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Procedural Approach to Sketching Graphs Using MS Excel

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1. Introduction

One unique feature of the computer as a teaching and learning tool is *visualization*. This powerful visualization capacity of the computer is unprecedented and incomparable with all other traditional teaching aids. Now abstract concepts that have proved difficult for teachers to explain or for students to grasp using traditional teaching approaches or aids can now easily be produced and understood using the powerful animation and graphical display capabilities of computers. Inline with this development, many specialized software are developed for graphics, and many others are having graphics as one of their capabilities. MS Excel is one of later. As a result, not many people are aware that one can use the software to sketch some sophisticated graphs. In this note, we shall show how MS Excel can be used to sketch different types of graphs and use them in some applications such as root finding or parametric studies. Although all what we are going present here can be implemented using other more specialized software and sometimes even more efficiently or effectively. The reasons for choosing Excel are for the fact that, the program is widely available. Furthermore, no purchase of any specialized software is necessary. Also, the ideas will help teachers and students in teaching and learning many things that have to do with graphs. And the moment users get grip of the ideas, they will be in full control of the implementation, and therefore increase their level of creativity.

2. Generating sequences of *x* values

In this section we discuss two methods for generating sequences of x values for graphing purposes. The first is an Excel auto-fill method and the second is a formula copying method.

2.1 The Excel auto-fill method

Suppose we want to generate values between -5 and 5 with a step of 0.2. Then the procedure is as follows.

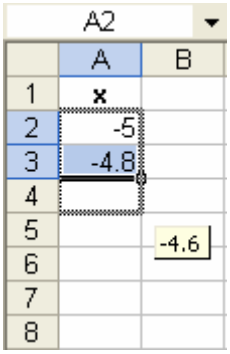
a) In cell A2 enter the first value (-5).

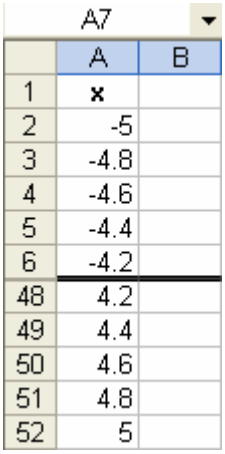
b) In cell A3 enter the next value (-4.8)

c) Select the range A2-A3.

d) Point the cursor to the fill handle (the little box at the lower right corner of the selected cells). The cursor will change to a **+**.

e) Click with the left mouse button and drag down. As you drag, you will see a yellow hint box containing the current value generated by Excel. Stop when you reach the last value (5 in this case). When you release the mouse button the desired sequence will be created.





2.2 The formula copy method

As in the above method, suppose we want to generate values between -5 and 5 with a step of 0.2. The procedure is as follows.

a) In the cell A2 enter the first value (-5).

b) In A3 enter the formula =A2+0.2.

c) Select A3, point the cursor to the fill handle, left click and drag down to cell A52 (note that 52=(5-(-5))/0.2+2). This will create the desired sequence.

The second method offers a lot more flexibility. To illustrate this, assume we want to generate a sequence of 100 *x*-values between a left endpoint *a* and a right endpoint *b*. We want the values of *a* and *b* to be variable. To do this we take the following steps:

a) Label cells A1, B1, C1 as a, b and h.

b) In A2 enter the values of a, in B2 enter the value of b and in C1 enter the formula =(B2-A2)/100. This sets the value of h.

c) In D2 enter the formula =A2. In D3 enter the formula =D2+$C$1 (note that cell C1 is fixed).

d) Select D3, point the cursor to the fill handle, left click and drag down to cell D102.

For instance, if *a = 0* and *b = 2*, the implementation of the above steps will yield the table below.

A7 f_x

	A	B	C	D	E
1	**a**	**b**	**h**	**x**	
2	0	2	0.02	0	
3				0.02	
4				0.04	
5				0.06	
6				0.08	
99				1.94	
100				1.96	
101				1.98	
102				2	

We will use the above method to implement a zooming technique later.

3. Sketching graphs with Excel

In this section we show how one sketchs different type of graphs using Excel.

3.1 Drawing a simple curve

We begin by showing how to use Excel to draw a simple curve such as that of $y = \sin x$ over the interval $[-\pi, \pi]$ (see also [2]). To do that we follow the following steps:

a) In the cells A1, B1 enter the labels x and y=sin x, respectively.

b) In A2 enter the first *x*-value by typing =-pi().

c) In the cell A3 enter the formula =A2+pi()/20 (thus we are going to take 40 values in the interval $[-\pi, \pi]$.). Generate the rest of the values as explained above.

d) In B3 type the formula =sin(A2) and press enter. Copy this formula along the range of the *x*-values.

e) Select the range of cells A1-B42, point to the Chart Wizard icon  on the main menu toolbar and click. The dialog box in Figure 1. appears.

f) Select XY scatter from the chart type pane and "Scatter with data points connected by smoothed Lines without markers" from the Chart sub-type pane as shown in Figure 1. If you click on "Press and Hold to View Sample" button you will see a preview of how the graph will look like. At this point, the graph is complete, you can click "Finish" to see the graph on the worksheet or you can click "Next" to view other options you can include in your graph. The reader is invited to experiment with these options. We used the next dialog boxes to obtain the graph appearing in Figure 2.

g) By double clicking in various parts of the graph, dialog boxes appear that enable you to control certain features of the graph like the color of the plot area, color of the graph line and its weight, ... etc. Figure 3 shows the result of some of these choices.

