NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 210 – Mechanics & Heat   Fall 2022

Lab #2

Lab Writeup Due: Tue/Wed/Thu, Feb. 13/14/15, 2022
Read OpenStax: Chapter 2, Lecture Notes #1

Plotting with Excel

This is a continuation of the Inclined Plane lab you did last week. You will need your lab notebook and the data file you saved last week (either on a USB flash drive or access through the internet).

Good laboratory practices

All students are to bring to lab a quad ruled notebook. The first thing that you should write in your lab notebook before you start is:

(1) *your name*
(2) the *date*
(3) a list of the names of your *lab partners*
(4) your lab *TA's name* and *Section #*

This should all be written in the upper right hand corner of your lab notebook:

Example:

Alberto Hernandez   Jan. 23, 2009
Lab Partners: Kenneth Payne
                        Carrie Butler
                        Mike Rodgers
Lab TA: Danny Amistoso, Section A

placed in upper right hand corner

See the Physics 210 laboratory WebPage for a link to *Lab Write-up Guidelines* and for an example of a *Sample Lab*.

Lab Write-ups

The lab writeups are to be done on a computer. In this lab we will use Word and Excel, but you may use any other similar document and spreadsheet program.

A. The first page of your lab writeup must have the same information (word for word) as in the upper right hand corner of your lab notebook (name, date, lab partners, etc.).

Title

B. The ***title*** of the lab follows next.

Abstract

C. Next follows the ***abstract*** (a one or two sentence brief explanation of what the lab is all about and what new physics you discovered).

Experimental Setup

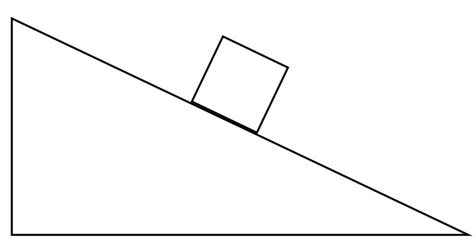
D. Next follows a cell phone picture of the experimental setup. Before you leave lab, you will need to take a picture of your lab setup that will be included in your lab writeup.

E. A graph or ***diagram*** detailing the experimental setup.

Example: Inclined Plane diagram

(a) Open up the Microsoft Word application.

(b) Select the **Insert** tab, then click on **Shapes** in the *Illustrations* section. Then select the triangle and draw it in your word document. You should be able to draw the basic block on incline diagram below. Notice that you can rotate the objects by moving the circular arrow (that appear when you select the object). To rotate the object by a fixed amount, right-click on it and select **More Layout Options**. Click on the **Size** tab and insert your desired rotation angle (useful to get the block to be parallel with the surface of the incline). When the block is selected, you can also move it by small amounts by using the arrow keys (up, down, sideways).



Results & Discussion

F. Next follows the data in the exact order you collected it during the lab. For a collection of data, such as velocity and time, the data should be presented in a table format.

We will mainly use Excel to make tables. It can be done using Word (select the **Insert** tab, and click on **Table** in the *Tables* section), but it is a bit awkward. Making Tables will be illustrated in the Excel Section below.

G. Next follows the *Data Analysis* section (each lab handout will have a *Data Analysis* section). If you are asked to make a calculation, first write the formula, then the formula with the appropriate numbers (and their units) substituting the variables, and then the final number with the appropriate number of significant figures.

To write the formula, put the mouse cursor where you wish to put an equation, then select the **Insert** tab, then click on **Equation** in the *Symbols* section. Type the following equation in your Word document:

$$x = \tfrac{1}{2}at^2$$

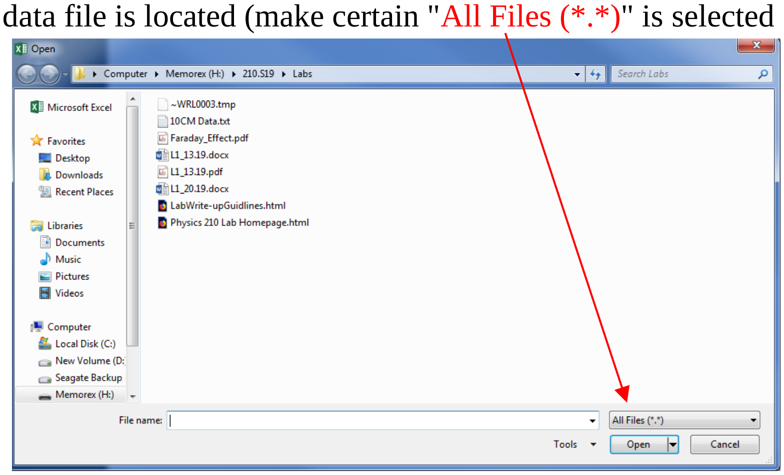
This is how calculations should be shown in the *Results & Discussion* section of your lab writeup.

H. Your lab handout will also ask you to discuss your results and interpret your data. You are encouraged to discuss these questions with your lab partners and others, but your final answer should be in your own words. Duplication of your lab partner's answers is unacceptable and will be penalized.

