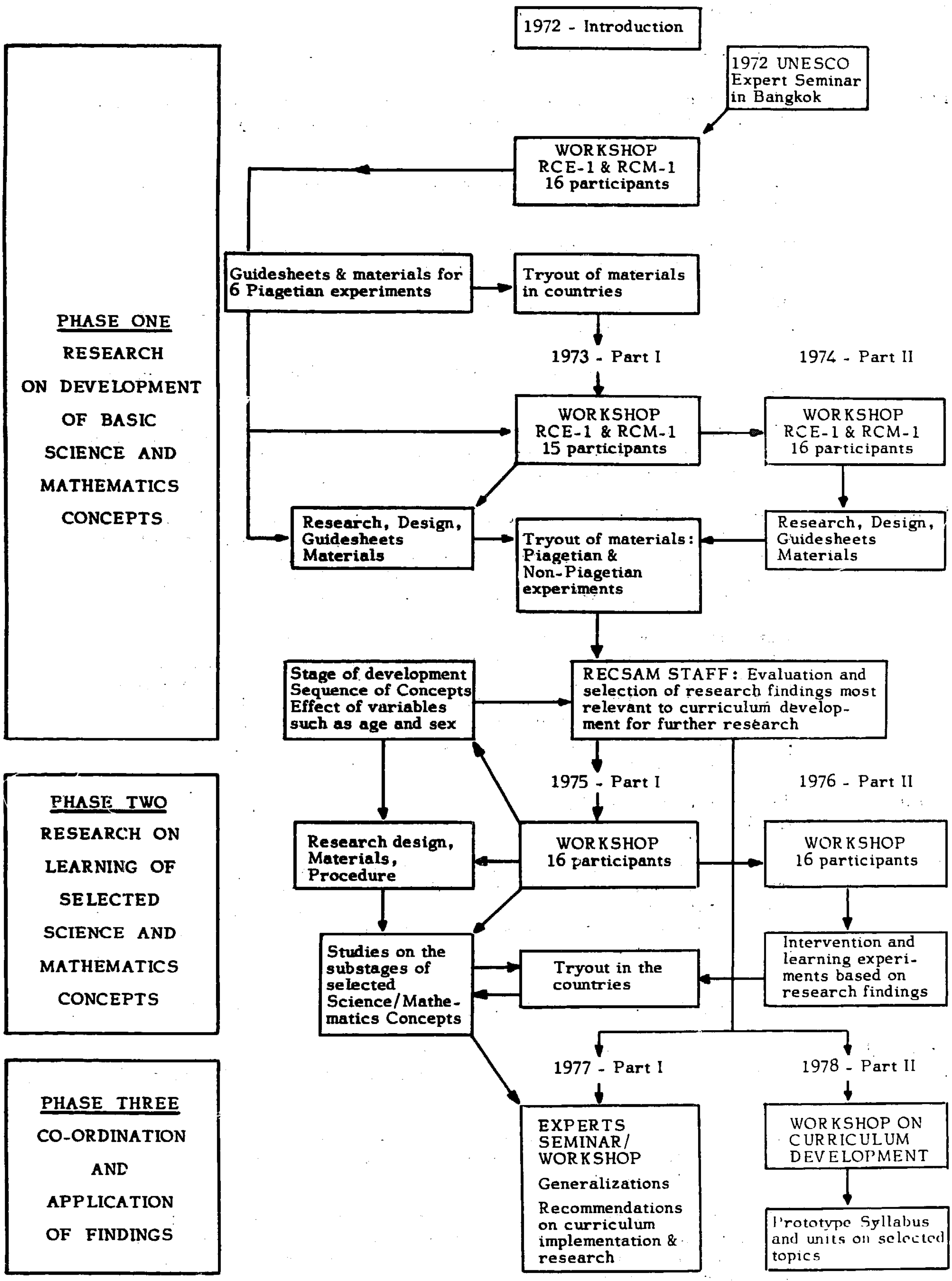
Objectives and Benefits This course is part of a series implementing RECSAM's Pilot Project on Science/Mathematics Concept Learning of Southeast Asian Children. The project aims to:

(a) Gain a better understanding through research, of how children in the region form science and mathematics concepts, and the variables influencing the process.

(b) Develop procedures, materials, research design and techniques for experimenting with children's thinking for possible use by member countries interested in conducting similar research or for diagnostic purposes in science classrooms.

PILOT PROJECT ON SCIENCE/MATHEMATICS CONCEPT LEARNING OF SOUTHEAST ASIAN CHILDREN

1973-1978



(c) Develop guidelines on how to teach primary science based on the findings of the research done by the participants and of similar research in the region.

