Using a spreadsheet to explore functions

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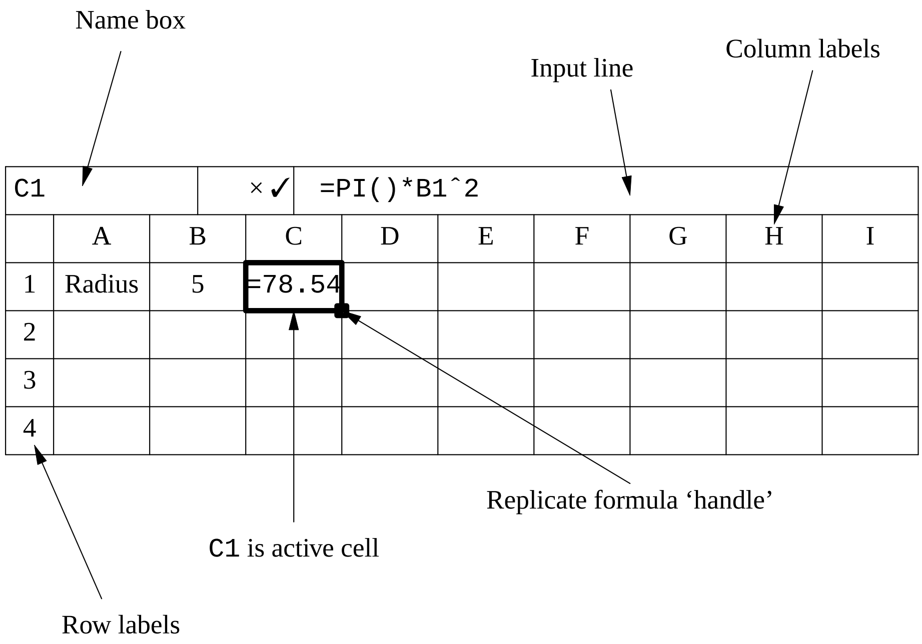
1. Basics

When you start your spreadsheet, you will see a window that looks a little bit like my diagram below. The very top of the window will have the usual toolbars and menus that all programs have. The main part of the spreadsheet window is divided into columns labelled `A`, `B`, `C` and so on. The rows are numbered `1`, `2`, `3` and so on. You won't run out of rows!



Each cell in the spreadsheet has an address given by its column letter and row number. When you click on a cell with the mouse, that cell becomes the *active cell*. The cell has a slightly darker box around it, and the cell address or name appears in the *Name box* box at the top left of the main spreadsheet window. In the diagram above, the active cell is `C1` and you can see what that cell contains in the 'Input line' on the top right of the main spreadsheet window.

Each cell can hold either text such as the word 'Radius' or a numerical value such as the number 5 or what is called a *formula* in the spreadsheet world, which is something that starts with an equals sign like `=PI()*5ˆ2`. Try copying the spreadsheet above. See what happens. There are more detailed instructions in the rest of this section.

The rest of this handout will explain how to use your spreadsheet to do calculations, build tables of values from an equation and to plot simple graphs. Working through this handout will take you through the basics of typing text, numbers and formulas into a spreadsheet as well as using a few of the built in functions. It will also cover refering to the values in one cell in formulas entered in other cells, and copying formulas to build tables of values and how to plot graphs from those tables. Along the way we will talk about parameters and variables and how you can solve any equation by trial and improvement.

In this handout I have kept to a set of functions that are common to all current spreadsheets designed for graphical user interfaces like Windows, MacOS or linux. I used LibreOffice Calc when I worked through the examples. I used one spreadsheet file and I put each example in a separate worksheet within that file. You need to find out how to add a new worksheet to your spreadsheet file and how to rename that worksheet.

2. Your spreadsheet as a calculator

Each cell in a spreadsheet has all the power of a scientific calculator. But the cell can only accept single line formulas, so $\frac{4 + 2\times 8}{10 - 2^3}$ would need to be written as `=(4 + 2*8) / (10 - 2^3)`. Fraction bar expressions have to be re-written using brackets, and you have to use `*` for multiplication, `/` for division and `^` for power.

Make a new worksheet in your spreadsheet file called ‘scratch’ or ‘calculations’. Click on a cell somewhere in the worksheet window and type something like

$$= 4 + 6 * 7$$

When you press the Enter key to enter this formula into the cell, the spreadsheet application will carry out the calculation and put the numerical answer in the cell. My example gives 46. Your spreadsheet program recognises a range of built in maths functions and follows the rules of BIDMAS, see the table below...

