Introduction to practicals

Most of the labs presented in this collection are simple labs that can be used to build a good practical lab program with very modest resources. There is at least one lab for every topic of the course (except Topic 8, Digital technology). The equipment necessary for these labs will almost certainly be found in every lab in any school. In many cases the same lab can be performed in more sophisticated ways, using sensors and more expensive equipment, but that does not detract, in any way, from a program based on the simpler version of the experiments without the fancy equipment.

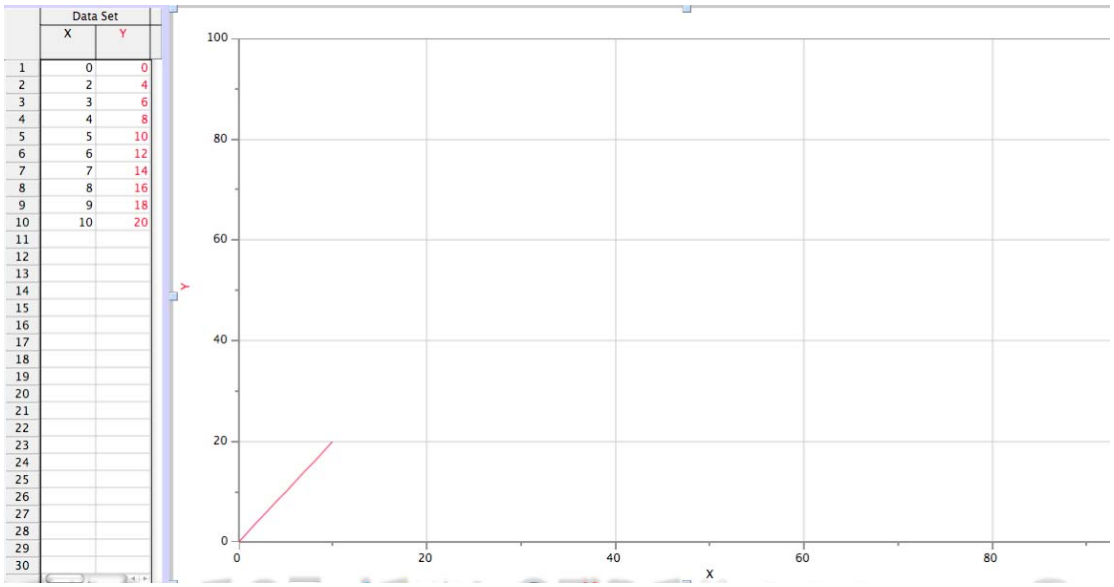
Many of the experiments can be given as design labs if less information is given to the students. More design labs have been published by the IBO on the OCC.

It is very good to have Logger *Pro* available to the students. Most, but not all, of the student reports included here have used Logger *Pro* for the graphs. For the kind of analysis that the IB requires Logger *Pro* is perhaps the best choice.

Using Logger *Pro*

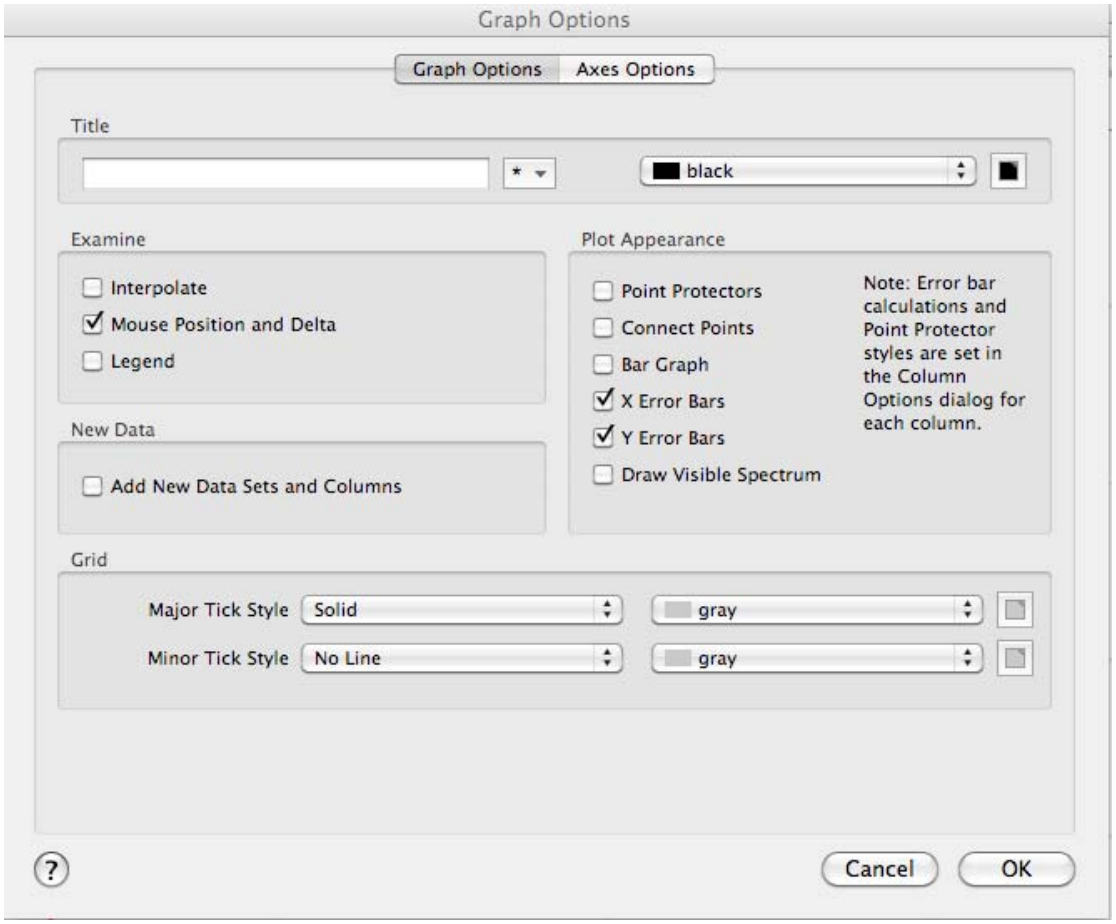
What follows is short tutorial on how to draw error bars and lines of maximum and minimum slope with Logger *Pro*.

