Excel is an electronic worksheet that adapts calculations from paper and the calculator to the computer. Well-designed worksheets can save hours of work and help you try a wide variety of scenarios with little effort

Opening Excel

When you open Excel, it will open in its own window and start with a blank worksheet. An Excel worksheet file is called a workbook. A workbook is the Excel worksheet file in which related data and information for a specific project are stored. A workbook consists of many worksheets, or multiple layers, which are for listing and analyzing data.

Saving Your Work

When saving your worksheet for the first time, you will want to use the *Save As* option. With this you will be able to give your worksheet a name and indicate the location where you want the file saved.

Saving for the First Time

The following steps will be used when you are saving a worksheet for the first time, when you want to save it in a new location (perhaps a backup), or when you want to save a copy of it with a different name.

1. From the *File* menu, select ***Save As ...***
2. From the *Save in* pull-down list, select the proper directory and disk drive
3. In the *File name* or *Name* text box, type a filename
4. When everything is correct, click **SAVE**
   The file is saved under the filename you selected.

Saving Subsequent Times

1. From the *File* menu, select ***Save***
   OR
   On the *Standard* toolbar, click **SAVE**
   The file is saved.

Creating a Workbook

An Excel file is called a workbook which contains multiple worksheets. The worksheet is a single layer or single sheet within the larger workbook. Worksheets can be used to group information together. A worksheet can contain either data or charts, or both.

Creating a Workbook: Menu Option

1. From the *File* menu, select ***New…***
   The *New Workbook* task pane appears
2. From the task pane, select ***Blank Workbook***
   A new workbook appears.

Creating a Workbook: Toolbar Option

1. On the *Standard* toolbar, click **NEW**
   A new workbook appears.

Entering Text

A cell which contains text and numbers or text only cannot be used in formulas (even if numbers exist with the alphabetic characters).

1. Select the cell where you want the text to appear
2. Type the alpha-numeric text that should be in the cell
   HINT: To enter numbers as text, change the *Cell Format* to text, then enter the data.
3. To accept the information, press [**Enter**] or an arrow key
   To force text to wrap at a specific point in a cell, press [**Alt**]+[**Enter**].

Entering Numbers

Numeric cells can be used for calculations and functions. A numeric cell may contain: numbers, plus (+), minus (-), currency (£).

1. Select the cell where you want the number(s) to appear
2. Type the numeric information that should be in the cell
3. To accept the information, press [**Enter**] or an arrow key
   NOTES:
   Excel automatically right aligns values and left aligns text.
   There can be no spaces or alphabetic characters in a calculation cell.

Entering Dates or Times

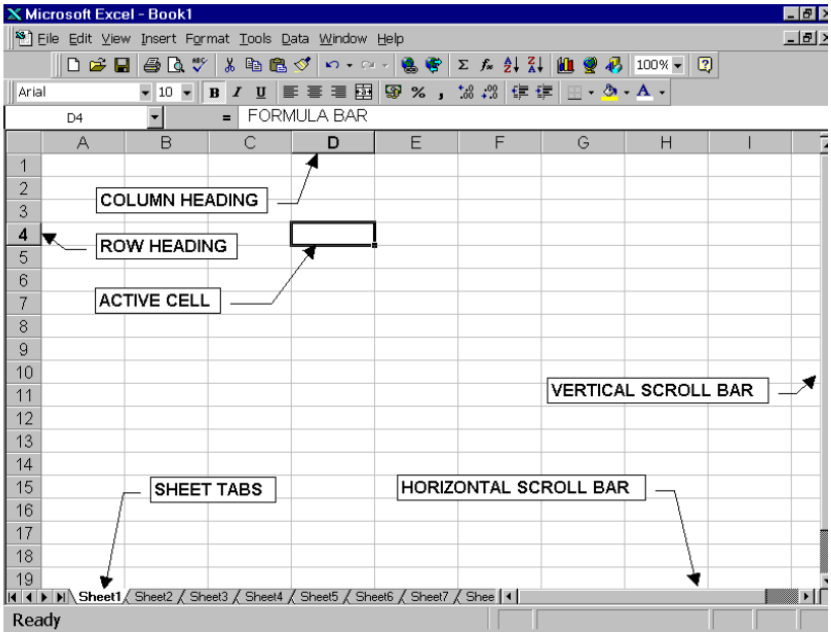
Enter Dates or Times Manually

1. Select the cell where you want the date or time to appear
2. If entering a date, type it in one of the following formats (6/23/2003, 6-23-2003, or June 23, 2003)
3. To accept press [**Enter**]

