Experiment 1

Introduction to Data Analysis Using EXCEL

I. Purpose

The purpose of this lab is to teach you a few basic things about using EXCEL 2016 to plot data, analyze results and work out answers to the pre-lab assignments. If you have somehow managed to get this far without learning how to use a spreadsheet, now is a good time to start to learn, especially since you will need to use it all semester for homework and labs.

Section VI is a general introduction to spreadsheets and then discusses how to use EXCEL 2016 for some basic tasks as well as some more advanced features. You need to read through this before you get to the lab. If you have not used EXCEL before, or are not familiar with some feature in EXCEL, start-up a spreadsheet and work along as you read through the write-up. Section VII has some useful shortcuts that make it easier to work with the spreadsheet.

The final part of this lab, Section VIII, is an exercise that takes you through many of the spreadsheet operations that are used in the labs. **Everyone must complete Part VII** and turn in a copy of his or her spreadsheet to ELMS Canvas before it is due to get credit for this lab.

II. Preparing for the Lab

You need to prepare before going to the lab and trying to do this experiment. Start by reading through this lab write-up before you get to the lab. The Introduction Sections VI and VII are long - you need to read them before you get to the lab. For a video introduction to Excel by Jordan Goodman, we recommend https://youtu.be/ZVkrjrDKMZw . Finally, don't forget to do the Pre-Lab questions and turn them in to Expert TA before your lab starts.

III. References

If you are **not** already comfortable with using EXCEL and need more detail than found in this write-up, try clicking on Excel's Help button.

IV. Equipment

You will need a copy of Excel Template for Lab 1 and a computer with Excel running Windows 10. Note: the lab templates may not work with older versions of Excel.

V. Pre-lab Questions *(Submit answers to Expert TA before your lab section meets)*

Questions and multiple choice answers on Expert TA may vary from those given below. Be sure to read questions and choices carefully before submitting your answers on Expert TA.

#1. A cell in an EXCEL spreadsheet contains A5. What does it mean? *(pick one)*
(a) Cell A5 is formatted as a currency. (b) Cell A5 is a fixed cell. (c) This tells Excel that cell A5 is text rather than a numerical input. (d) This means the cell contains a formula. (e) This is EXCEL's way to indicate the cell contains an error.

#2. Given an x-coordinate and a y-coordinate for a point, which type of chart in EXCEL will actually plot the point at its Cartesian coordinates? *(pick the best answer)* (a) line chart, (b) pie chart, (c) scatter chart, (d) bar chart, (e) all of the others except the pie chart.

#3. In EXCEL, what is the Solver used for? *(pick the best answer)*
(a) Finding errors in a formula, (b) minimizing or maximizing a cell by varying other cells, (c) doing error analysis, (d) solving algebraic equations, (e) solving differential equations.

#4. To run a macro in EXCEL, you may need to first click on.....? *(pick the best answer)*
(a) a cell and type in the macro formula, (b) the home tab and then click on the paste button, (c) the insert tab and then enter your macro into a cell, (d) the view tab and then click on the macro button.

#5. Before the lab template will let you exit from EXCEL, you must have (a) entered your name in the designated area of the spreadsheet, (b) entered your section number in the designated area of the spreadsheet, (c) saved the file using the gray save button in the body of the spreadsheet, (d) all of the above.

VI. Introduction

Spreadsheets

A spreadsheet is a computer program that makes your computer display act like a smart piece of paper. It removes much of the grunt work associated with repetitive calculations and lets you easily see the results of your work. Traditionally accountants used spreadsheets to do bookkeeping and budgets, but they make outstanding tools for scientists as well. In the physics labs, using a spreadsheet reduces the amount of time it takes you to plot and analyze data. In particular, you can enter raw data, manipulate it and plot it with a few simple commands.

One thing that makes an electronic spreadsheet much more powerful than a calculator or a paper spreadsheet is that every time you change a number or formula in your spreadsheet, everything else in the spreadsheet gets **automatically recalculated**, including plots. So if you make a mistake and have to re-measure a quantity, or change a formula, all numbers connected to it are automatically updated. Another thing that makes a spreadsheet powerful is that everything is displayed in an intuitive graphical interface (the spreadsheet). With everything displayed, it is easier to understand your data and spot problems.

Yet another reason spreadsheets are extremely useful for data analysis is because of their ability to plot data. Rather than having to draw a graph by hand, you can just select the numbers you want to plot and let the spreadsheet do the work. Even better, if you change the numbers or formulas, the graph changes automatically. If you want to copy a plot, you can make as many as you want and paste them into **MS Word** files or **PowerPoint** slides. Still another advantage of a spreadsheet is that it can easily handle the **statistical analysis** of data sets with hundreds, thousands, or even tens of thousands of points, something that you would never want to try doing on a calculator. Some examples of functions that are particularly useful in analyzing data are the **average**, the **standard deviation** and a least square fit of a straight line (known as a linear regression) to find the **slope** and the **intercept**.

