NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 210 – Mechanics & Heat — Spring 2021

Lab #2

Lab Writeup Due: Tue/Wed/Fri, Sept. 2/3/5, 2021
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 with the data you took last week.

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

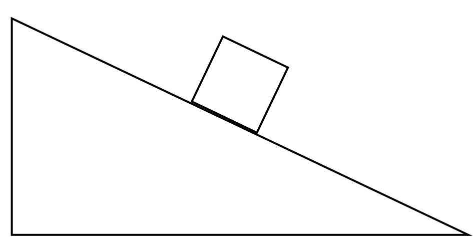
D. Next follows a cell phone picture of the experimental setup. Before you leave lab, you will need to take a picture of your lab setup that will be included in your lab writeup.

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:

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

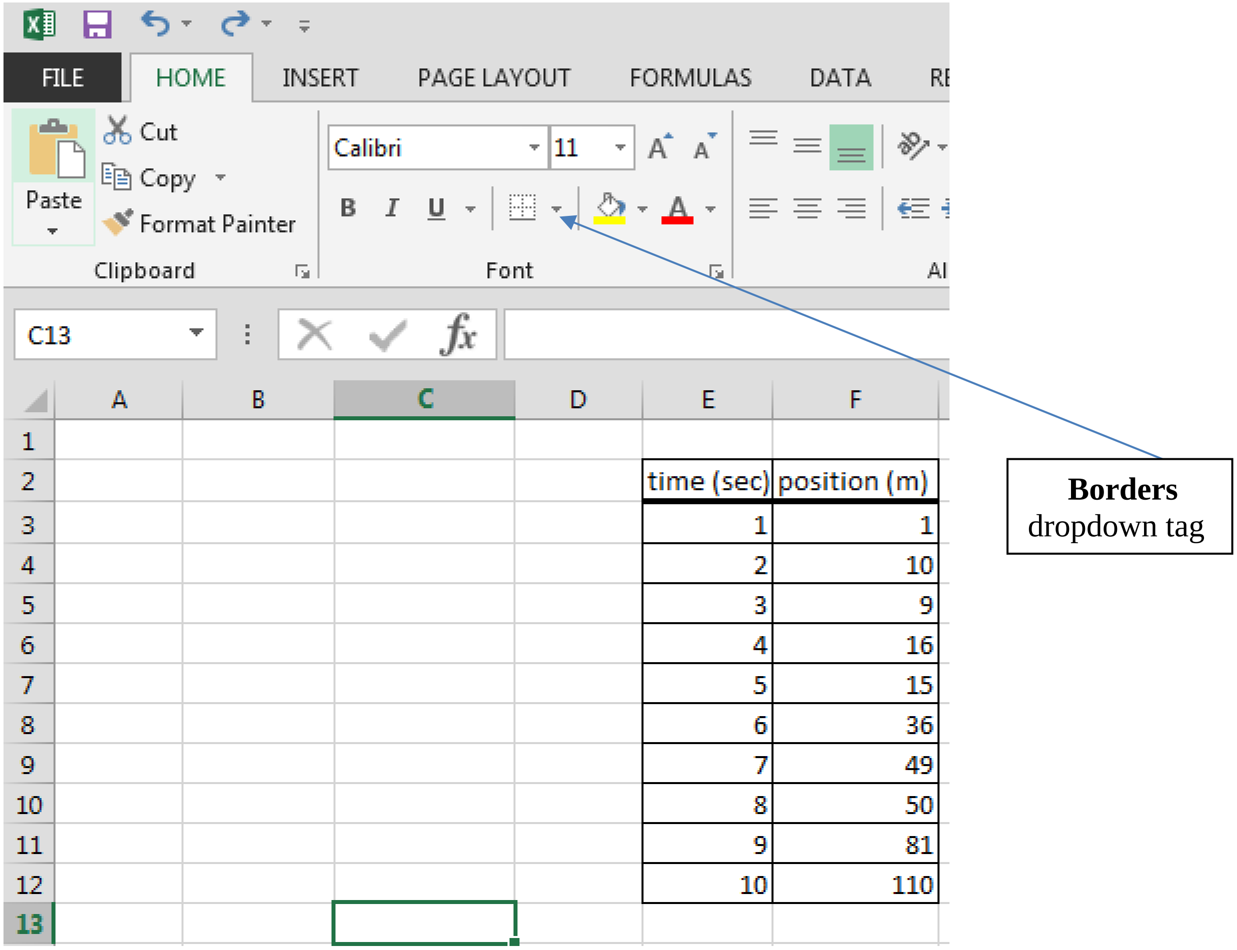
This is how calculations should be shown in the *Results & Discussion* section of your lab writeup.