Enter Today's Date or Current Time Automatically

1. To enter today's date, press [**Ctrl**]+[**;**]
   To enter the current time, press [**Ctrl**]+[**Shift**]+[**;**]
2. To accept press [**Enter**]

Excel Terminology



Workbook
A workbook is a Microsoft Excel file that contains multiple worksheets where related data and information for a specific project are stored.

Worksheet
The worksheet is a single layer or single sheet within the workbook. A worksheet can contain data, charts, or both. Instead of compiling all of your information into one worksheet, you can create several worksheets within the one workbook file. With this organization, similar information is grouped together to make it easier to locate and work with. The worksheets for your workbook will vary based on its content and purpose.

Workspace
The workspace contains information about a group of Microsoft Excel files. The workspace file saves information regarding screen position, window size, and file locations. The workspace file does not save the content of the workbooks. Each workbook needs to be saved individually.

AutoFormat

To make formatting your worksheets a little easier, Excel has several "preset" formats available for you. With these preset formats, you can select all of the characteristics or only some (e.g., just the borders). Either way, it can be an efficient way to start formatting your worksheet. Once you apply the formatting with *AutoFormat*, you can still make adjustments to the cells.

1. Select the cells you want to format
2. From the *Format* menu, select ***AutoFormat ...***
   The *AutoFormat* dialog box appears.
3. From the listing of options, select the desired option
4. OPTIONAL: If you want to apply only some of the characteristics
   a. Click **OPTIONS ...**
      The *AutoFormat* dialog box expands.
   b. Under *Formats to apply*, select/deselect the desired options
5. When finished, click **OK**

Formatting Fonts

There are two different options for formatting fonts in Excel: the *Formatting* toolbar option and the *Format* menu option.
NOTE: In addition to font choices, the *Format Cells* dialog box contains many other style choices that are not available on the *Formatting* toolbar.

Formatting Fonts: Toolbar Option

1. Select the cell(s) you want to enhance
2. On the *Formatting* toolbar, click the option you want

Formatting Fonts: Menu Option

1. Select the cell(s) you want to enhance
2. From the *Format* menu, select ***Cells…***
   The *Format Cells* dialog box appears.
3. Select the ***Font*** tab
4. Make the desired changes
5. Click **OK**

Formatting Numbers

There are two different methods for formatting numbers in Excel: the *Formatting* toolbar option and the *Format* menu option.

Formatting Numbers: Toolbar Option

1. Select the cell(s) you want to enhance
2. On the *Formatting* toolbar, click the desired option you want

Formatting Numbers: Menu Option

1. Select the cell(s) you want to enhance
2. From the *Format* menu, select ***Cells…***
   The *Format Cells* dialog box appears.
3. Select the ***Number*** tab
4. From the *Category* listing, select the appropriate number format

5. Based on your selection, make the appropriate choices from the options that appear
6. Click **OK**

Four-Digit Years

1. Select the cells you want to format
2. From the *Format* menu, select ***Cells ...***
   The *Format Cells* dialog box appears.
3. Select the ***Number*** tab
4. From the *Category* listing, select ***Date***
5. From the *Type* listing, select the desired four-digit year option
6. Click **OK**

Merging and Centering Text

There are two methods for merging and centering text in Excel: the *Formatting* toolbar option and the *Format* menu option.

