Engineering Computation with Spreadsheets

By:

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Online:

< http://cnx.org/content/col11235/1.12/ >

C O N N E X I O N S

Rice University, Houston, Texas

Collection structure revised: September 30, 2011
PDF generated: September 30, 2011
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Preface[1]

In my tenth year at the Institute,
I dedicate this book to
the dedicated members of the BCIT community.

This textbook has no goals to become The New York Times best-seller however it should help readers to learn several problem solving techniques and introductory level engineering computation. This text can also serve as a companion course manual for various engineering courses such as Engineering Laboratory, Applied Mechanics and Heat Transfer within the Power and Process Engineering program.

The best way to learn about engineering computation with spreadsheets is to actually do it. We will therefore solve many engineering problems mainly using Microsoft Excel in this book. Since the focus of the book is engineering computation, we will concentrate on the mathematical solutions, built-in engineering and scientific functions and, to a limited extent, the presentation of computational results. Thus, I assume the reader has a working knowledge of Microsoft Excel under either OS X or Windows operating systems. Those readers who are not comfortable with the basic functionality of Microsoft Excel should keep a good reference book handy as they read this text. I also assume that the reader is competent at first year Mathematics and Physics. However, access to good reference books are highly recommended.

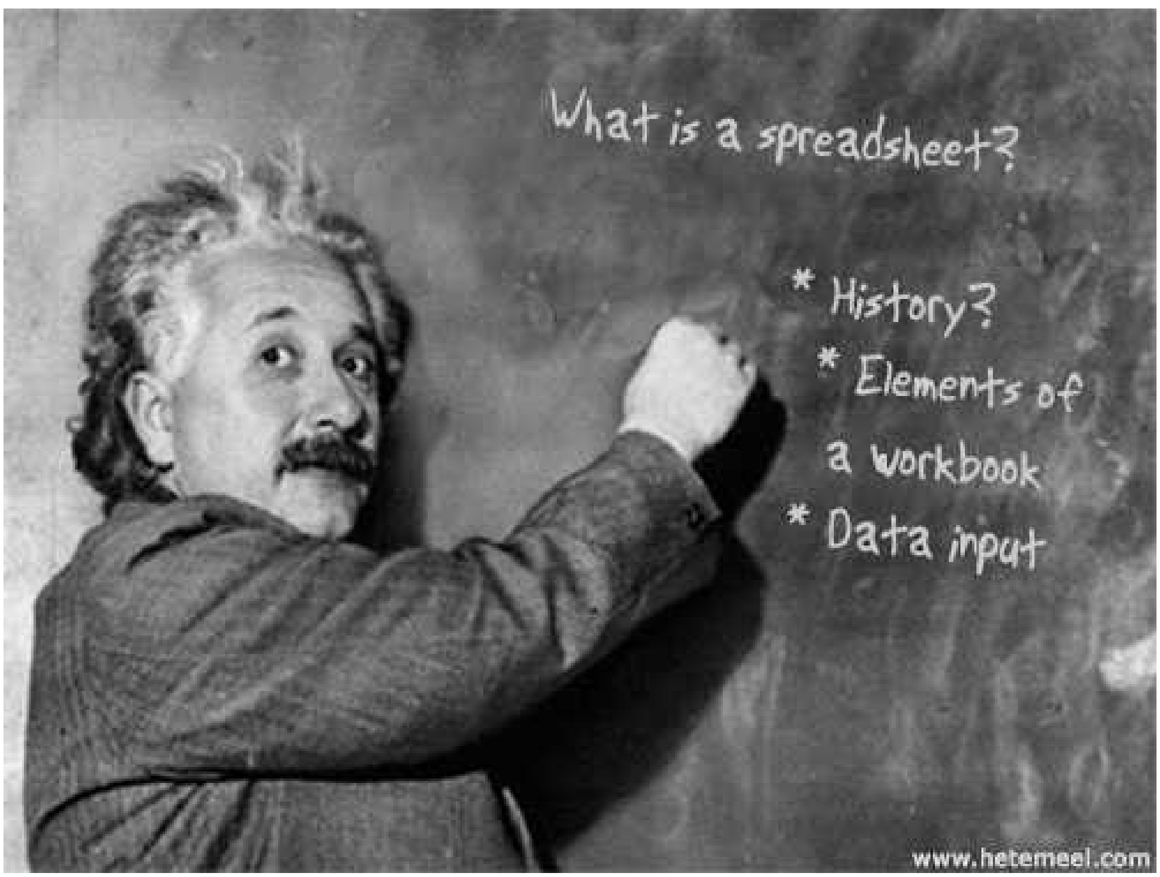
> NOTE: Spreadsheets have evolved since their first appearance. I have used spreadsheets since 1997 and witnessed their visual transformation (i.e. GUI). While the current version of mainstream spreadsheet applications can offer attractive GUIs, process much more data and perform faster calculations, the commands and their syntax have hardly changed. What you will learn in this book is mostly independent of the various versions of Microsoft Excel available today.

