

# **LinReg 2.06 Manual**

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120 Physics I and 130 Physics II

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**About LinReg:**

LinReg is a program used extensively in DePauw's physics laboratory classes. It is a general-purpose graphing and data analysis program specifically designed for the labs of an introductory calculus-based physics course. LinReg can tabulate, save, plot experimental data, and calculate a linear best fit for lines. The most important feature of LinReg is that it takes into account uncertainties of measured quantities and will propagate those uncertainties through calculations.

LinReg can be accessed and downloaded at the following URL:

<http://www.physics.pomona.edu/sixideas/sicpr.html>

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## I. Starting LinReg

Once LinReg is installed and started, the opening page should appear as in Figure 1.

Untitled

File Edit Help

Names Data Graph

**Welcome to LinReg 2.0**

Please enter the following information to continue:

Your name(s):

Basic Horizontal Variable  
Name:  Units:

Basic Vertical Variable  
Name:  Units:

Hints:

- If a variable is unitless, enter "none" for its units.
- You can choose to plot any power or function of either or both of the basic variables you choose.

Enter

Clear Names

*Figure 1: Start-up Screen*

LinReg requires that you fill out all cells on this page: Name, Horizontal Variable, Vertical Variable, and units for both variables. You will avoid future problems and error messages by not using spaces when naming your variables. For instance, instead of naming your horizontal variable "Distance Traveled", name it "Distance\_Traveled" or simply "Distance".

## II. Entering Data

The initial "Data" screen in LinReg will be blank (Figure 2). There are two columns for each variable: one for the value of the measurement and one for its associated uncertainty.