Merging & Centering Text: Toolbar Option

1. Type the text in the first cell of the group
2. Select the text and a cell from each column that you want to center across (e.g., to center across columns A through D in row 2 of the worksheet, you will select cells A2, B2, C2, and D2)
3. On the *Formatting* toolbar, click **MERGE AND CENTER**

Merging & Centering Text: Menu Option

1. Type the text in the first cell of the group
2. Select the text and a cell from each column that you want to center across (e.g., to center across columns A through D in row 2 of the worksheet, you will select cells A2, B2, C2, and D2)
3. From the *Format* menu, select ***Cells…***
   The *Format Cells* dialog box appears.
4. Select the ***Alignment*** tab
5. From the *Horizontal* pull-down list, select ***Center Across Selection***
6. Under *Text control*, select ***Merge cells***
7. Click **OK**

Unmerging Text: Menu Option

3. Select the merged cell
4. From the *Format* menu, select ***Cells ...***
   The *Format Cells* dialog box appears.
5. Select the ***Alignment*** tab
6. From the *Horizontal* pull-down list, select ***General***
7. Under *Text control*, deselect ***Merge cells***
8. Click **OK**

Wrapping Text

If you have text that appears in a single cell but you want to increase the height of that cell to accommodate all of the words, you can use the *Wrap text* option.

1. Select the cells that you want to apply *Wrap text* to
2. From the *Format* menu, select ***Cells…***
   The *Format Cells* dialog box appears.
3. Select the ***Alignment*** tab

4. Under *Text Control*, select ***Wrap text***
5. Click **OK**
   NOTE: To display all of the text, it may be necessary to adjust row height.

To unwrap text:

1. Select the cell which has wrapped text
2. From the *Format* menu, select ***Cells ...***
   The *Format Cells* dialog box appears.
3. Under *Text Control*, deselect ***Wrap text***
4. Click **OK**

Formatting with the Painter

The typical *Copy* & *Paste* will copy the information (text or formula) and the formatting of the cell(s). If you want to copy only the formatting, you can use the *Painter* option. This will format the destination cell the same as the source cell without changing the content.

Formatting with the Painter: Single Cell

1. Select the cell that contains the formatting you want to copy
2. On the *Standard* toolbar, click **FORMAT PAINTER**
   The pointer changes shape to include a paint brush next to it.
3. Click the cell to which you want the copied format applied
   NOTE: You can also select a range of cells by clicking and dragging.

Formatting with the Painter: Multiple Cells

1. Select the cell that contains the formatting you want to copy
2. On the *Standard* toolbar, double click **FORMAT PAINTER**
   The pointer changes shape to include a paint brush next to it.
3. Click the cell where you want the copied format applied
   You can also select a range of cells by clicking and dragging.
4. Repeat step 3 for additional cells in which you want the format applied
5. When done, to turn off the *Painter*, click **FORMAT PAINTER** again

Clearing All Formatting from a Cell

If you want to remove all formatting from a cell but leave the contents (text, value, or formulas), use the following command.

1. Select the cells that you want to clear the formatting from
2. From the *Edit* menu, select ***Clear » Formats***

Moving Information

Often, your first approach at organization will not be the same as your final organization. For this reason, you may want to reorganize information.

Drag & Drop vs. Cut & Paste

Drag & Drop allows you to move the information from a single cell or a range of cells. *Drag & Drop* is great for moving short distances, but challenging for moving to cells that are not displayed on the current screen. The Excel default settings will warn you if you try to drop on cells that already contain information. *Cut & Paste* is the better method when moving information over long distances

Moving Information: Drag & Drop

Unlike your word processor, where it does not make much difference if you drag and drop text rather than cut and paste it, the difference is significant when formulas are involved. When using the drag and drop method, cell references are updated.