1 Write your data in columns X and Y.

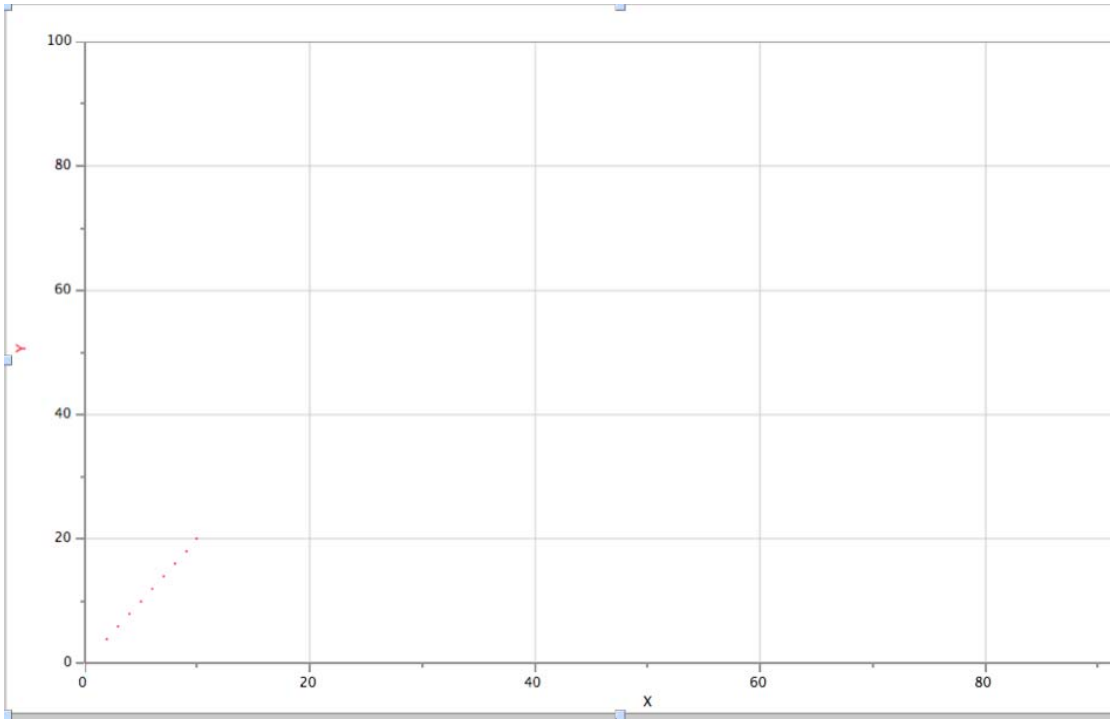


You must now choose the range on the axes.

2 Double click on the graph to open the following box, where you need to choose Graph Options and you will unclick the Connect Points box:

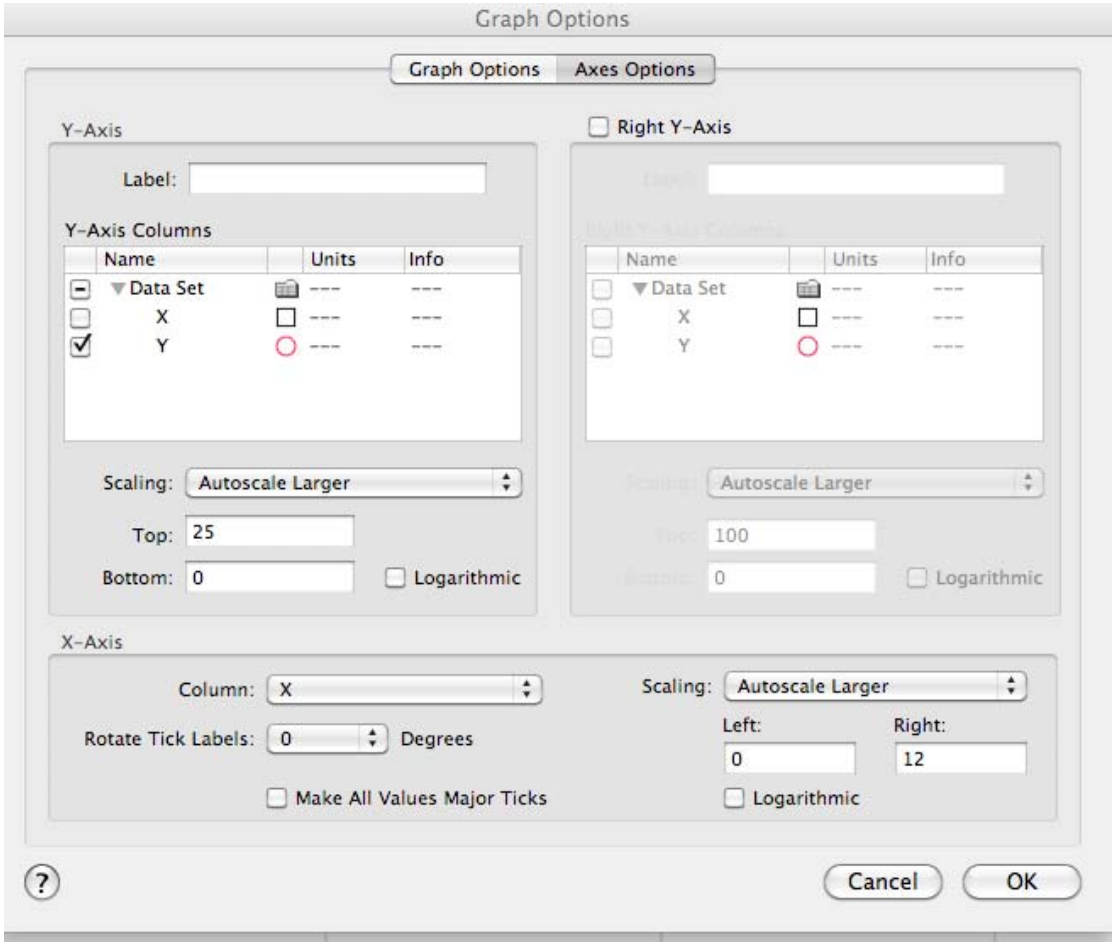


This will now give you:

