LAB 2
Experimental Uncertainty

OBJECTIVES

(1) Practice organizing and analyzing quantitative data.
(2) Create a spreadsheet using the Excel program.
(3) Use Excel to calculate the mean and standard deviation of a set of values.
(4) Determine whether your standard deviation is consistent with statistical theory.

EQUIPMENT

Assorted dice and EXCEL program.

PROCEDURE

Part 1: Step Right Up and Roll the Dice

(1) Examine your set of four dice. *If you rolled all four of these dice many times and took the average (mean) of all the rolls, what value would you get?* With your group, come up with a **theoretical** value. Do not guess. Make sure you have some reasoning behind your value. (Note: if the group can't agree on a single theory, it's ok to have two competing theories.)

(2) Roll the set of 4 dice together and record the total in a data table. Repeat this a total of 5 times. Find the average or mean value of your 5 rolls. Answer the following questions:

- *Was your experimental average value equal to your theoretical average value?*
- *What is the difference (or discrepancy) between the two values? What is the percent discrepancy between the two values?* To find this, divide the difference by the experimental value and express the answer as a percentage.
- *If your experimental average didn't match your theoretical average, does that mean that your theory was inconsistent ("wrong") with your data? Why or why not?*
- People sometimes say that their experimental results were off because of something they call 'human error'. *Do you think 'human error' caused your experiment to give different results that the theory predicted?*

When a theory agrees with what you observe in an experiment, we say that it is **consistent** with your observation**.** If it doesn't agree, the theory is **inconsistent** with observation.

Sometimes an experimental result is "pretty close" to what a theory predicts, and leaves you unsure about whether or not to reject the theory. The question you might ask is: "*How far off do they have to be to make me confident that the theory is wrong, or **inconsistent** with my observation?"*

The answer to that question depends on how precise your experiment is. If you repeat it many times, will you always get the same value, or will there be some fluctuation?

(4) To find out how much fluctuation there is in our dice experiment, many more measurements will have to be taken. Work with your group to repeat the experiment 14 more times. ***(Remember, each experiment is the average of 5 rolls).*** Record the average values of all 15 experiments in EXCEL. Based on these results, come up with what you think is a "reasonable spread of uncertainty" by answering the following questions:

- *When we perform this experiment many times, we are pretty confident that the results will come out somewhere between ____ and ____*. This interval is called your **confidence range**.
- *If we did the experiment one more time, our best guess for the result would be _____.*

(5) Based on your answers to the two questions above, restate your experimental results in the following form:

"Our observation is that the average value of the 4 different dice rolled together is __________ +/- __________. "

The "+/-" part at the end is what is called your experimental **uncertainty.** All experiments have an uncertainty because they never produce the exact same result every time.

(6) **Uncertainty and multiple trials.**
Here we're going to look at what happens to your uncertainty as you increase the number of trials in the experiment. Rather than having each group roll the dice more times, we'll combine the results from all the groups and see what they look like.

Go to the whiteboard and add your results to the group chart. (ask instructor for help if this isn't clear.)

Looking at this curve, or histogram, answer the following questions:

- *What is our new confidence interval for the 'whole class' data? That is, "most" of our results fall within the range __________ to ___________.*
- *How does this compare to the intervals you got in your groups?*
- *From this graph, what would we say is our "best guess" at the 'right answer'?*
- *How does that compare with what you got in your groups?*

(7) Make a histogram chart (by hand) to display the results of your group's 15 rolls. (Note: please ask for the help of the instructor if needed.)

(8) Use Excel's AVE function to find the mean (or average) and Excel's **STDEV** function to find the **standard deviation** (σ) of your group's 15 experiments. The standard deviation is the best estimate of the uncertainty in your individual measurements. It gives an indication of how "spread out" the values are in your data set.

(9) On the histogram (of your group's rolls) that you created in step 7, draw a bell curve that approximately fits your histogram and mark the 1σ and 2σ "confidence intervals". *Where does the theoretical value that you predicted in step 1 fall on this curve? How does the peak of the bell curve compare to your mean value?*

Part 2: Compare Your Theoretical Prediction to Your Experimental Values

In Physics 11 lab, our "test for consistency" will be whether the theoretical value (or predicted value) falls within one standard deviation of our mean experimental value. In other words, we will conclude that the experiment and theory are consistent and agree if:

$$\textbf{(mean} - \sigma\textbf{)} \leq \textbf{theoretical value} \leq \textbf{(mean} + \sigma\textbf{)}$$

If the theoretical value is not within one standard deviation of the mean, we will conclude that the experiment and theory are not consistent and do not agree.

(10) Using this "test for consistency", answer the following question:

- *Would you conclude that your theoretical value is consistent with your experimental measurements? Explain.*

Part 3: Compare Your Values with "Statistical Theory."

(11) Statistical theory predicts that approximately 68% of the values of any measurement should fall within one standard deviation of the mean value. This means that 68% of your measured values should be $\geq$ (mean - σ) and $\leq$ (mean + σ). *What percentage of your 15 values fall within one standard deviation of the mean? Is this consistent with statistical theory?*

(12) Statistical theory also predicts that approximately 95% of the values of any measurement should fall within two standard deviations of the mean value. This means that 95% of your measured values should be $\geq$ (mean - 2σ) and $\leq$ (mean + 2σ). *What percentage of your 15 values fall within two standard deviations of the mean? Is this consistent with statistical theory?*