1. Select the cell(s) you want to move
2. Point to and click the heavy border surrounding the cell(s)
3. Holding the mouse button, drag the cells to the new location
4. When you reach the new location, release the mouse button to drop the cell(s)

Undoing Drag & Drop

1. From the *Edit* menu, select ***Undo Drag and Drop***
   OR
   On the *Standard* toolbar, click **UNDO** 

Moving Information: Cut & Paste

When using cut and paste, double check formulas to ensure that the cell references were properly updated.
WARNING: The Excel *Paste* command works differently from most Windows programs. Information remains on the clipboard only until another action is executed (e.g., typing information in a cell).

1. Select the cell(s) you want to move
2. From the *Edit* menu, select ***Cut***
   OR
   On the *Standard* toolbar, click **CUT** 
   A moving border appears around your selection.
3. Select the cell where you want the cells to be pasted
4. From the *Edit* menu, select ***Paste***
   OR
   On the *Standard* toolbar, click **PASTE**

Basic Functions & Formulas In Excel

To create spreadsheets that are productive, you need to insert formulas. A formula is used to perform calculations. Formulas calculate values, usually based on other values elsewhere in the spreadsheet. The result of the formula appears in the cell, but not the formula itself (this can be viewed and edited in the formula bar). A function is a type of formula that performs calculations on multiple inputs. Excel features a number of built-in functions. Common functions used in formulas include the following

- SUM(...) adds up each value or cell referred to
- AVG(...) finds the mean average of all the values and cells referred to
- MAX(...) finds the largest of all the values and cells referred to
- MIN(...) finds the smallest of all the values and cells referred to

The Structure Of Formulas

All formulas in Excel begin with an equals sign "=". This tells Excel that the contents of the cell are to be treated as a calculation as opposed to textual or numeric data. The equals sign is then followed by a a combination of the following:

Mathematical Operators

- + Addition =A1+A2 The total of the values in cells A1 and A2
- - Subtraction =A1-A2 The result of subtracting the value in cell A2 from the value in cell A1
- Multiplication =A2*3 The result of multiplying the value in cell A2 by 3
- / Division =A1/50 The result of dividing the value in cell A1 by 50

The simplest formulas involve numbers, such as =10+10 or =50/5. However, when typing in formulas and functions you should try to use cell references rather than the numbers themselves. The reason for this is that if you use cell references in formulas, when you change the numbers in the cells, all the dependant formulas will be updated automatically. If you used numbers in the formulas themselves this would not happen, and you would have to manually change the data in each formula.

For example, if you were to find out how much VAT is to be paid on a particular product, you could create a formula which multiplies the cell reference of the product by the VAT percentage (eg. A1*17.5%). However, it would be much better to put the VAT rate in a separate cell , and reference this cell in the formula .

As a general rule, important numbers, like these should always be placed in separate cells, and then the cell referenced in any formula. Then, if the VAT rate changes you only need to change the data in one cell, and all the other related cells that reference the percentage will update automatically.

Replication Of Formulas

When you create a formula in a spreadsheet it is often the case that the same formula needs to be applied to the data in the next cell down or across. If you want to use the same formula on a range of cells, you generally only need to write the formula once, then you can replicate it into adjacent cells. Formulas are replicated using the Autofill tool. The small black cross that appears when you click on the bottom right corner of a cell can be dragged into adjacent cells, copying the formula into those cells.

Relative And Absolute Referencing

When you try to replicate formulas in this way, Excel guesses which cell references to use in the adjacent cells. It does so using relative referencing. An example of a relative address is =A3*B4. The message you are sending to Excel when copying a relative address is "get the next value relative to the current cell's position."
If relative referencing doesn't produce the right results, you may need to use absolute referencing. Here one cell is fixed, and all calculations are made against that cell. To make a cell reference absolute, you select the cell reference in the formula bar, then press F4 (this will put dollar symbols in front of the column letter and row number). An example of absolute addressing is (=A3*$B$4). The message here is "Don't change this cell reference" (the cell reference, in this case, being B4). Absolute cell references are commonly used in calculations involving fixed percentages, tax or VAT rates, or any formula where one part of the calculation remains static (or absolute).