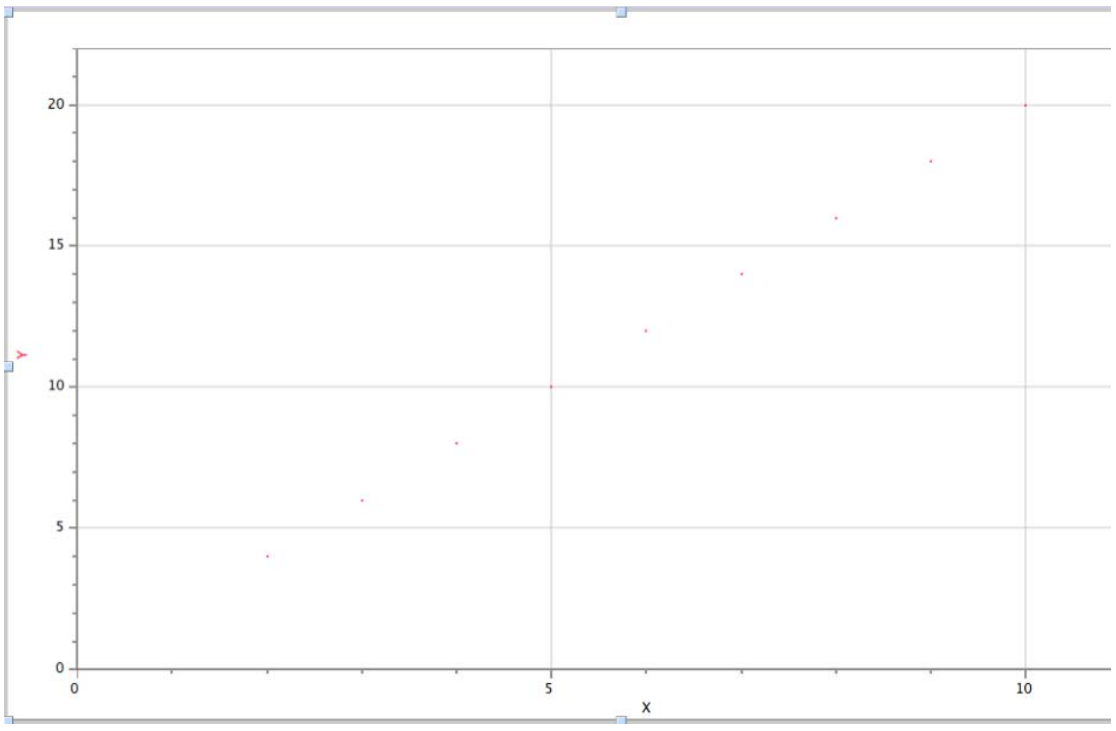


You must now choose the range on the axes.

3 Double click on the graph again to open the following box, where you need to choose Graph Options and choose the range of the variables *x* and *y*:

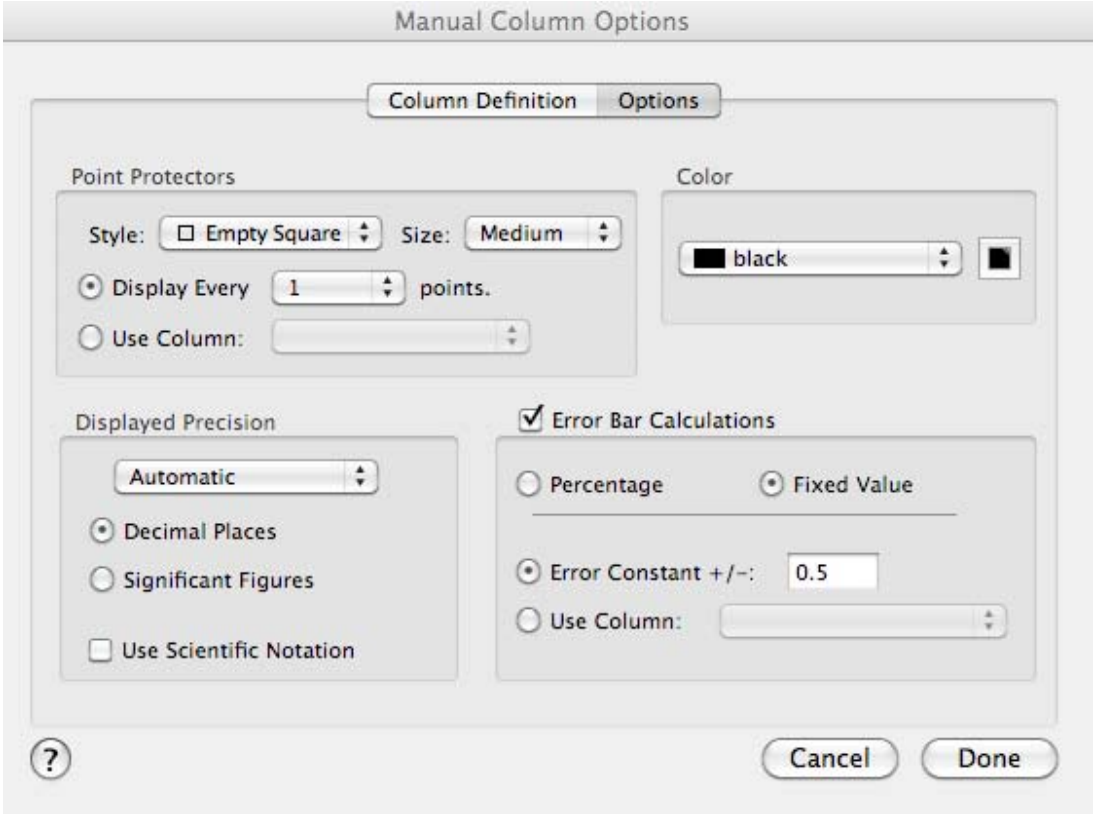


The graph now looks better:

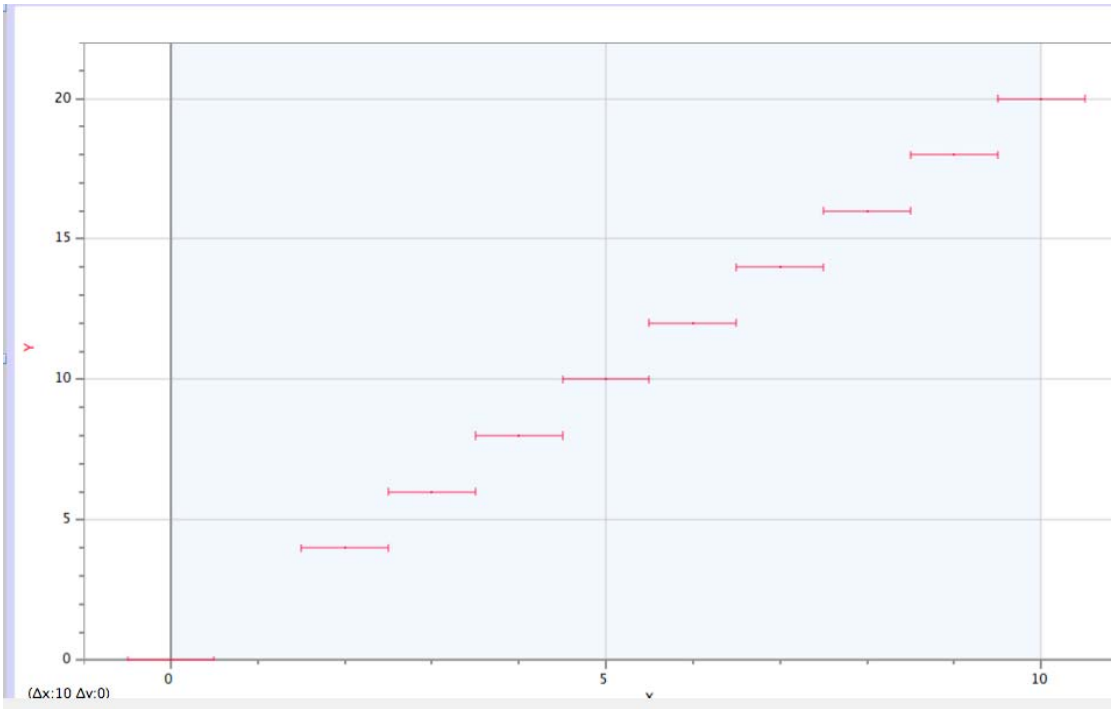


We must now insert error bars.

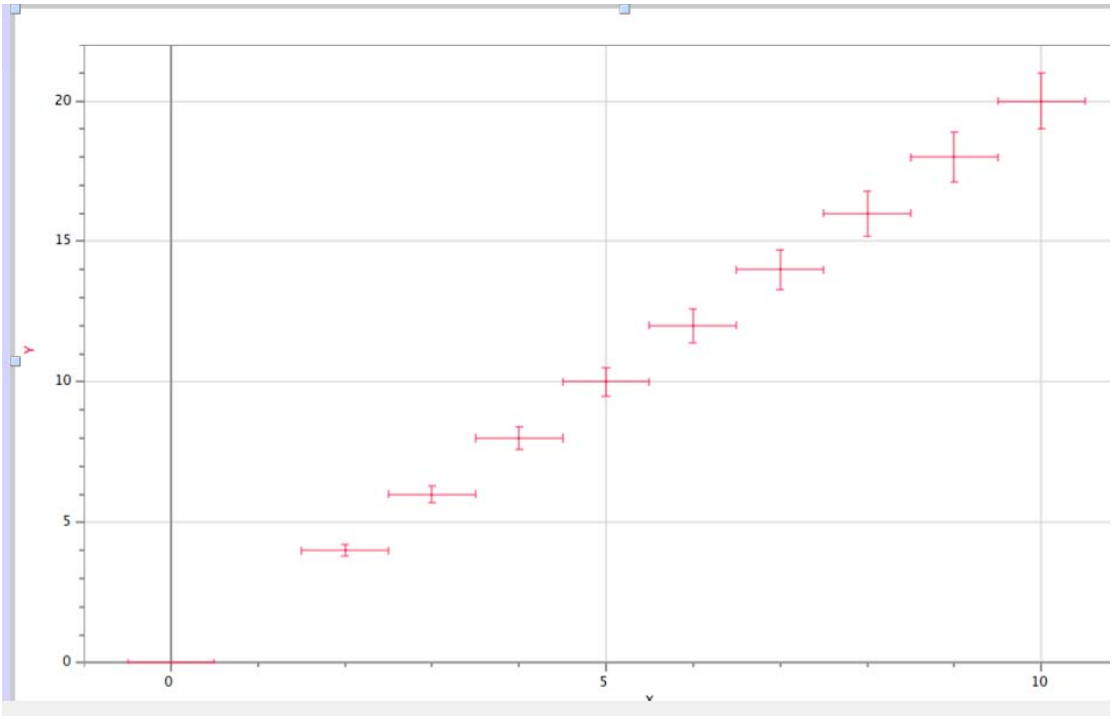
4 Go to the data set under X and select the column and double click on the name X to get the screen:



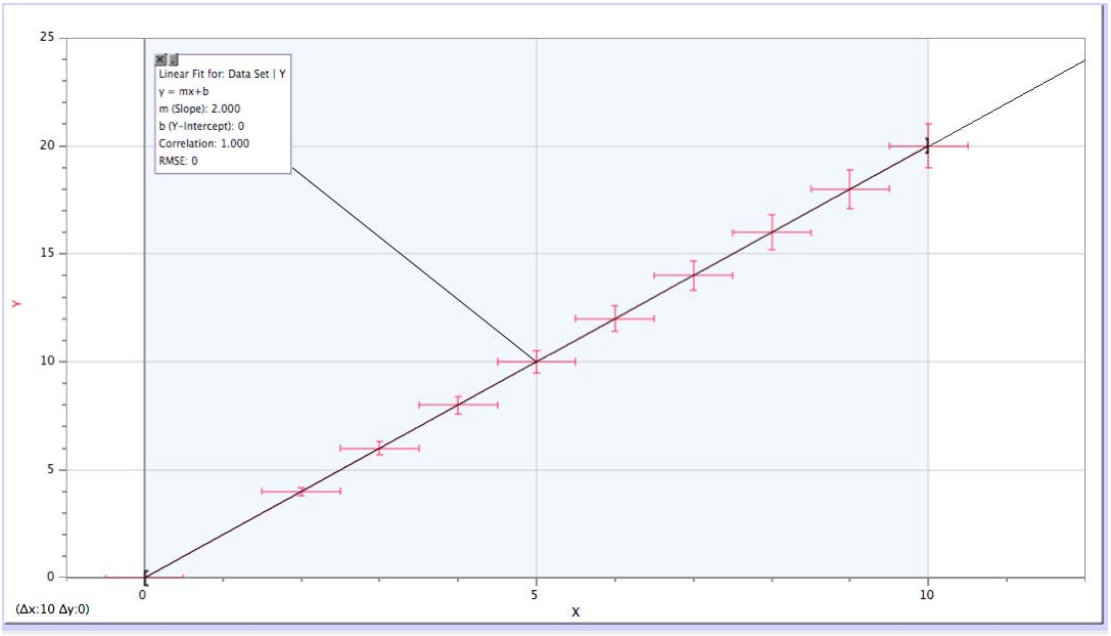
5 We have chosen Options, clicked on Error Bar Calculations and chose a fixed uncertainty of ± 0.5 for the *x* axis. If we click on Done the graph becomes:



6 We now repeat this process for Y to deal with the *y* axis, and this time we will choose a fixed percentage uncertainty for all the data points. We get (with ± 5% uncertainty):