(d) Design and test learning experiences which utilize the research results and which can be incorporated in the primary science curricula of member countries.

An added benefit is the training and experience gained by the participants in designing, conducting and evaluating research of this kind.

Description

The stages in the development of the project are shown in the flowchart on page 44. The 1976 course, which is now in progress, concentrates on the learning of science concepts. By the end of this phase of the programme, it is expected that participants will have devised or replicated intervention experiments for the basic science concepts and creative learning experiences for the various substages of certain concepts.

Phase 3 begins in 1977 when findings at RECSAM and those of other researchers will be co-ordinated. Tentative generalizations will be made about how Southeast Asian children develop and learn science/mathematics concepts. Recommendations for curriculum implementation and further research in the region are expected. The course will be in the form of an expert's seminar.

The last course in the project is that of 1978 wherein the participants, after examining the various primary science curricula in the region and the recommendations of the 1977 seminar, will co-ordinate with the SEASAME Project to develop a prototype syllabus and selected units for primary science.

Participants

These should be from one of the following groups:

(a) Researchers (graduate students or college lecturers) who have been involved in children's learning and/or the teaching of primary science.

(b) Senior teachers or educators connected with primary science teaching who, upon their return to their own countries, are likely to be involved in research or curriculum innovation.

(c) Classroom teachers or inspectors or supervisors of primary science who have shown active interest in children's thinking or the teaching of science.

Duration

Ten weeks.

RESEARCH PROJECTS

The Southeast Asian Science and Mathematics Project (SEASAME) aims to design, develop and produce relevant teaching and learning modules which include teachers' guides, pupils' worksheets, evaluation procedures and instruments, and appropriate apparatus and equipment. It is hoped that the modules will complement and supplement national efforts to innovate primary science and mathematics curricula.

The initial unit "Introduction to Systems", comprising twelve lessons as well as teaching aids and evaluation instruments, was developed early in 1973 and tried out in Penang. Some 600 primary children were involved in the trials. The materials were developed and tested by course participants in the first half of 1973. At the same time a course for senior national administrators recommended that each member country should have a national co-ordinator in charge of the whole project at national level. This recommendation was accepted by the member countries, and a workshop for the national co-ordinators was held in March 1974 under local conditions. The workshop produced regional and individual country plans for trying out the materials.

Trials were carried out in the eight member countries and, as a result of the feedback, modifications were carried out in courses during 1975. In addition, new units were prepared and trial tested in Penang. The second phase of country tryout was prepared for testing in late 1975/early 1976.

Another research project on "Science and Mathematics Concept Learning of Southeast Asian Children" commenced in 1972 with two courses in which the participants were exposed to concept formation in general. From these courses guide sheets were developed, and selected Piagetian experiments were tried out in schools in Penang.

The 1973 courses again discussed general theories of learning and then critically examined the material prepared and used in the previous year. Further tests were developed as well as guide sheets, work sheets and summary sheets which were then tested in seven Penang schools. RECSAM requested the national Ministries of Education to release the participants from regular duties so as to carry out the field trials in their respective countries. In all, 2,860 tests were carried out on 847 seven- to twelve-year-olds using the eight experiments so far developed.

The 1974 courses built on the previously-developed material, and field trials were again carried out in the participants' home countries with three additional experiments. Twelve participants returned their results containing 6,460 tests involving 1,086 children.

At the 1975 course, which included five participants who had been on the 1974 course, the activities involved analysis of the 1974 field trials as well as the preparation of further material and its trial in schools. A longitudinal study also commenced in 1975 using twelve children from near-by areas. Equipment to suit the study was constructed both by the participants and the technical staff at RECSAM and all the experiments developed on previous courses were used.

A third project, on self-instructional materials, is related to the functioning of RECSAM. Basically, the eight member countries can be divided into English speaking or French speaking, although each country has its own language and regional variations. This presents a problem for RECSAM in that participants on courses have different levels of understanding. To overcome the problem of language, and other possible areas of weakness, a programme has been implemented on preparing self-instructional, self-paced materials in defined areas. Four areas have been chosen, namely: instructional goals and objectives; how children learn; evaluation; and science/mathematics topics.

The material prepared so far has been translated into Lao, Indonesian and French. It has been tested, and is currently being revised. The development of this project is being undertaken by members of the RECSAM staff. The provision of research fellowships is another component of the RECSAM research programme.

