Physics 152 Laboratory
Spreadsheets: Simulations and Equation Solving

Introduction
Spreadsheets have a wide variety of uses in both the business and academic worlds. The study of physics is no exception to this, and spreadsheets are a useful tool in the laboratory for both modeling and computation. We have already made extensive use of *Microsoft Excel* to plot data and do straight line fits with error analysis, using the *linest()* function. This lab will introduce you to some new features of Excel. Excel was not really designed to do physics or science, but some of the 'business' functions are very powerful and we can 'bend' them to our purposes.

Equipment/Supplies
1. Computer equipped with *Microsoft Excel* software

Section 1: PRIMER
This section contains basic information and terminology regarding the use of spreadsheets. It is intended for those students who have no previous experience working with spreadsheets. For those students with a working knowledge of spreadsheets, this section can serve as a review. We need a working knowledge of **cells**, **functions**, **relative** and **absolute references**, and the **'dragging'** of cells to **duplicate** and **increment formula**.

Basic terminology:

1. A **cell** is one item in the spreadsheet. It may contain text, a number, or a ***function*.** It is identified by a letter/number pair (e.g., A2 or DD38) which identify its column and row position.
2. A **function** is literally a mathematical function. It may contain numbers, ***operators***, ***basic functions***, and ***references***. **Note**: a function <u>must</u> always starts with an equals sign.
3. An **operator** is one of the familiar mathematical operators: +, –, *, /, and ^.
4. A **basic function** is also from math, examples are sum(), exp(), sin(), atan(), and sqrt().
5. A **reference** is the value in another cell, named by its column and row as a pair, e.g., A1 or D3.

This last definition, is crucial to what we will do. References will often serve as the "variable" in our functions.

The references shown below are what Excel calls 'Relative References'. More on this later.

	A	B	C	D	E
1					
2					
3					
4					
5	yada yada yada		3.14159	0.50	4.00
6					
7			3.14159	=sin(c5/6)	=3+4*d5^2
8					
9					
10					

In the figure above several cells are shown as examples. Cell A5 has text typed into it. Cell C5 has the constant, pi, typed into it. Cells D5 and E5 have functions in them. However, Excel does not normally display the functions. Instead, it shows the result of calculating the function. There is something in cell D5 which evaluates to 0.50. Similarly, the 'invisible' function in cell E5 evaluates to 4.00. Row 7 shows what was typed into row 5, columns C, D, and E, to yield the results shown. (In order to show the functions, they were typed in as plain text by using quotes marks, "", at the time of function entry in cells D7 and E7.

This last explanation included several more ideas that could use definitions of their own:

6. A **column** is a complete vertical set of cells. It is designated by a letter .

7. A **row** is a complete horizontal set of cells. It is designated by a number.

8. A **range** is a set of cells that may be horizontal, vertical or rectangular. It is designated by the first and last cells in it, separated by a colon (:).

Examples of ranges: Above, there are entries in ranges C5:E5. There are no entries in B1:B9. The entire area shown is A1:E9. Note that for rectangular ranges the first and last cells are the upper left and lower right respectively.

To enter information in a cell just click in it and start typing. What you type will appear in the cell and on a line near the top of the window (Edit Bar). If you need to edit what you have typed, work in the Edit Bar. Use the mouse to move the cursor around in the Edit Bar, the **arrow keys will not work**, as these will move you to a new cell. If you type a function, the function will be evaluated when you hit return (or arrow to a new cell).
Using only the ideas mentioned so far, we can already get a glimpse of how to do physics with a spreadsheet. In the following example, it is illustrated how to calculate a basic 152 problem: the height of a ball that is thrown upwards with initial velocity v_0. The left-hand panel cell, A8, shows what is being typed to find the time of the first computation, namely 0.1 seconds. The right-hand panel cell, B8, shows the formula being entered to find **Y** at t = 0.1 seconds. Note, it is just our standard kinematics formula, $y = \mathbf{y_o + v_o y + \frac{1}{2} a t^2}$

	A	B
1	initial h (m)	10
2	gravitational a	9.8
3	initial v (m/s)	30
4	delta t (s)	0.1
5		
6	t	y
7	0	10
8	=A7+B4	

	A	B
1	initial h (m)	10
2	gravitational a	9.8
3	initial v (m/s)	30
4	delta t (s)	0.1
5		
6	t	y
7	0	10
8	0.1	=b7+b3*a8-0.5*b2*a8^2

This is OK so far, but it is an awful lot of typing. Spreadsheets, however, have a wonderful feature that simplifies things dramatically.