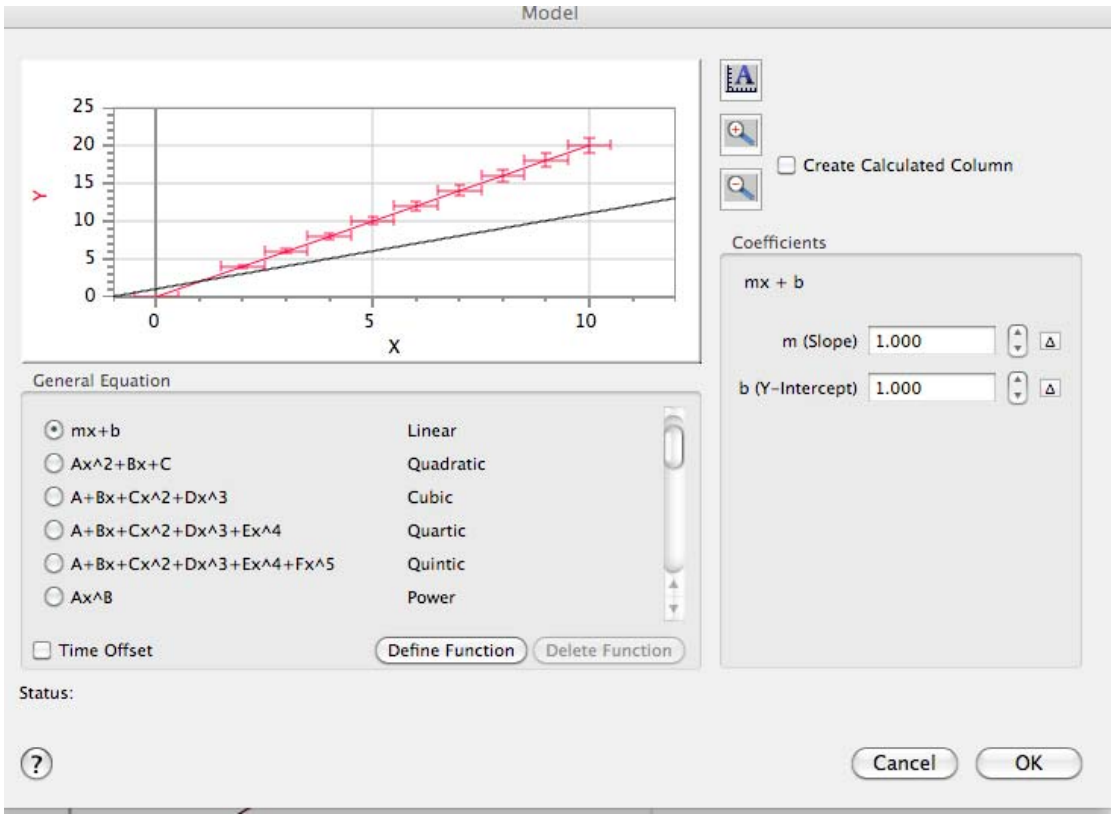


7 Now go to Analyze and then Linear Fit to get the equation of the line of best fit:

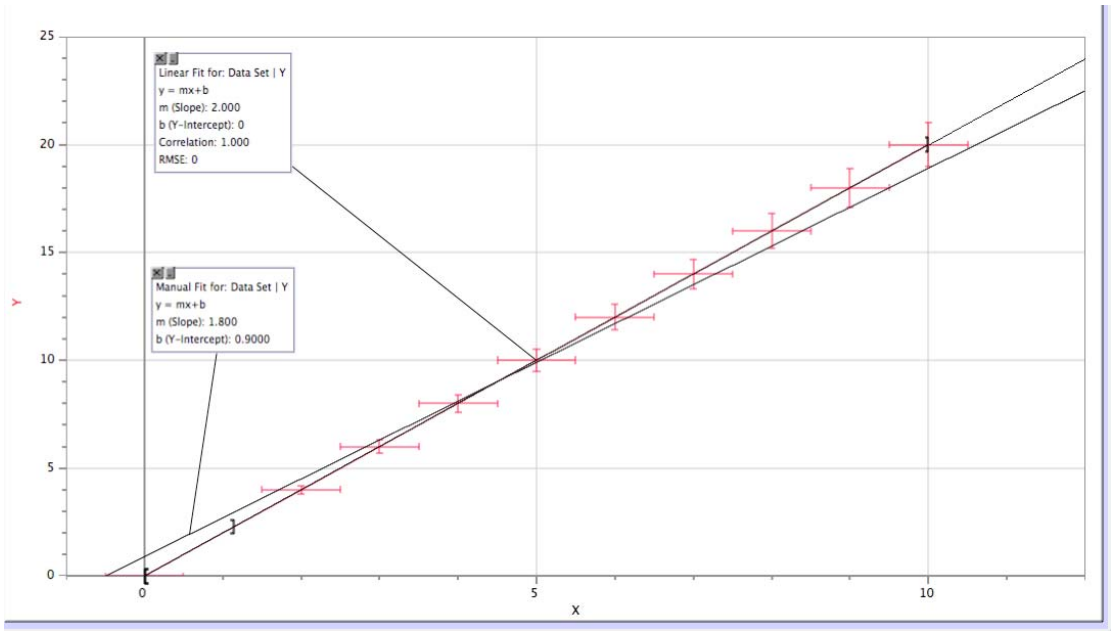


We must now find the equations of the lines of minimum and maximum slope.

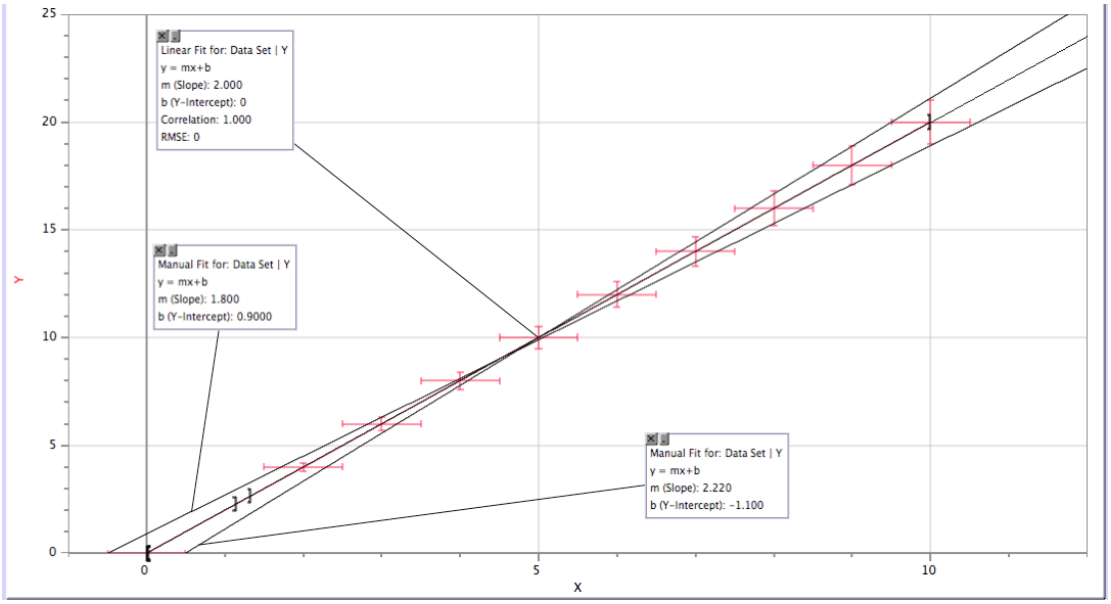
8 Go to Analyze again and choose Model. You will get this box, where you need to click on the first option, a linear equation of the form $y = mx + b$.



9 You can now change the slope until the line just passes to the right of the of the error bar of the last data point and then adjust the intercept so that the line passes through the left most error bar of the first data point. Get the rough line and then adjust the increase step to a smaller value to get a good fit. You can mark part of the curve and zoom in so you can better see where to draw your line.