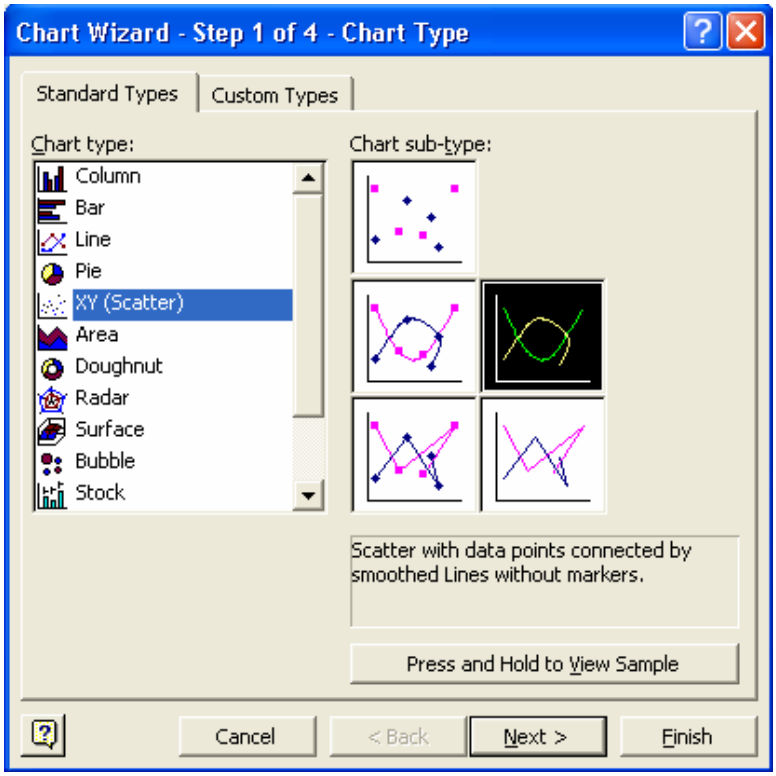


Figure 1 : The first dialog box in the Chart Wizard

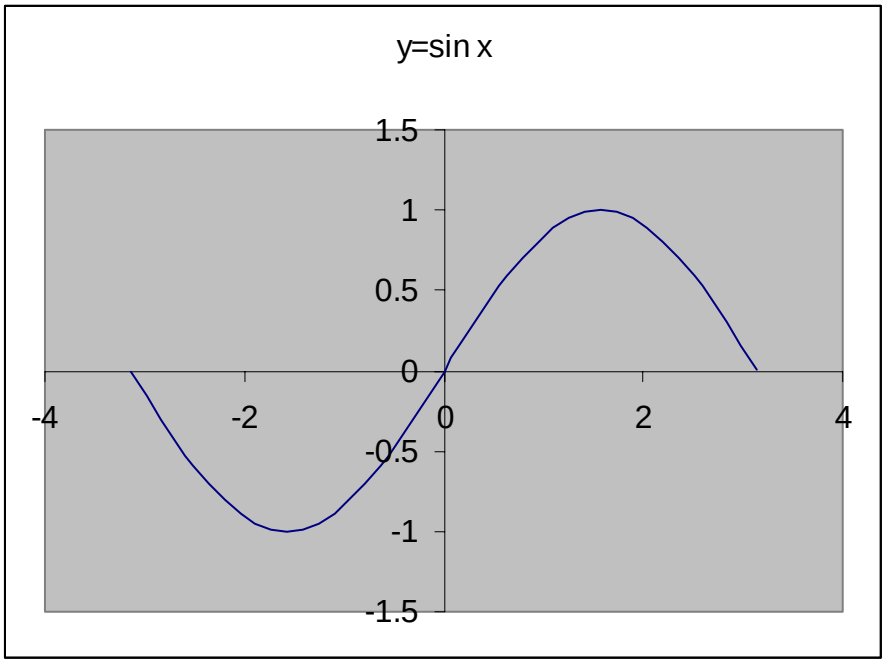


Figure 2: The plotted sine function

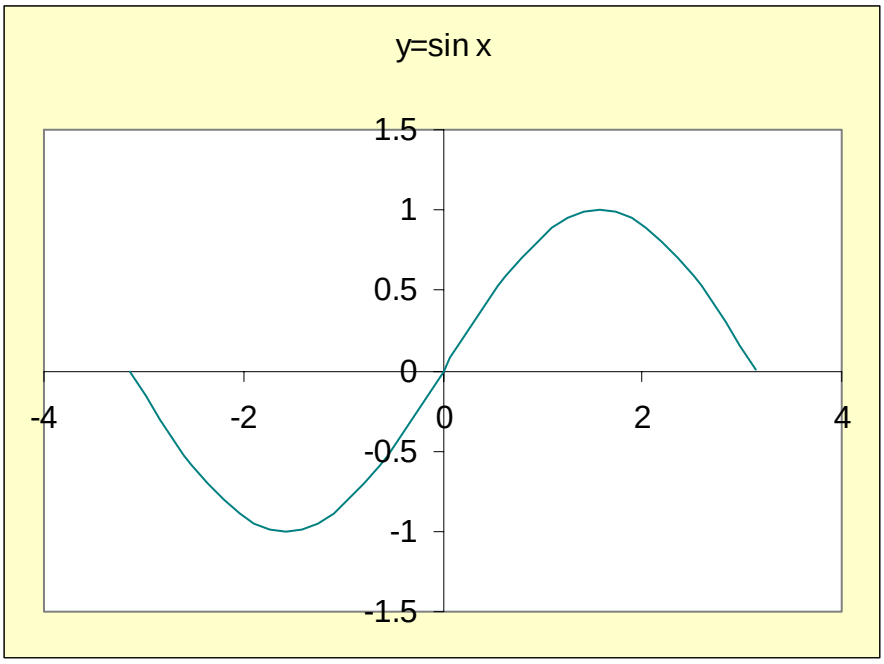


Figure 3: The edited graph

3. 2 Drawing more than one curve on the same chart

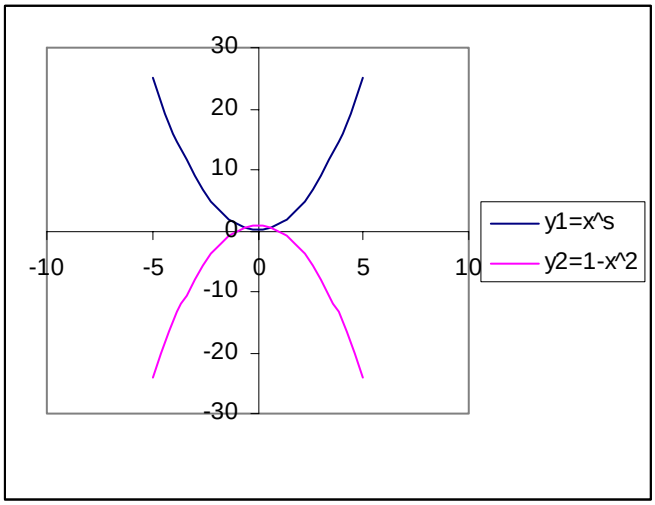
There are two ways to draw more than one curve on the same chart. The first is best used when the points for all graphs are generated before plotting and for the same *x*-values. The second is best used when the points for each graph are generated separately or when they do not have the same *x*-values. We illustrate the two methods by examples.