Equipment Unit

In October 1973, RECSAM hosted a regional workshop on the "Production of Low-cost Teaching Materials for Primary Science and Mathematics" which was sponsored jointly by SEAMEO and Deutsche Stiftung Fur Internationale Entwicklung (German Foundation for International Development). Amongst the recommendations of that workshop were:

SEAMEO Regional Programmes

1. There should be established a regional equipment unit at the SEAMEO Regional Centre for Education in Science and Mathematics, with the following functions:

(i) Designing and fabrication of prototype equipment for science and mathematics.

(ii) Training of key personnel from the SEAMEO countries for designing and production of prototype materials.

(iii) Acting as a clearing house for collection and dissemination of information regarding materials for science and mathematics.

(iv) Exploring ways and means by which the science and mathematics equipment needs of the region can be met.

National Programmes

1. Each member country examines the feasibility of establishing a national design and prototype production unit as a component of its curriculum development centre or similar institutions. Multilateral and/or bi-lateral assistance in establishing such a centre should be explored.

2. Countries should decide on their own priorities for prototype equipment development which should cater for the present curricula in mathematics as well as science.

The Fifth Governing Board Meeting of RECSAM, held in September 1974 decided "that the Centre in its attempts to implement some of the recommendations of the Workshop, should develop the necessary materials only to the stage of educational prototypes, and that the emphasis should be on the training of personnel who would be likely to be employed as designers in national equipment workshops."

One member of the academic staff, namely the Training Officer (Science), is responsible for the technical component of the course work as well as arranging the specialist courses on laboratory management/equipment, etc. In addition, he is involved in other duties related to his own academic discipline, and he is assisted by one workshop technician, two laboratory assistants and a laboratory attendant. Technical staff are trained by the RECSAM staff. The workshop facilities consist of a laboratory area equipped with hand tools and workbenches (see photo). The new building will have two workshops - one for course work etc, and one for prototype design and development.

Those courses that relate specifically to equipment offered at RECSAM are perhaps best described in the following extract from a paper entitled "RECSAM's Programmes and Courses for Development and Production of Prototype Science Equipment" presented at the aforementioned workshop:

To assist each member country build up a core of equipment key personnel who could develop prototype equipment and produce design plans for dissemination, as well as organize in-service training of teachers and laboratory personnel in equipment production, RECSAM has successfully implemented the course 'Development of Primary Science Apparatus' code titled RMI-1 in 1972 and again in 1973. This intensive course of about ten weeks' duration is specially designed for SEAMEO key peronnel who are actively involved in equipment design, development and manufacture in their respective countries, or who are in positions which make them likely to be so. So far, fourteen SEAMEO key personnel have undergone this course, namely, two each from Indonesia, Khmer Republic, Malaysia, Philippines, Singapore, Thailand, and one each from Laos and Vietnam.

The terminal behavioural capabilities expected of participants on completion of the RME-1 course are that they should be able to:

(a) improvise simple science and mathematics equipment for use in the primary grades.

(b) carry out routine maintenance and minor repairs on simple equipment.

(c) transform new ideas for simple equipment into reality through designing, constructing and testing of such.

(d) produce an equipment design plan acceptable for publication with the necessary technical drawings and parts specification included.

(e) provide sound advice for the procurement of equipment from commercial sources.

(f) carry out refinements on prototype equipment for possible mass production.

(g) advise on plans for mass production of prototypes by government and non-government agencies.

(h) assist in development of curriculum materials through design, and development of equipment hardware for these materials.

(i) organize and conduct in-service courses for teacher trainers, teachers and laboratory personnel, to train them in the basic skills for equipment production leading to actual production of urgently needed equipment.

(j) play leadership role in science/mathematics exhibitions and in school science/mathematics activities.

The course work described above has been continuing, and the Centre has a display area for apparatus developed. In addition, the workshop staff have been constructing apparatus for the Concept Learning Project.

Audio Visual Aids

The Centre has a specialist in audio-visual aids on its staff, and this topic is a constituent part of the majority of courses offered at RECSAM. A small darkroom is available where course participants are able to receive instruction in the use of photographic materials and techniques, and a small amount of resource-centre space is available for using a range of audio and visual apparatus and for receiving instruction in the operating techniques and the preparation of material. It is expected that, along with the expansion of the workshop facilities in the new building, an expansion of the audio-visual facilities will also take place.