2.1. Examples of formulas

Formula	Value	Comments
`=30 / 6`	5	/ is division sign
`=4*256`	1024	* is multiplication sign
`=-3*8`	–24	– is both subtract and unitary minus
`=-5^2`	25	Note that the power is applied to the number with sign. This is different to a scientific calculator.
`=(2+7)/3+2^3`	11	bracket conventions apply as usual.
`= sqrt((24-6)/(10-8))`	3	sqrt() is a built in function
`=PI()*12.7^2`	506. 707	number of places shown depends on formatting of the cell
`=radians(180)`	3. 1416	radian function converts degrees to radians
`=degrees(0.785398)`	< 45	degrees function converts radians to degrees
`=12*sin(radians(30))`	6	spreadsheets use radian measure for trigonometry
`=degrees(asin(12.5/25))`	30	inverse trig functions use the old names because $\sin^{-1}(x)$ won’t fit on a single line
`=1024(1/10)`	2	you can get n^{th} roots using reciprocal powers
`=power(2,3)`	8	the power function can be used to raise powers
`=power(125,1,3)`	5	the third argument is a reciprocal so you can find roots
`=power(4,3,2)`	8	raises 4 to third power and then finds power half or square root of result

Some keywords are used to describe things you type into cells. A *function* is a named formula like `=sqrt()`. Some functions have more than one thing in the brackets, the things in the brackets are called *arguments*. An example would be `=product(2, 3, 4)`. The product function can have as many arguments as you want but it needs at least two to do anything useful!

2.2. Error messages and what they mean

If you type something wrong in the formula, the spreadsheet program will give an error message of some kind and you will end up with a non-numeric result in the cell. The LibreOffice help has a full list of the error messages. Other spreadsheet programs will report errors in different ways but most will allow editing of the formula on the input line. The table below shows a selection of the various kinds of error message you might see in LibreOffice. Try typing them in somewhere on your 'scratch' worksheet and see what the errors look like in your spreadsheet program.

Formula	Cell contents	Comments
`=o.44 + 2.96`	Err:522	Displays `=#REF!.#REF!44+2.79` on input line
`=1o97 + 1066`	#NAME?	Input line displays original for correction. Note how the position of the incorrect character changes the error message
`=sqrt(-9)`	Err:502	Correct format but gives impossible value, input line displays original formula so you can correct it
`=power(1,3,4,2)`	Err:504	You have too many arguments or too few
`1999999999`	###	If you make the column very narrow with a large numerical entry, the cell will show hash marks. Just make the cell wider to see the number.

If you get an error message after typing in a formula, click in the cell. The ✓ and × buttons will appear next to the Input line. You can click in the Input line and correct the error, and click the ✓ button to apply the change. If your attempt to edit the formula goes wrong, you click × to reject the changes and try again.

2.3. Accuracy, rounding and cell format

The spreadsheet program calculates results to 16 significant figures internally. Most spreadsheets will display fewer significant figures depending on the width of the cell. You can control the number of decimal places displayed by using the *cell format* and *number* option as follows;

- **Click** on the cell containing the number to make the cell the current cell
- **Right click** and select **Format | Cells** from the context menu
- Select the **Number** category in the dialog box that appears
- Set the value in the **Decimal places** number box to the number of decimal places you want
- **Click OK** to make the change

You can apply cell formatting to a selection of cells that you make by dragging the mouse, or to an entire column by clicking on the letter label at the top of the column, or to an entire row by clicking on the number label at the left side of the row.

In summary a single cell in your spreadsheet is like a scientific calculator. But a spreadsheet has a lot of cells. so you have thousands of scientific calculators. And you can connect them together so the answer from one cell is used in other cells.

3. Cell references: substituting into formulas

Most spreadsheets have columns labelled with letters `A`,`B`,`C` and so on and numbered rows. Each cell in the resulting grid has an address given by a letter and a number, so cell `B7` is the cell in row 7 in the column headed by the letter `B`. These addresses or*cell r eferences* can be used to refer to values in other cells.

As a concrete example suppose you wanted to be able to work out the circumference and area of a circle given any (positive!) value of the radius. You could add a worksheet called ‘circle’ and add some labels and a cell to type in the radius like this:

- Put the label ‘Radius’ in cell `A1` and put the value 12 in cell `B1`
- Put the labels ‘Circumference’ and ‘Area’ in cells `A2` and `A3`
- Put the formula `=2*PI()*B1` in cell `B2`
- Put the formula `=PI()*B1^2` in cell `B3`

See how the cell reference `B1` in the formulas stands for the value in `B1`? The magic is that changing the value in `B1` causes the spreadsheet program to recalculate all the cells that depend on that value. Try typing different values in for the radius and check a few of the results.

3.1. Volume and surface area of a sphere

The best thing to do now would be to try building some formulas for yourself. Make a new worksheet called ‘Sphere’ or something similar in your spreadsheet file. Try making the formulas to calculate

- the surface area of a sphere $A = 4\ \pi r^2$
- the volume of a sphere$V = \frac{4}{3} \pi r^3$

in cells `B4` and `B5` with suitable labels in cells `A4` and `A5`. Check one set of answers with a calculator. My Sphere worksheet looked something like this

	A	B	C	D
1	Sphere calculations			
2		Radius	`8`	
3		Surface Area	`201.06`	
4		Volume	`2144.66`	
5				

Try right clicking over the answer cells and formatting the number style to give a sensible number of decimal places - you might have to use the help function for your particular spreadsheet to find how cell formatting works.