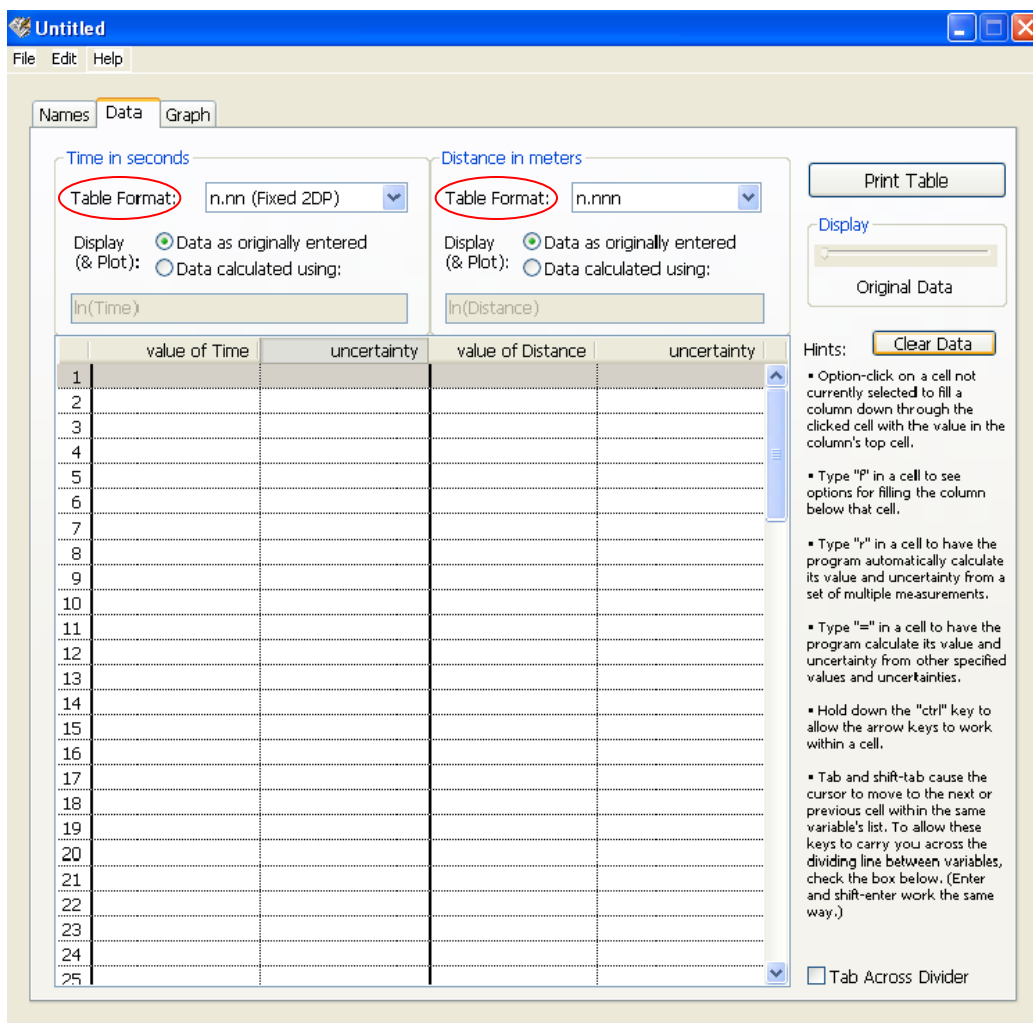


Figure 2: Data Entry; red circles indicate menu for changing number of significant figures

For each variable, under “Table Format” there is an option of how many decimals to display. The default for the horizontal variable is “n.nn”, which means LinReg will display two decimal values after your number. For the vertical variable, the default is “n.nnn”, which means three digits after the decimal will be displayed. This setting can be changed to reflect how many significant digits are in your measurements or how many decimal places you wish to see.

### III. Statistical Analysis: Using “r”

If you have multiple measurements/trials for one data point (i.e.: if you measured the time of four trials at a single distance), LinReg can do statistical analysis of your set of data, including the uncertainty. By putting the cursor in the cell you want the data to appear in and pressing “r”, a dialog box will pop up within the LinReg program, as in Figure 3. This is referred to as the Statistical Analysis tool.

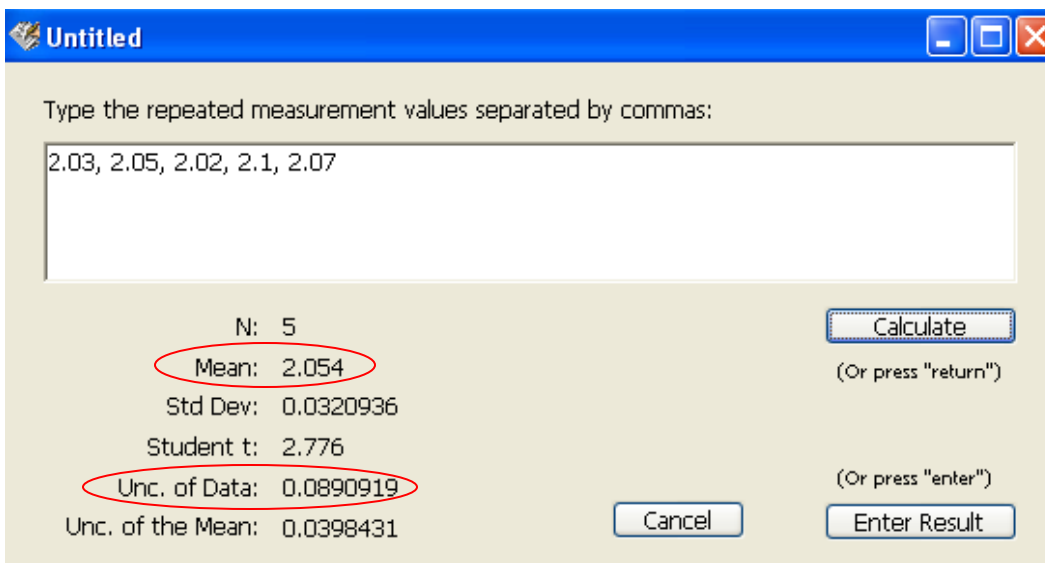


Figure 3: Statistical Analysis Tool; red circles indication mean value and corresponding uncertainty

Type in the values of your multiple measurements, separated by commas. Press “Calculate” and then if you are satisfied with your results, press “Enter Result”. The average value and its uncertainty will be automatically inserted in the two corresponding cells in the data sheet. This can be repeated for as many trials as you have. (Please take note that your data will *not* be saved in the Statistical Analysis Tool. It will not provide you with your previous average from the last time it was opened and used, it will only be saved in the data sheet if you hit “Enter Result”).