[1] This content is available online at <http://cnx.org/content/m35867/1.6/>.

Chapter 1

Introduction

1.1 What is a Spreadsheet?[1]



A spreadsheet such as Calc and Excel is an office productivity application that allows us to analyze quite large amounts of data. With spreadsheets, we can easily input and manipulate data and carry out engineering computations. We can also summarize and present compu-

[1]This content is available online at <http://cnx.org/content/m35872/1.6/>.

tational results with tables and graphs which then can be displayed on screen or printed.

Let's consider the examples below.

Example 1.1
In industry, insulating a pipe is a common practice because it is an inexpensive method of retarding heat loss. In some cylindrical geometry cases, however, adding insulation causes an increase in the heat loss. Consider a 1 nominal pipe (OD = 3.340 cm) covered with kapok insulation (k = 0.035 W/[mK]). Assume that the outside-pipe-wall temperature is 200 °C and that the insulation covering the pipe transfers heat to ambient air at 20 °C, with a = 1.7 W/(m2K). We have not stated an insulation thickness but instead will allow the thickness to vary from 0 (no insulation) to 2.5 cm. The effect we are examining is how the insulation thickness affects the heat-transfer rate (neglecting radiation loss). [2]

In this problem we can investigate the effect of insulation thickness using a spreadsheet. We can compute the heat loss from the insulated pipe when the thickness varies from 0 (no insulation) to 2.5 cm say, using 0.1 cm increments. We can then plot the output data on a graph, Heat loss per unit length (y-axis) – Insulation thickness (x-axis). The spreadsheet we have created clearly displays this interesting phenomena.

Example 1.2
One side of a refrigerated cold chamber is 6 m long by 3.7 m high and consists of 168 mm thickness of cork between outer and inner walls of wood. The outer wood wall is 30 mm thick and its outside face temperature is 20 °C, the inner wood wall is 35 mm thick and its inside face temperature is -3 °C. Taking the thermal conductivity of cork and wood as 0.042 and 0.2 W/mK respectively, calculate the heat transfer per second per square metre of surface area. [3]

For this problem, we can quickly input the given data and calculate the heat transfer in a spreadsheet. In a follow up problem, for instance if a better insulating material is used in the same configuration, we can easily find the percentage reduction in heat transfer for the cold room and calculate the savings.

In a nutshell, spreadsheets can minimize or eliminate repetitive calculations when solving engineering problems.

1.2 A Brief History of Spreadsheets[4]

Probably, you did not think that I would talk about "history" in an engineering course. However, the history of spreadsheets is quite interesting and a brief section is included

[2] *Engineering Heat Transfer* by Janna, William, CRC Press. ©2009, (p.xx)
[3] *Reed's Applied Heat for Engineers* by Embloton, W., Jackson, L. Thomas Reed Publications. ©1999
[4] This content is available online at <http://cnx.org/content/m35870/1.2/>.

here. Students should feel free to fast-forward to the next section, and no, the history of spreadsheets is not on the test.

It all started with VisiCalc. [5] Dan Bricklin and Bob Frankston built the world's first electronic spreadsheet application VisiCalc in the late 1970s. VisiCalc was written for the Apple II computer and it became popular very quickly. As a result of that, VisiCalc is often credited for the Apple II's early success.