Try customising the fonts and perhaps using a background colour to distinguish the cell where you type in the radius values and the cells that display the results of the calculation. You can also set a ‘printing area’ to control the appearance of the spreadsheet when printed out. In some laboratories one person sets up a calculation on a spreadsheet, then everyone else enters their data and prints out the results and puts them on file. This simple procedure ensures consistency in calculation.

3.2. Your turn

Make another new worksheet in your spreadsheet file. I called mine ‘Right Angled Triangle’. Build a spreadsheet to calculate the length of the hypotenuse of a right angled triangle. Take the lengths of the two short sides as input. Check that your worksheet gives the correct answers to a few examples.

Extend your worksheet to calculate the area of the right angled triangle.

Then if you want more of a challenge, extend the worksheet again to calculate the sizes of the two acute angles in the right angled triangle. You will need to plan out the labelling of the answer cells carefully so you can work out which angle value is between which of the two sides.

I used the ‘three letter’ or ‘vertex’ notation for the triangle. In triangle ABC, AB was one of the short sides, and BC was the other short side. Angle ABC was the right angle, and angles BAC and ACB were the two acute angles.

3.3. Solving equations by trial and improvement

Once you have a spreadsheet that can calculate the value of a formula by substitution, you can solve equations using trial and improvement. For example, I can use my ‘Sphere’ worksheet to guess what radius is needed for a sphere of exactly 1000cm^3. I am trying to solve the equation

$$\frac{4}{3}\pi r^3 = 1000$$

by trial and improvement so I made a quick table on scrap paper to record guesses and results sytematically.

Guess $\left(\frac{R}{cm}\right)$	**Volume** $\left(\frac{V}{cm^3}\right)$	**Comment**
5	166.67	much too small
10	1333.33	big but not by a huge amount
8	682.67	too small
9	972.00	still too small
9.1	1004.76	too large but getting close
9.09	1001.45	still too large by half a teaspoon
9.086	1000.13	pretty much there

You will need to make choices about the accuracy of a trial and error solution, and you need to experiment with the cell formatting to see how many decimal places you need in the numbers.

3.4. The ‘Goal Seek’ procedure: let the spreadsheet do the guessing

Some spreadsheets have internal routines or procedures for automatically solving equations of the form $f(x) = c$ to a specified level of accuracy. Look for something like ‘Goal Seek’ in the help for your particular spreadsheet. In LibreOffice the Goal Seek function is in the Tools menu. To use Goal Seek to solve (say) $4\pi r^2 = 5$ you could;

- Insert a new worksheet in your spreadsheet file with title ‘goal seek’
- Put the formula `=4*PI()*C6^2` in cell `C7` with label ‘Surface Area’ in cell `B7`
- Put a value (say) 2 in cell `C6` and then
- Select **Tools | Goal Seek** from the **Tools** menu
- Type `C7` into the **Formula** cell entry box
- Type 5 into the **Target** value space in the dialog box
- Type `C6` into the **Variable** cell box and click **OK**
- If the goal seeking is successful at finding a value, an answer appears in a smaller dialog box and you can click **OK** to have that answer written in the Target cell

Some formulas are too complex or too rapidly changing for the Goal Seek procedure to work properly. See if you can find one. A good starting point would be a cubic equation like $y = (x - 1)(x - 1.1)(x - 1.2)$. That equation has three closely spaced roots at $x = 1, x = 1.1$ and $x = 1.2$.

The **Tools | Solver** has an inviting looking name, but is for a *completely different* kind of problem. This procedure is for solving linear programming problems to do with optimising solutions to multiple linear equations under constraints.

4. Cell ranges

This section is a little outside the main topic of using a spreadsheet to explore functions. But cell ranges are an important feature of a spreadsheet, and they can be used later in section 6 where you use the chart facilities in your spreadsheet to actually plot a table of values.

The spreadsheet below calculates the total weight in grammes of the ingredients that you type into cells `A2`, `B2`,`C2`,`D2` and puts the value into cell `E2`.

	A	B	C	D	E
1	Flour	Water	Salt	Yeast	Total
2	300	170	2	2	474
3					

Cell `E2` contains this formula `=sum(A2:D2)`. The`A2:D2` bit is a *cell r ange*, and it refers to the contents of cells `A2`, `B2`, `C2`, and `D2`. Cell ranges can be rectangular so`A1:Z200` refers to the 5200 cells in a huge block. Cell ranges are usually used with functions that work on a whole list of numbers. The `=sum()` is very common in spreadsheets for calculating budgets and VAT and so on. The key thing is if you change any of the quantities in cells `A2`, `B2`, `C2`, and `D2`, the total in cell `E2` is *automatically* recalculated.