Mixed Cell References

Cell references can also be a mixture of absolute and relative references. In mixed cell references, one row or column will be absolute (i.e. fixed) while the other remains relative. The following are examples of mixed cell references:

- =$A3+$B5 (Absolute column and relative row)
- =A$3+B$5 (Relative column and absolute row)

Copying Formulas

With a relative formula, the cell references change in relationship to the new location of the cell. For example, if you copied the formula from column A to B and the formula used a value in cell A12, the formula would now be referring to cell B12. If you cut the formula, it would refer to the original cell, A12.
With an absolute formula, in the same example, the cell reference to A12 would remain constant.
A formula can have both relative and absolute components. When formulas are created, they are created as relative. By adding a dollar sign ($) before either the column or row location or both, that reference becomes absolute.
When copying formulas, cell references are important to the result of the formula. If you want to copy the formula and look at cells with similar information one column over, a relative formula is the best choice. However, if you want to copy the formula and refer to the same cell (perhaps the wage rate of a student employee), you should be working with an absolute formula, not a relative formula.
NOTE: Absolute references are automatically updated for column and row additions and deletions.

Example	Description
=A12+B12	Formula with relative references
=SUM(A12:A16)	Function with relative references
=$A$12+$B$12	Formula with absolute references
=SUM($A$12:$A$16)	Function with absolute references
=$A12+$B12	Formula with absolute column reference but relative row reference
=SUM(A$12:A$16)	Function with absolute row references but relative column references

Using the Fill Command

Instead of copying cells, you can use the *Fill* option to repeat information to contiguous cells. If the first cell contains a formula, the formula will be repeated in the additional cells. If the first cell contains text, the text will be repeated in the additional cells. However, with the *Fill* option, if Excel recognizes a pattern of information, the additional cells will contain the next item in the pattern. For example, if the first cell contains the day Sunday, Excel will fill the following cells with Monday, Tuesday, Wednesday, etc.
Select the cell(s) that contain what you want to repeat
Click and hold the **FILL HANDLE**
Drag to select new cells in the range
Release the mouse button
The range will be filled with information from the original cell(s).

Hiding Columns

If there is information on your worksheet you do not need to see or if you want to print only certain columns, you can hide those columns you do not want to see or print.

1. Select a cell within the column(s) to be hidden
2. From the *Format* menu, select ***Column » Hide***
   The column is hidden.

Redisplaying Columns

1. Select at least one cell from both of the columns around the hidden column(s) to be redisplayed, e.g., if column B is hidden, select a cell from both columns A and C
   HINT: If you cannot select the appropriate cells, you can use the Go To command.
2. From the *Format* menu, select ***Column » Unhide***
   The column reappears.

Redisplaying Column A: Quick Menu Option

This option works well for redisplaying column A, since there are not columns on both sides of column A.

1. Hold you cursor over ID for column B toward the left side
   The cursor will change to an open, double sided arrow as shown here.
2. Right click » select ***Unhide***

Hiding Cell Contents

You have the ability to hide the contents of individual cells if you do not need to view their contents or you simply do not want to print certain cells.

1. Select the cell(s) to be hidden
2. From the *Format* menu, select ***Cells ...***
   The *Format Cells* dialog box appears.
3. From the *Format Cells* dialog box, select the ***Number*** tab
4. Under *Category*, select ***Custom***
5. In the *Type* text box, type three semicolons (***;;;***)
6. Click **OK**
   The cell(s) is now hidden.

To redisplay cell information:

6. Select the cell(s) to be redisplayed
7. From the *Format* menu, select ***Cells ...***
   The *Format Cells* dialog box appears.
8. From the *Format Cells* dialog box, select the ***Number*** tab
9. Under *Category*, select the appropriate date, time, or number format
10. Click **OK**
    The cell(s) reappears.

Graphs

General Hints

Generally, effective charts use the simple (and easily learned) techniques of good design. Any book discussing page layout will assist you in this area. However, some design techniques should be specifically mentioned, as they relate directly to charting. These techniques include:

- ***Choosing the correct chart format***
  Chart formats are designed to portray certain types of information; you must therefore choose the correct chart format for the information you wish to project.
- ***Maintaining simplicity***
  Clarifying information is the main goal of creating a chart in the first place, and complicated charts only serve to make the information they present less clear.