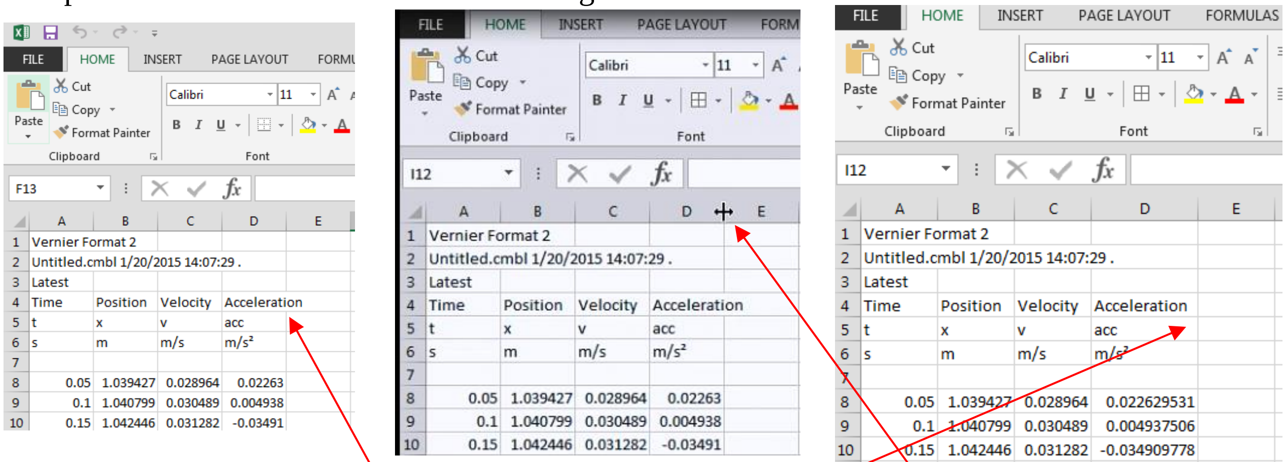
Making Plots using Excel

A. Open up the Microsoft Excel application. Right-click on the *Sheet 1* tab in the lower left hand corner, and select *Rename*. Type in the word "Position".

Retrieve the data file you saved from the Incline Plane lab you did last week. Transfer the data to Excel. Go to the **File** tab, click on *Open*, Click on *Computer*, and *Browse* to where your data file is located (make certain "All Files (*.*)" is selected when you browse instead of "All Excel Files") You should be able to find your text file.

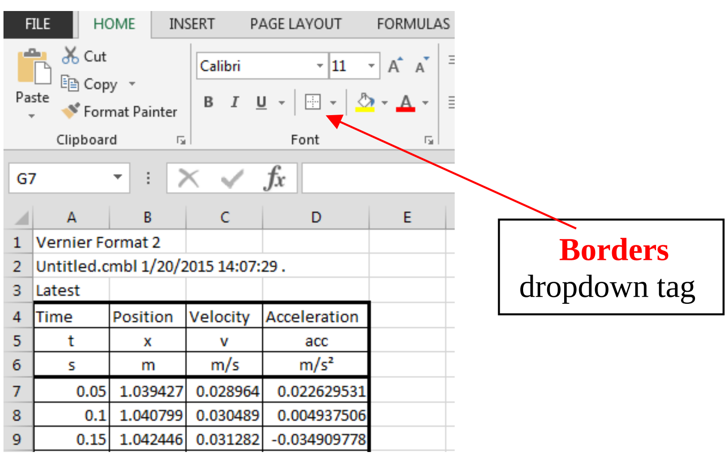


In the Text Import Wizard, accept the defaults by selecting *Finish*. Your Excel spreadsheet should look like the following:



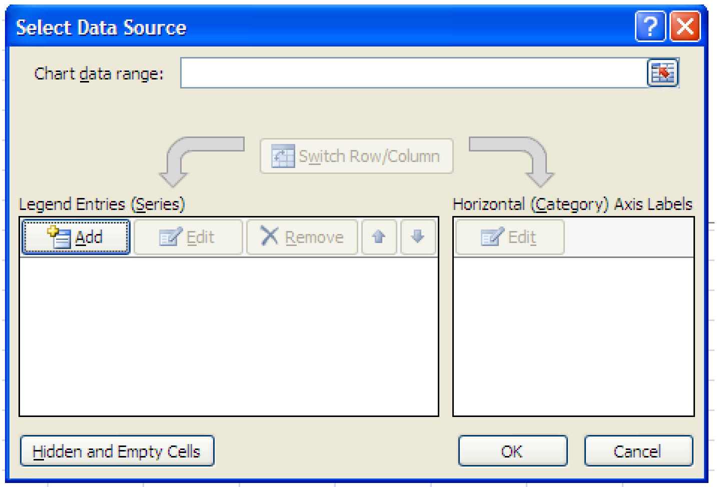
Notice that the word "Acceleration" falls outside the column border. Hover your cursor between the column labels "D" and "E" until it changes to a double arrow, then left double-click your mouse. The column border will self-adjust its width to accommodate all text within the column.

B. To make a table, holding down your left mouse button, drag the mouse so that you select all headings and numbers. Then, on the **Home** tab, in the *Font* section, select the **Borders** dropdown tag (you will have to hover over the tag to see it labeled). Then choose *All Borders*. By hovering over *Line Style* and choosing the thickest line, you can draw the thick line that separates the header (time & position) from the numbers. See the results above.

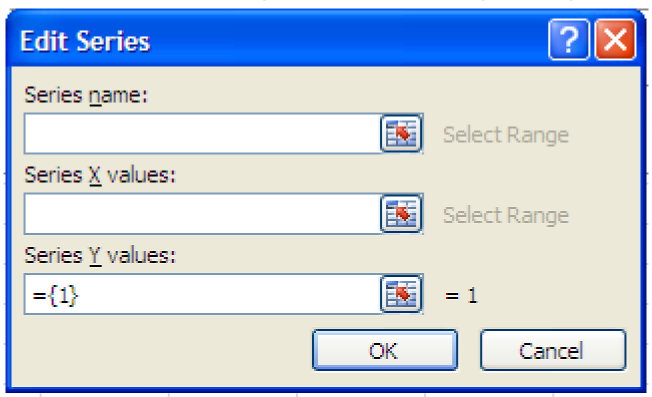


Select the entire table, and copy and paste it into your Word document. From there you can modify the table as you see fit.