Curriculum Development Centre - Kuala Lumpur, Malaysia

This is an example of a national centre established by a member country of RECSAM. It is a division of the Ministry of Education and was established in January 1973 with assistance from UNESCO. The activities of the centre include: (a) curriculum development at primary and secondary school levels with an emphasis on science and mathematics; (b) research in conjunction with a Malaysian university on problems related to linguistics in education; (c) preschool education and compensatory education; and (d) prototype equipment research and production.

The curriculum development projects are related to an integrated approach to learning and also reflect some of the materials developed at RECSAM.

The workshop unit of the centre constructs apparatus in wood, metal and plastics, and has workshop capacity for developing prototypes. Once a design is accepted, the designs are made available to local commercial manufacturers who construct and market the approved article.

Course work is carried out at the centre and is particularly related to key personnel from the Federation, who in turn are in a position to further expand the "multiplying effect" in their own states.

The centre has a comprehensive resource area containing a range of audio-visual aids as well as the Library and a printing/publication section for producing its own materials. In addition, a number of vans, located at selected establishments (often teacher training colleges or higher secondary schools), serve schools within their area. They carry a kit of tools developed at the centre and other equipment, and they act both as repair units and as in-service training centres.

The centre has received assistance from UNESCO, UNICEF and other donor agencies. It will be moving into its own purpose-built facilities late in 1976. Besides having workshop and teaching facilities it will have hostel accommodation for some 140 persons.

Section 5

GENERAL CONSIDERATIONS

"Local production" and "improvisation" are not synonymous with one another, although they are often used in the same context. Teachers can readily improvise, using local materials, for their own requirements, and they are increasingly being encouraged to do so during their pre-service training. Local production, which implies a sophistication over and above local improvisation, is related to producing apparatus for the needs of the whole school system rather than for the needs of the individual school.

Local production is being implemented by many countries for basically two reasons: the lack of financial resources to supply the whole school system with equipment which has to be imported, and the development of curricula related closely to the local environment.

To reconcile local production with improvisation we can say that the local production unit provides the teacher with his basic requirements. The teacher then extends his teaching resources by improvisation. Whittell summarizes this distinction quite ably*. The NCERT publication, Improvising Science Teaching Kits for Schools is an example of the mis-use of the word "improvisation" since it really relates to the development of kits for the whole school system.

The foregoing chapters deal with centres developing school science equipment. Apart from DAYM these centres could also be classified as assisting with improvisation through their in-service course work. In this section it is perhaps worthwhile to indicate some of the less evident areas of concern which became apparent during the case studies, and which may be of help to a country when it considers establishing a production unit.

DEVELOPMENT OF APPARATUS

Kit Development

Two centres are concerned with developing kits for teaching science. These kits are basically demonstration kits, although one centre has also developed pupils' kits. The lack of adequate finance for school equipment often limits the purchase of apparatus to one-off demonstration items. In India for example, with some 460,000 primary schools,

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* Whittell, J.M.S., "Local Production: Principles and Practice", School Science Review, Vol. 56, No. 197, June 1975, pp.669-84.

the development of a demonstration kit is probably the only way of getting practical science introduced into the schools. Naturally such introduction is also coupled to teacher competence. If the teacher education system does not orientate teachers towards practical science, then the teacher demonstration kit, rather than the kit for pupil involvement, is likely to be the norm. The project operated by the Educational Technology Department of the NCERT to investigate the use of satellite television to provide in-service training to rural teachers would be worthy of closer examination as a means of orientating serving teachers towards practical science teaching.

The development of a kit pre-supposes that it is to be an integral part of the teaching syllabus (although this is not necessarily so). Consequently curriculum and equipment development should proceed together. In India the two units are part of the same Department which work together to produce the whole. In Kenya the production unit is remote from the curriculum development unit. Hence the production of kits was only undertaken after the production unit had made a survey of the needs of the schools and the availability of teaching apparatus from local commercial suppliers. It is obvious therefore that before a kit is developed a thorough identification of the role of the kit must be made, particularly its relationship to the curriculum.

Non-Kit Equipment

The DAYM production unit in Turkey is an example of a production unit which concerns itself with producing some 80% of the school science equipment requirements, as compared to India and Kenya which produce only kits. Because such a production unit produces apparatus for use in many learning environments, it can operate independently from curriculum development. One of the dangers of this isolation is that too little innovation may take place, and the items produced may be stereotyped year after year. To prevent this from happening the design and development section of such a production unit needs to have close links with curriculum developers so that changing curriculum requirements can be reflected in their products.