- ***Maintaining consistency***
  When creating several charts, use a design grid. This grid will help you maintain a consistent chart format, eliminating distractions for your audience.
- ***Using labels***
  Effective use of labels, created using legible typefaces, will assist your audience in understanding a chart's information.

Each of these design factors is important, but the choice of chart format comes first. For this reason, the following sections discuss the design considerations for three of the most common chart formats.

Pie Charts

Pie charts are best used to compare parts of a whole; in other words, they help divide a group into the components that make it up.

Bar Graphs

Bar graphs work best to emphasize the contrast between quantities. Two types of bar graphs can be used: vertical and horizontal. Vertical bar graphs work well for comparing quantities at different times, while horizontal bar graphs compare different quantities when time is not an important consideration.

Line Graphs

Line graphs best indicate the relationship of one variable to another, and they can be created using either straight or curved lines. Which type of line graph you use depends on the type of information you wish to convey: straight line graphs show specific observation points, while curved line graphs show general trends.

Summary

Following the guidelines in this document will help you create pie charts, bar graphs, and line graphs that present information clearly. Of course, these three chart formats are not the only ways to convey numerical data; other formats can effectively portray information as well. The following table provides a quick guide to most of your choices:

Chart Format	Description
Pie	Compares parts of a whole.
Bar	Shows contrast between quantities.
Line	Indicates the relationship of one variable to another.
Area	Indicates the volume relationship of one variable to another.
Scatter Plot	Correlates two factors by marking the points where particular events occurred.

Designing Your Worksheet for Charting

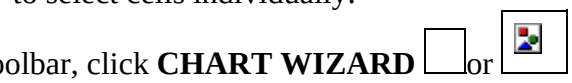
There are two basic options for setting up your worksheet. First, you can design your worksheet so the information to be charted is close together. Second, you can create a summary section for charting.

Recommended: Range Names

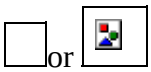
Before you create your chart, you should create a range name to represent the data on your worksheet. Range names refer to a specific group of cells. They are often used for cell references in functions, charting, and printing. Using range names when creating a chart rather than using the cell references will reduce the chance of error and allow you to add data to your chart in the future.

Using the Chart Wizard

Using the Chart Wizard: Selecting Your Data

1. Select the data you want to appear in a chart
   NOTES:
   If you are selecting data from different areas of your worksheet, you can add a block of data by holding down the [**Shift**] key while selecting the cells using your mouse. In addition you can use the [**Ctrl**] key to select cells individually.
2. From the *Standard* toolbar, click **CHART WIZARD**  or
   The *ChartWizard-Step 1 of 4-Chart Type* dialog box appears.
3. Under *Chart type,* select the appropriate chart type
4. Under *Chart sub-type,* select the appropriate sub-type and click **NEXT>**
   The *Chart Wizard Step 2 of 4-Chart Source Data* dialog box appears.
5. Select the ***Data Range*** tab
   You may need to specify whether you would like to chart the row or column information. The sample chart will change accordingly.
6. Click **NEXT>**
   The *Chart Wizard-Step 3 of 4-Chart Options* dialog box appears.
7. Select the ***Legend*** tab
8. If you would like a legend, select ***Show legend***
   HINT: If you are using a pie chart, labels are recommended instead of a legend.
9. Under *Placement,* select the appropriate option button corresponding with where you would like your legend
10. To create a title for your chart, select the ***Titles*** tab
11. In the *Chart title* text box, type the desired title
12. In the appropriate boxes, type the desired x and y-axes labels and click **NEXT>**
    The *Chart Wizard-Step 4 of 4-Chart Location* dialog box appears.
13. If you would like your chart to appear within the Excel sheet, select ***As object in***
14. If you would like your chart to appear as a separate sheet, select ***As new sheet***
15. Click **FINISH**