Given the many advantages of using a spreadsheet, you should never use a calculator in any of the labs because it is poorly suited to the job of recording, plotting, analyzing and saving data. Of course, spreadsheets do have some significant limitations. They are not good for working with data sets that are very large, or that require symbolic manipulation, or that involve extensive signal analysis, sophisticated physical modeling, or custom image processing, are best handled using more sophisticated programs or custom written software routines.

Cells, Rows and Columns

A spreadsheet display consists of a collection of **cells** arranged in a table. The cells are labeled by their column and row location (see Table 1 below). For example cell B3 is in the second column, the third cell down. A cell can contain **text**, a **number**, a **formula**, or a **logical value** (true/false). To **enter** something into a cell, click on it with the mouse, type in some text, and then hit enter. The spreadsheet will display the text in the cell (see cell A1 or cell C1 below in Table 1). You can also enter numbers like 15 (see cell A2) and formulas (see cells A2 and A3). Cell B1 contains a simple **formula** that is, of course, equal to 6. In Excel, all formulas begin with an equals sign. If you type this formula into cell B1 and then hit enter, you will see that the spreadsheet now displays the number 6 instead of the formula =3*2 (see Table 2).

The formula in cell B2 shows a different example. It says =2*A2. What this means is twice the value of the cell A2. Since A2 is currently 15, B2 displays the value 30 (see Table 0.2). If the number 15 in cell A2 is changed to 20, then the spreadsheet will immediately recalculate everything and cell B2 would get changed to 40. This way of setting up formulas, with parameters being displayed in other cells, is very useful because it makes it easier to find and correct mistakes.

So if a cell has a formula in it, and EXCEL displays this as a number, what do you do if you want to see the formula and not the number? If you want to check a formula or change a formula, you need to see it. The best way to get EXCEL to **display a formula** in a cell, rather than the result produced by the formula, is to double-click on the cell. When you double-click on a cell, EXCEL not only shows you the formula in the cell but also **highlights any cells that the formula is using**. This simple feature turns out to be especially powerful for helping you find mistakes in a formula.

Another really convenient feature of spreadsheets is the ability to replicate formulas. As an example, suppose that you wanted to extend the above spreadsheet so that the numbers go from 15 and 16 all the way to 25. Of course you could type 17, 18, … into cells A4, A5 *etc.*, but this is unnecessary. Instead, you can use the **copy** and **paste** tools to replicate the formula in cell A3 to

Table 1- This shows what to put in various cells in the spreadsheet.

	A	B	C	D	E	F	G
1	text	=3*2	mass				
2	15	=2*A2					
3	=A2+1	=2*A3					
4							

Table 2- This shows what the spreadsheet displays.

	A	B	C	D	E	F	G
1	text	6	mass				
2	15	30					
3	16	32					
4							

the cells A4 to A12. Cell A3 has the formula =A2+1 in it. Now what you would like in cell A4 is not exactly the same formula as A3, but you would like it to say A3+1 (not A2+1). This way it will become 17. When you copy and paste a formula, the formula is automatically changed in just this way. For example, if you copy the formula A3 and paste it into cells A4 through A12, the formulas will become =A3+1, =A4+1, =A5+1 *etc.* all the way to A11+1. If you were to copy the formula in B2 and paste it into C2, it would change in a similar manner. It would change from =2*A2 to =2* B2, and in your example the value would become 2*(2*15) or 60. You rarely have to type a formula more than once, even if it is used frequently. Also if you have a column of formulas and you want to change, you can change one cell and copy it to all the others.

Sometimes you will want to copy a formula, or move it from one place to another, without having it change. There are a several ways to do this in Excel. The simplest way is to use **cut** and **paste** instead of copy and paste. For another way, see the discussion of the $ symbol below.

Excel 2016

If you are not already familiar with Excel 2016 in Windows 2010, open up a worksheet and try using all the commands as you go through this section at home on your own computer. We also recommend viewing https://youtu.be/ZVkrjrDKMZw which is Jordan Goodman's video introduction to Excel. On the other hand, if you are familiar with Excel, you can skip this section, but make sure you read through the Section VII on *Excel Shortcuts & Tools*.

1. Opening and Saving Files

You can open an Excel spreadsheet by clicking on the Excel icon on the desktop and selecting **Blank Workbook**. After the spreadsheet opens, click on the **Save** button on the left top side of the menu bar and then enter a file (make sure your name is in the file so you can find it). Excel will save the file in the **Documents** folder - our desktop setup prevents you from saving files in other folders. You should try to remember to regularly resave your files!