Suppose you had 10 numbers in the first column of a spreadsheet and you wanted to calculate some statistics. The functions below could be useful.

mean	`=mean(A1:A10)`
median	`=median(A1:A10)`
min	`=min(A1:A10)`
max	`=max(A1:A10)`
lower quartile	`=quartile(A1:A10,1)`
upper quartile	`=quartile(A1:A10,3)`

The cell you put your formula in can't be within the cell range you use in the formula. For instance in the statistical examples above, trying to put any of the formulas in cell (say) `A1` won't work, and you will get a formula error.

4.1. What if?

In the days before cheap personal computers and the 'electronic spreadsheet', recalculating a complex budget or costing for a project took a lot of people a long time. Because of that, people did not explore the implications of changing values in the costing. When spreadsheets became available, people could try out different values and see what effect the changes had on the outcome very quickly. They referred to this trying out process as 'What if?' analysis.

As an example of a 'what if' calculation, suppose a school is putting on a play in the hall. The director has put together a spreadsheet with *estimates* of likely costs and possible income. Remember the students and teachers are donating their time and efforts. The costs might look something like the top part of a spreadsheet below

Costs	**Unit**	**Number**	**Subtotal**	**Notes**
Scenery and paint	200	1	200	DIY
Prop hire	100	1	100	
Costume hire	200	1	200	
P.A. Hire	300	1	300	Includes technician
Lighting hire	300	1	300	Includes technician
Programme costs	0.5	250	125	Special deal from printer
Refreshment costs	2	250	500	School catering company
Refreshment labour	18	3	54	Number 3 waiters at 1 hour
Car park attendants	18	12	216	4 attendants at 3 hours
Total			1995	

And the income might look like the lower part of the spreadsheet

Income	**Unit**	**Number**	**Subtotal**	**Notes**
Ticket sales	5	250	1250	
Less percentage to school funds		30	-375	
Adverts in programme	50	10	500	
Sale of programmes	2.5	125	312.5	
Parking charge	5	50	250	
Total			1937.5	
Net surplus			-57.5	

As you can see, the show is currently in deficit by a small amount of money. Some of the assumed costs and income figures may look a bit suspect as well.

Try setting up a worksheet called ‘Budget’ and make these calculations live. Then try different assumptions about how many programmes you might be able to sell, how many local companies might want to advertise in the programme, how many of the audience might want to park a car, and how many hours of carpark attendant you might need. Do you think you could pursuade more audience members to partake of school catering during the interval?

5. Constructing a table of values: replicating formulas

Suppose you wanted to construct a table of values for the equation $y = 2x + 1$. And suppose you wanted x values that ranged from $x = -5$ to $x = 5$. Spreadsheets can automate parts of the table construction and save you typing in the same formula multiple times.

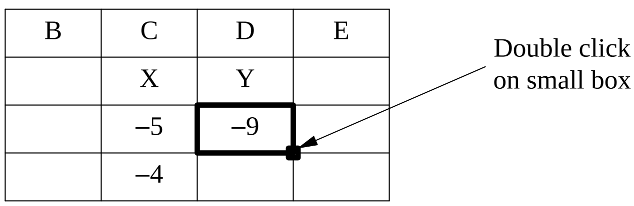
5.1. Replicating down to make a table

Make a new worksheet called ‘straight line’ in your spreadsheet file. It is easier to use vertical columns for x and y on a spreadsheet, so you could decide to use the `C` column for the x values and the `D` column for the y values. Spreadsheets can generate a linear sequence of values given the first two or three values in the sequence at the top of a column of cells. You need to;

- Put X in cell `C1` and Y in cell `D1` as headings
- In cell `C2` type –5 and in cell `C3` put the value –4.
- **Highlight** both cells `C2` and `C3` by clicking in the first cell and dragging down one cell.
- With cells `C2` and `C3` highlighted, **click** on the small black box on the bottom right of the cell `C3`. The mouse pointer will change from an arrow into a crosshair.
- Click on the crosshair and **drag the mouse down** to cell `12`. As you drag past each cell in between, a small ‘tooltip‘ will show the value being put in that cell.
- When you reach cell `C12` release the mouse button and you should see the set of x values increasing down the column and reaching 5 in cell `C12`.

Now to generate the y values;

- In cell `D2` type `=2*C2+1` and press the **enter** key. You should see the value –9 appear in cell `D2`
- Notice how cell `D2` has the bolder outline as it is the currently active cell. And look for that small black box in the bottom right corner of the cell.



- You *could* click on the small black box and drag down to cell `D12` like you did in the C column. But there is another trick: just **double click** on the small black box. All of the *y* values magically appear as far as cell `D12`.

Click on (say) cell `D12` and the input line of the spreadsheet should show the formula `=2*C12+1`. The formula you typed in cell `D2` has been 'replicated' down. Notice that the cell references in the formulas change for each line. Cell references that change in this way are called *relative cell references*. In effect the formula in each row of the D column is saying 'twice the value of the cell on my left then add 1'.

5.2. Variables, parameters and absolute cell references

If you would like to calculate a table of values for (say) the equation $y = 3x - 4$ instead of the previous one you would need to;

- Change the formula in cell `D2` to `=3*C2-4`
- Replicate down in column D again

There is a better way.

