Interpreting Last Week's Results:
Finding the Systematic Error
Spring 2018

Introduction

When the results from last week's experiment on Ohm's Law were assembled, it was clear that there was a systematic error in the experiment. In every case, \( R_1 + R_2 < R_{\text{set}} \). The purpose of this lab is to figure out why the sum of resistances measured separately was less than the measured combined resistance. Be sure to use the same resistor set as last week!

EXPERIMENT 1

1. Your instructor will perform a demonstration using conductors (metals), semi-conductors (e.g. the carbon resistors you used in last week’s experiment) and liquid nitrogen (\( LN_2; T = 77 \text{ K} = -196 \text{ °C} = -321 \text{ °F} \)). Record the results and briefly describe the demonstration.

EXPERIMENT 2

1. Set up your multimeter as an ohmmeter to measure resistance (refer to the document “Using a Digital Multimeter”). Without connecting the resistors to a power supply, use the ohmmeter to measure \( R_1, R_2, \) and \( R_{\text{set}} \). Set the ohmmeter to measure resistance as precisely as possible. Draw your ohmmeter connection to the resistors and record your results.

2. How do the direct measurements of resistance with the ohmmeter compare to the values you calculated last week from your \( I \) vs. \( V \) graph – are they higher or lower?

3. Calculate \( R_1 + R_2 \) from the individual ohmmeter measurements, and compare to the direct ohmmeter measurement of \( R_{\text{set}} \); how do they compare with each other? Were the ohmmeter measurements higher, lower or the same as the values calculated last week? What conclusion can you draw? Be sure to state your results from last week!

EXPERIMENT 3

- Note: Before proceeding, you must correct any calculation or plotting errors you might have made last week!

1. Open your KaleidaGraph plot from last week, and click on the “grid” icon in the upper right corner of the graph window to extract your data from the plot, as shown at right. (If you chose not to follow the instructions from last week, create a plot of \( I \) vs. \( V \), and make linear curve fits for \( R_1, R_2, \) and \( R_{\text{set}} \)).

2. Follow the instructions in “Graphing & Curve Analysis Using KaleidaGraph” to easily calculate the residuals from your graph. Recall that the residuals are the difference between the predicted \( y \)-value of a data point (as indicated by the best-fit line) and the measured \( y \)-value. Each residual indicates the amount by which the best-fit line misses each data point.

3. Rename each residual column (e.g. “Residuals R1”, “Residuals R2”, etc.) in the data window. You should include the residual units as well!

4. Graph the residuals vs. voltage for all three sets of data on one KaleidaGraph plot. Fit a 2nd order polynomial curve to each residual set (don’t display the equations; they aren’t important here.)

5. Examine the curve fits you just applied. Which set of residuals show the greatest deviation from the expected current? Which has the smallest deviation? What does this tell you?

6. Print the residuals plot you just created.
Experiment 4

1. The resistors used in this experiment will produce $\frac{1}{4}$ Watt of power when used at the rated current and voltage suggested by the manufacturer. Use your measured resistance for $R_1$ (from Experiment 2) to calculate the rated current for $R_1$; that is, find the amount of current that will produce $\frac{1}{4}$ Watt of power dissipation (recall that $P = I^2 R$, where $R$ is in ohms).

2. We’ll call the amount of voltage needed to produce the rated current just calculated $V_{\text{max}}$. Calculate $V_{\text{max}}$ for resistor $R_1$.

3. Look at the range of voltages used in last week’s experiment. What does your calculated value of $V_{\text{max}}$ tell you might have happened to your resistor last week?

4. Connect a circuit with a voltmeter, ammeter, and the single resistor, the same as last week. You will be using a different power supply this week, so your instructor will assist you. Draw a circuit diagram in your report. Measure the current (with the ammeter set to read to 0.01 mA) through the resistor as a function of the voltage, up to $V_{\text{max}}$. Then increase the voltage higher than $V_{\text{max}}$ until you reach a maximum of 50 volts; record at least 6 data points above $V_{\text{max}}$. Note that the resistor will get very hot above $V_{\text{max}}$!

5. We wish to see what happens in the resistor as the voltage goes over $V_{\text{max}}$. You will create a plot of $I$ vs. $V$ in Kaleidagraph, but enter the data as shown at right. $I_{\text{low}}$ represents the current measured up to and including $V_{\text{max}}$, $I_{\text{high}}$ is the current measured above $V_{\text{max}}$. Each dash (–) represents your measured voltage and current data (your table will obviously have more data than that shown.)

6. Set the minimum $x$- and $y$-axis values of your graph to 0 (Plot $\rightarrow$ Axis Options)

7. Apply a simple linear fit to $I_{\text{low}}$, the points below $V_{\text{max}}$ (you don’t need to display the equation). Do the data points above $V_{\text{max}}$ lie on this best-fit line? Print the graph, label the $V_{\text{max}}$ point and explain what your graph shows.

8. Create a second graph of the resistance vs. the voltage for all the data you just collected (use the “Formula Entry” window to calculate the resistance – see page 4, steps 14-16 of your KaleidaGraph instructions). Mask the point at {0,0} by selecting the coordinates in the data table, then choosing Mask from the Functions menu, and then updating the plot. Print this graph as well, again labeling $V_{\text{max}}$. What do you notice happening to the resistance as the voltage increases?

9. Draw and label a horizontal line across your resistance vs. voltage graph that represents the resistance measured using the ohmmeter (Experiment 2, step 1).

Discussion

- Using what you have learned today, and your $I$ vs. $V$ graph from last week, explain the cause of the systematic error in last week’s lab; specifically, why was $R_1 + R_2 < R_{\text{set}}$? Be sure to cite specific examples from each experiment performed today to support your explanation.

WHEN FINISHED, PLEASE TURN OFF THE POWER SUPPLY AND MULTIMETERS, AND DISCONNECT ALL THE WIRES!