3.2.1 First Method

Suppose we want to plot the graphs of $y = x^2$ and $y = 1 - x^2$ on the interval $[-5, 5]$. In this case we follow exactly the procedure explained in the previous section except that we generate the points for the two curves simultaneously and we select the 3-column range of cells that contains these points before clicking the Chart Wizard. The following two figures illustrate the details.

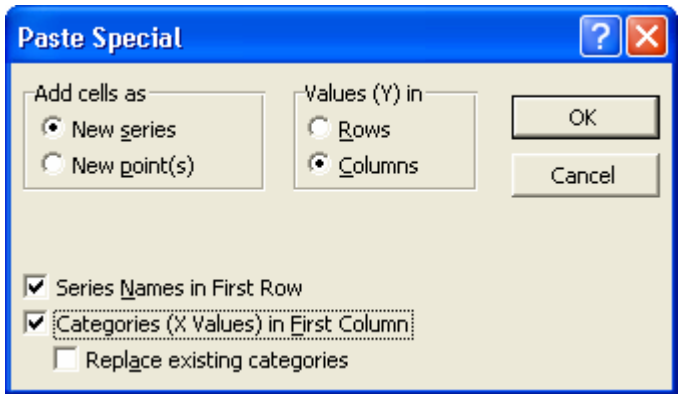
C2 =1-B2

	A	B	C
1	x	y1=x^s	y2=1-x^2
2	-5	25	-24
3	-4.6	21.16	-20.16
4	-4.2	17.64	-16.64
5	-3.8	14.44	-13.44
6	-3.4	11.56	-10.56
7	-3	9	-8
22	3	9	-8
23	3.4	11.56	-10.56
24	3.8	14.44	-13.44
25	4.2	17.64	-16.64
26	4.6	21.16	-20.16
27	5	25	-24

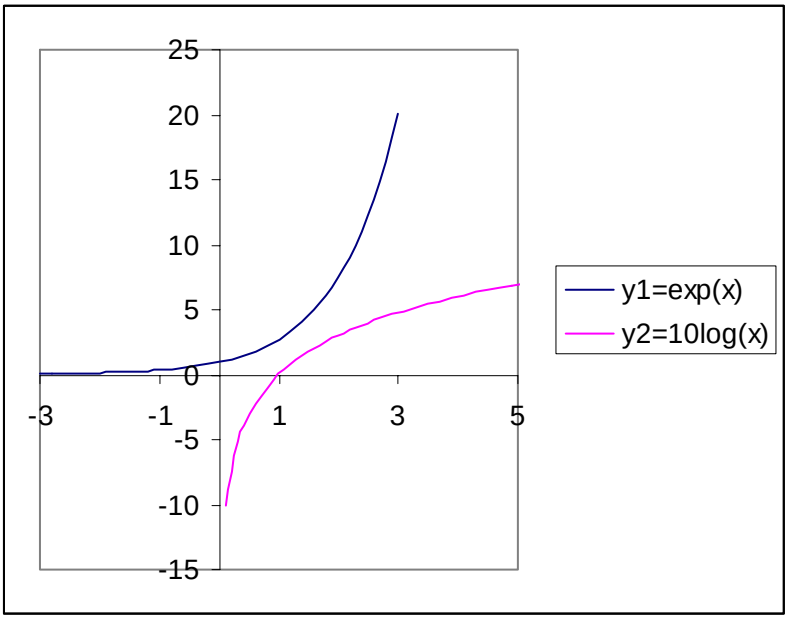


3.2.2 Second Method

Here, we plot the graphs of $y = e^x$ over the interval $[-3, 3]$ and $y = 10\log x$ over the interval $[0.1, 5]$. We begin by generating and plotting the graph of $y = e^x$ in the usual manner. Next we generate the points for the graph $y = 10\log x$. To plot the latter graph on the same chart, select the range of x, y points for the graph, point to the border of the selection, drag and drop in the chart area. A dialog box appears as shown below.



Select: Add Cells - New Series, Values (Y) in - Columns, Series Names in First Row, Categories (X Values) in First Column. When you press ok, the graphs below will appear. We did some editing to have the figure actually displayed here.

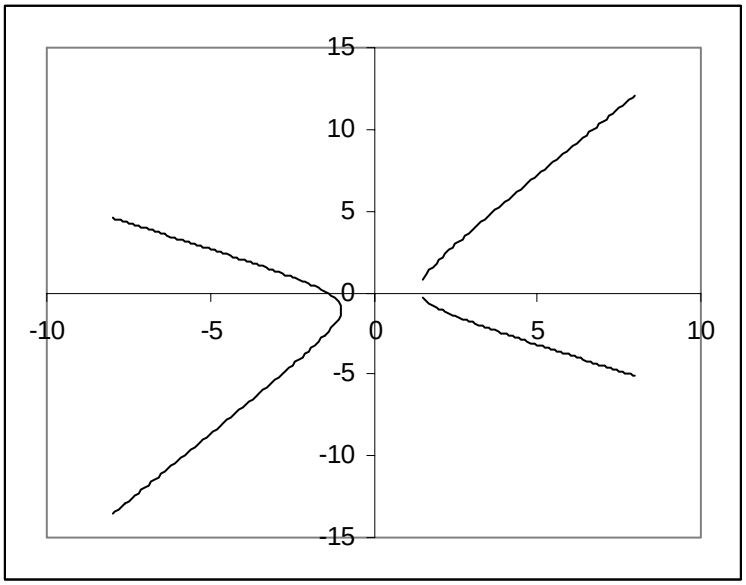


3.3 Graphs of curves that do not represent functions

Suppose we want to draw the graph of the equation $y^2 - xy - x^2 + y = 2$. The graph does not represent a function since $y = \dfrac{(x-1) \pm \sqrt{5x^2 - 2x - 7}}{2}$, i.e., every x corresponds to two values of y. An added difficulty here arises because of the range of allowable x-values. For instance, $x = 0$ is not allowed. We want to show that this will present no problems as far as graphing is concerned. The idea is to draw two graphs on the chart, one for each value of y. Thus we will be plotting the graphs of