Quality of Products

There is quite a difference between a good idea and a quality-produced piece of science equipment, and appropriate staff are necessary for all stages of development. Many factors have to be taken into account before a good idea reaches the classroom. This is best illustrated by an example from NCERT. The primary science kit was originally designed to be wall-mounted and at the same time to provide a safe storage for the apparatus. So the container had to be sturdy. With village schools having mud walls, the fixing of this robust container proved difficult or even impossible, and when mounted the demonstration surface was not always at a suitable height for the children. The kit went through a series of containers before one was found suitable to meet the requirements of the village schools.

A further example from NCERT relates to the quality of product. Under its component of assistance, UNICEF provided kits of apparatus which, though based on the workshop designs, had to be purchased from commercial suppliers (due to the production load on the workshop). Considerable quality control problems existed, and the workshop department held three courses in 1974 to train key personnel from each State in the inspection and quality control of science kits. The courses included introduction to engineering instruments and materials, particularly related to the kits developed. An inspection kit was developed during the course and supplied to each key institution in the States. Since the kits include items manufactured by local industrial concerns, the department has its own quality control unit. In addition, by implementing the tender requirements on a batch number basis, no supplier is able to become complacent in the belief that he will automatically receive an order. Nor is the lowest tender bound to be accepted, although reasons have to be given to justify any action taken. Where the department finds sub-standard quality it refers the items to the National Standards Institute. The Institute on its part occasionally requests the department to supply specifications for certain items. Hence a close co-operation exists in an attempt to maintain standards.

IN-SERVICE TEACHER TRAINING/CURRICULUM DEVELOPMENT

NCERT in India and RECSAM in South-East Asia are two centres which provide course work. RECSAM in particular is concerned with curriculum activities and is not a production unit as such, though eventually it will have workshop facilities for developing and producing prototypes which member countries can then reproduce in their own centres. (The Curriculum Development Centre in Kuala Lumpur is an example of one such centre in one of the member countries.)

At NCERT, most course work has been related to the primary science project, with selected State institutions providing facilities for the in-service training of teachers. The choice of such institutions needs to be carefully made so as to ensure that they are all able to support the duties required of them. The successful running of courses requires the timely provision of the necessary finance and materials.

It is important that courses should be provided over as wide a geographical area as possible and not only in the Centre. This not only helps the teachers in their own environment but assists the public relations that are needed to establish the credibility of the Centre. It also provides the basis for the multiplier effect whereby the Centre's activities can reach persons who themselves are not directly involved but who nevertheless may be required to make a decision affecting the implementation of the Centre's activities.

RECSAM, as a regional centre, relies on the multiplier effect in operating its courses. On returning to their countries, participants are expected to be in a position to train others and influence local developments. Ideally, this pre-supposes that course participants should be selected from those (such as senior teacher educators, curriculum developers, and administrators) who can wield some influence. In practice, it is unlikely that such individuals can be released for extended periods of some twelve weeks duration and course participants are therefore generally chosen from the teacher or teacher educator level. Nevertheless, this does not necessarily negate the multiplier effect as long as courses for the senior educational administrators are provided so as to orientate them towards the effective use of the course participants within the national system.

At RECSAM a procedure exists for providing an overlap to courses, and for enabling some participants from a previous course to return to participate in later courses. In this way feedback is obtained, and continuity in the development of curriculum materials and equipment is ensured. In India a similar process has been tried. In 1975, a seminar for participants from selected teacher training institutions was held to deal with the use of local resources to supplement the developed kits. Such a seminar was found necessary to overcome the immediate impracticality of providing every primary school with a kit. A UNICEF consultant specializing in local resources related to the child's environment assisted with this course. A second workshop was held early in 1976 using previous participants who presented and discussed their prepared materials. The workshop then considered further possibilities in the use of local resources as well as media of instruction. Workshop assignments were related to the use of pictorial posters as a medium of instruction for primary school children. The results of this approach will be analysed at a further workshop to be held at a later date. (The UNICEF consultant was again present at this workshop.)

ESTABLISHMENT OF LOCAL PRODUCTION CENTRES

It is worth noting the efforts referred to on page 20 to produce school science equipment in Kenya prior to the existence of SEPU. These were made at educational institutions which either utilized the services of school-aged children or university students and teachers in training who did not have the necessary technical training or skills to produce the required items. In addition to this problem, it was found that a term-based programme was not conducive to effective continuous development or quality production. Only when SEPU came into existence as a separate entity with its own autonomy could it really be said that a production unit existed to serve the needs of the school system. In Turkey DAYM started as a component of a technical/vocational teaching establishment which rapidly developed an autonomy of its own (i.e. not tied to term-time operating). In practice this autonomy was brought about by employing craftsmen and others to provide the continuous operation while at the same time, the students in training participated in the activities during their teaching programmes. NCERT and RECSAM were established as continuous-operation educational establishments.

