

## Experiment 1A: Excel Graphing Exercise

The data for this exercise comes from measuring the time for a simple pendulum to swing back and forth 20 times as a function of the length of string.

1. Type the following data into EXCEL in columns A and B. Don't forget to label the columns.

<b>Length (cm)</b> <b>±0.4 cm</b>	<b>Time for 20 Swings (s)</b> <b>±0.5 s</b>
5	9.0
10	12.7
20	19.3
40	25.5
60	31.2
80	36.0
100	41.2

2. Highlight the first 12 columns of this sheet and format them so they wrap text. Click on Home-Format-Format Cells-Alignment-wrap text.
3. Name this sheet Data. Right click on Sheet 1 at the bottom of the page then choose Rename and type Data.
4. In column C calculate the time for 1 swing using the formula ( $=B2/20$ ) etc. This is the period of motion. Label the column with Period of Motion T (s). After typing this formula in C2 you can click on the bottom right corner of the cell and drag the formula down the whole column.
5. Calculate the absolute uncertainty for the period and put it into column D. The absolute uncertainty is  $0.5/20$  for every entry of column D. Label the column Abs Unc T (s).
6. Calculate the percent uncertainty for the period in column E. The percent uncertainty for the first entry would be ( $=D2/C2*100$ ). Label the column % Unc T (%). Format the values so they only have 1 decimal place. Click on Home-Format-Format Cells-Number-Number-Decimal Places-1.
7. Calculate  $T^2$  in column F and label it  $T^2$  ( $s^2$ ). To make a superscript type the 2 then highlight it then click Home-the little arrow at the right of the Font box-superscript OK.
8. Calculate the percent uncertainty in  $T^2$  in column G. The first entry would be ( $=E2*2$ ). Label the column % Unc  $T^2$  (%).
9. Calculate the absolute uncertainty in  $T^2$  in column H. The first entry would be ( $=G2/100*F2$ ). Label the column Abs Unc  $T^2$  ( $s^2$ ).

10. Calculate a new data series in column I using the uncertainties calculated in column H. This data series will be used to find the maximum slope. The series is made up of the minimum values for the first 3 data points and the maximum values of the last 3 data points. The middle data point is omitted. So the first entry in column I would be  $(=F2-H2)$ . Drag this formula for the first 3 rows only, leave the next row blank and then enter  $(=F6+H6)$  in the next row and drag this formula for the last 2 rows. Label this column Max slope.
11. Calculate a new data series in column J using the uncertainties calculated in column H. This data series will be used to find the minimum slope. The series is made up of the maximum values for the first 3 data points and the minimum values of the last 3 data points. Label this column Min slope.
12. Calculate the values to go on the x axis in column K. These values are  $\pi^2*L/g$  where L must be in meters. So the first entry would be  $(=PI()^2*A2/100/9.8)$ . Label this column X values. (We are not going to worry about the uncertainty in the x values because it is in general much smaller than for the y values).
13. You will now construct a graph that has three lines on it similar to the graph shown on page 14 of this lab manual. I like to reorganize my data at this point so I have the data for the graph in consecutive columns with the x values on the left and the three columns for the y values on the right. To do this highlight the entries in column K, click ctrl C then click in A11 and click Home-Paste-paste values. In columns B, C and D put values from columns F, I and J. Label column B Experimental Data, keep the other labels the same. (If you don't want to reorganize your data before plotting you can always just highlight the x values, hold down the CTRL key and then highlight the y values. Make your xy scatter plot using these values and then if you want to add more data to the same plot click Design-Select Data and then Add.)
14. Highlight this whole block of data including the labels and insert an xy scatter plot. Click Insert-Scatter. Choose the option for the graph that only has the points (no lines).
15. Make this plot a new chart by clicking Design-Move Chart Location-New Sheet. Name this chart Period of Pendulum.
16. Add a title by clicking Layout-Chart Title-Above Chart then click in the formula bar and type  $T^2$  versus  $\pi^2*L/g$ . You can only add the symbol  $\pi$  after you finish typing the title and then clicking out and then clicking back into the title and clicking Insert-Symbol. (I don't know why). To add a superscript you can use CTRL-SHIFT-+.
17. Add the axes titles from Layout-Axes Title, make both titles horizontal and outside the graph. The y axis is called  $T^2$  ( $s^2$ ) and the x axis is called  $\pi^2*L/g$  ( $s^2$ ). Increase the font size of the axes titles to 16.
18. Now add error bars to the experimental data series. Click on the center experimental data point that doesn't have any other points above or below it. All the data points of this

series should now be highlighted. Sometimes it is difficult to highlight the data point you are interested in, to make it easier you can zoom in on the chart by clicking View-Zoom-200%. Click on Layout-Error Bars-More error bars options. The vertical error bars dialogue box should be on your screen. Drag this box to the far left of your screen. Click Both, Cap, Custom, Specify Value in this box. Now you need to go to the data sheet to get the Abs Unc in  $T^2$  values. You do this while the positive values are highlighted in black in the second small box on your screen. Just click on the Data sheet at the bottom of the page and then click and drag down the values in column H. Do the same for the negative values but be careful that the equal sign is in this entry just like the positive values entry.