#### IV. Propagation of Uncertainty: Using “=”

Another way to enter data and do calculations is to press “=”. This will give another pop-up dialog box within LinReg as seen in Figure 4. This is the Propagation of Uncertainty tool (aka: PropUnc). It will allow you to make calculations using equations and multiple variables, then will propagate (calculate) uncertainty based on your direct measurements and from the lab and your uncertainties corresponding with those measurements.

First, define your variables by naming them. Again, use no spaces to avoid error messages (the simplest name is likely the easiest name). Under “Values” and “Uncertainties”, put in the corresponding information.

Underneath your variable information is “Expression”, a long empty cell. Here is where you will type in the equation that you wish LinReg to calculate, using your defined variables. For example: To have LinReg calculate Newton’s Second Law (force=mass\*acceleration), you would type in the names, values, and uncertainties for mass and acceleration (See Figure 4). If you call mass ‘m’ and acceleration ‘s’, then in the “Expression” bar you would type  $m \cdot a$  (without the “Force=” portion of the equation). When typing in your variable names, note that PropUnc is *not* case sensitive, so ‘M’ and ‘m’ are indistinguishable in the program and shouldn’t be used for two different variables. Instead, try m1 and m2.

When you hit “Calculate”, LinReg will give you a calculated value and a corresponding uncertainty for your data. Click “Enter Data” to have LinReg put this information in the cells of your data sheet.

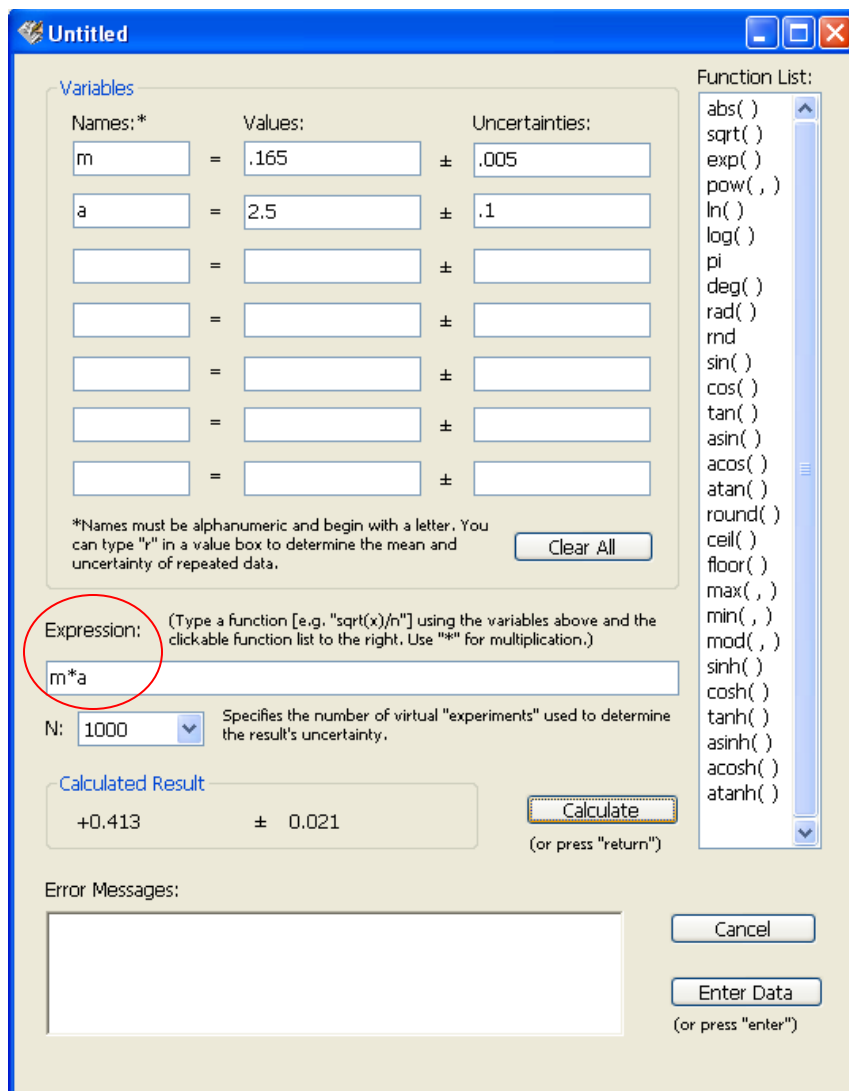


Figure 4: PropUnc; red circle indicates the location of Expression cell

LinReg automatically saves the equation and values from cell to cell, which is convenient if you intend to use the same equation multiple times. This is useful, but you should be careful to notice any variables whose values or uncertainties need to be changed for the next calculation.

