EXCEL EXERCISE for PHY2048

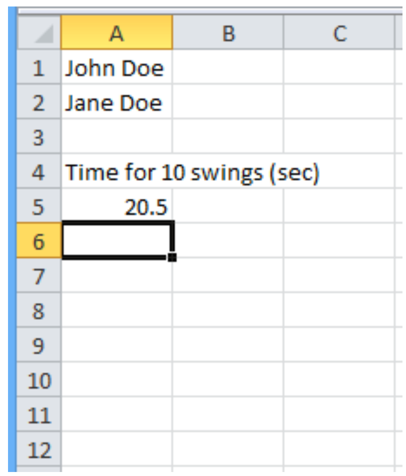
Objective: The following exercises will help you practice how to use the Excel spreadsheet to record your data, calculate some values and make graphs.

Exercise 1. Entering Data and Calculations in Excel

Fifteen students of a Physics Class observed a swinging pendulum. Each of them was holding a stopwatch and each one timed the pendulum as it made 10 swings back and forth. The times recorded by individual students are shown below.

Measurements in seconds:

20.5
21.2
19.9
20.6
18.9
21.1
20.6
20.3
19.8
20.0
19.6
20.4
21.5
20.2
20.8



a) **Enter the data in column A of Excel:** (An Excel spreadsheet contains cells which are arranged in columns and rows; columns are labeled by letters and rows by numbers. The top left cell is labeled A1). Enter your name in cell A1 and your lab partner's name in A2. In cell A4, type in *Time for 10 swings, (sec)* to identify the data and its unit. You may need to widen your column. On the second row (cell A5), start typing in the above data. See example on top.

b) **Calculate the period T of the pendulum using Excel, where T = (Time for 10 swings)/10:** On the top row of Column B (cell B4), type in *Period T, (sec)*. Equations in Excel always start with the "=" sign. On the second row of column B (cell B5), input the equation =*A5/10* and hit 'Enter'. You just divided your first time measurement (20.5 sec) by the number of swings (10) which gave you a period T = 2.05 seconds.

Excel makes it easy for you to calculate the rest of the periods. Go back to cell B5. Note the little square on the bottom right corner of the cell. With your mouse, left click on that square and drag it down to the cell beside the last data entry, i.e. B19, then release. This translates the equation for the period T to the selected cells and instantly calculates the rest of the periods.

Using Built-in Functions in Excel

Excel has built-in functions that can be used to obtain values like the AVERAGE and STANDARD DEVIATION for numbers in a column of cells. These functions can be invoked by using the form *=FUNCTION(starting cell:ending cell),* where the starting and ending cells define the range of data to be used. This range can be selected by left clicking on the starting cell and dragging it down to the ending cell.

c) **Get the average of the period T:** The average value of the period T can be obtained by adding all the values for T and dividing the sum by the number of T's added.

$$T_{ave} = (T_1 + T_2 + \ldots + T_N) / N$$

This can be done easily in Excel by using the built-in function AVERAGE. Go to cell B20 and type in *=average(starting cell:ending cell),* e.g. =average(B5:B19) then hit 'Enter'. This gives you the average period T_{ave}. Label it by typing in *AVERAGE PERIOD* in the cell to its left.

d) **Get the standard deviation of the period T:** The standard deviation σ is given by the equation

$$\sigma = \{((T_1 - T_{ave})^2 + (T_2 - T_{ave})^2 + \ldots + (T_N - T_{ave})^2) / (N - 1)\}^{1/2}$$

This can be a lengthy calculation but is done easily in Excel by using the built-in function STDEV. Go to cell B21 and type in *=stdev(starting cell:ending cell),* e.g. =stdev(B5:B19) then hit 'Enter'. This gives the standard deviation σ which is the uncertainty in the individual measurements of the period T. Label it by typing in *STANDARD DEVIATION* in the cell to its left.

