E&M Lab 1: Statistics and Spreadsheets

The goal of this lab is to familiarize you with the basic tools of experimental data collection and analysis. These include the use of statistics to analyze experimental data, and the use of spreadsheets to perform important calculations. The handout "Statistics and Spreadsheets" describes the tools you'll need to complete this lab. The handout "Lab Writeup Expectations" describes what your final writeup should look like.

Experiment Overview

You'll be provided with a large number of resistors. You'll measure their resistance using a multimeter, record the resistances in a spreadsheet, and use the spreadsheet to measure their mean resistance and its uncertainty.

Setup

1. Log in to Google Docs. You can use your Wheaton email and password, or your personal Gmail info if it's more convenient (but be aware that you'll be sharing the address with me in step 2). You can even use Google with two accounts simultaneously: ask me how.
2. Create a Google Docs spreadsheet. Hit the "share" button to share it with your lab partners, and with me (goodman_jason@wheatoncollege.edu).

Procedure

1. You will find two kinds of resistors at your lab station. We haven't talked about what resistors do yet, but you probably remember from Intro Physics, and it doesn't matter: they're just an easy thing to measure. The ones with the "red red brown gold" stripes are labeled as 220 ohm resistors. The black ones with printed text are labeled as 10,000 ohm resistors. We'll start with the 220 Ω ones.
2. Set your multimeter to the "2000 Ω" setting, and measure the true resistance of each 220 Ω resistor by touching one probe to each of the resistor's two wires. Make sure you have good metal-to-metal contact, or the meter will read "I." Record the values in a column of your spreadsheet.
3. Next, take any *two* 220Ω resistors and connect them in series like this:

   

   Just hold them together with your fingers. Measure the combined resistance of the pair. You may remember from introductory physics that the resistances should add: $R = R_A + R_B$. Confirm that this is indeed the case.
4. Measure the resistance of many randomly-selected pairs of resistors in series. Record the values in a new column of your spreadsheet.
5. Repeat Part 2 for some 10,000 Ω resistors. (Don't redo step 4 for these.) You will need

to change the scale on your multimeter. It's important to measure these without holding the metal leads with your fingers! (Try it, see happens if you hold the resistor in both hands while measuring. This is an example of a "systematic", nonrandom error.)

Analysis

1. Use the spreadsheet to calculate the following:
   - The mean of the resistance data
   - Standard deviation of the data
   - Standard deviation of the mean
   - Uncertainty (95% confidence interval) of the mean.
2. Do this for each of your three data columns (220 Ω resistors, pairs in series, 10,000 Ω resistors).

Discussion

1. What is the measured mean resistance of the resistors labeled 220 Ω? Include the uncertainty as part of your answer. Is the mean resistance you measured equal to 220Ω, to within your margin of error?
2. Suppose I wanted to measure the mean resistance of these resistors to a precision of ±0.1Ω (95% confidence interval). How many resistors would I need to measure?
3. How does the uncertainty of the mean of pairs in series compare with a single resistor? (Does doubling the number of resistors double the error?) Does the expected uncertainty, calculated using the "propagation of uncertainty" rule, agree with the actual measured uncertainty of the pairs?
4. Are the 10,000 ohm resistors more or precise than the old 220 Ω ones? (Since their mean values are different, you should compare their *relative* precision, as a percentage of their average value.)
5. When I did this experiment, I noticed that many of the resistors had a resistance different from what they were labeled. Do yours have a mean resistance which is significantly different than their labeled value, to 95% confidence?
6. If so, this doesn't mean the manufacturer screwed up. The gold band on the 220 Ω resistors indicates their "tolerance": that the manufacturer only promises that they will be within 5% of their labeled value. Is the label accurate? (Does *each* of the resistors measure within 5% of the labeled value, in all cases?) The 10,000 Ω resistors have a tolerance of 0.1%. Is this label accurate?
7. Why did I warn you not to touch the metal leads of the 10K resistors with your hands? Explain what happens if you do, and why this affects the measurement. Why is this less important for the 220 Ω resistors?