$$y = \frac{(x-1) + \sqrt{5x^2 - 2x - 7}}{2} \text{ and } y = \frac{(x-1) - \sqrt{5x^2 - 2x - 7}}{2}$$

over the interval $[-8, 8]$, a subinterval of which is not in the allowable range of x-values. When producing the points for these graphs you will notice that Excel produces the error message #NUM! for the range of x-values that are not allowed. You simply need to delete the cells that contain these errors. You should leave at least on empty row of cells between the undeleted ones (try to see what happens if you do not leave an empty row, you can always undo the changes by clicking the undo button in the toolbar). The following figure shows the graph corresponding to an x-step of 0.1.



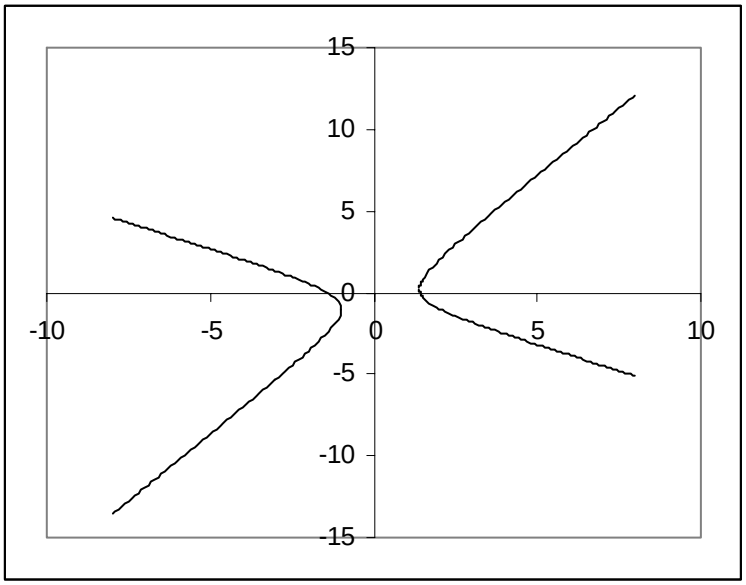
You will notice that part of the graph is missing. This is because the 0.1 step was too big for the rapidly changing graph around $x = 1.5$. This brings us to the idea of adding points to a graph. We will use this idea to add more points near 1.5. This is done as follows.

a) At the end of the table of *x*-values generate a sequence between 1.401 and 1.5 in steps of 0.01, say, and extend the *y*-values correspondingly. This can be done by copying the formulas to the corresponding cells in the usual manner.

b) Select the range of cells containing all the points for the graph.

c) Click the Sort Ascending button on the main toolbar. The added points will now sit in their correct place. You will need to insert an empty row again after the *x*-value -1.

d) Click somewhere in the chart area to select it. The range of points used to generate the graph will be highlighted by Excel. You will notice that the highlighted range misses some values towards the end of the table. To extend the highlighted range point to the little red box at the end of the highlighted *x*-values. The cursor will change to a diagonal double headed arrow. Click and drag to extend the highlighting to the end of the generated points. The following figure shows the results.



3.4 Parametric and Polar curves

Parametric and polar curves pose no special challenge to Excel graphing. In the case of a parametric curve ($x = f(t), y = g(t)$), an extra column for the values of t is needed. The values of x and y are then generated using the functions f and g. For a polar curve ($r = f(\theta)$), a column of values of θ is first generated, a corresponding column of the values of r is then computed. The x and y values are generated using the formulas $x = r\cos\theta, y = r\sin\theta$. The following two figures show parts of Excel charts for the cycloid $x = t + \cos t, y = \sin t$ and the butterfly curve $r = e^{\cos\theta} - 2\cos 4\theta + \sin^3\theta$ [1].

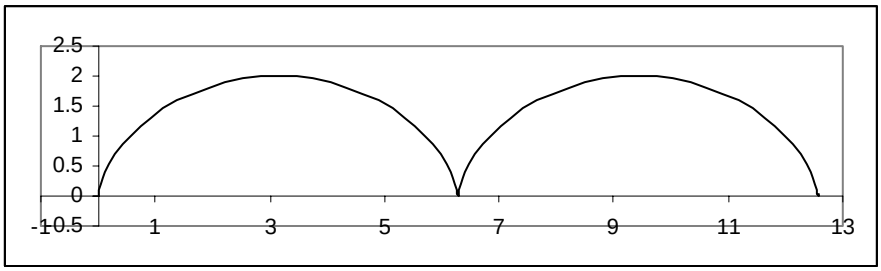
B2 =A2-SIN(A2)

A	B	C	D
t	**x**	**y**	
0	0	0	
0.314159	0.005142	0.048943	
0.628319	0.040533	0.190983	
0.942478	0.133461	0.412215	
1.256637	0.305581	0.690983	
1.570796	0.570796	1	
1.884956	0.933899	1.309017	
2.199115	1.390098	1.587785	
2.513274	1.925489	1.809017	

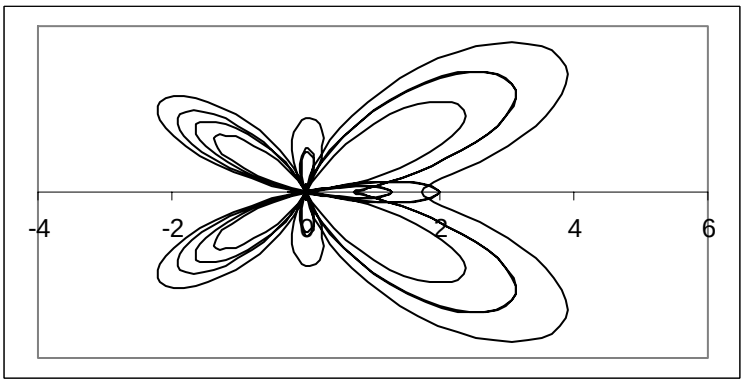
C2 =B2*COS(A2)

A	B	C	D
Theta	**r**	**x**	**y**
0	0.718282	0.718282	0
0.15708	1.067047	1.05391	0.166923
0.314159	1.970892	1.87443	0.609039
0.471239	3.05724	2.72402	1.387958
0.628319	3.867562	3.128923	2.273296
0.785398	4.03554	2.853558	2.853558
0.942478	3.430753	2.016546	2.775538
1.099557	2.212617	1.004507	1.971456
1.256637	0.77356	0.239043	0.735699

The graph of two cycles of the cycloid is shown below



while graph of the butterfly curve is shown below.