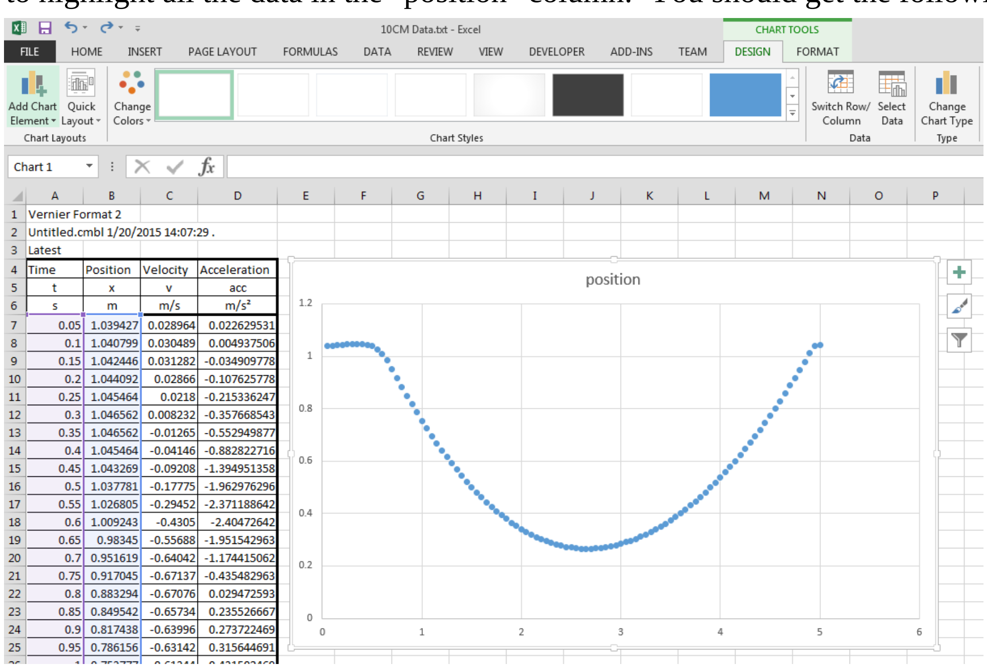
C. To plot this data: (1) click on a cell on your spreadsheet outside the table, (2) go to the **Insert** tab, (3) select **Insert Scatter (x,y)** dropdown tag in the *Charts* section, and then (4) choose **Scatter** (with no lines between points). You will get an empty chart region. Then select **Select Data** in the *Data* section (or, right click in the empty chart region and select **Select Data**). You should get the following dialog:



Click on the **Add** button, which will give the following dialog:



For the *Series name*, type in: position. For the *Series X values*, click in the edit field to make it active, then select the points for the horizontal axis by dragging your cursor to highlight all the data in the "time" column. For the *Series Y values*, delete the "={1}" garbage in the edit field, then select the points for the horizontal axis by dragging your cursor to highlight all the data in the "position" column. You should get the following plot:



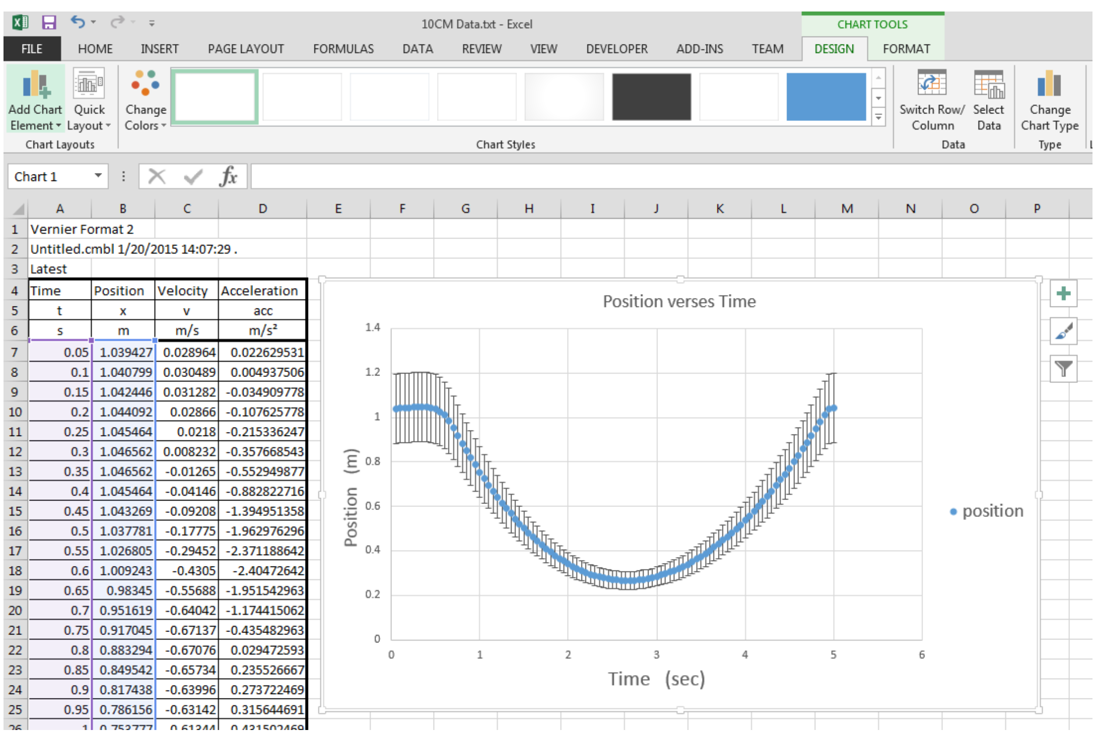
To change the size of the plot (make it larger): In the *Chart Tools* tab, select **Format**, then in the *Size* section select *Size and Properties*, and with the aspect ratio locked, change the *Scale Height* to something larger, like 150 % (you can also get to the *Size* menu by right-clicking on a blank area of the chart and selecting **Format Chart Area**). If you are seeing a curve plotted through the data points, go to the **Chart Tools Design** tab (or right-click on a blank area of the chart), select **Change Chart Type** in the *Type* section. Choose **X Y (Scatter)** in the *All Charts* tab. Press ok. Data points should have no curve or line connecting the points.)

Save your Data: At this point, save your data as a ***.xlsx** file. **<u>Do not</u>** save your data as a *.txt file or you will lose all your plots and calculations. Make certain you select from the "save as type" dropdown the "Excel Workbook (*.xlsx)" item.