Recall the *general* equation of the straight line equation $y = mx + c$. The letters x and y represent the *variables*. Each new value of x results in a new value of y and each pair of values will enable you to plot another point on a graph of the equation.

The letters m and c are different. They specify the whole equation and picking a different value for m or c will produce a whole new table. I call m and c the *parameters* of the equation. You can modify the 'straight line' worksheet so that has the values of m and c in cells and the formulas in column `D` refer to those cells. Changing the values of m and c will then update the table. You need to refer to the cells that contain the values of m and c using an *absolute cell reference*, one that does not change when you replicate the formula down the table.

As a concrete example you can modify the previous spreadsheet as follows;

- In cell `B2` type the value 2 and in cell `A2` type the label 'm'
- In cell `B3` type the value 1 and in cell `A3` type the corresponding label 'c'
- Change the formula in cell `D2` to `=$B$2*C2+$B$3`
- Replicate this formula by **double-clicking** on the small box in the bottom left of cell `D2` as before
- You should see the same values as before because $m = 2$ and $c = 1$.
- Now change the m value to 3 and change the c value to -4. The table should update and give you the new set of values.

This works because the $ signs in front of the column letter and row number in the cell references for the m and c tell the spreadsheet to *not* to automatically change the cell references in each new row. Check cell (say) `D12` and it will contain `=$B$2*C12+$B$3`. In words this formula says 'multiply the cell to my left by the value in cell `B2` and add the value in cell `B3` to the answer'. The cell reference `$B$2` is called an absolute cell reference because it always points to the same cell at a fixed position in the spreadsheet. The cell reference `C12` is called a relative cell reference, because it points to a position that changes as you replicate the formula.

Just when we have that all cut and dried, there is a complication. Suppose you *moved* all the cells by selecting a whole region of cells (say select from A1 to D12) and then dragging them down a couple of rows. The absolute*and* relati ve cell references would change, so really the key thing about absolute cell references is that they don't change when you are replicating a formula somewhere else in the spreadsheet. Most spreadsheet programs will let you name a cell and then use that name as an absolute cell reference. However each program has its own way of doing this so you can check your programs approach using the help system. The dollar sign notation is universal so I'm using it here.

5.3. Your turn

Try changing the m and the c systematically and see what changes in the values. For instance, changing m from 2 to 3 will mean that the Y values increase by 3 instead of 2 for each row down the table.

- Suppose you changed the value of c from 1 to –4. How would you describe the effect on the values in the Y column?
- Suppose you changed the value of m from 2 to –2. How would you describe the effect on the values in the Y column?
- Can you find the values of m and c for the linear equation where $y = 0$ for $x = 4$ and $x = 0$ when $y = 10$?

5.4. Table of values for a quadratic equation

The general formula for a quadratic equation is $y = ax^2 + bx + c$. You can build a table of values for a quadratic equation and you can see the effect of changing the parameters a, b and c by using absolute references in the formula. Suppose as an example you started with $y = x^2 + 2b - 3$, so $a = 1$, $b = 2$ and $c = -3$ initially, and you keep the range of x values as $x = -5$ to $x = 5$.

Make a new worksheet named 'Quadratic' in your spreadsheet file and

- In cell `B2` type the value 1, and type the parameter label 'a' in cell `A2`.
- In cell `B3` type the value 2, and type the parameter label 'b' in cell `A3`.
- In cell `B4` type the value –3, and type the parameter label 'c' in cell `A4`.
- Type labels X and Y in `C1` and `D1`
- Build a sequence of x values from –5 to 5 as before for the linear equation, type –5 in cell `C2` and –4 in cell `C3`, highlight the two cells and drag down to cell `C12`
- In cell `D2` put the formula `=$B$2*C2^2 + $B$3*C2 + $B$4` and press the enter key
- Replicate the formula in cell `D2` down by double clicking in the small box in the bottom right corner of the cell

The completed table might look something like this

	A	B	C	D	E	F	G
1			X	Y			
2	a	1	–5	12			
3	b	2	–4	5			
4	c	–3	–3	0			
5			–2	–3			
6			–1	–4			
7			0	–3			
8			1	0			
9			2	5			
10			3	12			
11			4	21			
12			5	32			

You now have a table of values for the equation $y = x^2 + 2x - 3$ and the Y values should range from 12 to 32. You can calculate the table of values for any other quadratic by changing the values of the parameters a, b and c.

Try changing the value of c from –4 to 1. How do the Y values in cells `D2` to `D12` change? What effect does changing a from 1 to 2 have? How would you describe that change in words? The effect of changing the value of b is more complex to describe. Remember that the equation of the axis of symmetry of a quadratic graph is given by $-\frac{b}{a}$. When you change the value of b the axis of symmetry and with it the position on the x axis of the maximum or minimum moves left or right.