Formatting your Cell Entries

There are several adjustments like centering, adjusting the number formats and many others that can be done to improve the appearance of your data tables. Some simple examples are shown below.

e) **Aligning your entries:** You may note at this time that all your numbers are staying on the right edge of your cells. A little bit of formatting may improve your data table. Try to center your entries by highlighting all the used cells (click on the first cell A1 and drag it down to the last cell used) and do the following:

Click on *Format Cells* – *Format Cells* – *Alignment* – select '*Center*' for Horizontal – *OK*

NOTE: A short cut to this operation can be done by highlighting the cells that need to be centered and then clicking on the '*Center*' option ≡ under '*Alignment*' of the HOME Tab.

f) **Setting the number of decimal places for your entries:** Some calculations in Excel turn out with a lot of decimal places, often many more than is warranted by the precision of our measurements. Then we need to round and drop the excess decimal places to make our result more meaningful and realistic. For example, the stopwatch used may only measure up to the hundredths of a second, so it may not mean much to have an average or standard deviation that is up to 8 decimal places. Set the average and the standard deviation to two decimal places by highlighting their cells and do the following:

Click on *Format Cells* – *Format Cells* – *Number* – *Number* – select '*2*' for Decimal Places – *OK*

NOTE: The short cut to this operation can be done by highlighting the cells that need to be adjusted and then clicking on the '*Decrease Decimal*' symbol under '*Number*' of the HOME Tab.

PRINT OUTPUT: See how much better your data table looks? Using *'File'* – *'Print'* and selecting the correct printer, print a copy of this table for each student in your group.

Exercise 2. Graphing Data:

When using Excel to graph data for two variables like velocity and time, you have to arrange the data in adjacent columns with the data on the left column plotted on the x or horizontal axis and the data on the right column plotted on the y or vertical axis.

A cart is moving and its speed was increasing constantly. The velocity of a cart was measured at different times and recorded as shown below. Using Sheet 2 in Excel, first type your name and your lab partner's name and then enter the following data in with time t in column A and velocity v in column B.

t (sec)	**v** (m/sec)
1	5.1
2	7.8
3	11.2
4	13.9
5	16.7
6	20.1
7	22.9
8	26.7
9	30.3
10	33.1

a) **Make a Velocity vs. Time graph with t plotted on the x axis and V plotted on the y axis:** To plot your data, highlight the t and V columns (the first column will be plotted on the x axis, the second column will be plotted on the y axis) then click on the 'INSERT' tab and click on the '*Scatter (X, Y)*' symbol under '*Chart*' and select '*Scatter*' symbol.

The graph of V vs t is now on your Excel sheet. Make the graph a little larger by clicking inside the graph near its border, moving the mouse to the corner of the graph, and dragging the arrow to resize the graph.

Next, label your graph! Click on the '+' symbol on the upper right hand side of your graph – click on the box for '*Axis Titles*'. On your graph, click on the title boxes twice and type in *'Velocity vs Time Graph'* for Chart Title, *'Time, t (sec)'* for the x-axis label and *'Velocity, v (m/sec)'* for the y-axis label. Note that in labeling your axes, it is important to always put in the variable name, its symbol and its units.

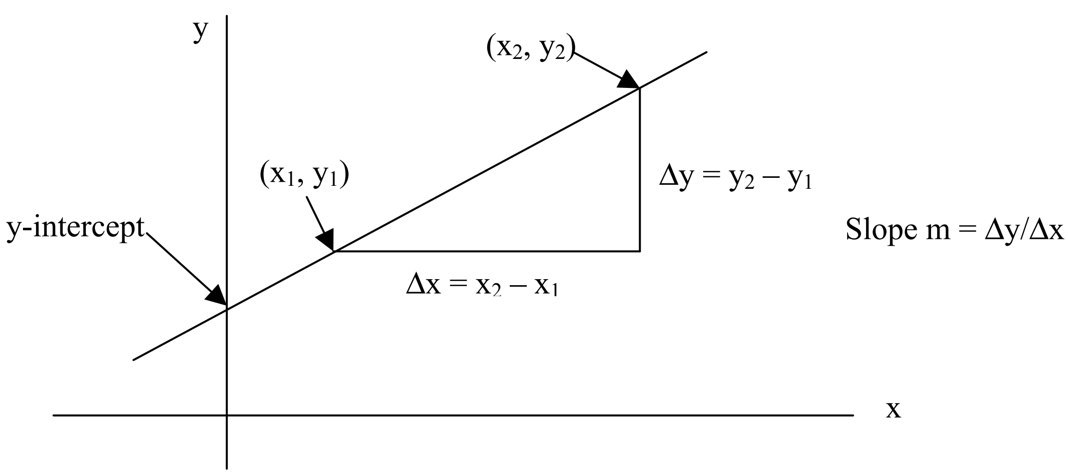
PRINT OUTPUT: Make sure your graph is active and selected (there should be little squares along its border, if not click on the outer edge of your graph). Print out a copy of this graph for each student in your group in order to do the activity (b) below.