2. Moving around the spreadsheet

You can move from cell to cell by using your mouse, the cursor keys, or by using the **PgUp** and **PgDn** keys. There are also sliding scales on the right side and bottom of the worksheet which you can move with the mouse to move around the worksheet. You can also go directly to a specific cell by pressing the **F5 key** and entering the cell address. The cell addresses in Excel are in the form "C23" or "sheet1:C23", which is cell C23 on sheet1.

Excel also lets you have many worksheets in the same "notebook". The tabs on the bottom of the worksheet let you switch from sheet to sheet.

3. Entering Information

To put information into a cell, click on the cell or move the cursor to that cell and type in the information. The characters that you type will appear on the top left of the page on the third line (called the **display line**). Press the **Enter** button after typing something and it will enter it into the sheet. If you press the **Esc** key it will abort the entry and leave the cell unchanged. To enter an expression in a cell, you can type in the cell or you can move the cursor to the **display line** at the bottom of the menu bar and edit the expression there.

4. Entering Numbers and Text Into a Cell

Numbers are entered by into a cell by simply clicking on a cell and typing a number. Try typing the number 15 in the cell B7. If the number is negative just start it with a minus sign.

Putting labels on your data lets you make your spreadsheet readable to you and to others. While there are some limitations (such as it is clumsy to get Greek letters), it is easy to add text to a spreadsheet. If you just type words into a cell they will show up in that cell. For example try typing your first and last name into cell A1. Actually, that is a good thing to do with all of your spreadsheets. If the text is longer than the cell width (which is adjustable) the whole text will show up if there are empty cells to the right of the cell with the text in it. If the string is long and the cell next to it is occupied the string will show up cut off, but it is all still there. You can adjust the width a column by clicking on the markers that separate the columns at the top of the worksheet (ask your instructor if you are not sure how to do this).

5. Entering Formulas

For a short video by Jordan Goodman on using formulas in Excel, see https://youtu.be/caQGqjFo3xY. Formulas are indicated by starting with = (an equal sign). For example, if you type **=2*3** into a cell and hit enter, it will display 6 in the cell. If you click on the cell, it will show you the formula in the cell and on the display line. Formulas can be much more complicated expressions, involving other cells and statistical and mathematical functions. A formula like =2*B5^3 means 2 times the contents of cell B5 raised to the third power. You can use parenthesis in a natural way, for example =1/((1/B3)^2+(1/B4)^2)^(1/2). The spreadsheet has functions such as sine and cosine. For example, to find the sine of the angle $\pi/2$, you would type =sin(pi()/2) into a cell. Note that Excel takes angles in radians, not in degrees. Also π in Excel is written as =pi() which is a function with no argument. If you type =sin(C3) this will take the Sine of the contents of cell C3. To find the cosine of the angle $\pi/2$, you would type =cos(pi()/2).

Excel has many familiar functions as well as many special functions that you are only likely to encounter in more advanced math, physics or statistics classes. Some examples of common spreadsheet functions are:

=average(…)	=stdev(…)	=count(…)	=sum(…)
=max(…)	=min(…)	=sqrt(…)	=slope(…)
=intercept(….)	=exp(…)	=pi()	=cos(…)
=sin(…)	=tan(…)	=atan(…)	

The list of available functions can be viewed by clicking on the **function button *fx*** on the menu bar at the top of the worksheet and choosing "all". If you want a description of the function, click on its name. A description will appear at the bottom of the function box. Function names in Excel are not sensitive to case. You can type =COS or =Cos or =cOs.

Some functions take lists of numbers or a range of cells. For example, =**Average**(5,6,7,8) will return the value 6.5. The formula =**Average**(A1:A20) will find the average of the values in all the cells from A1 to A20. The **colon** between A1 and A20 is Excel's way of saying A1 to A20, inclusive. If you used a comma instead to separate the A1 and the A20, it would just find the average of the numbers stored in A1 and A20. Most spreadsheet functions are "smart"; if your range includes empty cells they are not counted in the average or other statistical function, but if there is a zero, it will be included. ***Note: there is a distinction between empty and zero.***

6. Pointing at Cells

When you first start using a spreadsheet, you may waste a lot of time typing cell numbers into equations and expressions and you will make many mistakes. A much better way to put a cell number into an expression is to **point** at it or **click** on it. For example, suppose you have recorded the value of an angle θ in Cell A10 and now want to find the cosine of θ. You can go to cell A11 and simply type =cos(then use the mouse to move the cursor to cell A10 and click on the cell. At this point your expression will read =cos(A10. Now just type in the closing parenthesis), which will give you =cos(A10), and hit enter.

7. Selecting Ranges

You can also select or point at groups of cells. This is useful for expressions such as the average or standard deviation that expect ranges as arguments. It is also useful when you want to mark a region that needs to be moved or copied. If you need a range of cells, use the mouse to move the cursor to the first cell in the range and hold the left mouse button. Now "drag" the cursor to the last cell in the range and release the button. You should now have the range highlighted and displayed in the display line.