The advent of IBM PC in 1982 popularized personal computers even more. VisiCalc was ported to the PC environment without delay. A small group of computer enthusiasts refined the spreadsheet concept in Cambridge, Massachusetts. Headed by Mitch Kapor and Jonathon Sachs, Lotus Development Corporation designed and launched Lotus 1-2-3 in January 1983. Lotus 1-2-3 was an instant success. Despite its high price tag, it quickly sold more than VisiCalc. Conceivably, Lotus 1-2-3 was the most popular application ever and contributed significantly to the success of the IBM PC in the corporate environment.

In 1982, Microsoft released its first spreadsheet app, MultiPlan a.k.a. EP (a code name for "Electronic Paper"). It was introduced as a competitor for VisiCalc and the app was subsequently ported to several other platforms, including Apple II, Apple III and MS-DOS. MultiPlan was difficult to learn and use, not surprisingly, Lotus 1-2-3 outsold MultiPlan.

Microsoft developed Excel originally for the 512K Apple Macintosh in the mid 1980s. This version of Excel was one of the first spreadsheets to use a graphical user interface (GUI). Many people bought Apple Macintoshes so that they could use Microsoft's Excel spreadsheet application. When Microsoft launched the Windows operating system in 1987, Excel was one of the first application products released for it and Excel became Microsoft's flagship product.

The most valuable player in the world of spreadsheets is probably Calc from OpenOffice.org[6] . To complete your awareness of various spreadsheet apps, google for the following programs (in no particular order):

- KSpread
- wikiCalc
- iWork Numbers
- Google Spreadsheets

[5] *Microsoft Excel 2000 Formulas* by Walkenbach, John, John Wiley and Sons. ©1999, (p.xx)
[6] http://www.openoffice.org/

1.3 Anatomy of a Spreadsheet[7]

1.3.1 Definitions

Definition 1.1: Workbook
A workbook is a spreadsheet file. By default, each workbook in Excel contains three sheets. Spreadsheet file names use .xls or .xlsx suffixes (i.e. file extension).

Definition 1.2: Worksheet
A worksheet is a single sheet in a workbook. By default, a workbook contains three worksheets.

Definition 1.3: Column
A column is a vertical block in a worksheet. Each column is identified by a letter in the column header.

Definition 1.4: Row
A row is a horizontal block in a worksheet. Each row is identified by a number in the row header.

Definition 1.5: Cell
A cell is the intersection of a column and a row. Cells are the basic building blocks of a worksheet. Each cell is assigned an address (e.g. cell reference, A1 means column A and row 1).

Definition 1.6: Range
A range is block of cells in a worksheet.

Definition 1.7: Formula
A mathematical formula that is run to compute results. Formulae are made up of standard arithmetic operations (e.g. +, -, *, /, ^).

Definition 1.8: Function
Functions are pre-constructed formulae that perform common calculations (e.g. summation and average). We can combine many functions and arithmetic operations in a single formula to carry out complex engineering computations.

1.3.2 Arithmetic Operators

To perform basic mathematical operations, use the following arithmetic operators.

[7]This content is available online at <http://cnx.org/content/m37231/1.3/>.

Arithmetic Operator	**Meaning (example)**
+ (Plus sign)	Addition (3+3)
- (Minus sign)	Subtraction (3-1) or negation (-1)
* (Asterisk)	Multiplication (3*3)
/ (Forward slash)	Division (3/3)
% (Percent sign)	Percent (20%)
^ (Caret)	Exponentiation (3^2)

Table 1.1: Arithmetic Operators

1.3.3 Comparison Operators

We can compare two values with the following operators, the result is a logical value either TRUE or FALSE.

Comparison operator	**Meaning (example)**
= (Equal sign)	Equal to (A1=B1)
> (Greater than sign)	Greater than (A1>B1)
(Less than sign)	Less than
>= (Greater than or equal to sign)	Greater than or equal to (A1>=B1)
Less than or equal to sign)	Less than or equal to
(Not equal to sign)	Not equal to

Table 1.2: Comparison Operators

1.3.4 Spreadsheet Window

Depending on the type and version of spreadsheet application you are using workbook window will contain many elements. Some of the major elements are illustrated below.