THE EQUATION OF A STRAIGHT LINE

A straight line is described by an equation of the form y = mx + b where y is the variable plotted on the y-axis, x is the variable plotted on the x-axis, m is the slope of the graph which gives you a measure of how steep the line is and b is the y-intercept which is the point where the graph intersects the y-axis. If m and b can be determined, then we can obtain an equation which relates the two variables that are plotted.

b) **On this printed graph, draw the best fit line using a ruler.** The best fit line must pass through the majority of the points plotted with about an equal number of points above and below it. Do not force the best fit line to go through (0, 0). Some of these lines actually cross the y axis or the x axis.

c) **Calculate the slope m of the graph and estimate the y-intercept by hand:**
To get the slope m, mark two points on the line and draw a triangle as shown below.



Get the x and y coordinates of these two points and calculate the slope m = $\Delta y/\Delta x$ (expressed in decimals) where $\Delta y = y_2 - y_1$ and $\Delta x = x_2 - x_1$. Estimate the y-intercept b from your graph.

Show your slope calculation and your intercept on the printed graph. Write down the equation of the line by substituting the values of m and b in the equation

$$y = mx + b.$$

It is also customary to replace the variables y and x with the physical quantities that are plotted in the respective axes. In this exercise, replace y with v (for velocity) and x with t (for time). Now, write down the final form of the equation using v and t. In this final equation form, what does the slope m represent? The intercept b represents? Write your answers on your printout. Make sure to put your name on your printout.

FINDING THE BEST FIT LINE – USING LINEAR REGRESSION AND THE METHOD OF LEAST SQUARES FITTING

In many experiments, the values of a variable Y are measured using different values of another variable X. The prime objective is then to find the equation that relates these two variables. This is done by plotting the results of the two measurements and finding the line that best fits through the data. This means of predicting the value of Y for a given X is called the regression of Y on X.

The Method of Least Squares Fitting is commonly used to find the best fit straight line. The criterion for fitting the line is based on the idea that the difference between the data and the fitted line must be minimized. The most accepted practice to do this is by choosing the best fit line such that the following sum is a minimum:

$$[y_1(\text{measured}) - y_1(\text{best fit})]^2 + [y_2\text{measured}) - y_2(\text{best fit})]^2 +$$

$$[y_3(\text{measured}) - y_3(\text{best fit})]^2 + \ldots + [y_N(\text{measured}) - y_N(\text{best fit})]^2 .$$

This computation can be easily done (and subsequently, the best fit line is determined) by using a computer program like Excel as shown in activity (d) below.

d) **Getting the equation of the line from Excel:**
Go back to your chart in Excel. The equation of the line y = mx + b can be obtained from Excel by doing the following:

Click on *'+'* and move the mouse over *'Trendline'* and click on the arrow that appears – click on '*More Options*'.

If 'Linear' option is not shown, click on the 'three columns' symbol under '*Trendline Options*'. Then select '*Linear*' and '*Display Equation on Chart*'.

This will draw the best fit line for the plotted data and display the equation of the line with the form y = mx + b.

Click on your graph and hold, and move it under your data table for V and t. Also, type your name and your partner's name near the top of the page.

e) **Adjusting the page before printing**. Ensure that the data table and the graph print together in one page. To avoid having tables and graphs cut off, check out the Page Break Preview before printing. To do this, click on an empty cell then

Click on the 'VIEW' tab – click on '*Page Break Preview*'.

The solid blue line defines the whole range to be printed. The dashed blue lines define the boundaries of each page. If any 'dashed blue line' cuts through a graph or data table, adjust the page size by moving the mouse over the 'dashed blue line' to see a horizontal 2-sided arrow. Click and hold and move the dashed line to the solid blue line on the right. Now, your graph and data table are all in one page.