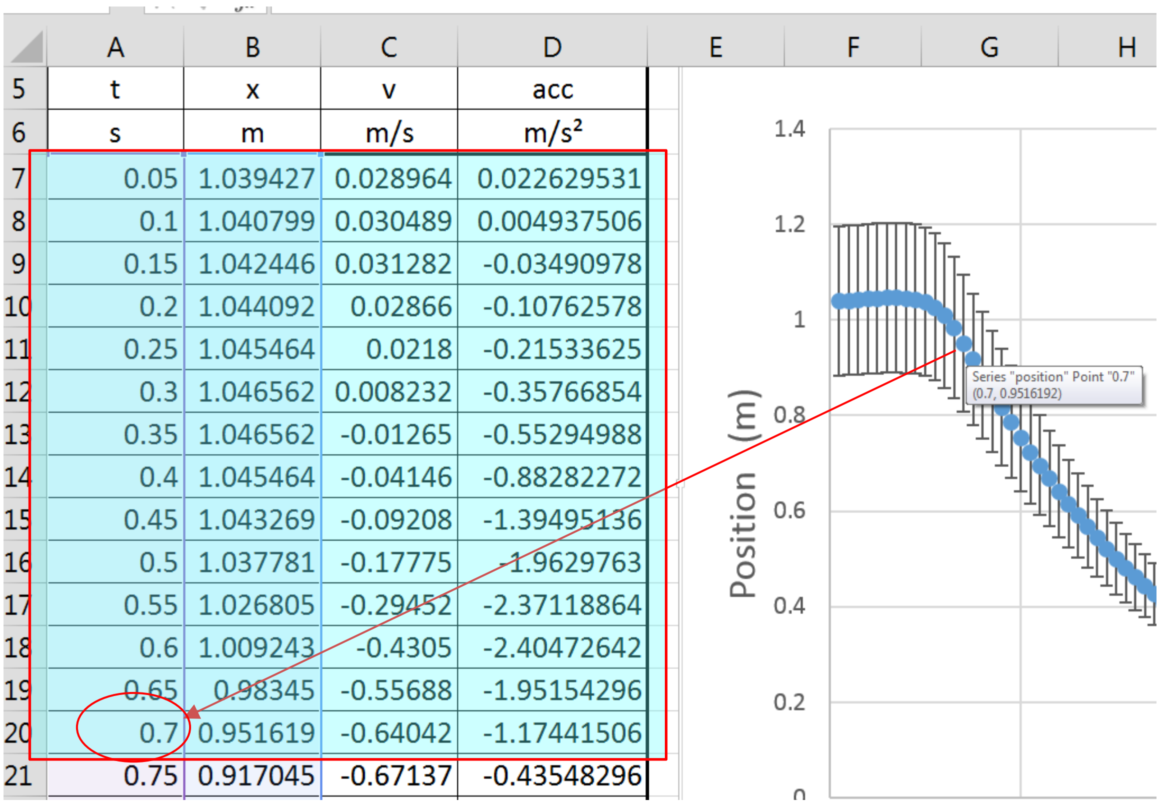
Legend: To add a legend, go to the **Chart Tools Design** tab, and in the *Chart Layouts* section click on **Add Chart Element**, hover over *Legend*, and the choose *Right.*

Labels: Go to the **Chart Tools Design** tab, and in the *Chart Layouts* section click on **Add Chart Element**, hover over *Axis Titles*, and the choose either *Horizontal* or *Vertical* for labeling the *x* or *y*-axes. Properly label the *x* and *y*-axes as "Time (sec)" and "Position (m)" always making certain you write out their units. Change the title "position" to the title "Position verses Time" by clicking on **Add Chart Element** and hovering over *Chart Title* and choosing *Above Chart.*

Error Bars: Go to the **Chart Tools Design** tab, click on **Add Chart Element** in the *Chart Layouts* section, hover over *Error Bars* and then choose *More Error Bars Options,* and set the percentage to 15 % (a large amount, but the error bars become easily observable). If you get horizontal error bars, click on one of the longest horizontal error bar line segments which will select all horizontal error bars (make certain not to select the vertical error bar line segment), and press backspace (or delete). Data should not be plotted with horizontal error bars. You should see the following plot:

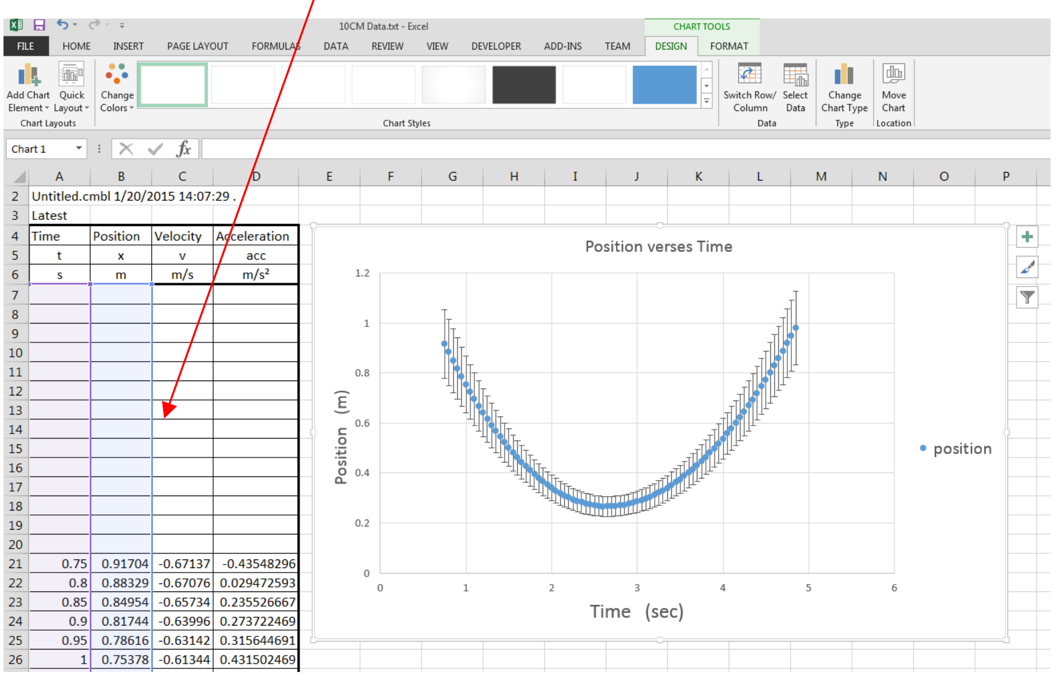


D. To perform a linear regression fit to the parabola, we need to eliminate the non-parabolic flat parts of the curve. Hover with your cursor over a data point just before the "flat" part. The coordinates of the point should appear.