Using the Chart Wizard: Range Names

1. Click **CHART WIZARD**  or
   The *Chart Wizard-Step 1 of 4-Chart Type* dialog box appears.
2. Select the appropriate chart type and click **NEXT>**
   The *Chart Wizard Step 2 of 4-Chart Source Data* dialog box appears.
3. Select the ***Data Range*** tab
   a. In the *Data range* text box, press [=]
   b. After the =, type the range name
4. Click **FINISH**
   The information that you selected appears in a chart on your screen. To enhance this chart, review the following charting options.

Modifying a Chart

Once your chart is created, you can modify it to fit your needs or the evolving nature of your data. You can select two different sections of the chart. The *Chart Area* is everything seen on the chart, including the border. In order to perform many of the formatting options, you must first select your chart.

Selecting the Chart

To select the *Chart Area*:

1. Click near the border
   The black fill handles appear when the chart is selected.

To select the *Plot Area*:

The *Plot Area* is only the pictures and figures on the chart, and is used mainly for formatting.

1. Click near the chart
   A gray box with fill handles appears when it is selected.

☐ Changing the Chart Type

If the default chart type is not appropriate for the information you are charting, you can change it by using the *Chart Type* selection from the *Chart* menu.

1. Make sure the chart is selected
   (outer borders have the handles)
2. From the *Chart* menu, select ***Chart Type...***
   The *Chart Type* dialog box appears.
3. Select the appropriate chart type and sub-type
   NOTE: You can preview your information in any chart before you create it. Just click **PRESS AND HOLD TO VIEW SAMPLE**.
4. Click **OK**

Positioning Your Chart

Moving Your Chart

The chart is an object on your worksheet. While your chart may cover some worksheet information, the information still exists. The chart can be moved anywhere on your worksheet.

1. Select your chart
2. Click and hold the chart
3. Drag the chart to the appropriate location
4. Release the mouse button
5. To deselect the chart, click elsewhere on the worksheet

Resizing Your Chart

As you resize the chart, the chart elements are adjusted proportionality.

1. Select your chart
2. Click and hold on one of the handles
3. Drag the handle in or out to adjust the size of the chart
4. Release the mouse button
5. To deselect the chart, click elsewhere on the worksheet

Excersise 1

Apply what you have learnt to these problems:
1. Create a spreadsheet to track your bank account. It should have the following format:

Date	Transaction	In	Out	Balance
10th November 01	Opening Balance	£50.00		£50.00
12th November 01	Salary	£49.50		£99.50
13th November 01	Our Price		£15.00	£84.50

Note that the final column should be calculated, not entered as figures. Make the spreadsheet do some work for you!

Hint: To allow the spreadsheet to calculate, you must NOT enter pound signs (£) in the cells. Enter the figures only and then format the cells as 'currency' to make the £s appear.

2. Calculate the energy you expend in an average week.
Set up a spreadsheet with the following column headings:

	A	B	C	D
1	**Activity**	**Energy use (Units)**	**Duration (Hours)**	**Energy total**
2				

Enter some activities such as sleeping, eating, studying, walking in column A. Estimate some values for column B e.g. sleeping = 10 units per hour, eating = 40 units per hour etc.

Move to the cell D2 and enter the formula **=B2*C2**. This calculates the Energy total for this first activity.
Copy the cell D2 into cells D3 to D10
Move to the cell D11 and enter the formula **=SUM(D2:D10)**. This calculate the total energy for all the activities.
Move to the cell C11 and enter the formula **=SUM(C2:C10)**. This calculate the total time spent on all the activities
Give the spreadsheet a title **Monday's Activities**
Copy Monday's sheet into a second sheet and retitle it **Tuesday's Activities.**
Repeat the this for the rest of the week
Save your workbook to floppy disk
As an additional activity you could try creating a summary sheet with links to each day of the week and totals for the week

Exercise 2

Use the above two examples to create relevant graphs