PRINT OUTPUT: Print this graph with the best fit line and equation on it with its corresponding data table, for each student in the group.

COMPARE THE RESULTS: On your graph print-out, write a comment on the following: Compare the slope m and intercept b that you obtained by hand in part c) to the slope and intercept of the equation obtained from Excel. Are your results obtained by hand close to the computed values? If not, you may need to review what you did and see where you made an error.

PLOTTING USING LINEAR REGRESSION IN EXCEL

So far a quick and easy way of plotting the variables and obtaining the equation from Excel had been utilized in this exercise. Oftentimes, your experiment requires a more in depth look at the plotted data – is the difference between the measured y values and the best fit y values (called "residuals") reasonably consistent? Are there any obvious outliers or bad data points? Also there are associated uncertainties or errors in the slope m and intercept b obtained in the equation for the best fit line and these uncertainties sometimes need to be addressed in the analysis of your experiment. In the next activity (f), the Linear Regression feature of Excel will be utilized to plot the Velocity vs. Time data.

f) **Plot Velocity and Time using Excel's Linear Regression**. To plot the Velocity vs. Time data using Linear Regression,

Click on the 'DATA' tab – click on '*Data Analysis*' and select '*Regression*' – OK.

In the window that comes out, click on *Input Y Range* – go to the column for Velocity, click on the top cell (i.e. the column title Velocity V (cm/sec)) and drag the mouse down to the last data cell. This defines the values to be plotted on the y axis. Click on *Input X Range* – go to the column for Time and click the top cell and drag the mouse to the last data cell defining the values to be plotted on the x-axis.

Note in this case that we have included the column titles in the range. Click on *Labels* specifying that the range includes the data labels. Also click on *Line Fit Plots – Residual Plots – New Worksheet Ply* – OK.

This gives two plots and some tables of statistical values. The Line Fit Plot shows the graph of velocity and time. The actual values of velocity are plotted in blue while the best fit values are in orange. (Note the plot titles include the variable plotted along the x axis, i.e. Time, t (sec) Line Fit Plot). The Residual Plot show how each of the actual values of velocity differed from the best fit values. The residuals (difference between the measured and best fit values) are shown in the "Residual Output". The table which has "Coefficients" and "Standard Error" columns gives us the values of the intercept b and the slope m and their associated uncertainties.

Click on the Residual Plot and drag it beside the Residual Output Table. Click on the Line Fit Plot and reposition it below the Residual Output Table. Resize the Line Fit Plot to make it bigger. Right click on a best fit point (pink) and *Add Trendline* which is *Linear* and *Display Equation* as done in activity (d). Go back to the top of the page and again, type in your names at a convenient location.

PRINT OUTPUT: **Adjust the page before printing** like you did in activity (e) using the *'VIEW' tab – Page Break Preview*. Make sure the tables and plots are all contained in 1 page before printing a copy for each group member.

g) **Finding the slope and intercept and their uncertainties.** On your print out, circle the number labeled "Intercept" under "Coefficients". This is the value of the intercept b in the equation y = mx + b. Circle the number labeled "Time t (sec)" under "Coefficients". This is the value of the slope m. The uncertainties for the slope and the intercept are the corresponding numbers beside each of them under the column "Standard Error". Identify and encircle each of these uncertainties on the print out.

h) **Inspecting the residuals of the data plotted.** Look at the Residuals Plot. Write a comment on whether the points are equally scattered above and below the best fit line. Are there stray points or obvious outliers or possibly a point which was entered erroneously?

TURN IN THE FOLLOWING TO GET CREDIT: (1) the data table for Period in Exercise 1, (2) the graph with the hand drawn line and slope calculations, (3) the Excel graph with the best fit line and equation of the line and corresponding comments and (4) the plots and statistical tables obtained from the linear regression activity and corresponding comments.

For more practice on Excel, checkout the following website:
http://www.usd.edu/ctl/self-paced-tutorials/microsoft-office-excel-2013

NOTE: Keep these exercises in mind as they will be greatly utilized in the data recording, calculations and graphing requirements of several lab experiments done in this course.

Prepared 2015 by B. Rimando Reyes
Excel Exercise V.3 (Microsoft 2013)