10 You need to repeat this procedure for the line of maximum slope:



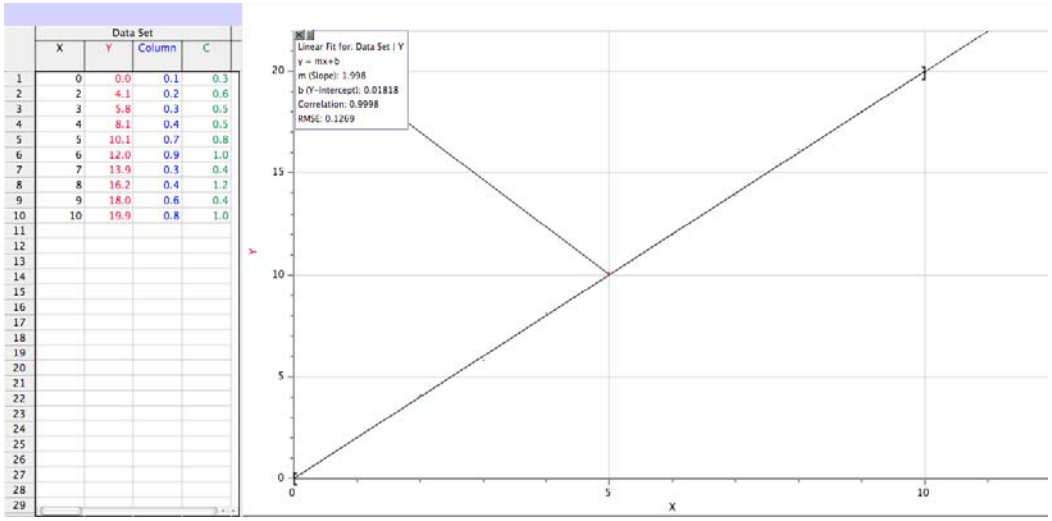
There can be some discussion here as to exactly which points the lines of maximum and minimum slope must pass through. Some take the extremes of the error bars themselves (as I have done here) but others make the lines go through the vertices of the *boxes* formed by the horizontal and vertical error bars. This is a mostly irrelevant discussion though, as we only want a *rough* guide to the uncertainty of the slope. The entire procedure may be severely criticised anyway (and justifiably so) for placing too much importance on the first and last data points.

11 The line of best fit has slope 2.00 and the extreme slopes are 1.800 and 2.220. The slope may then be quoted as:

$$m = 2.000 \pm \frac{2.220 - 1.800}{2} = 2.00 \pm 0.21 \approx 2.0 \pm 0.2$$

(The uncertainty is quoted to 1 s.f. as always and so the slope has only 1 decimal place since the uncertainty is in the first decimal place.)

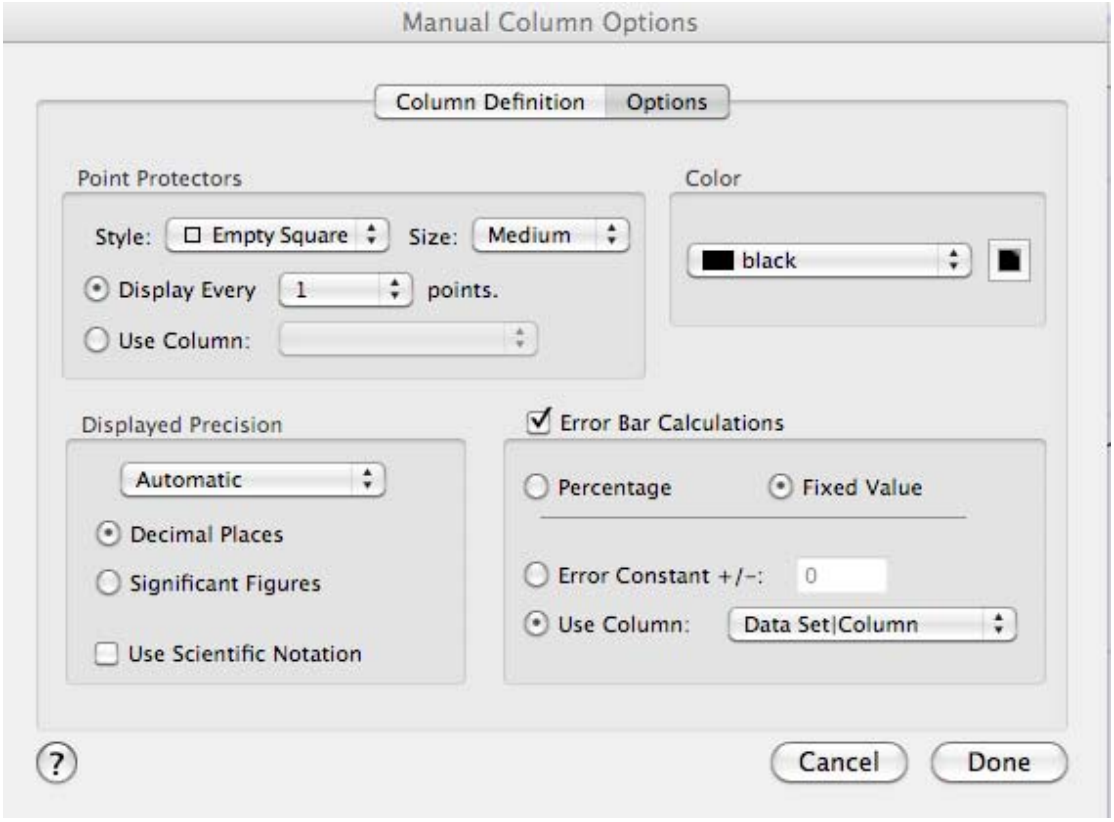
It now remains to re-examine this process for data points that have different uncertainties. This does not cause any problems – all we have to do is create new columns which will contain the uncertainties for each data point. To do so, consider the new data set written under columns X and Y. Here two new columns have been inserted. The third column has the uncertainties in the x variable and the fourth column has the uncertainties in the y variable. The next graph shows the line of best fit that has already been drawn.