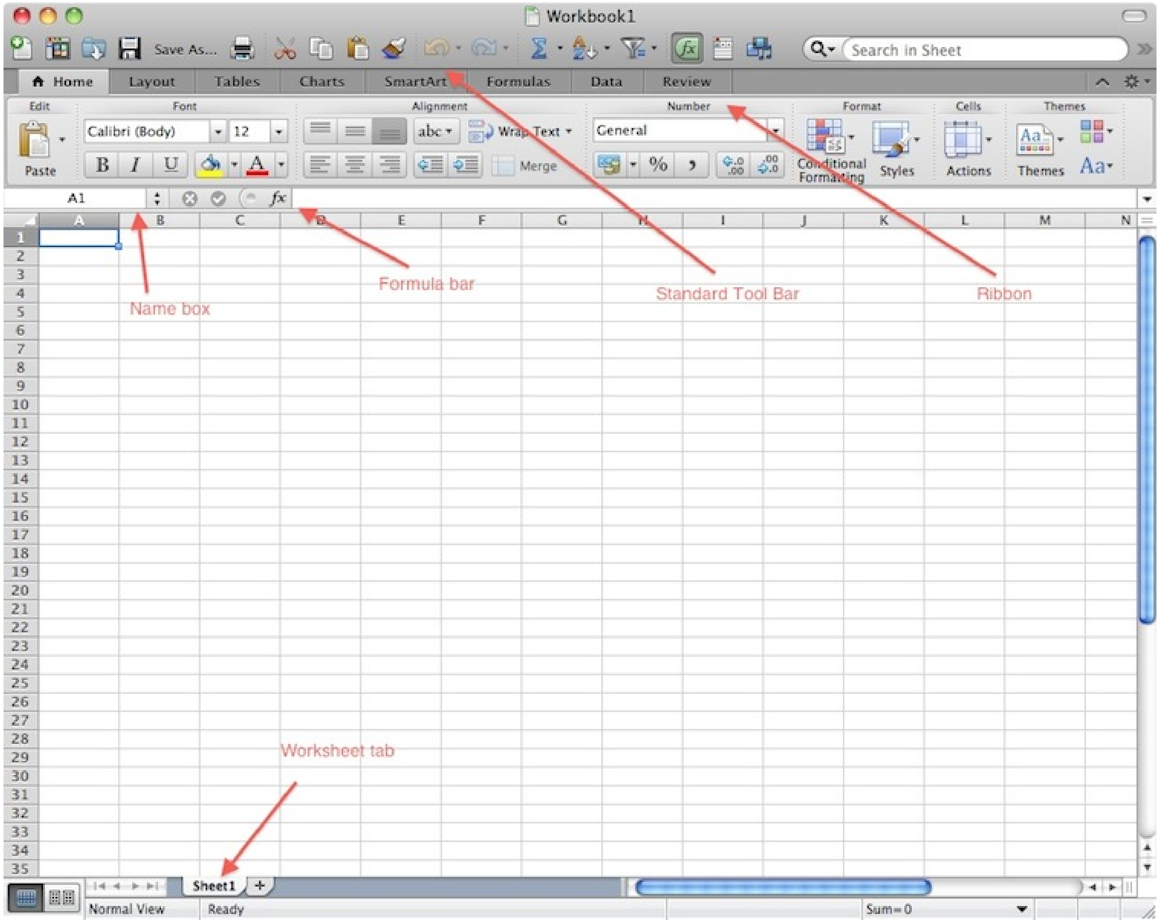


Figure 1.1: Workbook window contains many elements.

1.4 Data Input[8]

1.4.1 Data Input

The data that we input into a spreadsheet can be numbers, text, dates, or times and we have several options for entering data in Excel.

1.4.2 Fill Series

1- Select the first cell in the range that you want to fill.

[8]This content is available online at <http://cnx.org/content/m37232/1.2/>.

2- Type the starting value for the series.
3- Type a value in the next cell to establish a pattern.
4- Select the cell or cells that contain the starting values.
5- Drag the fill handle (the bottom right corner of the cell or range selected) across the range that you want to fill

NOTE: To fill in increasing order, drag down or to the right or to fill in decreasing order, drag up or to the left.

1.4.3 Auto Fill

This feature creates a series that produces the same results as dragging the fill handle in "Fill Series" procedure and is useful when we want to enter months, days and dates in general.