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 "Tutorial".

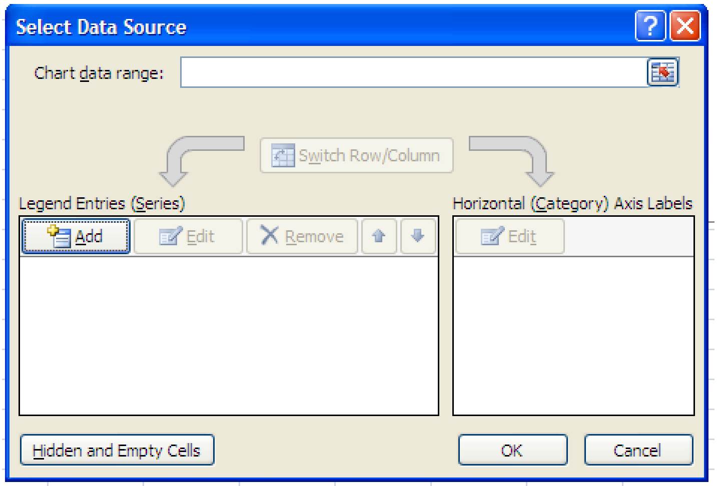
In the worksheet, label one column *time* and the next column *position*. In the time column, insert the values from 1 to 10 in steps of 1. In the position column insert the values: 1,10,9,16,15,36,49,50,81,110.



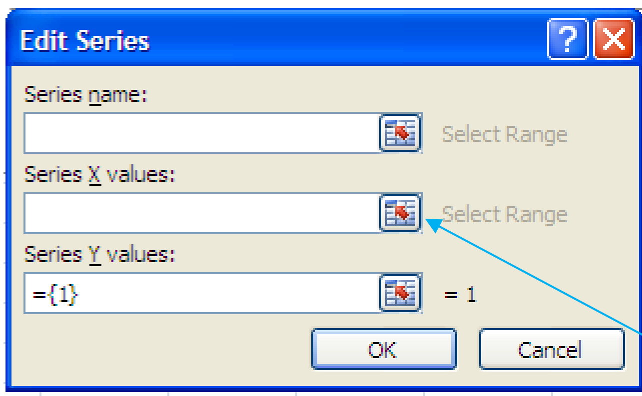
B. To make a table, holding down your left mouse button, drag the mouse so that you select the heading and numbers above. Then, on the **Home** tab, in the *Font* section, select the **Borders** dropdown tag (you will have to hover over the tag to see it labeled). Then choose *All Borders*. By hovering 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:

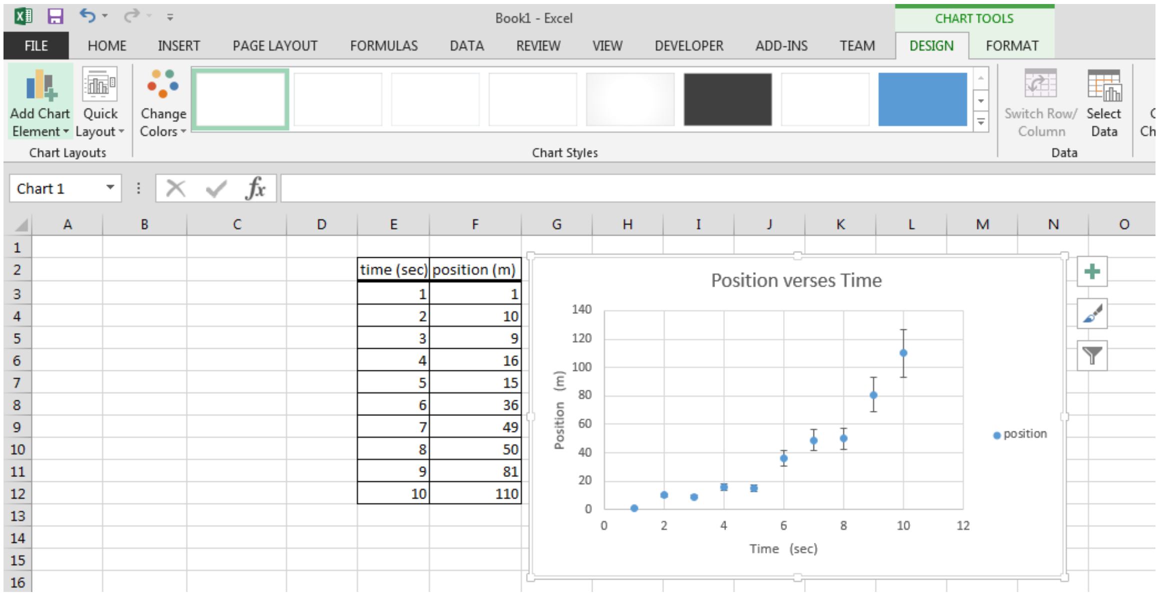


Click on the **Add** button, which will give the following dialog:



For the *Series name*, type in: position. For the *Series X values*, click on the selection tool (the far right icon which has the red diagonal arrow). You will get another dialog shown below:

Then, select the points for the horizontal axis by highlighting the data in the time column. Then press return (or enter). For the *Series Y values*, click on the selection tool. Delete the strange "={1}" symbol. Then select the points for the vertical axis by highlighting the data in the position column. Then press return (or enter). You should get the following plot (if you are seeing a curve plotted through the data points, go to the **Chart Tools Design** tab, 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.) [error bars will be discussed shortly]:



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.*

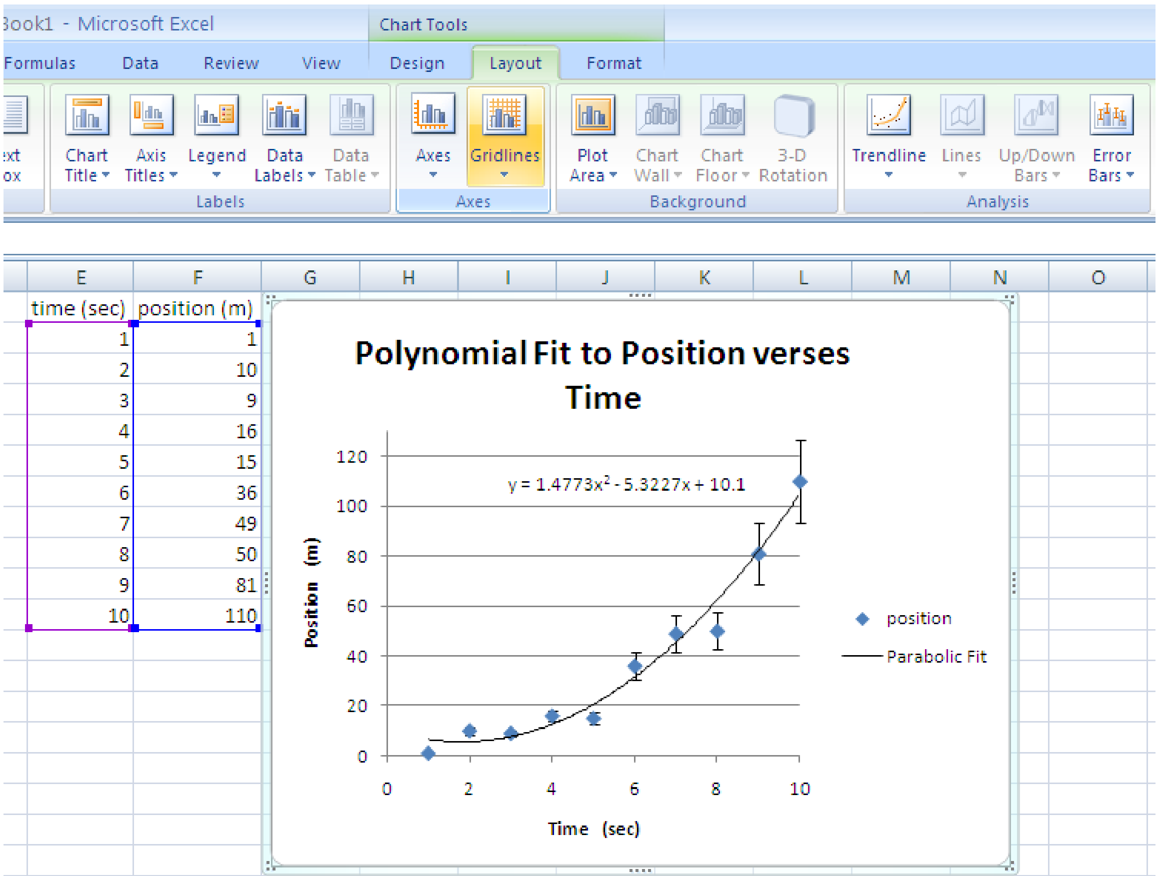
Labels:

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*.