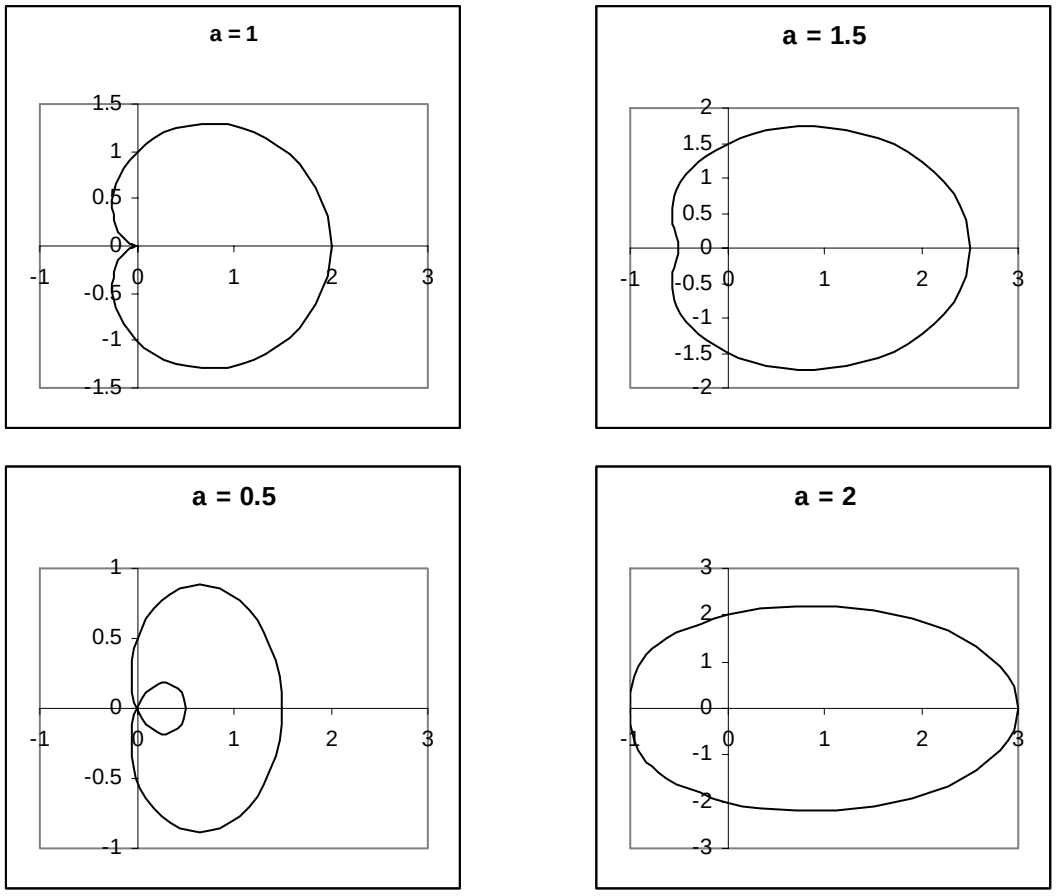
3.5 Parametric studies

Excel graphing is also a great tool to study the dependence of graphs on parameters. We illustrate this by plotting the graph of the polar curve $r = a + \cos\theta$ for various values of *a*. The table set up is the same as the one for polar curves except that we need an extra cell to store the value of *a*. The lay out of the table is shown below.

C2 f_x =$A$2+COS(B2)

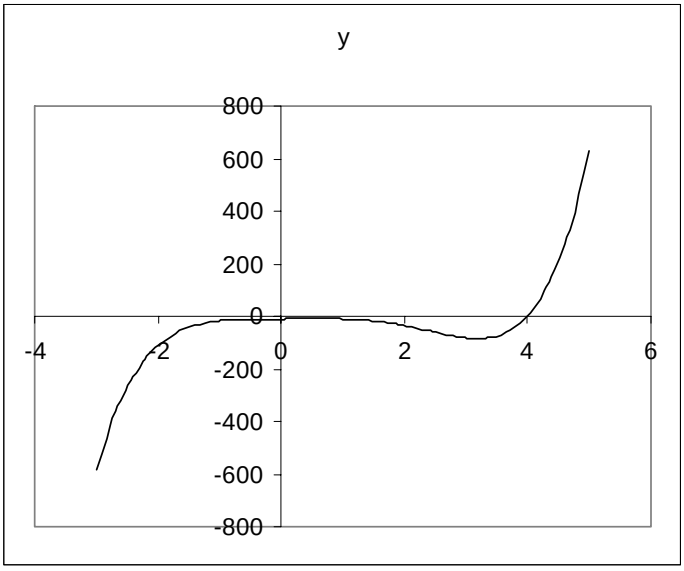
A	B	C	D	E
a	Theta	r	x	y
1	0	2	2	0
	0.15708	1.987688	1.963217	0.310943
	0.314159	1.951057	1.855565	0.60291
	0.471239	1.891007	1.684899	0.858499
	0.628319	1.809017	1.463525	1.063314
	0.785398	1.707107	1.207107	1.207107

The graphs for several values of *a* are shown below.