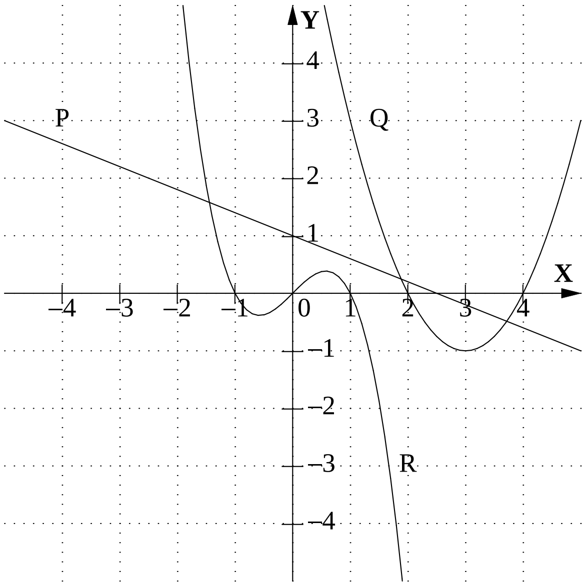
5.5. Your turn

Use another worksheet in your spreadsheet file to construct the table of values for a cubic equation. The general formula is $y = ax^3 + bx^2 + cx + d$. Start with $y = x^3 - x^2 - 16x + 16$, so $a = 1$, $b = -1$, $c = -16$ and $d = +16$.

Because cubic equations can have up to three roots, you might want more detail in the table of values. Try putting -5 in cell `C2` and -4.5 in cell `C3` and then highlight those two cells and click on the little square in the bottom right of cell `C2` and then drag down to cell `C22`. The X values increase by 0.5 instead of 1. Using more divisions with smaller increases each time helps when you are working with equations that are very 'bendy' or corrugated like cubics and even quartics.

6. Plotting graphs

Now you have tables of values for various equations you can use the spreadsheet to draw graphs. Below is a complex example with three different equations plotted on the same axes.



Challenge: can you work out the equations of each of the three different plots labelled P, Q and R? Hint: look at the roots for the curved graphs. If α and β are the roots of the quadratic equation then you know that $y = (x - \alpha)(x - \beta)$.

Each spreadsheet program has slightly different facilities and procedures for putting graphs into a spreadsheet, so I will base this section on LibreOffice and OpenOffice chart types.

6.1. Insert an X-Y scatter chart in your worksheet

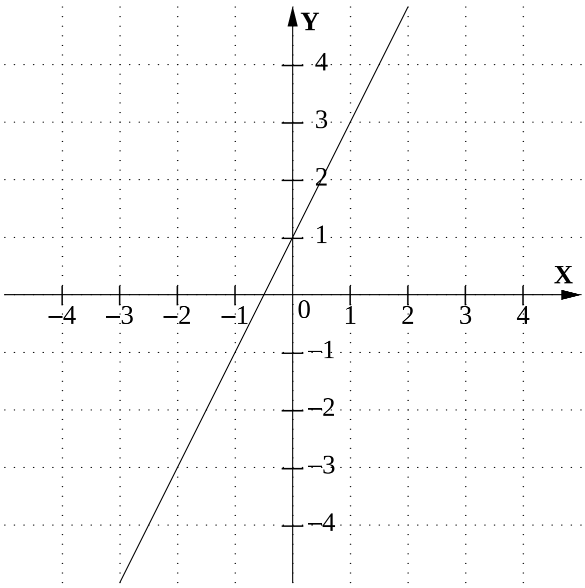
The general approach is the same for Microsoft Excel and other spreadsheets that work in graphical environments like Windows or MacOS or a Linux desktop.

Look at the worksheet you made for the 'straight line' graph. The rectangular cell range `C2` to `D12` contains the table of values, and you can plot each pair of x and y coodinates as a series of points, but you can also make the spreadsheet draw a nice line through the points. The spreadsheet chart function can usually be found as a small bar chart icon on the toolbar. To insert a chart in your worksheet, you need to;

- **Highlight** the cell range `C2` to `D12` with the mouse
- **Click** on the chart icon in the toolbar (or use the Insert | Chart menu item)
- The '**Chart Wizard**' appears and shows four steps to inserting a chart. The first step is to choose the **Chart Type**

- Pick **X-Y (Scatter)** from the list box on the left hand part of the smaller **Chart Wizard** window
- Choose lines from the four options offered in the right hand part of the Chart Wizard window for X-Y graph type. I like to use **Lines Only**. Later with curved graphs you might want to tick the checkbox for '**smooth lines**'.
- Click the **Next** button to see the **Data Range** dialog. Just untick the **First Row as Label** checkbox if it is ticked and then click **Next** step in the wizard
- The **Data Series** dialog needs no modification so just click **Next** again
- The **Chart Elements** dialog lets you name various parts of the graph. I untick the '**Display Legend**' checkbox on the right hand side of this dialog, and then I add a Title and label the axes as X and Y. I also like to Display grids so I check both the *x* and *y* checkboxes under that heading.
- Finally, click **Finish** and your chart will appear in your worksheet - usually in the wrong place. You can click on the *frame* of the chart to drag it around.