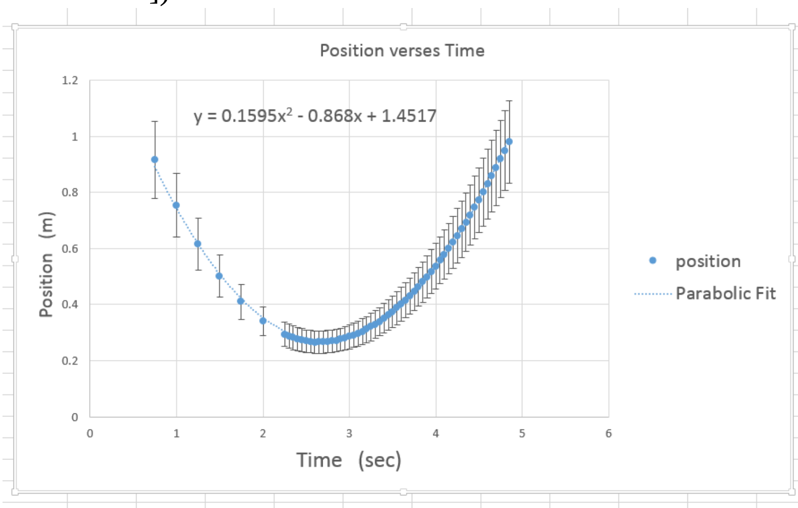
	A	B	C	D
5	t	x	v	acc
6	s	m	m/s	m/s²
7	0.05	1.039427	0.028964	0.022629531
8	0.1	1.040799	0.030489	0.004937506
9	0.15	1.042446	0.031282	-0.03490978
10	0.2	1.044092	0.02866	-0.10762578
11	0.25	1.045464	0.0218	-0.21533625
12	0.3	1.046562	0.008232	-0.35766854
13	0.35	1.046562	-0.01265	-0.55294988
14	0.4	1.045464	-0.04146	-0.88282272
15	0.45	1.043269	-0.09208	-1.39495136
16	0.5	1.037781	-0.17775	-1.9629763
17	0.55	1.026805	-0.29452	-2.37118864
18	0.6	1.009243	-0.4305	-2.40472642
19	0.65	0.98345	-0.55688	-1.95154296
20	0.7	0.951619	-0.64042	-1.17441506
21	0.75	0.917045	-0.67137	-0.43548296

For example, all the data in the red box above should be erased (select the data, then right-click and select *Clear Contents* [do not use delete]) since the data belongs to the flat part of the curve. Notice the graph automatically updates itself when you erase the data. Do the same for the other side of the parabola. You should get the following:



	A	B	C	D
2	Untitled.cmbl 1/20/2015 14:07:29 .			
3	Latest			
4	Time	Position	Velocity	Acceleration
5	t	x	v	acc
6	s	m	m/s	m/s²
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21	0.75	0.91704	-0.67137	-0.43548296
22	0.8	0.88329	-0.67076	0.029472593
23	0.85	0.84954	-0.65734	0.235526667
24	0.9	0.81744	-0.63996	0.273722469
25	0.95	0.78616	-0.63142	0.315644691
26	1	0.75378	-0.61344	0.431502469

To perform a linear regression fit to the parabola, go to the **Chart Tools Design** tab, click on **Add Chart Element** in the *Chart Layouts* section, hover over *Trendline* and choose *More Trendline Options*. Then select **Polynomial** and set the *Order* to 2 (a parabola). Also check the box *Display Equation on chart*. For the trendline name, select the *Custom* button and type in: parabolic fit. You should be able to reproduce the graph shown below: (note: I have eliminated some points so that you can see the parabolic trendline that fits the curve [do not do this to your data—this is just for illustration])



E. Let's now shift the parabola to the origin (like you did by hand in the last lab). Find the minimum position value in your data point—highlight this row in yellow.

54	2.4	0.27714	-0.09101	0.342153086
55	2.45	0.27303	-0.07226	0.347065185
56	2.5	0.27001	-0.05427	0.326315802
57	2.55	0.26809	-0.0436	0.368153333
58	2.6	0.2648	-0.0189	0.427606667
59	2.65	0.26617	0.0061	0.367899259
60	2.7	0.26617	0.01829	0.296080988
61	2.75	0.26781	0.03247	0.276432593
62	2.8	0.26946	0.04497	0.283970123

minimum position
value for my data

Insert a new column after the "Acceleration" column. Label this column "Shifted x". Subtract the *minimum position* from all *x*-values.

x position is in column B

minimum position is in cell B58

subtracting minimum position (cell B58) from the 1st position (cell B21): =B21 – B$58

	A	B	C	D	E
1	Vernier Format 2				
2	Untitled.cmbl 1/20/2015 14:07:29 .				
3	Latest				
4	Time	Position	Velocity	Acceleration	Shifted x
5	t	x	v	acc	x - B58
6	s	m	m/s	m/s²	m
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21	0.75	0.91704	-0.67137	-0.43548296	=B21 - B$58
22	0.8	0.8[illegible]329	-0.67076	0.029472593	
23	0.85	0.84954	-0.65734	0.235526667	

To do this, click in the cell at the beginning of the data (cell E21 for my case above). Type: = B21 – B$58 into this cell. This subtracts the minimum position (cell B58 for my case) from the 1st x-value in cell B21. Using the "$" symbol constrains cell B58 to be a constant. Using the "=" symbol informs Excel that you are creating a formula. To repeat this formula for all the other rows of data, drag the bottom left corner of the cell to the last row.