Initial selection	**Extended series (example)**
1, 2, 3	4, 5, 6,...
1:00	2:00, 3:00, 4:00,...
Monday	Tuesday, Wednesday, Thursday,...
Jan	Feb, Mar, Apr,...

Table 1.3: Auto Fill examples.

1.4.4 Auto Complete

When we enter data in a column, typing the first few letters in a cell will suggest the existing value. Using this technique will eliminate typing errors.

1.4.5 Pick From List

When we enter data in a column, right-clicking the first blank cell will trigger a shortcut menu list. Selecting "Pick from List" option lists existing values and we can choose one of the values. By using this technique we can eliminate typing errors.

1.5 Key Points[9]

1.5.1 Key Points

Key Points made in Introduction

[9] This content is available online at <http://cnx.org/content/m37262/1.1/>.

1.5.1.1 Commands List

Commands used in this chapter:

- Command 1
- Command 2
- Command 3

1.5.2 What is Next?

"what is next?".

1.6 Problem Set[10]

1.6.1 Problems

Intro paragraph here.

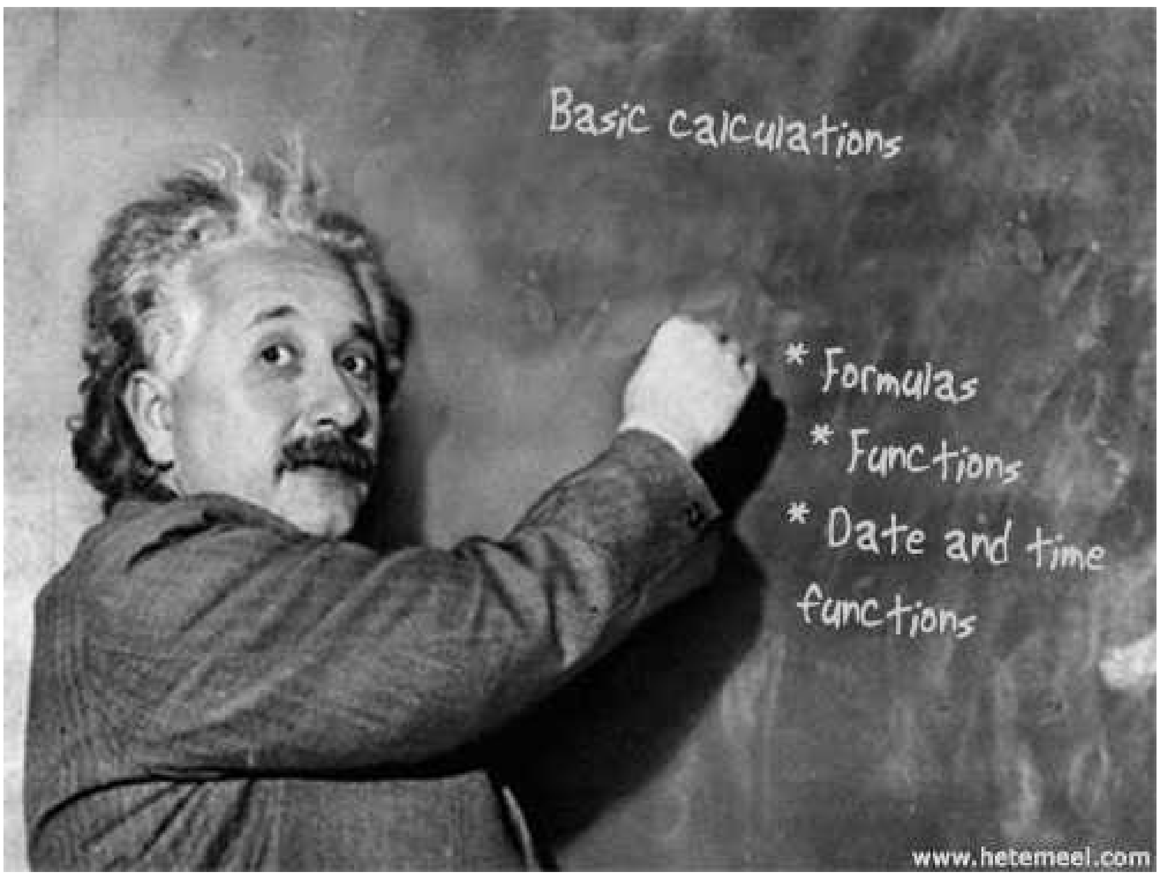
1. First item here
2. Second item here
3. Third item here

[10]This content is available online at <http://cnx.org/content/m37270/1.2/>.