A nice function of using PropUnc is that when your cursor is in the “Values” cell for one of your defined variables, you may press “r”. The Statistical Analysis tool window will pop up *within* the PropUnc window. This allows you to do averages and uncertainties of multiple measurements within the propagation of uncertainty feature.

LinReg also has built in functions that allow you to manipulate your data or make further calculations. The complete list is on the right side of the PropUnc menu; you can either click on the function you wish to insert into the Expression cell or simply type it in yourself. (More instructions on entering equations correctly can be found in Appendix A).

[Note: If you are wondering what the setting for N means, it is related to the process in which LinReg determines the uncertainty of your calculation. N is the number of “simulations” LinReg runs based on the various uncertainties of your data. The more simulations LinReg runs, the more accurate your answer. N=1000 is generally accurate enough for your lab work and the option can be left alone.]

If you are satisfied with your results, press “Enter Data” and review your data set. A sample data set is shown in Figure 5.

Time in seconds		Distance in meters		
Table Format: n.nn (Fixed 2DP)		Table Format: n.nnn		
Display (& Plot): <input checked="" type="radio"/> Data as originally entered <input type="radio"/> Data calculated using:		Display (& Plot): <input checked="" type="radio"/> Data as originally entered <input type="radio"/> Data calculated using:		
In(Time)		In(Distance)		
	value of Time	uncertainty	value of Distance	uncertainty
1	1.00	0.10	2.054	0.400
2	2.00	0.10	8.952	0.350
3	3.00	0.10	24.862	0.430
4	4.00	0.10	49.038	0.290
5	5.00	0.10	80.967	0.370

Figure 5: Data Set

## V. Graphing

After you’ve entered all your data, you are ready to graph. At the top of the LinReg window, press the “Graph” tab. For this sample data set, the graph appears in Figure 6.

