Interpreting Last Week’s Results: Finding the Systematic Error
Spring 2017

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 (LN2: T = 77 K = -196 °C = -321 °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 \( R_{\text{set}} \). 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: you should correct any calculation or plotting errors you might have made last week before proceeding!

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 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. They show how much the best-fit line misses the data points.
3. Graph the residuals vs. voltage on KaleidaGraph, including all three sets of residuals on one plot. Do you notice any pattern in the residuals? If so, describe it. (Fitting a 2nd order polynomial curve to each residual set might help you visualize the pattern. Don’t display the equations; they aren’t important here).
4. Print the residuals plot you just created.
Experiment 4

1. Again measure the resistance of one of the resistors with an ohmmeter. These resistors will produce ¼ Watt of power. Calculate the rated current for the resistor, i.e., find the amount of current that will produce ¼ 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 current just calculated \( V_{\text{max}} \); calculate \( V_{\text{max}} \) from your current. What does your calculated value of \( V_{\text{max}} \) tell you about the resistor? Think about the range of voltages used in last week's experiment!

3. 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 ask your instructor for assistance. 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 \( V_{\text{max}} \)!

4. 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.)

5. Set the minimum x- and y-axis values of your graph to 0 (Plot → Axis Options)

6. 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.

7. 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?

8. 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 site specific examples from each experiment performed today to support your explanation.

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