Physical Facilities

If the Centre is to be of a multi-purpose nature (i.e. equipment development/curriculum development/course work/repair maintenance), considerable care is necessary in providing adequate facilities to meet the demands. If course work is to be a regular component hostel accommodation as at NCERT and RECSAM needs to be provided. In the RECSAM development, priority was given to hostel accommodation with the purpose-built facilities for course work and administration following as a second phase. In practice, the planned dining and recreational building was used for teaching purposes, and will revert to its intended function on completion of phase 2. Phase 2 will have prototype production workshop facilities as well as a small practical area for course work (improvisation). This highlights the need to separate the design and production component of a centre from the course work component. A workshop trying to cater for production as well as training is not usually successful at either. NCERT was developed as a whole, but its course work activities are carried out separately from the production workshop area. DAYM and SEPU are not directly involved in course work but at SEPU the facilities of the teacher training college could be utilized for course work.

Finance

A centre must be provided with enough money to enable it to operate properly. The amount will depend upon the manner in which the centre is going to work. For example, it was envisaged that after its initial establishment, SEPU would become a self-financing operation, and in actual fact it has a sales manager concerned with the marketing of its products. DAYM is a Ministry establishment, and its products are ordered directly by the Ministry and distributed accordingly by them. Similarly, NCERT has its own budget with State Ministries of Education purchasing directly from NCERT. The production of kits at NCERT is mainly related to a primary education project which is supported largely by UNICEF.

Staffing

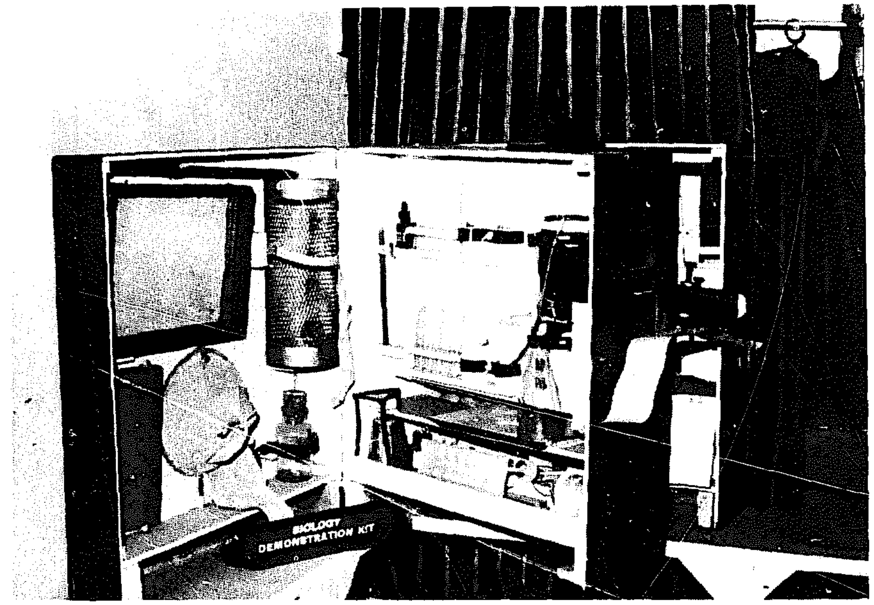
The staff of a centre must have the right type and level of training. For example it is not realistic to expect a science teacher to be competent in the design, development and production techniques of school equipment. RECSAM, for example, will need to consider this problem when the section dealing with the development of prototypes comes into existence because this operation requires personnel with an engineering background who can liaise and interpret the requirements of the educationist. The other centres have met these requirements, as can be seen from the example of the personnel involved at NCERT.