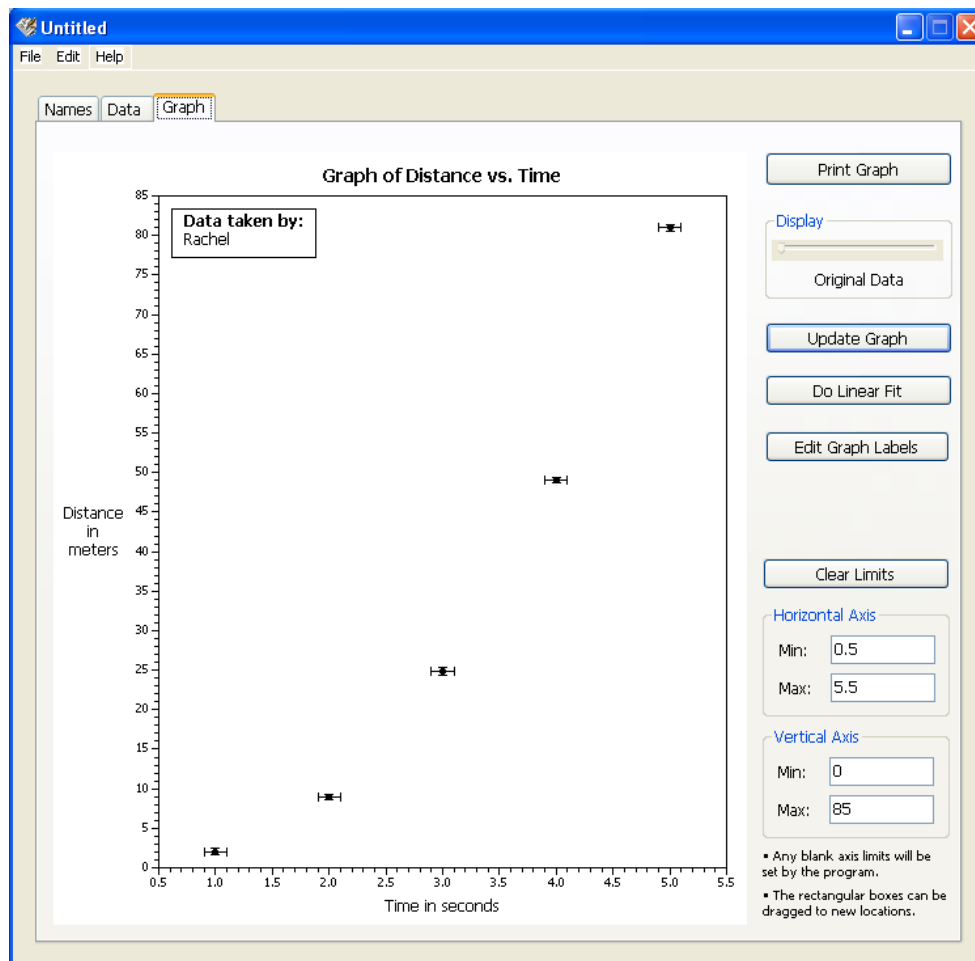


Figure 6: Graph of Distance vs Time



The graph is automatically scaled and the uncertainty bars will also be inserted automatically. On the graph page, it is possible to adjust the scale of each axis and the graph labels.

If your data appears linear and you wish to insert a best-fit line, click “Do Linear Fit”. This will calculate and display the slope and y-intercept with uncertainties.

## VI. Calculations of Data

If your data doesn’t look linear (i.e.: Figure 6), you may wish to manipulate and re-graph your data. This can be done in the data section, under “Display (&Plot)”. The default choice is “Data as originally entered”, where you put in your raw data. Under this choice is “Data Calculated Using”, which provides a space underneath it for an equation.

The default setting is “ln(variable)”, or the natural logarithm of your variable, whatever it is named. However, this can be changed to produce whatever kind of calculation you want to apply to your data, provided it follows the rules of entering expressions (see Section IV and Appendix A). An example of calculations using ln(variable) is seen in Figure 7.

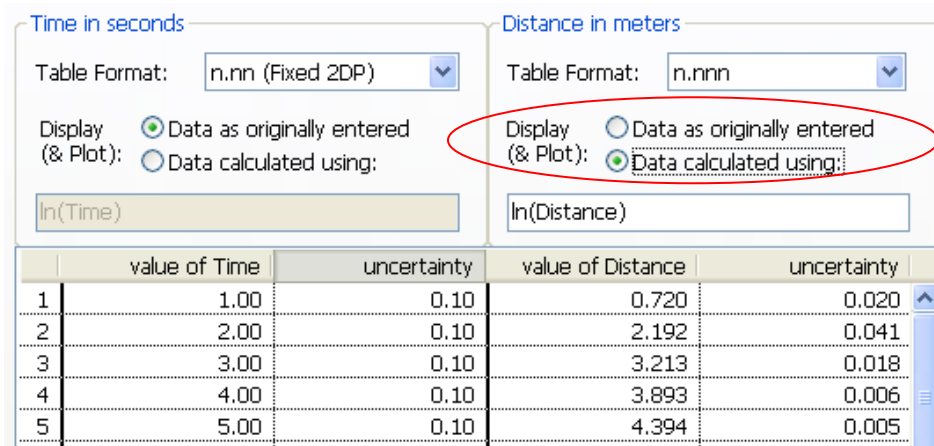


Figure 7: “Data Calculated Using”; red circle indicates options for the vertical data

This feature can be used separately for each the horizontal and the vertical data sets, so you can apply different functions to each set of data.

If your equation is input incorrectly and not accepted by LinReg, you may see your columns go blank. However, your original data is never deleted: to see it, just click back on “Data as originally entered” and your original numbers will reappear.

After calculating data, you can click back to the “Graph” tab. If your data isn’t automatically refreshed, click on “Update Graph”. Your new calculations should take effect. Do a new linear fit to get the updated slope and y-intercept (as seen in Figure 8 with the new data from Figure 7).