Chapter 2

Getting Started

2.1 Basic Calculations[1]



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[1]This content is available online at <http://cnx.org/content/m37256/1.2/>.

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2.2 Formulas[2]

2.2.1 Elements of a Formula

Formulas are instructions that perform calculations on the worksheet. Formulas can be very simple or extremely complex. A formula begins with an equals sign (=) followed by one or more values and functions to calculate. The values can be entered directly into the formula, but it is more effective to enter the values into cells on the worksheet and make references to those cells in the formula.

A formula can consist of five elements:

Elements of a Formula

- Numerical values or text-strings (such as 1.2, or HeatLosses.
- Cell references (including named cells and ranges).
- Operators.
- Worksheet functions (e.g. SUM or AVERAGE) and their arguments.
- Parentheses to control the sequence in which expressions within a formula are evaluated.

TIP: To display the syntax of all formulas in a sheet: Press "Ctrl+ë" (the ë symbol is located to the left of the number 1 on the keyboard).

2.2.2 Cell and Range References

Most formulas make a reference to one or more cells by using the cell or range address or name. Cell references come in four styles; the dollar sign differentiates them:

Definition 2.1: Relative reference
The reference is fully relative. When the formula is copied, the cell reference adjusts to its new location. Example: A1

Definition 2.2: Absolute reference
The reference is fully absolute. When the formula is copied, the cell reference does not change. Example: A1

[2]This content is available online at <http://cnx.org/content/m37233/1.1/>.

Definition 2.3: Row absolute reference
The reference is partially absolute. When the formula is copied, the column part adjusts, but the row part does not change. Example: A$1

Definition 2.4: Column absolute reference
The reference is partially absolute. When the formula is copied, the row part adjusts, but the column part does not change. Example: $A1

TIP: The "F4" keyboard shortcut has four states:

- Absolute reference to the column and row, `=$A$1`
- Relative reference (column) and Absolute reference (row), `=A$1`
- Absolute reference (column) and Relative reference (row), `=$A1`
- Relative reference to the column and row, `=A1`

2.2.2.1 Referencing other worksheets or workbooks

References to cells and ranges do not need to appear in the same sheet as the formula. To refer to a cell in a different worksheet, precede the cell reference with the sheet name followed by an exclamation point. Here is an example of a formula that uses a cell reference in a different worksheet (Sheet3): `=Sheet3!A1+1`

You can also create link formulas that refer to a cell in a different workbook. To do so, precede the cell reference with the workbook name (in square brackets), the worksheet name, and an exclamation point like this: `=[Maintenance.xls]Sheet3!A1+1`

If the workbook name in the reference includes one or more spaces, you must enclose it (and the sheet name) in single quotation marks. For example: `=\[Maintenance Records.xls]Sheet1í!A1+A1`

If the linked workbook is closed, you must add the complete path to the workbook reference. For example: `=íC:\ExcelCourse\[Maintenance Records.xls]Sheet1í!A1+A1`

2.3 Functions[3]

2.3.1 Functions

The vast majority of engineering computations require a complex set of mathematical operations such as logarithms and trigonometric functions. Functions are predefined formulas that simplify manual entry and allows us to carry out calculations that would otherwise be impossible. Excel and other mainstream spreadsheet apps have an extensive library of built-in functions. For example, we can use the SUM function to total all the values in a

[3] This content is available online at <http://cnx.org/content/m37244/1.1/>.

column or use the MAX function to find the biggest number in a range of cells. However, functions can do a lot more than just math. They can look up data in another location, calculate cells only if they meet a specific criteria and combine the contents of two or more cells.