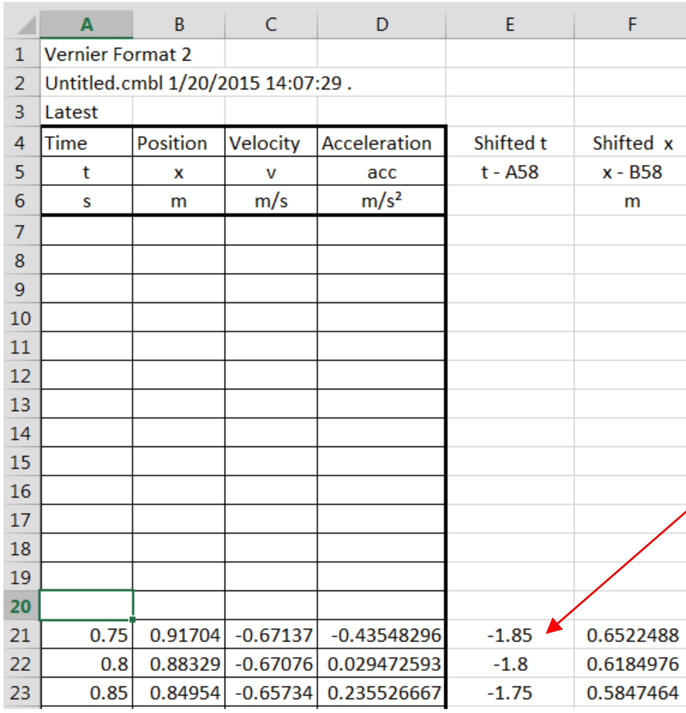
9					
0					
1	0.75	0.91704	-0.67137	-0.43548296	0.6522488
2	0.8	0.88329	-0.67076	0.029472593	
3	0.85	0.84954	-0.65734	0.235526667	

19					
20					
21	0.75	0.91704	-0.67137	-0.43548296	0.6522488
22	0.8	0.88329	-0.67076	0.029472593	
23	0.85	0.84954	-0.65734	0.235526667	

Notice how the cursor changes from a fat + sign to a thin one when it hovers over the tiny square at the bottom right hand corner of the cell—one can now drag this corner down to repeat the formula for all the other rows.

	A	B	C	D	E
1	Vernier Format 2				
2	Untitled.cmbl 1/20/2015 14:07:29 .				
3	Latest				
4	Time	Position	Velocity	Acceleration	Shifted x
5	t	x	v	acc	x - B58
6	s	m	m/s	m/s²	m
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21	0.75	0.91704	-0.67137	-0.43548296	0.6522488
22	0.8	0.88329	-0.67076	0.029472593	0.6184976
23	0.85	0.84954	-0.65734	0.235526667	0.5847464
24	0.9	0.81744	-0.63996	0.273722469	0.5526416
25	0.95	0.78616	-0.63142	0.315644691	0.52136

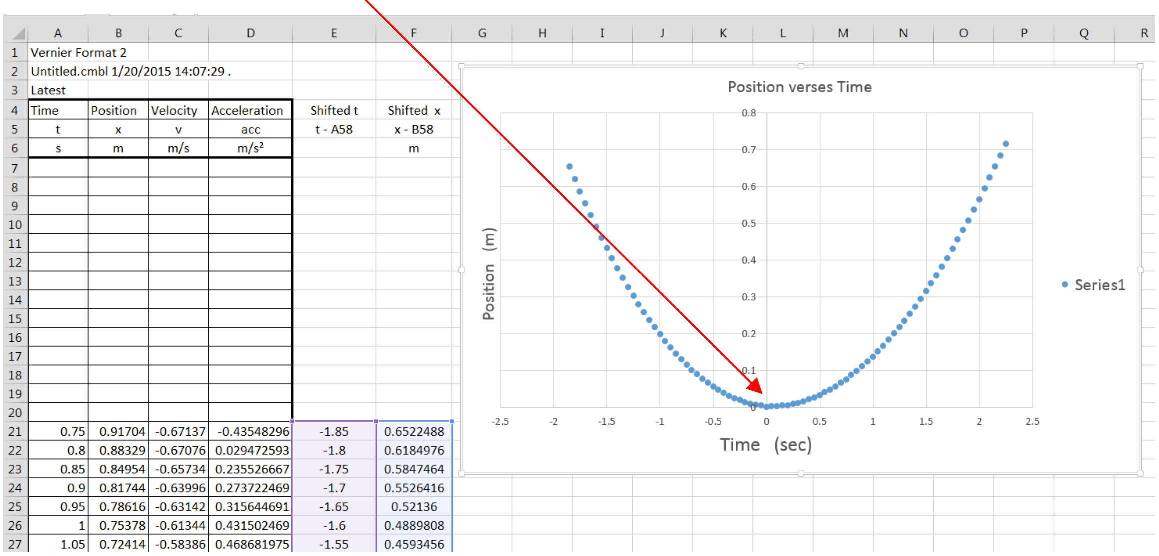
We also need to shift all the time values so that the parabola lies at the origin. Create another column after the "Acceleration" column and call it "shifted t". Do the same procedure for this column that you did for the "shifted x" column. For my case, the formula to use would be: = A21 – A$58.



	A	B	C	D	E	F
1	Vernier Format 2					
2	Untitled.cmbl 1/20/2015 14:07:29 .					
3	Latest					
4	Time	Position	Velocity	Acceleration	Shifted t	Shifted x
5	t	x	v	acc	t - A58	x - B58
6	s	m	m/s	m/s²		m
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21	0.75	0.91704	-0.67137	-0.43548296	-1.85	0.6522488
22	0.8	0.88329	-0.67076	0.029472593	-1.8	0.6184976
23	0.85	0.84954	-0.65734	0.235526667	-1.75	0.5847464

subtracted time at minimum position (cell A58) from the 1st time value (cell A21):
=A21 – A$58

Now we need to plot the shifted data. Right-click on an empty space on your chart and select **Select Data**. Click on *Remove* to remove the previous plot. Click on *Add* to insert a new plot. For *Series name*, write position, for the *Series X values* (horizontal axis) select the data in the "shifted t" column, and for the *Series Y values* (vertical axis) select the data in the "shifted x" column. You should now have a parabola shifted to the origin.