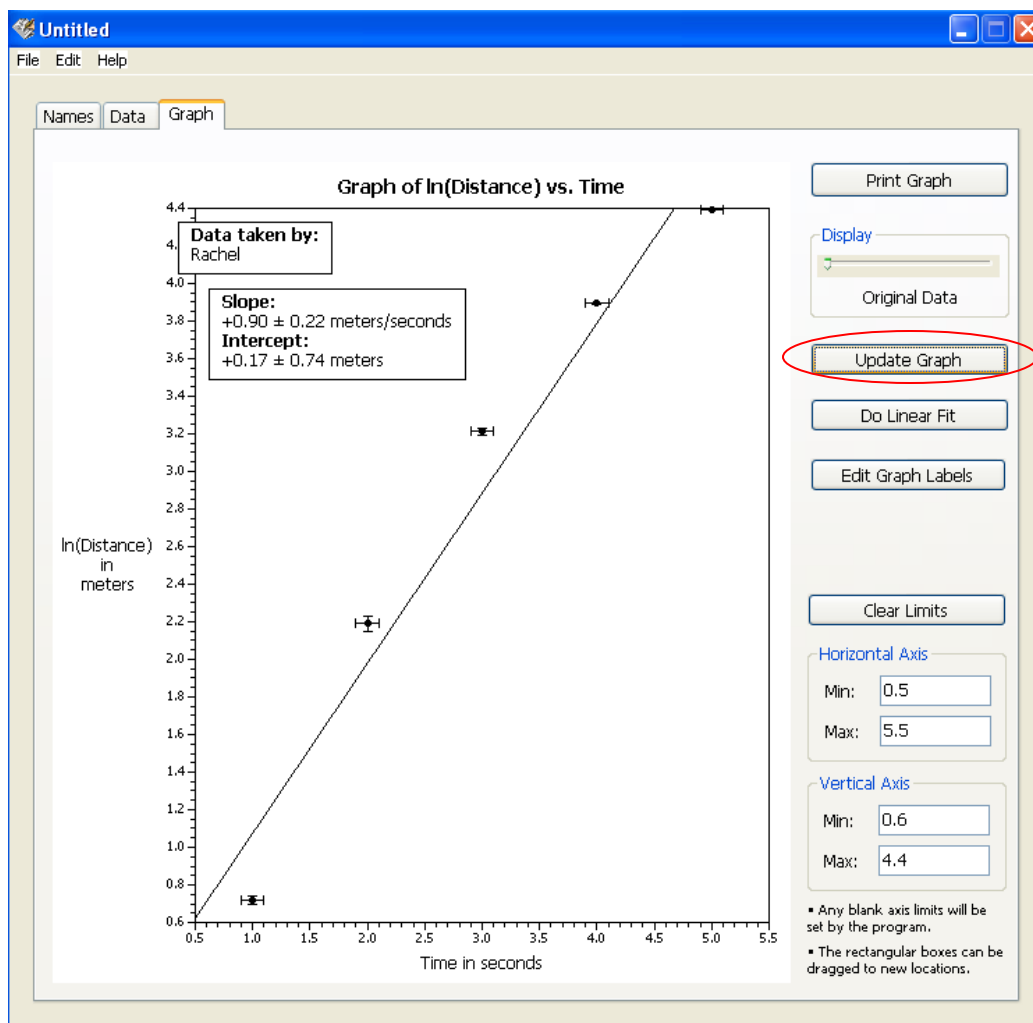


Figure 8: New Graph; red circle indicates 'Update Graph' button

## VII. Tips and Other Features

- When using "=" to calculate several different or particularly long equations, it is useful to save them in "notepad" or "wordpad" or a similar program. This will allow you to switch back and forth between calculating different equations without having to retype them in the "Expressions" cell each time. Just copy and paste to and from the "Expressions" cell and the notepad.
- Fill options: pressing "f" will bring up a small window (see Figure 9).
  - "With this calculated sequence": this option will start at a number and increase or decrease incrementally for a number of times. "From" is the number you wish to begin at, "End" will be the end of your sequence, and "Step" will be the amount of increase or decrease between each number.
    - Example 1: The default setting is from 1 to 10 with a step size of 1. This will put each of the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 in their own row.
    - Example 2: From 5 to 2.5 in steps of -0.5. This will put each of the numbers 5, 4.5, 4, 3.5, 3, 2.5 each in their own row with a total of six rows.
  - "With blanks": This will clear all cells in the column your cursor is in "With this value": This will put the same value in each row for a set number of rows; i.e.: a value of 8 filled down 12 rows.