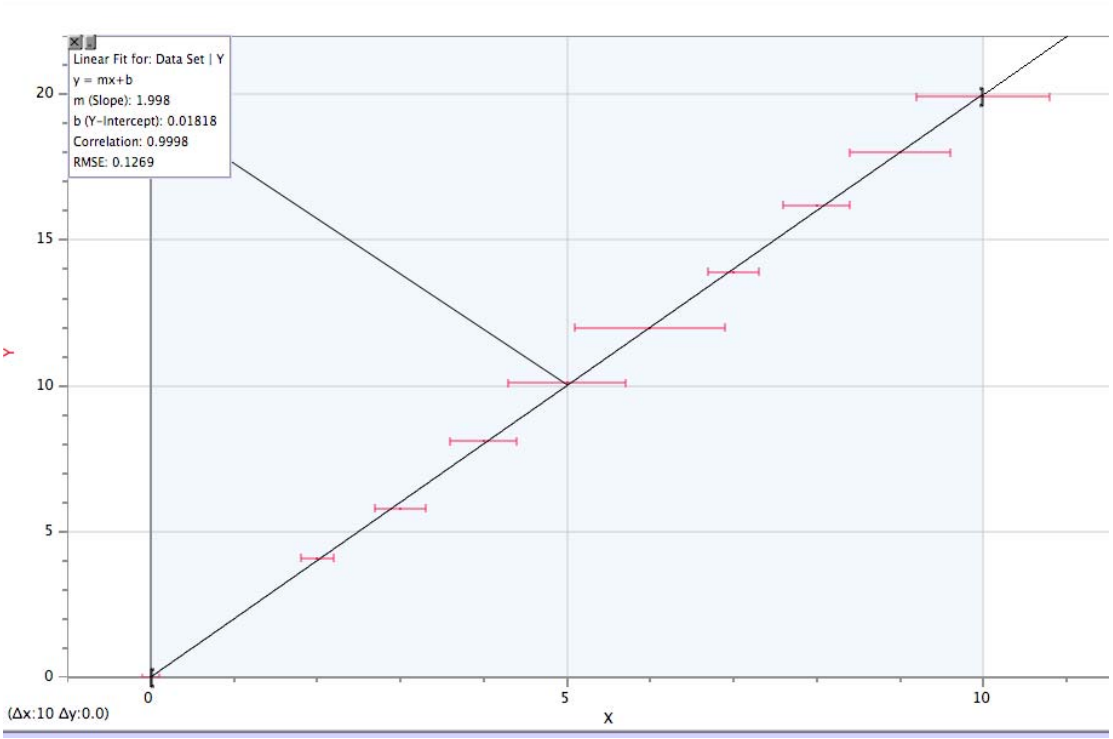
Data Set

	X	Y	Column	C
1	0	0.0	0.1	0.3
2	2	4.1	0.2	0.6
3	3	5.8	0.3	0.5
4	4	8.1	0.4	0.5
5	5	10.1	0.7	0.8
6	6	12.0	0.9	1.0
7	7	13.9	0.3	0.4
8	8	16.2	0.4	1.2
9	9	18.0	0.6	0.4
10	10	19.9	0.8	1.0

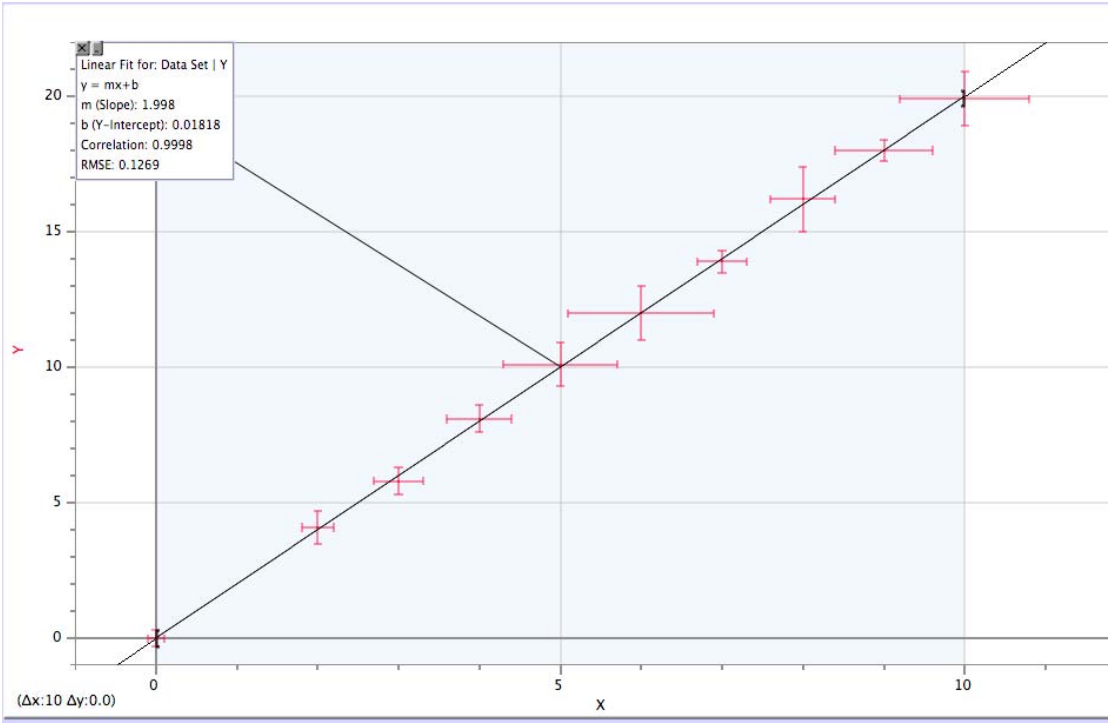
12 We can now include the error bars by double clicking on the label of the first column (X), as we did earlier to get the same window, and, as before, we now click on Options and then Error Bar Calculations. Click on Use Column and finally choose the name of the column where the uncertainties are stored.



This gives



13 We now repeat for the vertical error bars:



14 To get the maximum and minimum lines, the procedure is the same as before.