8. Copying a formula

EXCEL allows you to copy the contents of one cell to another. However, it is a "smart copy", and will often change the contents during the copy. Most of the time you will find this is an extremely useful feature, as you will see below, but whenever you do a copy using EXCEL, be sure to check and make it did what you wanted!

To see how the smart copy works, suppose you have 20 numbers in cells A1:A20 and you want to find the Sine of these numbers (see Figure 1). To do this, enter in cell B1 the formula =sin(A1). Now that you have the formula in one cell, there are several ways to copy it to cells B2:B20, including using the **Copy button** and using **Ctrl c**. In this case you need to copy to cells right below cell B1 and the simplest way to do this is to click on cell B1 and notice that Excel has not only highlighted cell B1 with a black box, but it has also put a small black square in the lower right corner (see Figure 1). Carefully place your cursor over this little square and then click, hold, and drag the square down to cell B20 and this will copy the formula into cells B2:B20. Note that in cell B2 that Excel has changed the formula to =sin(A2), and not =sin(A1). This means column B has the sine of the values in column A, which is what you want. The way that Excel updates the cell names as it copies is what makes Excel's copy so smart.

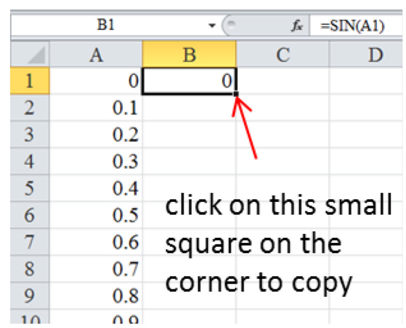

Figure 1. Clicking on a cell highlights it and Excel places a small black square in the corner.

Of course sometimes it will happen that you do not want the cell location to change when you copy a formula. This is called making a "fixed cell". To make a fixed cell in a formula so that it doesn't change when copying, you need to add dollar signs, for example B1. There are two dollar signs in the expression shown here because it is possible to fix the column and the row or both. If you just wanted to fix the row, you would use B$1. The "B" would then change according to the **"smart copy"** rules during the copy. If you just wanted to fix the column, you would use $B1. An example where you might want to use this is: You have a column (A1:A20) of measured accelerations "a" and you want a column of forces and all objects have the same mass. If the mass "m" is in cell D1 your formula for the force "F" in B1 might be =D1*A1. This way when you copy the formula to B2 it will be =A2*D1. If you didn't use $ signs, the formula would have been $A2*D2 which would be wrong if the mass was in D1. For a short video on fixed cells, see https://youtu.be/zjWWIhb4XTs.

9 - Plotting Data

The **only** type of chart you should ever use in Excel is a **Scatter** chart. Using any other type of chart can cause serious mistakes. Although Excel can draw many different types of charts, only a Scatter chart will plot an x-value and a y-value as a point at the coordinates (x,y) in the Cartesian plane. For example, a Line chart plots the y-values versus the order in which the points are given and it does not use the x-values to determine the x-coordinate. To be clear, you should **only use a Scatter chart** and **never use any other type of chart in Excel**.

Typically you will plot one column of numbers (y coordinates) versus the numbers in a second column (x coordinates). For example, suppose you want to plot y = sin(x) versus x. To do this, you will need to put some x-values into one column and then put the sine of them in a second column. Start by entering the label "X (rad)" into cell D1. Next enter 0 into cell D2. Then in D3 enter =D2+0.3. Next copy this formula from D2, D3, ... D20. Next enter the label "y=Sin(X)" into cell E1. Now in E2, enter =SIN(D2). Copy this formula to cells E2,...E20.

To plot this data, go to the top of the spreadsheet and click on the **Insert** tab (see Figure 2). Now use your mouse to select cells D1 to D20 and cells E1 to E20 (to select the group of cells just click on cell D1, hold the left mouse button down as you drag the mouse to cell E20, and then release the mouse button). Then look for the section of the menu at the top of the spreadsheet that says **Charts** and click on **Scatter** (see the note below about why you should always use Scatter plots). You will be presented with a sub-menu of different types of scatter plots (just points, just lines, lines and points, etc.), choose any one of these by clicking on it. You should now see a plot and notice that the menu at the top of the spreadsheet has changed. Click on the **Chart Layout** menu and try selecting Layout #10, which has a nice format. All of your plots should have labels on the x and y-axes. In this case, Layout #10 just has default labels that say "Axis Title". To change the **axes labels**, just click on them and type in "X (rad)" for the x- axis label and "y=Sin(x)" for the y-axis label.