2.3.2 Elements of a Function

A function can consist of five elements:

- Numerical values or text-strings (such as 1.2, or HeatLosses).
- Cell references (including named cells and ranges).
- Operators.
- Worksheet functions (e.g. SUM or AVERAGE) and their arguments.
- Parentheses to control the sequence of arithmetic operations.

2.3.3 Miscellaneous Functions

The AVERAGE function returns the average of all the values in that array. The syntax is as follows: `=AVERAGE(A1:B5)`

The MIN function returns the smallest number in a set of values. The syntax is as follows: `=MIN(A1:B5)`

The MAX function returns the largest value in a set of values. The syntax is as follows: `=MAX(A1:B5)`

The SUM function adds all the numbers specified in a range. The syntax is as follows: `=SUM([number1],[number2],...])`

The CONVERT function converts a number from one measurement system to another. The syntax for the CONVERT function is: `=CONVERT(number,from_unit,to_unit)` The CONVERT function's arguments are as follows:

- number: The value in from_units to convert.
- from_unit: The unit for number.
- to_unit: The unit for the result.

Temperature	**From_unit or to_unit**
Degree Celsius	"C" (or "cel")
Degree Fahrenheit	"F" (or "fah")
Kelvin	"K" (or "kel")

Table 2.1: Conversion of Temperature Units

Power	**From_unit or to_unit**
Horsepower	"HP" (or "h")
Watt	"W" (or "w")

Table 2.2: Conversion of Power Units.

Force	**From_unit or to_unit**
Newton	"N"
Pound force	"lbf"

Table 2.3: Conversion of Force Units.

Example 2.1
To convert kilometers to miles: `=CONVERT(A2,"km","mi")`

Example 2.2
To convert Celsius to Fahrenheit: `=CONVERT(A6,"C","F")`

Example 2.3
To convert milligrams to kilograms: `=CONVERT(A10,"mg","kg")`

Example 2.4
To convert days to seconds: `=CONVERT(A14,"day","sec")`

2.4 Date and Time Functions[4]

2.4.1 Date and Time Functions

To Excel, a date is simply a number. More precisely, a date is a "serial number" that represents the number of days since January 0, 1900. A serial number of 1 corresponds to January 1, 1900; a serial number of 2 corresponds to January 2, 1900, and so on. This system makes it possible to deal with dates in formulas. For example, you can create a formula to calculate the number of days between two dates.

[4]This content is available online at <http://cnx.org/content/m37250/1.1/>.

2.4.2 Inputting Dates

You can enter a date directly as a serial number (if you know it), but more often you'll enter a date using any of several recognized date formats. Excel automatically converts your entry into the corresponding date serial number (which it uses for calculations), and also applies the default date format to the cell so it displays as an actual date rather than a cryptic serial number. For example, if you need to enter January 25, 2010, you can simply enter the date by typing January 25, 2010 (or use any of several different date formats). Excel interprets your entry and stores the value 38741—the date serial number for that date. It also applies the default date format, so the cell contents may not appear exactly as you typed them. `January 25, 2010`

2.4.3 Inputting Times

When you need to work with time values, you simply extend Excel's date serial number system to include decimals. In other words, Excel works with times by using fractional days. For example, the date serial number for January 25, 2010 is 38741. Noon (halfway through the day) is represented internally as 38741.5. `01/25/10 12:00 PM`

Example 2.5
To calculate the difference between two times, you can subtract the earlier time from the later time to get the difference. For example, if cell A2 contains 5:30:00 and cell B2 contains 14:00:00, `=B2-A2` returns `08:30:00` a difference of eight hours and 30 minutes. If the subtraction results in a negative value, however, it becomes an invalid time; Excel displays a series of pound signs (#######) because a time without a date has a date serial number of 0. A negative time results in a negative serial number, which is not permitted. This problem does not occur when you use a date along with the time.

Example 2.6
To convert decimal hours to a time, divide the decimal hours by 24. For example, if cell A1 contains 9.25 (representing hours) `=A1/24` returns `09:15:00` nine hours, 15 minutes.

Example 2.7
To convert decimal minutes to a time, divide the decimal hours by 1,440 (the number of minutes in a day). For example, if cell A1 contains 500 (representing minutes) `=A1/1440` returns `08:20:00` eight hours, 20 minutes.