You can highlight a cell with a function in it, click and hold the little box in the lower right corner and drag. This will "fill" a whole range with the equation you want, furthermore, the spreadsheet will automatically increment the row # or column letter as it goes.

	A	B
1	1	= a1^2+3
2	2	
3	3	
4	4	
5	5	
6	6	

	A	B
1	1	4
2	2	7
3	3	12
4	4	19
5	5	28
6	6	=A6^2+3

An example is shown above (the lower case '*a*' should be a capital '*A*'). The equation, as seen on the left, was typed in, then "pulled down" to achieve the result on the right. Double clicking on a cell shows the function. This is illustrated for cell B6. Note that when cell B1 was pulled down, the spreadsheet automatically incremented the index (variable) from A1 to A6.

There is one last useful method that you ought to know. That is, how can you stop the spreadsheet from incrementing, for instance, if you want to use a cell to store a constant such as the *delta t* in our original example. The answer is to use dollar signs ($). A dollar sign in front of the column reference (letter) prevents it from incrementing, and a dollar sign in front of the row reference (number) prevents it from incrementing. Thus if you want to store and use a constant in the cell B4 in your formulas, you would refer to the constant in the formula as B4. Then when you drag the formula to replicate it, the constant B4 remains fixed rather than incrementing. In the example below, the acceleration of gravity (g) in cell B2 is a constant. Most generally we would want to refer to it as B2. However, in the example below, the formula are being replicated by being dragged downward. Thus we only have the block row incrementing and B$2 works. The $ in front of the row reference (**2**), locks the (**2**), so that as the formula is dragged downward it remains a **2**. Using the **$** sign to lock a cell address creates an **Absolute Reference** in Excel speak. In Windows, after entering a cell reference, hit the F4 key to cycle through the Absolute Reference choices. Or if you highlight a cell reference in a formula, you can hit F4 to cycle through the Absolute Reference choices. On the **Mac**, *Cmd T* produces the same result as F4 on the PC. Don't look for this in the documentation. Only high priests are allowed to know these shortcuts; oops, shh.

	A	B	C
1	initial h (m)	10	
2	gravitational a	9.8	
3	initial v (m/s)	30	
4	delta t (s)	0.1	
5			
6	t	y	
7	0	10	
8	0.1	12.951	
9	0.2	15.804	
10	0.3	=B$7+B$3*A10-0.5*B$2*A10^2	
11	0.4	21.216	
12	0.5	23.775	

What was typed into A8 before pulling down?

More on Functions:

In the Error Analysis Lab, we will have occasion to use Excel functions such as average, *average(),* and standard deviation, *stdev()*. Typically we will apply these to an entire column of data. It is possible to manually type in the column range in Excel, but it is much more convenient to point to the column with the mouse. Consider the example shown below. In cell B13 we have already computed the average of the 'Car' velocities, 58.75. I.e. Excel has computed the average value of all the velocities listed under 'Car'. If we placed the cursor on this cell, B13, we would

AVERAGE | =average(C4:C11

	A	B	C	D	E
1					
2		**Velocities (mph)**			
3		Car	Truck		
4		54	45		
5		65	60		
6		50	42		
7		66	55		
8		62	50		
9		59	47		
10		64	57		
11		50	52		
12					
13	average	58.75	=average(C4:C11		
14	stdev	6.61			
15					
16					

see the following [=average(B4:B11)], where we have used the [ ] to set off the cell contents in this text. The [ ] don't actually appear anywhere in the spread sheet. We could have typed that all in by hand, but let's use the mouse. Cell C13 shows this process in action. Up to this point, the user has typed in [=average( ], i.e. up to the left parenthesis. Now move the mouse pointer to cell C4, click and hold, and drag the pointer to the bottom of the column at cell C11, and release the mouse. Now you have the dotted line around the column and Excel has automatically placed the cell address, C4:C11, into the partially completed function. All that is necessary now to complete the process is the type in the final right parenthesis, [ )] and press return. The function is complete and Excel will place the result in C13. You should get 51.00 for the data shown here. A similar process was used to create cell B14. What are the contents of cell B14? The technique described here can also be used to highlight rows and most any data in Excel which you want a function to operate on. (When the data are in non-adjacent columns or rows, the control key can be used in conjunction with the mouse to highlight non-adjacent columns or rows; on a PC at least.)

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