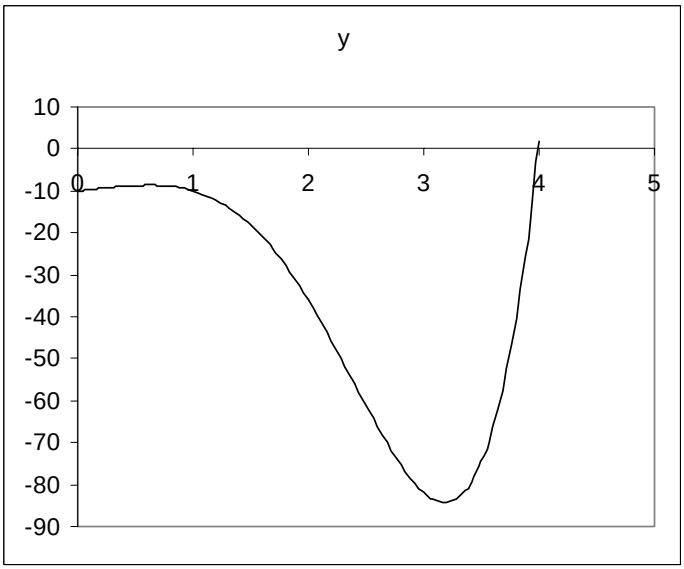


4 A zooming technique

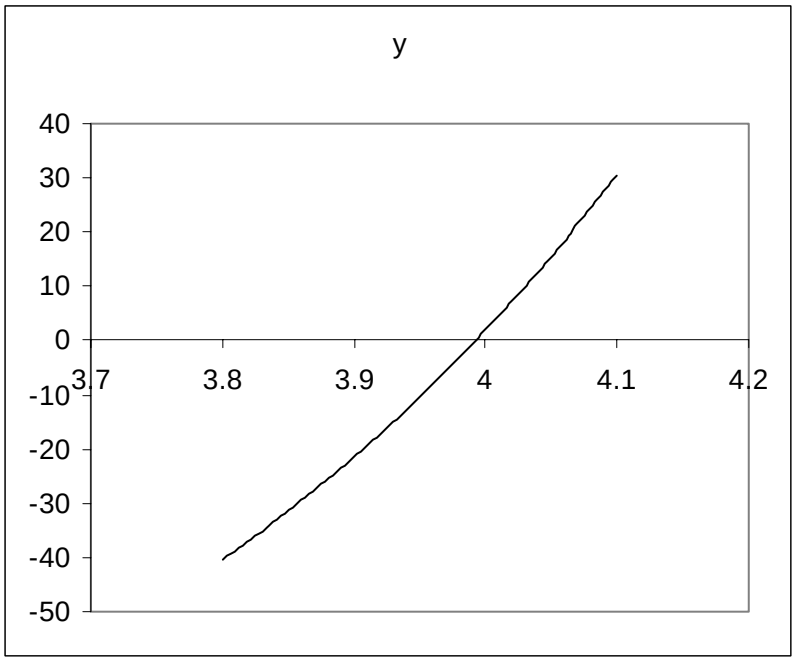
Suppose we want to find the roots of the equation $x^5 - 4x^4 + 3x - 10 = 0$. One way to do this is to plot the graph over a large range and then zoom in on the roots one by one to better bracket them. For this purpose we use the technique for generating values in an interval $[a,b]$ that was explained in Section 2.2. We started by plotting the function over the interval $[-3,5]$. The graph is shown below.



It shows that the roots of the function are located in the interval $[0,4]$. So we change the values of *a* and *b* to 0 and 4. This gives the graph below.



From this graph, it is clear that the root is near 4, so we change *a* and *b* to 3.8 and 4.1.



At this point, by looking at the table of generated y-values we see that the root is actually between 3.992 and 3.995. This means we have bracketed the root to two decimal places. Observe also that if you move the cursor near the root, the yellow hint box will appear giving the points

Series "y" Point "3.995"
(3.995, 0.711388) and Series "y" Point "3.992"
(3.992, -0.0556651),

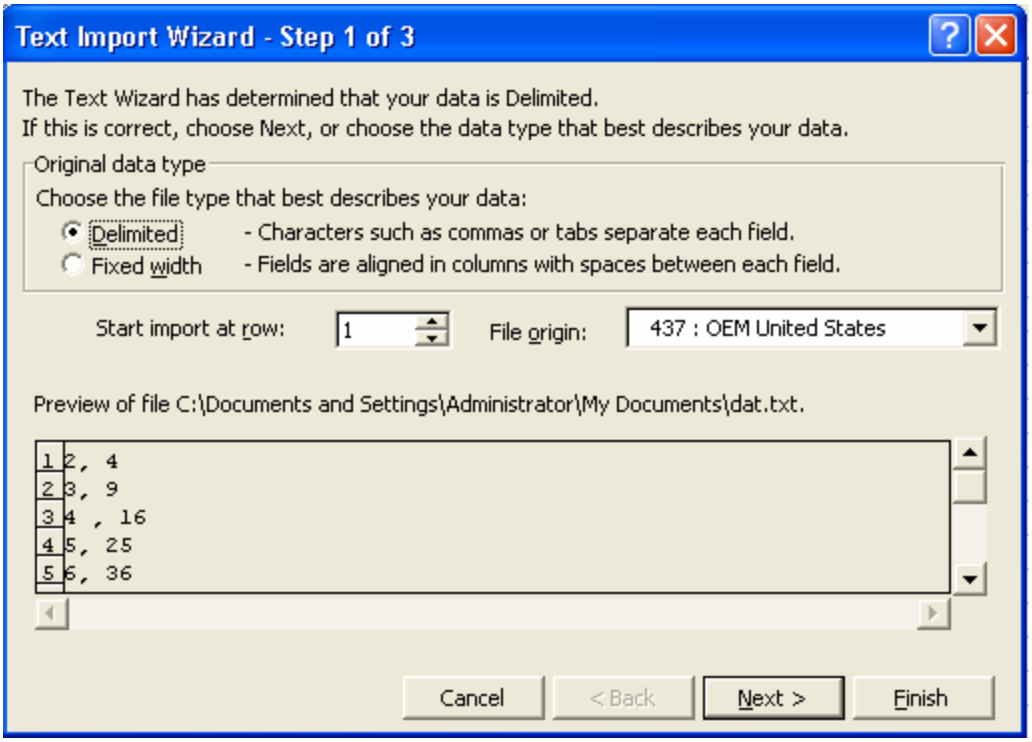
so there is actually no need to look up values in the table. By continuing this process, we can bracket the root to any degree of accuracy we desire.