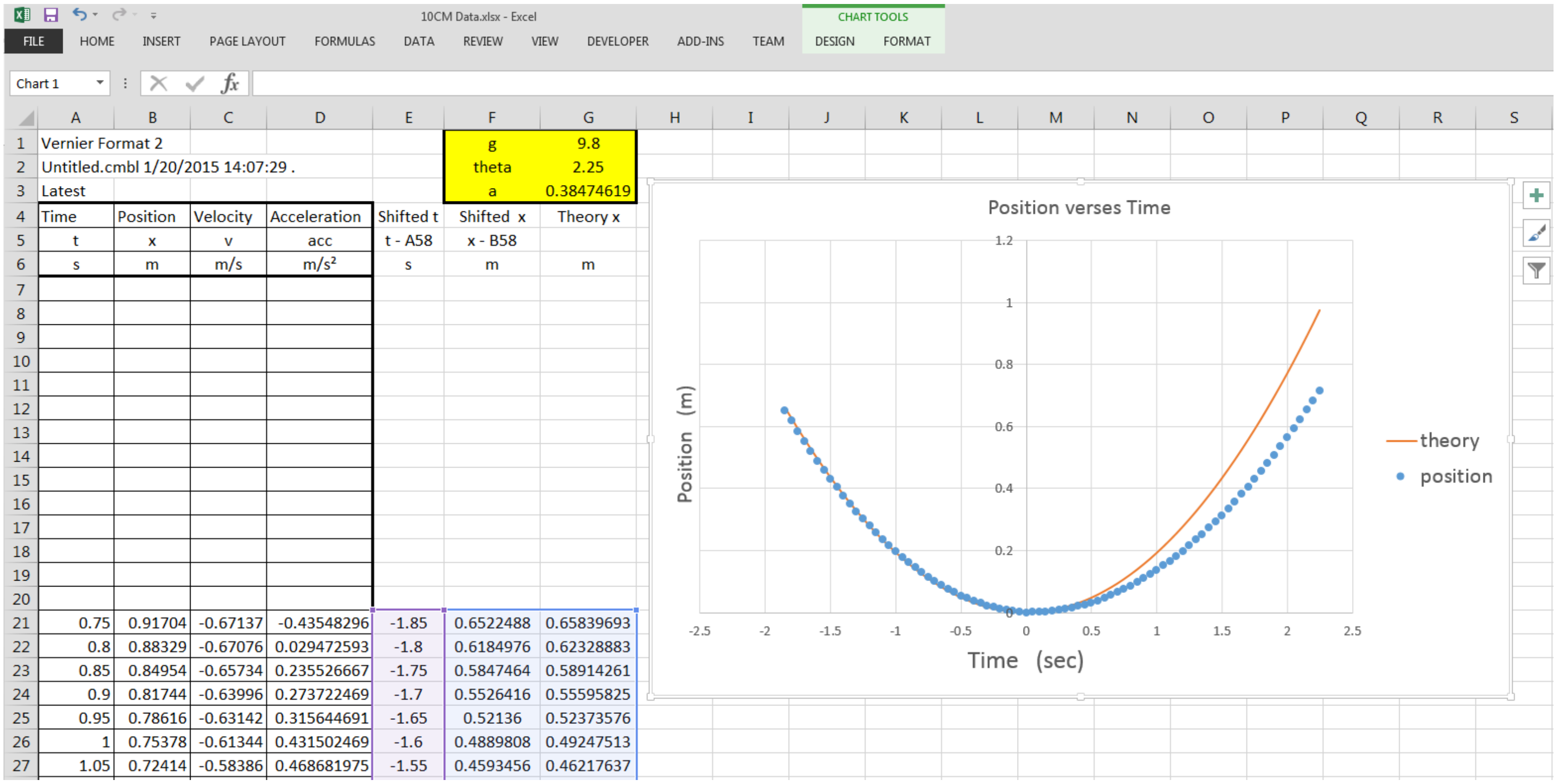
	A	B	C	D	E	F
1	Vernier Format 2					
2	Untitled.cmbl 1/20/2015 14:07:29 .					
3	Latest					
4	Time	Position	Velocity	Acceleration	Shifted t	Shifted x
5	t	x	v	acc	t - A58	x - B58
6	s	m	m/s	m/s²		m
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21	0.75	0.91704	-0.67137	-0.43548296	-1.85	0.6522488
22	0.8	0.88329	-0.67076	0.029472593	-1.8	0.6184976
23	0.85	0.84954	-0.65734	0.235526667	-1.75	0.5847464
24	0.9	0.81744	-0.63996	0.273722469	-1.7	0.5526416
25	0.95	0.78616	-0.63142	0.315644691	-1.65	0.52136
26	1	0.75378	-0.61344	0.431502469	-1.6	0.4889808
27	1.05	0.72414	-0.58386	0.468681975	-1.55	0.4593456

F. Now we need to overlay a theory curve onto the plot. For a parabola situated at the origin, the position, in theory, should obey the following relation: $x = \frac{1}{2}at^2$. The value of the acceleration, a, comes from your measurements last week: $a = g\sin\theta$. The value θ should be in your lab notebook (you determined it last week). Make a

new column called "theory x". Put your values of g, θ, and a (note: in Excel π is written as "pi( )" with open and closed parenthesis) in your Excel spreadsheet (I put them at the top) Write the formula $x = \frac{1}{2}at^2$ into the 1st row of the "theory x" column: my equation would be = (1/2)*(G$3*E21^2).
Note: in Excel, the caret symbol "^" is used for exponentiation (raising a number to a power). Apply your formula to all your rows by dragging the bottom right hand corner of the cell to the last row.