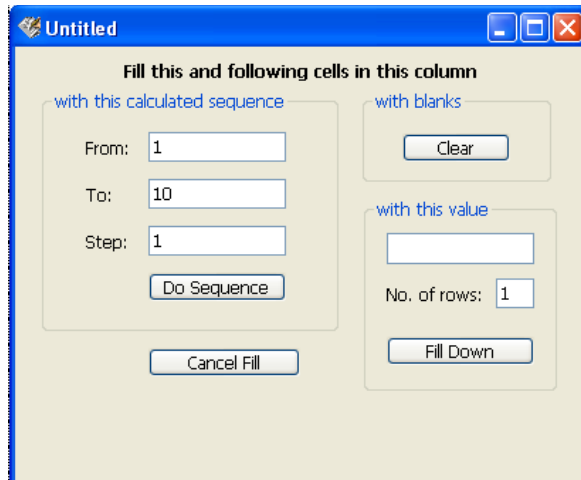


Figure 9: Fill Options

- You can import data files from text editors, as long as the file is a tab-delimited text file (such that your numbers are separated by “Tab” to make different columns, and your rows separated by the pressing enter).
  - Select the "Import" item from the File menu, open your file, and select the appropriate format.
  - Your text file can contain four columns of data (data and uncertainty for both horizontal or vertical data) or two columns (horizontal and vertical data with no uncertainties)
  - Example of importable text file seen in Figure 10.

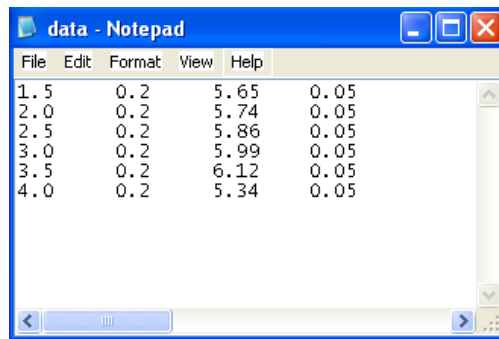


Figure 10: Importing Data

- Once in LinReg’s Data tab, go to “File”, then “Import...,” and a window, shown in Figure 11, will appear. Depending on which columns you want your data to be entered in, pick the appropriate choice.

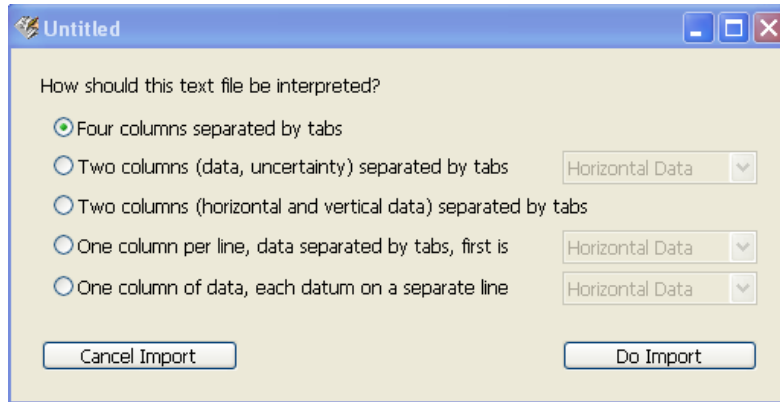


Figure 11: Importing Data

### VIII. Troubleshooting

LinReg is a useful program, but is often picky about the details. Some frequent problems/errors are listed below with possible solutions.

- You are trying to utilize “Calculate Data Using” and are receiving error messages:
  - Make sure there are no spaces in your variable names. For instance “Time of fall” is not acceptable, but “Time\_of\_fall” or “Time” are acceptable.
  - Check to see if your data falls within the appropriate range of the function. For example,  $\ln(0)$  is undefined and cannot be calculated. If this is in your data, you may have to drop that data point in order to continue.
- You changed your data but your graph looks the same:
  - Try clicking “Update Graph”
  - Under the “data” tab, check to see that your data is present and accurate without errors
  - Check that your graph axes cover your entire range of data for both the horizontal and vertical values
- You want to save your graph as a picture but there isn’t an option for it:
  - The easiest solution to this problem is to take a screenshot
    - For Mac users: Mac screenshots will save the screenshot on your computer (most likely on the desktop, but you may have to search for it)
      - “Command-Shift-3” takes an image of your entire screen
      - “Command-Shift-4” gives you the option to take an image of a specific portion of the screen (click and drag)
      - Click the “Print” button. In the dialogue box, there is an option in the lower left “PDF”, and then you may choose to save your graph as a PDF. From here, you can import the file into your Word document.
    - For PC users:
      - The “Print Screen” button on the keyboard (usually desktops) will copy the entire screen as an image
        - The program Paint will allow you to paste the image there in order to crop it to your liking, then save the file as an image
        - The copied screen may also be pasted into a Word document, although you will get the image of the entire screen
      - On laptops, follow the same procedure, although you may have to press “fn” then “Prt Sc” (print screen).