If your plot is covering some cells that you want to see, just click on the chart and you can move it to the side with the mouse. Notice that when you click on the chart, Excel will **highlight columns that are being plotted**. This is very useful because a common and confusing mistake is to plot the wrong set of numbers. To avoid this mistake, you should get into the habit of clicking on your charts and letting EXCEL show you what cells it is using for the plot.

10 - Modifying Charts, Adding Titles and Labels, and Copying charts

If you want to change something in a chart, just try right-clicking or left-clicking on it - you can change the axis limits, the chart background, the type of chart, the curves being displayed, the grid, the tick marks, and the maximum and minimum range being plotted. To change the x-axis label, the y-axis label or title on a chart, just click on it and type in the new label or title. Clicking on one of your points in the chart lets you change the symbols used in the plot, as well as their size and color, and the line-width and color of the line in the plot. If you forgot to add an axes labels or a chart title, just right click on the chart, then go to the **Chart tools** area on the menu bar, click on the Layout tab and hit the chart title or axis titles buttons.

It can takes time to get a chart with the axes properly labelled and everything else looking just right. If you have to make another plot of some more data, you could just go through the same steps needed to make a plot from scratch. However, there is an easier way. Just click on the plot you made (this selects it) and then click on the **Copy** button on the **Home** tab. Next click on an empty cell and hit the paste button. This creates a copy of your plot. Of course it is plotting the same thing as your first plot, but it is very easy to change what is being plotted. Click on one of the data points and EXCEL will highlight the cells that are being plotted by drawing a cyan box (x-coordinates) or blue box (y-coordinates) around them. To change what is being plotted on the x-axis, just move your mouse over the border of the cyan box, click and hold, and then move your mouse until it is over the x-coordinates for the plot that you would like to create - the cyan box will follow - release the button when the box is over the coordinates you want to plot. You can choose a new set of y-coordinates the same way.

11 - Adding Another Curve to an Existing Plot

Suppose you have already made a plot of your data and you want to add a curve for a theory. One way to do this is to **right click** on the plot and then click on **Select Data** in the pop-up menu that appears. A new pop-up menu will open and you should click on the **Add** button. Once you do this, another pop-up menu will appear which will allow you to enter a series name and select the x and y columns for the second data series. Once you fill these in, just click OK and you should see your new plot with both curves. Of course for this to work, you need to have set up columns with x and y theory values that you can select.

Sometimes you will make a plot and forget to add axes titles. Just click on the chart and notice a small menu opens up to the right of the chart. Click on the + symbol in this menu and you will see check-boxes for things like the **chart title**, **axis titles**, **error bars and legend**. A new menu also appears at the top of the spreadsheet called **Chart Tools**. Select the **Design** tab and then select **Add Chart Element and choose** from this menu what you want to add. Another way to add axes labels is to click on the chart, select the **Design** and then pick a chart from one in the **Quick Layout** menu that has axes labels already in them (edit the default titles by clicking on the label and typing).

12 - Modifying Charts, Adding Titles and Labels, and Copying charts

If you want to change something in a chart, just try clicking on it - you can change the axis limits, the chart background, the type of chart, the curves being displayed, the grid, the tick marks, the maximum and minimum range being plotted, and the error bars. To change the x-axis label, the y-axis label or title on a chart, just click on it and type in the new label or title. Clicking on one of your points in the chart lets you change the symbols used in the plot, as well as their size and color, and the line-width and color of the line in the plot. If you forgot to add axes labels or a chart title, just click on the chart and a small menu will appear to the right of the chart. Click on the + symbol in this menu and you will see check-boxes for things like the **chart title**, **axis titles**, **error bars and legend**.

It can take a fair amount of time to get a chart with the axes properly labelled, error bars in place and everything else looking right. If you have to make a second plot of some other data, you could just go through the same steps outlined above. However, after you have made one plot, you can click once on it (this selects it) and then click on the **Copy** button on the **Home** tab. Next click on an empty cell and hit the **paste** button. This creates a copy of your plot. Of course it is plotting the same thing as your first plot, but it is easy to change what is being plotted. Click once on one of the data points and EXCEL will highlight the cells that are being plotted by drawing a cyan box (x-coordinates) or blue box (y-coordinates) around them. To change what is being plotted on the x-axis, just move your mouse over the border of the cyan box, click and hold, and then move your mouse until it is over the x-coordinates for the plot that you would like to create - the cyan box will follow - release the button when the box is over the coordinates you want to plot. You can expand or shrink the box by clicking on the corners.

13 - Adding Graphics to a Plot

Charts in EXCEL are created with a uniform white or gray background. If you have a file with a photograph or image, Excel can plot on top of it by changing the chart background. To do this, right-click on an open part of the plot - you need to click inside the area of the plot and avoid data points and grid lines. A window will open and you need to click on **Format Plot Area** - if you don't see it, then you probably clicked outside the plot area or clicked on a gird line or data point and you just need to try clicking on another location in your plot. After you click on Format Plot Area, the Format Plot Area window will open. Select **Fill**, then select **Picture or Texture Fill** and finally select **From File**. A browsing window will open and you can now locate your image file that you want to use as the chart background.