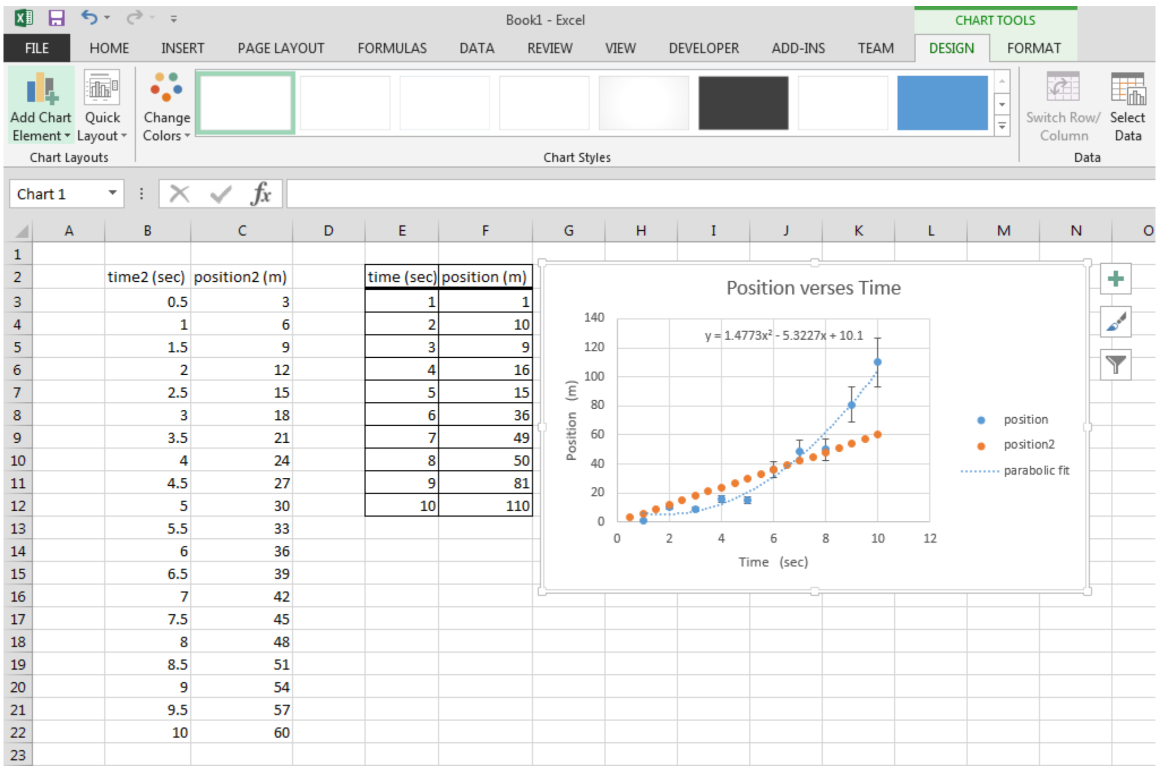
Error Bars:

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.

D. 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.



E. To make multiple plots, add a new time and position (time2 & position2) column as shown in the figure below. Click on the chart, then go to the **Chart Tools Design** tab, then click on **Select Data** in the *Data* section. Click on the **Add** button and type in a series name (call it *position2*). In the **Series X values** field, click on the far right data selection icon and then select the *x*-data in the *time2* column, and then press return. In the **Series Y values** field, click on the far right data selection icon and then select the *y*-data in the *position2* column, and then press return. This should produce the two plots on one graph.



Data Analysis

(*this is to be included in your Lab Writup due next week*)

(1) Using the data you obtained last week for the inclined plane lab, plot in Excel the *position verses time* graph. Put all data for *zero friction* for the two inclination angles (do not plot Procedure 10 where friction is involved) from last week's lab on the same Excel plot (and plot *all data points*). Make certain the *x* and *y*-axes are properly labeled with the right units.

$$v = v_0 + at \tag{1}$$

$$x = x_0 + v_0 t + \tfrac{1}{2} a t^2 \tag{2}$$

(2) Fit your position verses time graph with a parabola and determine the values x_0, v_0, and a from your fit.

(3) Using the data you obtained last week for the inclined plane lab, plot in Excel the *velocity verses time* graph (put all data for the two inclination angles [*for zero friction*] on the same plot). Fit this data with a linear fit and determine the values of v_0 and a from your fit.

(4) The theoretical acceleration is $a = g \sin\theta$ where $g = 9.8\,\mathrm{m/sec^2}$ and θ is the inclination angle. For the two inclination angles you used last week, what are your theoretical acceleration values for a ?

(5) How does your experimental values (from your *position* and *velocity* fits) of acceleration compare with the theoretical values? In this comparison, compute a *percent error* between your measured values of a (or *experimental value*) and the theoretical (or *accepted*) value:

$$\%Error = \left| \frac{Experimental - Theoretical}{Theoretical} \right| \times 100$$

noting that percent errors of 0.1% are excellent, 1%-5% are very good, 5%-15% are fairly good (expected in this lab course), and greater than 15% are poor measurements.

(6) Is there good agreement between theory and data? What may be possible sources, or causes, for the discrepancies?