Components

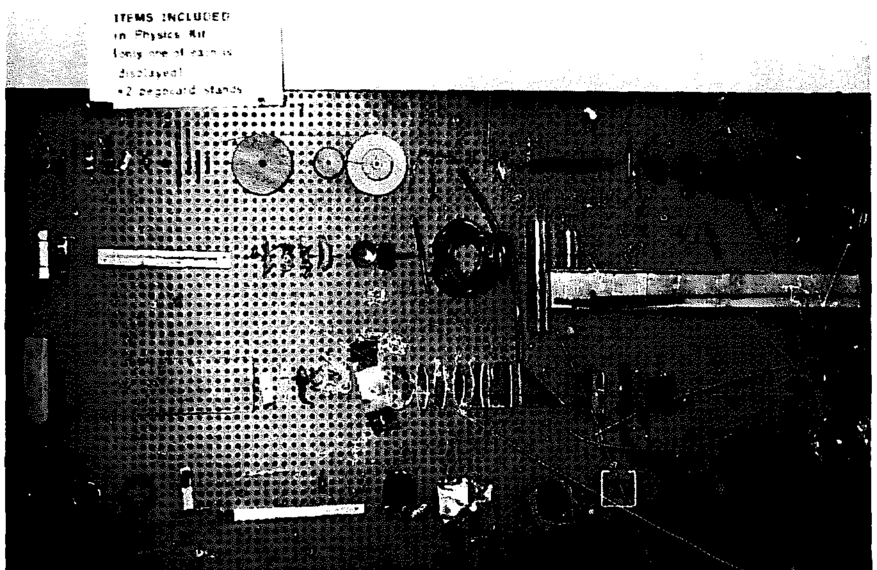
Mention has already been made of the multi-purpose nature of a centre concerned with the development and production of school science equipment. Not only is it necessary to produce the equipment and get it into the schools but it is also necessary to consider that the equipment will need some follow-up replacement of parts. Consequently, the requirements of staff and facilities for repair and maintenance should be considered when establishing such a centre. Trained laboratory technicians may also be needed in the schools. It is worth noting that of the four production centres only one was concerned with this aspect of equipment care.

SECTION 6: ILLUSTRATIONS OF SOME OF THE APPARATUS AT THE CENTRES

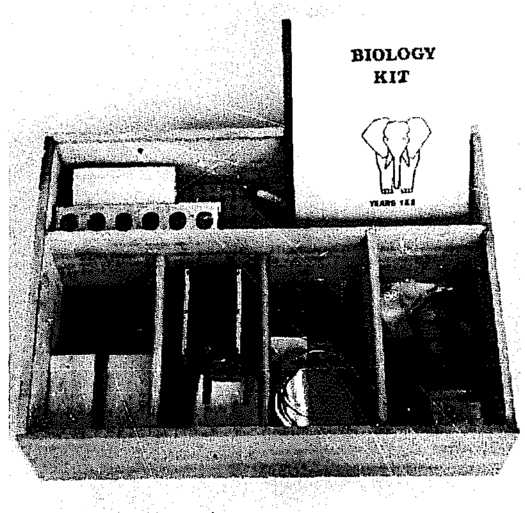
NCERT: 1. Secondary School Chemistry Demonstration Kit



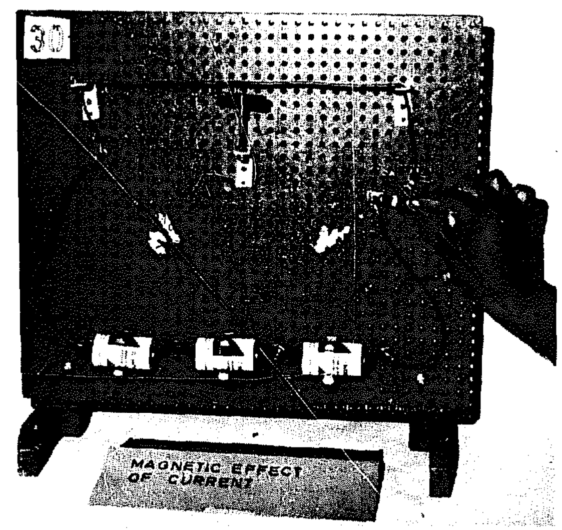
2. Secondary School Biology Demonstration Kit