6.2. Fix your axes scales



By default the graph has axes that automatically adjust to changes in the data. This actually makes it hard to see the effect of changing *m* and *c*, the gradient and the intercept. Try changing the gradient *m* from 2 to 5 or something to see what happens - the line more or less stays still and the *chart axes* change scale. If you were to fix the scale of the graph axes so the line moved around the graph as you change the parameters you would be able to see what increasing the gradient or decreasing the *y* intercept does more clearly.

You can edit the appearance of the graph by double clicking in the graph. There should be a light grey border around the graph with middle of each side. As you point to various parts of the graph with the mouse, tooltips should appear with the name of that part of the graph. Have a look around the graph to get an idea of the parts you can change.

The graph scale is set separately for each axis. To set the X axis scale you need to;

- **Double click** in the graph to get the grey handles
- **Point** at the X axis with your mouse until the tootip that says 'x-axis' appears
- **Click once** on the x-axis so green 'handles' appear
- **Double click** again so the x-Axis dialog box appears
- **Click** on the '**Scale**' tab to bring up the dialog where you can change scales

- **Untick** the '**Automatic**' checkboxes so you can put your own scale in each section
- For this graph, use –5 for minimum and 5 for maximum and 1 for major interval
- I like to have a tick mark between the numbers on the axis so I set the **Minor interval** count to 2, and then click on the '**Positioning**' tab. Clicking '**inner**' for the **minor ticks** and both '**inner**' and '**outer**' for the **major ticks** with the x-axis values on makes the display clearer
- **Click OK** to accept the changes and check what the x-axis looks like. Then click somewhere else in the spreadsheet so the graph becomes 'fixed' in the worksheet.
- Repeat these steps for the y-axis, again using –5 and 5 for the minimum and maximum.

Experiment with changing the m and the c values now and see what a difference fixed scale axes make. Your line will be dancing around the graph grid as you change the parameters.

I do spend some time with the line and font styles in the format dialog for the x and y axes making my chart look more like a graph that you will see in a textbook. That is just cosmetic but I like the look in my worksheets.

6.3. Challenge: Build a quadratic graph and try different parameters

Use the 'quadratic' worksheet you built for section 4.3 and

- Highlight the table of values from `C2` to `D12` and **Insert | Chart**
- Work through the **chart wizard** just as for the straight line
- Chose '**lines only**' and tick the '**smooth**' option for **Line Style**
- Remember to fix the scales of the X and Y axes by using the format axis dialog box once you have inserted your graph into the worksheet. I would use –5 to 5 for the x-axis and –10 to 10 for the Y axis to allow for a wider range of different quadratics.

Now that you can illustrate any quadratic by changing the parameters a, b and c try the sets of values below and compare the resulting graphs. You can click on a graph so the 'handles' appear and then copy the entire graph to the clipboard. Switching over to a wordprocessor and pasting the graph in will allow you to preserve a copy. Then you could try a different set of parameters to generate a new quadratic and compare the graphs. I sometimes use the**P aste | Special** command in LibreOffice and paste graphs as 'GDI metafiles'. They behave like drawings and can be edited.

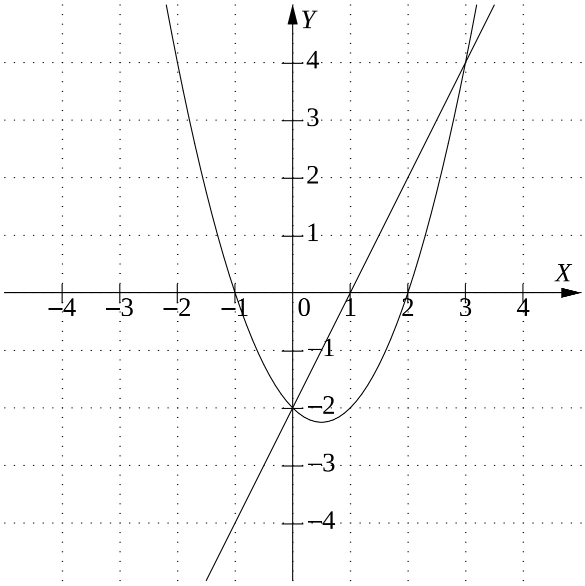
- The table below contains values of the parameters a, b and c for four different quadratic equations labelled i to iv

Eqn	a	b	c
i)	1	–4	3
ii)	–1	4	–3
iii)	2	–8	6
iv)	–2	8	–6

- Try displaying each equation in turn in your spreadsheet
- Try to describe the changes in each graph in words, write a sentence about i to ii and then about ii to iii and then about iii to iv
- Look at the y-intercept, the roots, and the location of the axis of symmetry to help formulate sentences
- Can you write down the equation (and parameter values) for a quadratic equation that has roots of $x = -3$ and $x = -1$?

6.4. Two graphs on the same axes: cell ranges

Challenge: Can you write down the formulas of the quadratic and linear graph below?