Example 2.8
To convert decimal seconds to a time, divide the decimal hours by 86,400 (the number of seconds in a day). For example, if cell A1 contains 65,000 (representing seconds) `=A1/86400` returns `18:03:20` 18 hours, three minutes, and 20 seconds.

2.4.4 Formatting Dates and Times

Excel recognizes dates separated with a slash (/) or a hyphen (-) or dates entered using the month name. Times should be separated by colons (:). You have a great deal of flexibility in formatting cells that contain dates and times. For example, you can format the cell to display the date part only, the time part only, or both the date and time parts.

2.4.5 The NETWORKDAYS Function

The NETWORKDAYS function returns the number of whole workdays between the dates entered in cells A2 and B2, for example, `=NETWORKDAYS(A2,B2)`

The syntax for the NETWORKDAYS function is: `NETWORKDAYS(start_date,end_date,holidays)`

The NETWORKDAYS function's arguments are as follows:

- Start_date: A date that represents the start date.
- End_date: A date that represents the end date.
- Holidays: An optional range of one or more dates to exclude from the working calendar.

2.4.6 The WORKDAY Function

The WORKDAY returns a number that represents a date that is the indicated number of working days before or after a date (the starting date). Working days exclude weekends and any dates identified as holidays. For example, if you start a project on January 25, 2010 and the project requires 10 working days to complete, the WORKDAY function can calculate the date you will finish the project. A working day consists of a weekday (Monday through Friday). `=WORKDAY("1/25/2010",10)` returns `7-Feb-06`

The syntax for the WORKDAY function is: `WORKDAY(start_date,days,holidays)`

The NETWORKDAYS function's arguments are as follows:

- Start_date: A date that represents the start date.
- Days: The number of nonweekend and nonholiday days before or after start_date. A positive value for days yields a future date; a negative value yields a past date.
- Holidays: An optional range of one or more dates to exclude from the working calendar.

2.5 Key Points[5]

2.5.1 Key points

Key Points made in this chapter

2.5.2 Commands List

Commands used in this chapter:

- Command 1
- Command 2
- Command 3

2.5.3 What is Next?

What is Next?

2.6 Problem Set[6]

2.6.1 Problems

Intro paragraph.

1. First item here
2. Second item here
3. Third item here

[5]This content is available online at <http://cnx.org/content/m37272/1.1/>.
[6]This content is available online at <http://cnx.org/content/m37269/1.2/>.

Glossary

A

Absolute reference

The reference is fully absolute. When the formula is copied, the cell reference does not change. Example: A1

C

Cell

A cell is the intersection of a column and a row. Cells are the basic building blocks of a worksheet. Each cell is assigned an address (e.g. cell reference, A1 means column A and row 1).

Column

A column is a vertical block in a worksheet. Each column is identified by a letter in the column header.

Column absolute reference

The reference is partially absolute. When the formula is copied, the row part adjusts, but the column part does not change. Example: $A1

F

Formula

A mathematical formula that is run to compute results. Formulae are made up of standard arithmetic operations (e.g. +, -, *, /, ^).

Function

Functions are pre-constructed formulae that perform common calculations (e.g. summation and average). We can combine many functions and arithmetic operations in a single formula to carry out complex engineering computations.

R

Range

A range is block of cells in a worksheet.

Relative reference

The reference is fully relative. When the formula is copied, the cell reference adjusts to its new location. Example: A1

Row

A row is a horizontal block in a worksheet. Each row is identified by a number in the row header.

Row absolute reference

The reference is partially absolute. When the formula is copied, the column part adjusts, but the row part does not change. Example: A$1

W

Workbook

A workbook is a spreadsheet file. By default, each workbook in Excel contains three sheets.

Spreadsheet file names use .xls or .xlsx suffixes (i.e. file extension).

Worksheet

A worksheet is a single sheet in a workbook. By default, a workbook contains three worksheets.

Index of Keywords and Terms

Keywords are listed by the section with that keyword (page numbers are in parentheses). Keywords do not necessarily appear in the text of the page. They are merely associated with that section. *Ex.* apples, § 1.1 (1) **Terms** are referenced by the page they appear on. *Ex.* apples, 1

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By: Serhat Beyenir
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