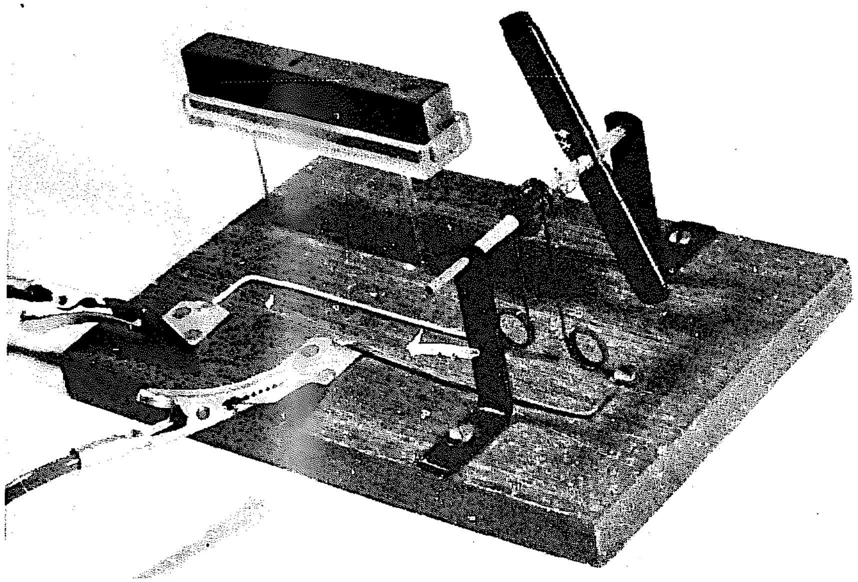
SEPU: 3. Physics Kit



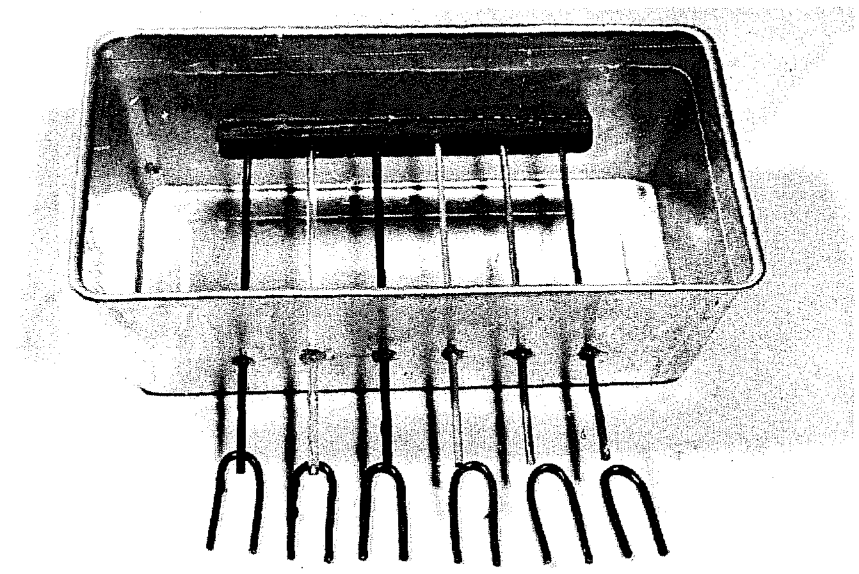
4. Biology Kit



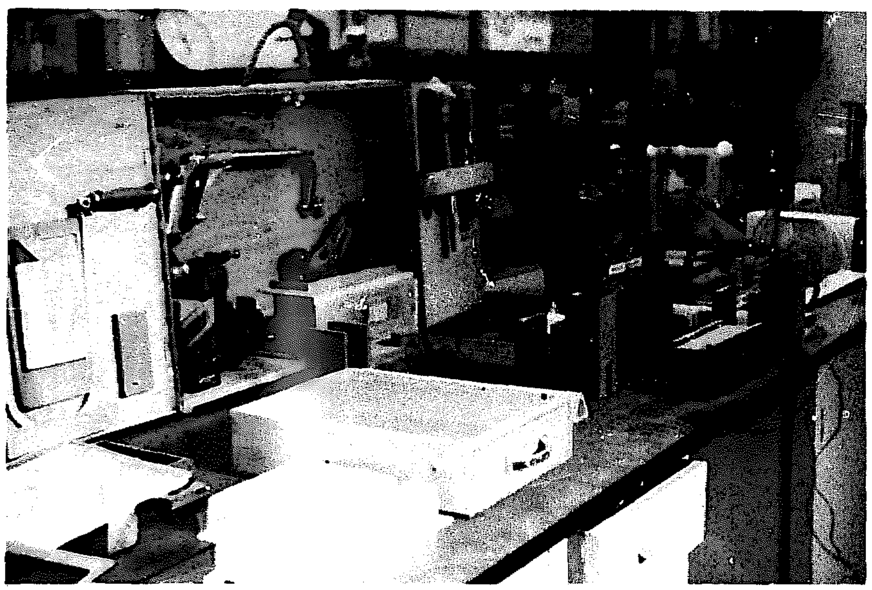
5. Part of the Physics Kit
(mounted ready for use)



RECSAM: 6. Single pole electric motor



7. Heat conduction set
(the rods are of copper, iron, wood etc.)



8. Tools for schools and resource centres

9. A praparium (for investigation into ecosystems)