You can plot several equations on the same set of graph axes. To do this, you add a new **Y** column for each new equation. Then you highlight the **X** and all the **Y** columns and insert the usual **X-Y** plot. The detailed steps below will add a straight line graph to the quadratic graph plotted in the last section.

- Put label ‘m’ in cell `A6` and label ‘c’ in cell `A7`
- Put the starting value for the gradient 2 in cell `B6` and the value for the y-intercept 1 in cell `B7`
- Put a heading for the Y values in cell `E1`. I used**Yl** for ‘linear’
- Put the formula `=$B$6*C2+$B$7` in cell `E2` and press enter. You should see –9 as the value
- Replicate the formula down by double clicking on the small square in the bottom right corner of cell `E2`.
- Your new column of values should appear, and cell `E12` will contain the value 11

Now you have the table of values you can insert a new chart just by selecting the whole table. Below are the detailed steps I used

- **Highlight the whole table from** `C2` to `E12`
- Select **Insert | Chart** from the **Insert** menu or right click and **Insert Chart**
- Select the **X-Y** Chart Type, and decide on the line type. I use **Lines only** and **Smooth** so the curve graph looks OK. Click Next to see the **Data Range** dialog
- The Data Range dialog will show something like `$'name-of-worksheet'.$C$2:$E$12`
- Click **Next** and **Next** to reach the **Chart Title** dialog and fill in the title and axes labels
- Click **Finish** to add the graph to your worksheet

The resulting graph will have the default spreadsheet styles for axes and line colours. You can change those to suit yourself. At least set the X and Y axis scales to manually chosen values so that each time you change a parameter, the graph scale does not change.

7. Things to try

Pick a few of the ideas in this section and try to build the worksheets. Or you could devise your own problems to solve.

7.1. What if? Compound interest

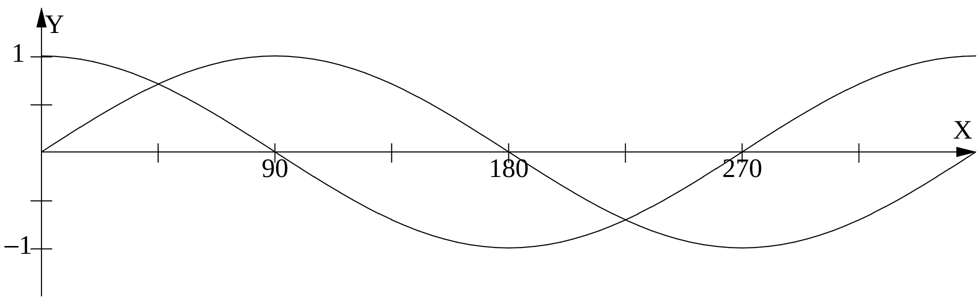
Build a spreadsheet to calculate the value of an investment (or the size of the debt) using the compound interest formula.

$$A = P\left(1 + \frac{R}{100}\right)^T$$

Where A is the *accrual* or the value of the investment at the end of$T$ time periods (lets say years for convenience). P is the *principal*, the amount you invest, and R is the percentage *rate of interest* per year. Check your spreadsheet against your calculator for a few example calculations. Then

- Take $P = £5000$, $R = 5.2\%$. Use trial and error with various values of$T$ to find the first year when the value of the investment A is more than double P.
- Take $P = £9000$ invested over thirty years. What annual interest rate is needed so that the principal is tripled? Find an answer for R to the nearest two decimal places.
- Suppose you had an investment at 3% over 25 years. How much would you need to invest to make the investment worth £20 000 at the end? Use trial and improvement with different values of P and work to the nearest pound.
- Someone says they have invested *about* £8000 at *roughly* 5% for 10 years. Assume ‘about £8000’ means £8000 to the nearest £100, and assume that the rate was 5% to the nearest percent. Work out the maximum possible value of the investment, and the minimum possible investment consistent with those figures.

7.2. Graphs of sine and cosine



Trig formulas on spreadsheets work in radian measure. To plot graphs of $sin(x)$ where x is in degrees, you have to use the `radians()` function. To make a smooth sine curve you would want to scale the x axis at 5° intervals, and your table will need quite a few rows to show a couple of cycles.

To plot the *sine* curve I had 0 degrees in cell `C2` and 5 degrees in cell `C3` then dragged down until I reached 360 degrees. Then I put`=sin(radians(C2))` in cell `D2` and double click ed on the small square in the right bottom corner. Finally I selected both columns of values and inserted an X-Y chart. Try building a graph like this in a new worksheet.

8. Conclusion

If you have followed the activities in this leaflet you should now be able to use a useful range of spreadsheet functions and be able to construct spreadsheets to solve common mathematical problems. Spreadsheets can do a lot more! There is a lot of information on the Web about spreadsheet applications and functions.

Some things to search for information on: simulations of probability using problems using the `=rand()` function; conditional statements using `=if()` and the various lookup functions that spreadsheets provide.