Checking Relationships using Graphs, Error Bars, and Linear Regressions

Error Bars

Something not covered in the lab module was how to add error bars to data points in an Excel plot. This is a quick guide assuming you have Excel 2013 (instructions for Excel 2010 would be similar with slightly different menu names and structure). While having the graph selected, in the *Chart Tools > Design* menu area at the far left click *Add Chart Element > Error Bars > More Error Bars Options.* A *Format Error Bars* menu should show up on the right side of the screen and Excel will have added some kind of default sized horizontal and vertical error bars (totally unrelated to your data). You can switch between editing the horizontal/vertical error bars by clicking on them in the graph window or by using the drop down selection near the top of the *Format Error Bars* menu.

You will generally only be interested in the *Fixed Value* option, where you would use a measured or calculated uncertainty that you found in lab assuming it is the same for all data points. You can also see there is an option *Custom* to select your own data, so it would be possible to have different sized error bars for individual data points (make sure this would make sense experimentally before doing that).

1. A student runs an experiment to check conservation of angular momentum in a rotating system and obtains the results shown in Table 1 for the initial and final angular momenta (L and L').

Initial L [$kg \cdot m^2/s$]	Final L' [$kg \cdot m^2/s$]	$L - L'$ [$kg \cdot m^2/s$]
3.0±0.3	2.7±0.6	.3
7.4±0.5	8.0±1.0	−.6
14.3±1.0	16.5±1.0	−2.2
25±2	24±2	1
32±2	31±2	1
37±2	41±2	−4

a. In the 3rd column show the difference $L - L'$ and calculate the uncertainty on each. Please show the equation you derived to calculate this uncertainty below.

$$\frac{\partial_{L'} - \partial_L}{(L-L')_{avg}} = \partial_{L-L'} =$$

$-.037$

b. Make a plot of the final angular momentum L' against the initial angular momentum L. You should include vertical and horizontal error bars using the uncertainties provided for each data point, label the axes including units, and include a linear fit with the equation displayed. **Include a printed copy of this graph with your worksheet.**

c. If angular momentum is conserved we would expect the data to follow $L' = L$. Using the *Regression* analysis in Excel what is the slope, and its uncertainty, of the linear fit to the data? What should the slope be? What is the discrepancy between your calculated slope and what it should have been? Does the data fit the theory to within experimental uncertainties?

The slope should be 1 or close to one when accounting for uncertainty in the values. The determined trend fit line comes out to 1.0383 which is a .0383 difference from the expected if angular momentum is conserved

d. What is the y-intercept of the linear fit? What should it be? If there is a discrepancy what might this represent?

Y-intercept should be 0, because of conservation

2. If a stone is thrown vertically upward with speed v, it should rise to a height h given by $v^2 = 2gh$. In particular, v^2 should be proportional to h. To test this proportionality, a student measures v^2 and h for seven different throws and gets the results shown in Table 2.

h [m] all $\pm$0.05	v^2 [m^2/s^2]
0.40	7 ± 3
0.85	17 ± 3
1.45	25 ± 3
2.00	38 ± 4
2.60	45 ± 5
3.35	62 ± 5
3.80	72 ± 6

a. Make a plot of v^2 vs h, including vertical and horizontal error bars using the uncertainties provided, label the axes including units, and include a linear fit with the equation displayed. **Include a copy of this graph attached with your worksheet.**

b. Using the *Regression* analysis in Excel what is the equation of the best-fit linear line using proper significant figures? Include proper units on the slope and the y-intercept if one exists.

$17.4376x + 2.9005$

c. From *Regression* what is the slope and its uncertainty to proper significant figures?

17.4576 ± 0.8709

d. Comparing the fit line equation to the physics equation what is the slope equal to?

$g = \frac{v^2}{2h} = 17.4526$ ~~$\frac{v^2}{2gh} = 17.4526 + 2.9005$~~

e. From these results what is the experimental value of g and what is the uncertainty in g?

~~$g = \frac{7^2}{2(.01)}$~~ $g = 61.25$ ~~$\frac{72^2}{2h(17.4376)} = g \rightarrow \frac{7^2}{2(.04)\,17.4376} = g \rightarrow g =$~~

f. Assuming that the accepted value of g is 9.8m/s^2 what is the difference between the accepted value and the experimental value? $61.25 - 9.8 = 51.45$

g. If the uncertainty in g is a standard deviation σ_g with the value found in step (e), how many standard deviations does it take to span the discrepancy between accepted and experimental?

h. From all your work so far would you say the results are consistent with the theory and accepted value of g?

PS253– Physics Lab for Engineers
Post-Lab Worksheet, Data Analysis & Plotting Data

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To complete this worksheet you will need to follow the same procedures you did while in lab to make histograms and graphs. You should refer back to the experiment module if you are having difficulties. Additionally, some of the data to be used to complete this worksheet is supplied in an Excel file.

Please make sure to include a copy of each plot you are asked to create and hand them in with this assignment. The plots should have all the proper formatting discussed in the lab module. They should also have detailed, appropriate captions (you can copy/paste the figures from Excel to Word as images and caption them nicely in Word, then save it).

NFL Game Score Statistics

In the Excel file provided you are given the final scores of all 256 games played during the 2015 NFL regular season. The final scores for each team are given as well as the combined total points scored in each game and the difference in points scored by each team. One histogram (H1) is already provided displaying the distribution of total points scored in each game; the y-axis is normalized frequency which can be thought of as the percentage of times that total score occurred out of all 256 games played. Source: http://www.nfl.com

1. Create two more histograms: (H2) "Distribution of final score differences (aka spread) between teams during a game" and (H3) "Distribution of points scored by a single team during a game." Note that since there are two teams in each game H3 will have $2 \times 256 = 512$ data points.

   The histograms you create should have the same format as the one already provided. The y-axis should be normalized frequency such that if you add up all bin frequencies you get 1.00. Each bin should encompass a single whole number (0,1,2,3,...) covering the full range of possible results for that statistic. For example, in the histogram already provided there were no games with total points scored over 89 points. The bins then span the range from 0-89.

   Format your histograms correctly, caption them, and print them for this assignment. Please print *all three* histograms together on a single side of one 8.5"x11" sheet of paper.

2. What is the mean total score and standard deviation of the data in H1?

   45 ± 13

3. From the data in H1 what percentage of games had final scores within ±1 standard deviations of the mean total score?

   11%

4. What were the two most likely total scores for a game, how many games resulted in these total scores, and together what percentage of all games had these total scores?

   41 points
   44 points

5. Using the data in H1 and H3, how many times was a single team able to score more points in a single game than the mean total points scored by both teams in any single game? What fraction of the 512 individual team game scores is this?

6. How many games resulted in a tie?

3 games

7. What percentage of games were won or lost by only 1 point?

8. In NFL football the two most likely ways to score are to successfully kick a field goal (3 points) or score a touchdown + extra point (7 points).

   a. What percentage of games were won by ≤3 points?

   b. What percentage of games were won by ≤7 points?

9. Looking at H1 and H3 describe the general shape of both distributions. Do they seem lopsided or evenly distributed? Do they appear to be roughly Gaussian(Normal) distributions? Note: The results of purely random phenomena tend to have Gaussian distributions.

10. From looking at your histograms and all your responses, in your opinion, does it seem like teams are generally evenly matched in any randomly chosen game?