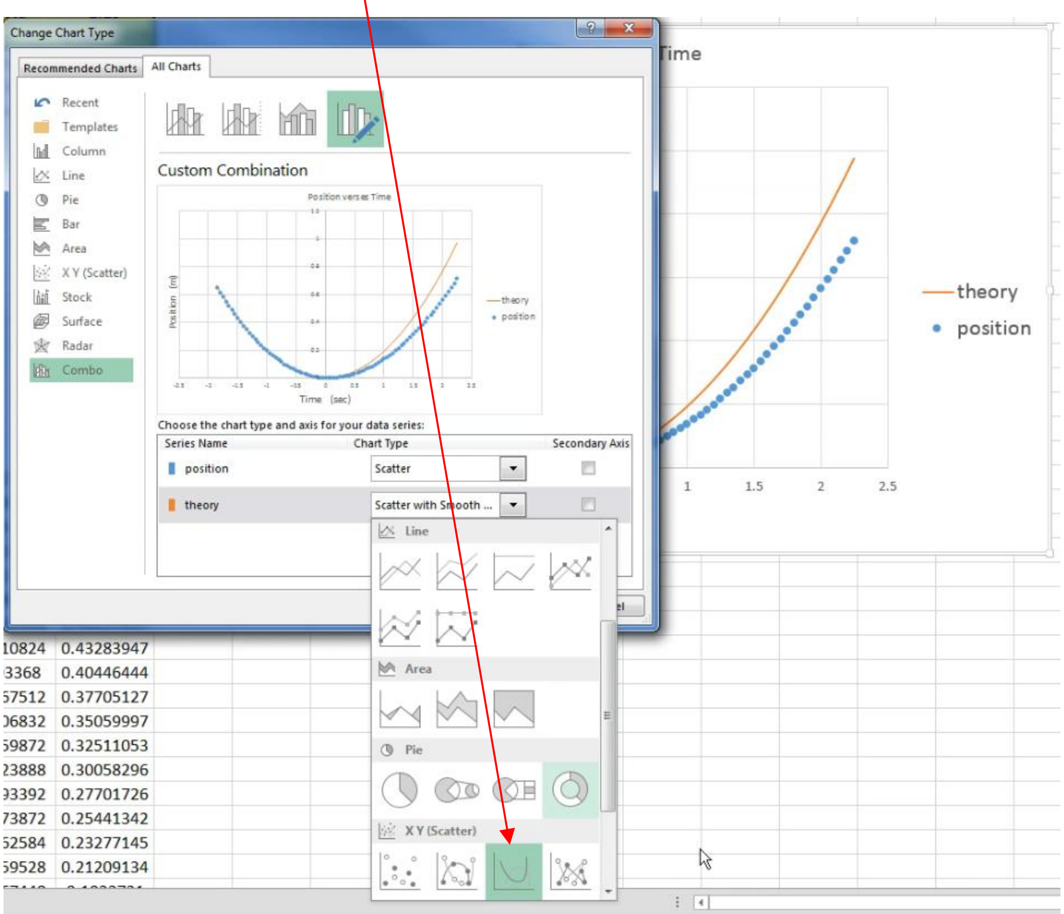
	A	B	C	D	E	F	G
1	Vernier Format 2					g	9.8
2	Untitled.cmbl 1/20/2015 14:07:29 .					theta	2.25
3	Latest					a	0.384746194
4	Time	Position	Velocity	Acceleration	Shifted t	Shifted x	Theory x
5	t	x	v	acc	t - A58	x - B58	
6	s	m	m/s	m/s²	s	m	m
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21	0.75	0.91704	-0.67137	-0.43548296	-1.85	0.6522488	=(1/2)*G$3*E21^2
22	0.8	0.88329	-0.67076	0.029472593	-1.8	0.6184976	
23	0.85	0.84954	-0.65734	0.235526667	-1.75	0.5847464	
24	0.9	0.81744	-0.63996	0.273722469	-1.7	0.5526416	

To add the theory curve to your plot: right-click on an empty space on your chart and select **Select Data**. Click on *Add* to insert a new plot. For *Series name*, write theory, for the *Series X values* (horizontal axis) select the data in the "shifted t" column, and for the *Series Y values* (vertical axis) select the data in the "theory x" column. You should now have two plots on your graph: a theory plot along with your original data plot.



	A	B	C	D	E	F	G
1	Vernier Format 2					g	9.8
2	Untitled.cmbl 1/20/2015 14:07:29 .					theta	2.25
3	Latest					a	0.38474619
4	Time	Position	Velocity	Acceleration	Shifted t	Shifted x	Theory x
5	t	x	v	acc	t - A58	x - B58	
6	s	m	m/s	m/s²	s	m	m
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21	0.75	0.91704	-0.67137	-0.43548296	-1.85	0.6522488	0.65839693
22	0.8	0.88329	-0.67076	0.029472593	-1.8	0.6184976	0.62328883
23	0.85	0.84954	-0.65734	0.235526667	-1.75	0.5847464	0.58914261
24	0.9	0.81744	-0.63996	0.273722469	-1.7	0.5526416	0.55595825
25	0.95	0.78616	-0.63142	0.315644691	-1.65	0.52136	0.52373576
26	1	0.75378	-0.61344	0.431502469	-1.6	0.4889808	0.49247513
27	1.05	0.72414	-0.58386	0.468681975	-1.55	0.4593456	0.46217637

Note: the theory curve should always be a smooth curve. To do this, right-click on an empty space on your chart, select **Change Chart Type**, choose on the drop down menu for "theory": *Scatter with Smooth Lines*.



Data Analysis

(1) On your position verses time graph, plot your data, error bars on your data points, a fit to your data (the parabolic trendline), as well as the theory curve (you should have done this by the end of the computer lab).

(2) From the coefficients of your parabolic fit to the position data, determine the acceleration of the cart—this is your measured acceleration. What is the theoretical acceleration of the cart (the value you used for the acceleration in your "theory x" column)? Is there good agreement between theory and experiment (answer this by calculating the *percent error*) for the acceleration? Is there good agreement between theory and experiment when examining the error bars?

(3) Make another worksheet called "velocity" (press the *New Sheet* button at the bottom of the spreadsheet (it's a "+" sign inside a circle), right-click on the new tab, and select *Rename*). Copy your "time", "velocity", and "shifted t" columns to your new worksheet. Make a new column called "shifted v" for a shifted velocity curve—for this column shift your velocity data points just like you shifted your position data points. Your velocity curve should now go through the origin.

(4) Create another column called "theory v". In this column calculate the theoretical velocities using the equation: $v = at$.

(5) On the same chart plot: (1) velocity verses time for your data, (2) put error bars on your data points, (3) fit your data (with a linear trendline), (4) and plot the theory curve.

(6) From the coefficients of your linear fit to the velocity data, determine the acceleration of the cart—this is your measured acceleration. Is there good agreement between theory and experiment (answer this by calculating the *percent error*) for the acceleration? Is there good agreement between theory and experiment when examining the error bars?

(7) Explain why there is a discrepancy between the measured and theoretical accelerations. That is, discuss the possible sources, or causes, for the discrepancy.

Due Next Week:

(1) a lab **writeup as a Word document with your Plots inserted** into your writeup (copy and paste from Excel), and **with the answers to Questions** in the *Data Analysis* above. Do not insert your data tables into your lab writeup—only the plots are needed.

(2) **Upload** your **lab writeup and Excel spreadsheet to Blackboard** before lab next week.