5 Online graphing

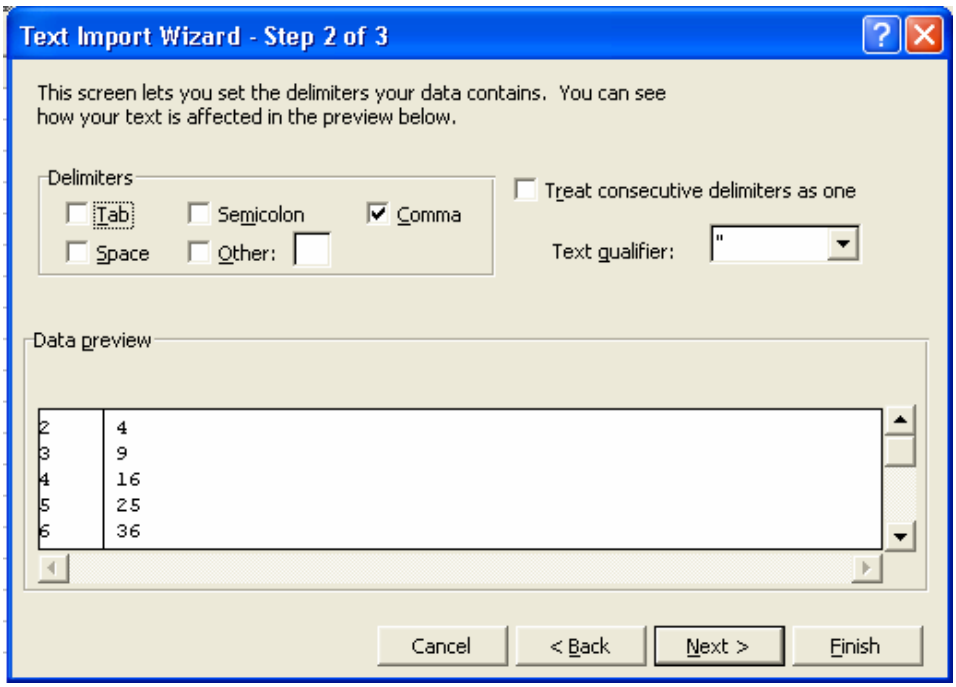
Sometimes need arises to graph data points that are generated online. For example, the computer may be hooked to a measuring device in an experiment, or the data is being generated by another program. Excel can be used to graph and update the graph periodically at time intervals of as little as one minute. The following procedure may be used to accomplish this. To simulate a data generating device, open a text file and type some (x, y) values. For example the following data was used initially.

2, 4
3, 9
4 16
5, 25
6, 36
7, 49
8, 64
9, 81
10, 100
11, 121

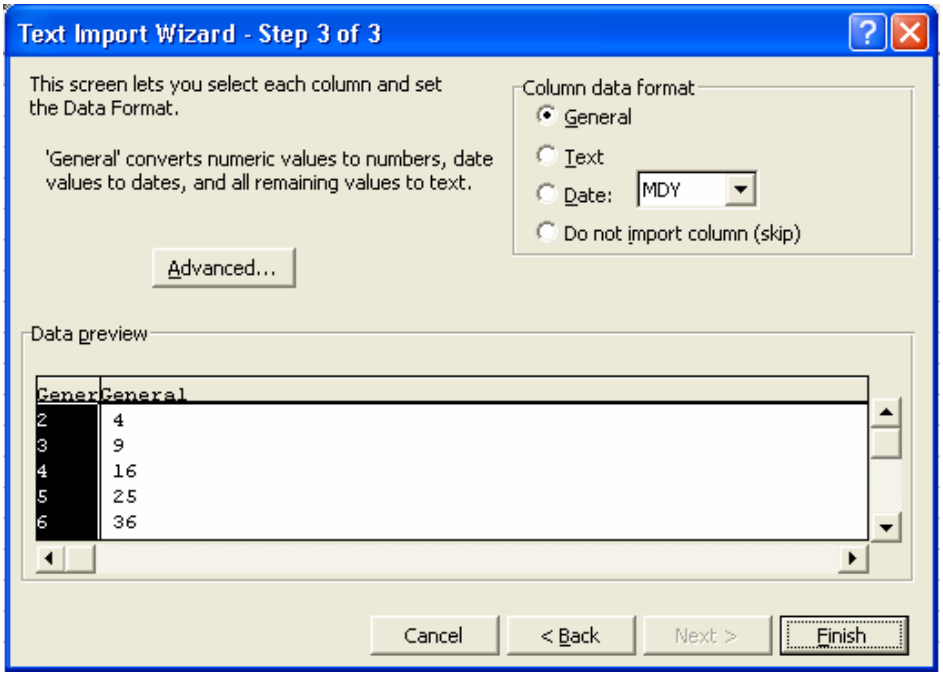
Save the file as, say, “dat.txt” in “my documents”, or some other convenient directory. In an Excel sheet, type the labels *x* and *y* in cells A1, B1 respectively. Select cell A2 and then click Data -> Import External Data -> Import Data... to open the Select Data Source dialog box. Navigate to where you saved the dat.txt file (my documents in this example), select the file and then click Open to bring up the Text Import Wizard shown below



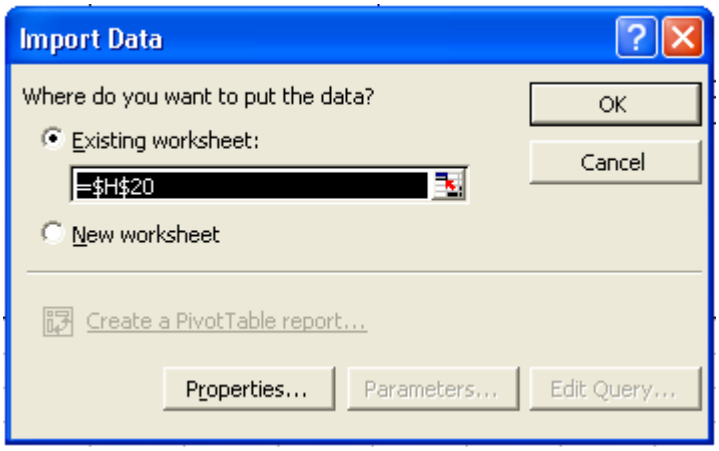
In this dialog box you can select the Original data type and at which row to start importing. Make the selections shown and click Next. In the next dialog box, check, the Comma box in the Delimiters sub-box to tell Excel that your data is separated by commas. Click Next.