- Another (though less tech-savvy) solution is to print the graph out, then scan in an image to your computer.
- You are using "=" but the functions won't appear in the sidebar or insert in the expression cell:
  - Try closing the pop-up window and trying again (your data should be saved in the window)
  - Carefully type in the desired function instead
- You are using trig functions (sin, cos, tan, or the inverses) but your calculated values seem odd:
  - LinReg *automatically* assumes any angle input is in radians. Using the function rad(your angle) will convert your angle from degrees to radians
  - Check your LinReg calculated value with a calculator to check correctness

If you are running into problems and nothing seems to help, save your work and try restarting LinReg. If the problem persists, consider using your lab partner's computer instead. LinReg is designed to work on all computers, but nevertheless will sometimes run into trouble.

### Appendix A\*: Entering Expressions

Please note the following when entering mathematical expressions into either the propagation of uncertainty dialog box (the window that pops up when you press "=" in a data cell) or the "Data Calculated Using:" box above each column. The variable "pi" is automatically defined and can be used in any expression. Valid operators are + (addition), - (subtraction), \* (multiplication), / (division), and ^ (raising to a power). Some examples of valid expressions are:

$2*\pi*r$                        $\text{sqrt}(a^3)$                        $(\text{Val1} + \text{Val2} + \text{Val3})/3$                        $\text{cos}(x)$

The usual rules of order of operations apply: for example in the expression  $a+b*c^{-(d+e)}$ , the quantity  $(d+e)$  is evaluated first (because it is in parentheses), the result is then negated, the value of  $c$  is then raised to that power (since powers have precedence over other operations), the result is then multiplied by  $b$  (because multiplication and division take precedence over addition and subtraction), and finally  $a$  is added to the result.

Keep in mind that PropUnc is *not* case sensitive. When PropUnc evaluates your expression, the variables 'M' and 'm' will be indistinguishable and therefore *cannot* be used for two different variables. Instead, try m1 and m2 or ma and mb.

The panel on the right side of the propagation of uncertainty dialog box shows a complete list of the valid functions you can use in your expressions. Simply type the function into the expression as it is shown in the list (or, if the list is visible, you can simply click on the function's name in the list to enter it into the expression.) The names are pretty self-explanatory, but here are some notes about ones that may not be so obvious.

The bolded functions are those you are most likely to use in physics lab:

pow(x,y) is equivalent to  $x^y$

deg(x) converts an angle x in radians to degrees

**rad(x)** converts an angle x in degrees to radians

**ln(x)** is the natural logarithm

log(x) is the base-10 logarithm

**sin(x), cos(x), and tan(x)** all take arguments in radians

**asin(x), acos(x), and atan(x)** are inverse trig functions and return results in radians

ceil(x) returns the next integer above (less negative than) x

floor(x) returns the next integer below (more negative than) x

frac(x) returns the fractional part of x (e.g.  $\text{frac}(-2.51) = 0.51$ )

rnd returns a random number between 0 and 1

min(x,y) returns x if  $x < y$ , or y if  $y < x$

$\max(x,y)$  returns  $x$  if  $x > y$ , or  $y$  if  $y > x$   
 $\text{mod}(x,y)$  returns  $x \bmod y$   
 $\sinh(x)$ ,  $\cosh(x)$ , and  $\tanh(x)$  are hyperbolic trig functions  
 $\text{asinh}(x)$ ,  $\text{acosh}(x)$ , and  $\text{atanh}(x)$  are inverse hyperbolic trig functions

[\*Appendix A taken from: <http://www.physics.pomona.edu/sixideas/source/AboutLinReg.html>]