14 - Significant Figures

EXCEL does not automatically keep track of significant figures. This is a serious shortcoming in science and engineering. However, you can manually format cells to display the desired number of digits after the decimal point. To do this, click on the cell, then click on the **Home** tab. Find the **Number** section of the menu (see Figure 2) and click on the buttons for increasing or decreasing the number of digits displayed - each click on the button changes the number of digits displayed by 1. Other options in the number section of the menu allow you to change the number format to scientific notation, percentage, date, or other common formats. If you need to set the number of digits displayed in front of the decimal point, you have to switch to scientific notation by going to the pull-down tab in the **Number** section.

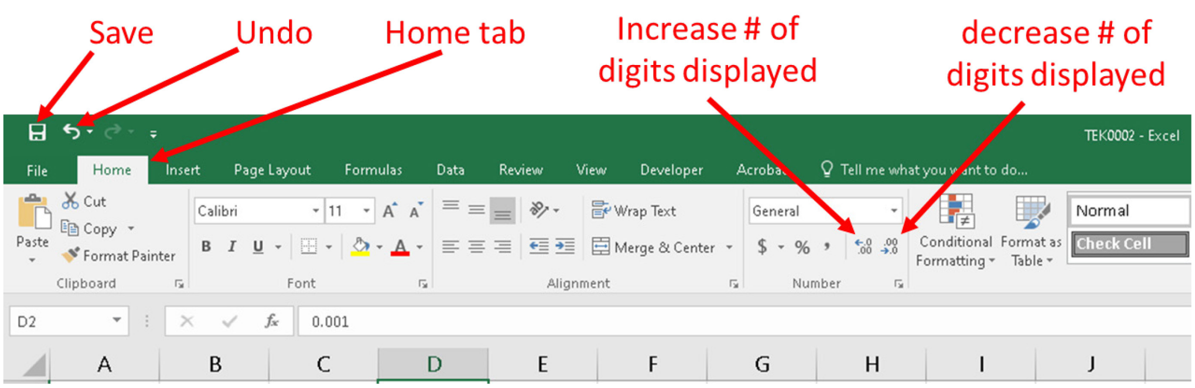

Figure 2. Buttons for changing the number of digits displayed in a cell.

15 - Fitting to Data - Least Square Fits to a Straight Line

There are several ways that you can use EXCEL to fit data to a straight line.

Suppose you have some data in the form of x and y-coordinates that you want to fit to a straight line. For example, suppose you have x-coordinates 1, 2, ..., 20 in cells H2 to H21 and y-coordinates 3, 5, 7, ..., 41 in cells I2 to I21. EXCEL has built-in functions that can determine the **slope** and **intercept** of the straight line that is the best least-square fit to the data. To determine the **slope** of the best least-square fit line, go to an empty cell, and enter =SLOPE(I2:I21,H2:H21). Note that first range of cells I2:I21 is for the y-values and the second range H2:H21 is for the x-values. If you put the x-range first and the y-range second, you will get the wrong slope. To determine the **intercept** of the best fit line, go to another empty cell enter the formula =INTERCEPT(I2:I21,H2:H21). You can now use these slope and intercept values to calculate the best fit y value for any given x value.

A second way to do a least-square fit of some data to a straight line is to click on the **Data** menu tab on the top of the spreadsheet, then click on **Data Analysis** (it's on the far right side), select **Regression** and fill in the pop-up menu.

If you have a plot of your data, then there is a third way to do a least-square fit of a straight line to your data by adding a **trendline**. To add a trendline, go to your plot and right-click on one of your data points. Then select **Add Trendline** from the pop-up menu. The **Format Trendline window** will open and you can now select **linear** to put a straight line through your data. You will also want to select the **Display Equation on Chart** option, which will then give you the equation of the best fit line.

Note that these three least-squares fits will give you exactly the same answer, but that does not necessarily mean the fits are meaningful. You need to exercise caution when it comes to fitting data and there are many subtleties. EXCEL can fit a straight line to any data, whether or not it looks anything like a straight line. What EXCEL cannot do is tell you whether the fit is good or whether it is reasonable to try to fit the data to a straight line. In fact, a least-square fit may not even be the best straight line fit to your data and EXCEL will not tell you if there is a better fit. To answer such questions, you need to use a more powerful fitting technique such as χ^2-fitting (chi-square fitting). See Section 9 below for how to do a χ^2-fit and Appendix A for a discussion of the differences between least-square fitting and χ^2-fitting and how to decide if a fit is good.