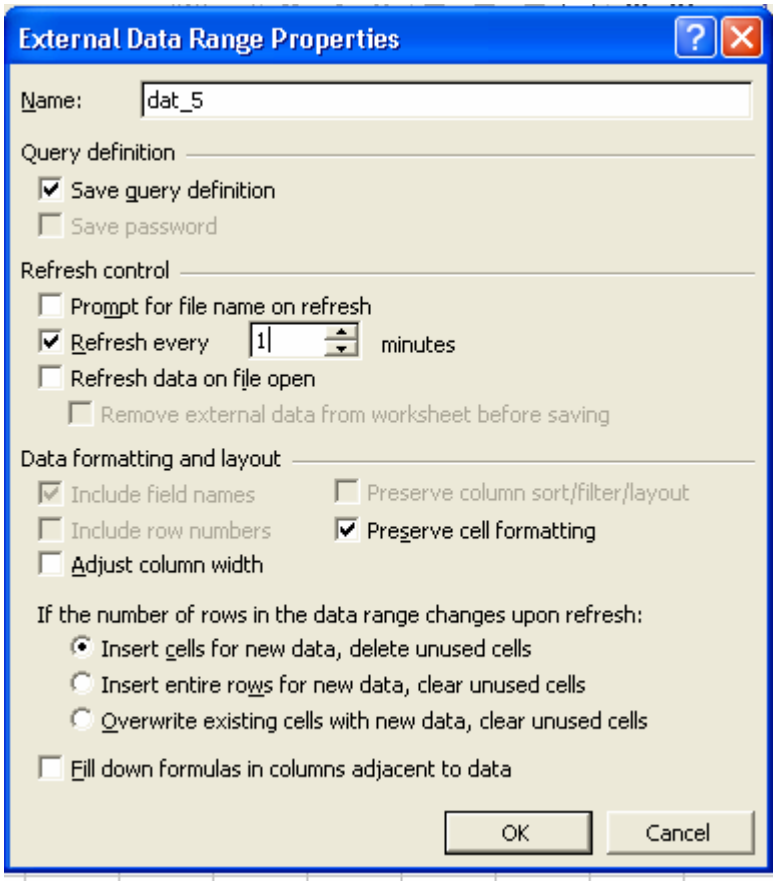
In the next dialog box, check General in the Column data format sub-box.



Click finish. The Import Data Dialog box starts. In this dialog box click Properties.

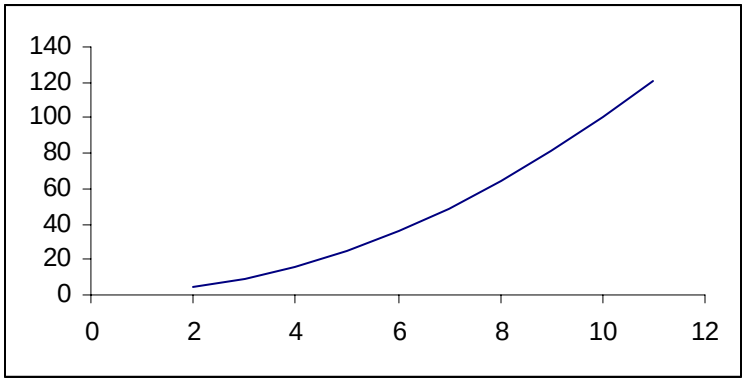


Make the selections shown below and set the Refresh every box to 1 minute. Click Ok.



The imported data appears as below

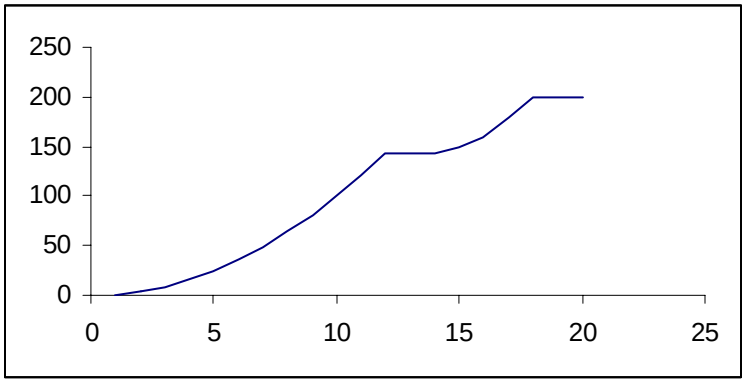
	A	B
1	x	y
2	2	4
3	3	9
4	4	16
5	5	25
6	6	36
7	7	49
8	8	64
9	9	81
10	10	100
11	11	121



Now select the range A1:B11 and graph the data as usual. You will get the graph shown above beside the data.

Now, to simulate the addition of data, open the file dat.txt and insert some more points (you can also change the existing points). Do not forget to save the changes. Here is what we did.

	A	B
1	x	y
2	2	4
3	3	9
4	4	16
5	5	25
6	6	36
7	7	49
8	8	64
9	9	81
10	10	100
11	11	121
12	12	144
13	13	144
14	14	144
15	15	150
16	16	160
17	17	180
18	18	200
19	19	200
20	20	200



The figure above shows actually the data after it was imported into Excel. This updating takes place within a minute of saving the changes. You will also notice that the graph is automatically updated as shown by the graph beside the data.

Further simulations can be done by actually adding or deleting points. Excel will update automatically every one minute. One point to notice here, if you exit Excel and reopen it again, a dialog box comes up asking you if you want to enable automatic importing or not. If you want to continue the updating choose Enable automatic refresh.

Acknowledgement: The authors would like to thank KFUPM for excellent research facility.

References

1. Anton, H., Bivens, I., Davis, S., *Calculus*, 7th edition, John Wiley, 2002.
2. Walkenbach, J., *Excel Charts*, Wiley Publishing, Inc., 2003.