19. Now get rid of the horizontal error bars that EXCEL just puts in for some unknown reason. Click on any horizontal error bar so they are all highlighted and then just hit delete. You'll notice that it is very hard to see the vertical error bars but they are there.
20. Add trendlines for all data series. Right click on a data point from each series then click Add Trendline-Linear-Display Equation on chart.
21. Move the equations so they are not near the lines. Click and drag them to do this. If you want to format the numbers in the equation you can right click on the equation then click Format Trendline Label-Number and choose the number format for the slope (keep 4 decimals).
22. Format the trendlines so the max and min slope lines are dashed. Right click on the line, Format Trendline-Line style-dash type.
23. Get rid of the data points for the max and min series so you can see the error bars more clearly. Right click on a data point, Format Data Series-Marker Options- None.
24. Format the experimental data series markers with small dots.
25. Type the 3 values for the slopes into your data sheet keeping 4 decimal places. Put the max slope in F12, the min slope in G12 and the experimental slope in H12. Note that the experimental slope is the slope of the trendline for the original data points. Put labels above them.
26. Calculate the absolute uncertainty in slope using the max and min slopes and put it in I12.  $\text{Abs Unc} = (\text{max slope} - \text{min slope})/2$ . Label this value Abs Unc slope.
27. Calculate the percent uncertainty in slope and put it in J12.  $\% \text{ Unc} = \text{Abs Unc} / \text{experimental slope} * 100$ . Label this value %Unc slope and color the cell yellow. Click on the paintbucket under the font tab in Home and choose yellow.
28. Use the LINEST function in EXCEL to calculate the uncertainty in slope. Type Linest in F14 as a label. Highlight a 2X2 block of cells starting in F15. i.e, F15, F16, G15 and G16. Click up in the formula bar and type =LIN (the LINEST function should now appear)

double click on it. For known y values, highlight the values in cells B12:B18, type a comma then highlight the cells A12:A18 for the x values then type a comma then type 1,true and close the brackets. So the formula should look like: =LINEST(B12:B18,A12:A18,1,true). Don't hit enter!! You must hold down ctrl-shift enter to get the 4 values from the LINEST function. The values are the slope in the top left, the uncertainty in slope in the bottom left, the y intercept in the top right and the uncertainty in the y intercept in the bottom right. The uncertainties are absolute uncertainties. Calculate the percent uncertainty in slope in cell I15. (=F16/F15\*100). Label this % Unc Slope LINEST. Color this cell yellow.

29. The theoretical equation for the period of a pendulum as a function of the length of string is  $T^2 = 4\pi^2 L / g$ . So if you graph  $T^2$  vs  $\pi^2 L / g$  the result is a straight line with slope equal to 4. Both LINEST and the Add Trendline function in EXCEL use the same algorithm to calculate the slope of the best fit line for the data points. Therefore the experimental slope in H12 should be the same as the LINEST slope in F15. Calculate the percent difference between this slope and the theoretical value of 4 and put it in cell J15. Label this % Diff and color the cell red. This is how much the experimental slope differs from the theoretical value.
30. Format all the cells in row 12 and rows below so they have only 2 decimal places.
31. Read about consistency checking in the introduction of this lab manual.
32. You will now do two consistency checks for the slope of the experimental data. One will use the uncertainty for slope from the max/min method and one will use the uncertainty for slope from LINEST.
33. Your percent difference between the slope of the experimental data and the theoretical value should be 2.94%. This tells you that your experimental result is out by 2.94%. This doesn't have anything to do with the uncertainty in your measurements; it is simply the difference between the value from the experiment and the theoretical value. The uncertainty in slope using the max/min slope method should be 3.98%. This tells you that when the uncertainty in your measurements, i.e. error bars on the data points, are taken into consideration you are allowed to be as much as 3.98% off the theoretical value. Is your experimental slope different than the theory by less than 3.98%? If so, then your result using the max/min method is consistent.
34. The uncertainty in slope using LINEST should be 2.09%. LINEST doesn't use the error bars to get this result. It uses the degree of scatter of the data (I'm not sure what the actual algorithm is). So according to LINEST you are allowed to have a slope that is within 2.09% of the theoretical value. Is your experimental slope different than the theory by less than 2.09%? If not, then your result using LINEST is inconsistent.
35. Type the appropriate word consistent or inconsistent below each of the yellow cells.

36. Write the inequality for the % Unc's that you used to determine whether your results are consistent or inconsistent. Put these beside the words consistent and inconsistent.
37. You will be required to repeat this analysis for 3 of your labs in the course so keep your EXCEL file and you may be able to just input your new data points. Beware of the copy and paste of the data points, if you are pasting values only then they won't change when you change your original data. You may want to play around with that part of the sheet.
38. Print out all of the sheets of your worksheet and make sure you save them. You'll need them when you do this exercise in Matlab.