16 - Macros

An EXCEL Macro is a program that Excel can run in the background. Macros can greatly extend the power of EXCEL by automating complex tasks, creating new functions that don't exist in EXCEL's standard library of functions, or handling a wide variety of data collection and manipulation tasks. In Physics 121, we provide macros in some experiments for collecting data or handling some particularly difficult, sophisticated or time-consuming parts of the analysis.

While you won't need to create a macro, you will need to know how to run them. To run a macro, you first need to get a spreadsheet template with the macro in it. For each experiment, the macros that you will need are included in the spreadsheet for that experiment. After you open the template, EXCEL may warn you that macros are present and it has disabled them - this is a security precaution and you should never enable macros on a spreadsheet from an unknown source since they can contain viruses. If you get this warning on a Physics 121 template, you will to click **enable macros** or else the macro will not run.

Before running a macro, you will need to enter any data that the macro will need - this depends on the macro and there will be explicit instructions in the lab write-up for each macro.

There are two ways that you can run a macro. In most of the spreadsheets we have added buttons to the spreadsheet that start the macro - just click on the button and the macro will automatically respond. The other way to run a macro is to click on the **view** tab, and then go to the far right end of the menu bar and click on the **macros** icon. A window will open with a list of all the macros that are available to that spreadsheet. Just select from the list the macro that you want and then click on the **run** button. If you don't see the macro that you want on the list, it means your spreadsheet does not have that macro and you have downloaded the wrong template.

VII. In-the-Lab EXCEL Exercise

Get Started

Step 1 - On the lab computer’s desktop, find the folder called **Lab Templates** and open the EXCEL template called **Phys 121 Lab 1 template**. Do not use any other spreadsheet or a copy of a template from someone else - we keep track.

Step 2 - If you get a warning that macros have been disabled, click on “enable macros”.

Step 3 - Your spreadsheet should look similar to Figure 3 with a table of simulated data and some highlighted cells, but without the plots and some of the other areas filled in. The spreadsheet shown in Figure 3 is from an early prototype and the colors and layout may be somewhat different in the final version you will get. Cells that are highlighted **beige** or **light brown** need to have answers filled in. The column with times t is meant to indicate when a measurement was made on the speed of a cart, the next column shows the corresponding measured speed v of the cart, and the next column shows the uncertainty Δv in each measurement of v.

Step 4 - Enter your name, your section number and the date in cells B4, B6 and B7. If you have a lab partner, enter their name into the designated cell (if you do not have a lab partner, you will need to type “none” or “NA” into this cell). The cells change from beige to yellow after you fill them in. ***The templates have been set up so that the usual EXCEL save button is disabled. Instead, to save the file, you must have entered your name, your lab partner’s name (or “none” if you do not have a lab partner) you’re your section number into the spreadsheet in the designated area and then click on the gray save button in the body of the spreadsheet. The template won’t let you exit from EXCEL until after you have saved.***

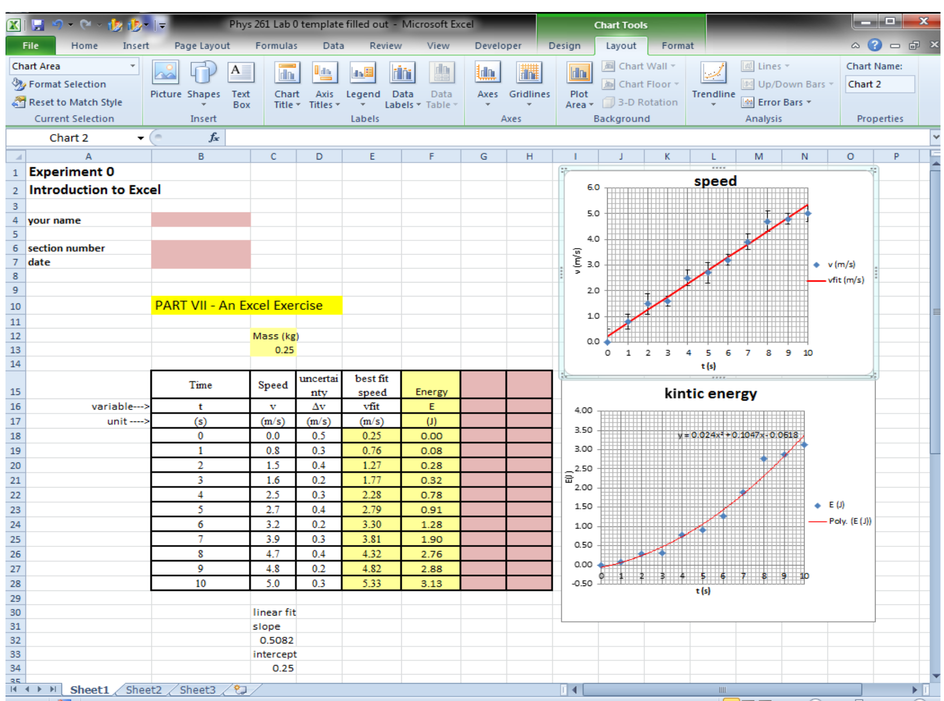

Figure 3. Prototype Spreadsheet for Lab 1. The upper plot has blue points showing v versus t with error bars and a red line for the best fit line. The lower chart shows a plot of the kinetic energy E versus time t (blue points) and the black curve is a polynomial fit (quadratic fit) to the blue points. Notice that the numbers in the table in columns E and F have been formatted to display two digits after the decimal point.

Plotting

Step 5 - Make a scatter plot of the speed v versus the time t. (discussed in section 9 above)

Step 6 - Label the x and y axes of your plot. The x axis should be labelled "t (s)" and the y-axis should be labelled "v (m/s)". (discussed in section 11 above)

Step 7 - Add error bars to your plot using the uncertainties Δv given in cells D18 to D28. (discussed in section 11 above)

Linear fit

Step 8 - In cells C32 and C34 calculate the **slope** and **intercept** of the v versus t data - make sure you treat the times as x-coordinates and the speeds as y-coordinates. (discussed in section 15 above)

Step 9 - Go to column E and use the slope and intercept values you just found to compute the best fit speed at each time. The best fit for the speed (which you should think of as the y-values) as a function of the time (which you should think of as the x-values) are found by using the formula for a line Y= mX + b. Also remember that the slope m (which is in cell D32) and intercept b (which you put in cell D34) should be "fixed" with $ signs in your formula so they don't change when you copy the formula.

Modifying a Plot

Step 10 - Add a curve showing a plot of the best fit speed versus time to the same graph as the v versus t data. To do this, try right-clicking on the chart and then click on select data and then click on add data. (discussed in section 11 above)

Step 11 - Figure out how to get the data to be plotted as blue points and the best fit to be plotted as a solid red line without points. Try right-clicking on a point in your plot, select Format Data Series and follow where it leads. (discussed in section 10)

Step 12 - Add a title ("Speed") to your chart.

Working with Formulas and macros

Step 13 - In cell F18, enter the formula for the kinetic energy of the object with the speed shown in cell D18. (Remember that kinetic energy is 1/2 mv^2). Check that you have used a fixed cell location for the mass. Your formula in cell F18 should be

=0.5*C13*C18^2

Step 14 - Copy the formula in F18 to the range F19…F28

Step 15 - Make a plot of the energy E versus time t. Add a chart title and label the axes.

Step 16 - Add a polynomial fit to your plot of the E versus t data (just right click on a data point on your plot, select add trendline and then choose polynomial). Make sure you also select display equation on the plot. If you forgot to select display equation and already closed the trendline window, just double-click on the fit curve to reopen the window and you can select display equation.

Step 17 - We have included a custom macro (discussed in section 16) in this template that does a fit to the E versus t data. This particular macro actually does all the work for you - it generates the uncertainty in E based on the uncertainty in v, fits to a quadratic dependence of enegy on the time, and displays a table of the results and best fit parameters. To run this macro, just try clicking on the "run χ^2 button" in the spreadsheet.

Finishing Up

Step 18 - Check your spreadsheet to make sure that you have not missed any steps and have no brown or beige cells that need to be filled in. Also check that there are no red feedback messages being displayed. If you see a red feedback message on your spreadsheet it means that you have done something wrong and need to fix it. The feedback system cannot detect all problems, so check your answers carefully.

Step 19 - Save your spreadsheet! ***Note: The templates have been set up so that the usual EXCEL save button is disabled. Instead, to save the file, you must have entered your name, your lab partner's name (or "none" if you do not have a lab partner) you're your section number into the spreadsheet in the designated area (see step 1) and then click on the gray save button in the body of the spreadsheet. The template won't let you exit from EXCEL until after you have saved.***

Step 20 - The saved spreadsheet will be put into the **My Documents Folder** on the desktop with a file name that includes your name. Check that it is there.

Step 21 - Log onto ELMS Canvas, go to the Physics 121 assignments, and figure out how to download and submit a copy of your spreadsheet for Lab 1 before you leave the lab. You do not need to do a separate lab report for this experiment - just make sure both you and your lab partner each work through Part VIII and each of you submit your work. You should also save a copy of the spreadsheet on a memory stick or e-mail yourself a copy before you leave the lab.

Step 22 - **Do not turn off the lab computers** - just close your spreadsheet and any other programs that you used

Step 23 - Finally, make sure you get your lab partner's name and his or her contact information and don't forget to prepare for the next lab and submit your answers to the prelab questions for the next lab before they are due.