Lab 11

Using Ohm's Law to Determine Equivalent Resistance

Experimental Objectives

- In this lab, after empirically verifying Ohm's Law, you would like to empirically determine the equivalent resistance of two resistors in series and of those two resistors in parallel.

When current moves through a wire due to an electrical potential difference (a voltage), it is literally electric charges falling through the wire due to an electrical field. This is completely analogous to gravitational charges (masses) falling through the air due to a gravitational field. Different types and sizes (gauges) of wire resist this current by different amounts. Ohm's Law describes (for some materials) just how this resistance affects a current for a specified voltage, i.e., it relates the current to the voltage. Using the equipment in the lab, you too will be able to discover Ohm's law! Hooray! Furthermore, we can investigate the effect of *multiple* resistors on a current in some voltage.

For each of the cases outlined below, we will measure at least eight voltage values (from a dc-power supply) and the corresponding current for a specific resistor or combination of resistors.

11.1 Pre-Lab

Answer the following questions before you come into lab.

1. Look up Ohm's Law. If you plot V versus I, what do you expect the graph to look like?
2. What units should the slope and intercept have?
3. What values do you expect the slope and intercept to have?
4. Draw one circuit diagram each for resistors in series and for resistors in parallel.
5. Look up the resistor color code in your textbook.

11.2 The Equipment

In the diagrams, A is an ammeter, which measures the current in amps (A), milliamps (mA), or microamps (μA). These measure the *current through* a wire and must be placed in series with the circuit element. Two circuit elements are "in series" if all of the current which goes through one also goes through the other. Current is the flow of charge (an amount of material); it does not diminish as it passes through the circuit elements.

In the diagrams, V is a voltmeter, which measures the voltage in volts (V). These measure the *voltage across* (the potential difference from before to after) a circuit element and must be placed in parallel with the circuit element. Two circuit elements are "in parallel" if the current gets split between one and the other. Voltage is related to the energy of the charges; it does diminish (or increase) as it passes through the circuit elements.

Figure 11.2.1 shows two configurations of ammeter and voltmeter. The small circles are the connections for the wires. In this lab, we are trying to measure the current through the resistor and the voltage across the resistor. On the left, the ammeter is in series with the resistor, but the voltmeter is not in parallel with the resistor. (I is correct, but V is too large.) On the right, the voltmeter is in parallel with the resistor, but the ammeter is not in series with the resistor. (V is correct, but I is too large.) You will be making a mistake either way, but hopefully neither is *too wrong*. For only one of your resistors, measure the data both ways and see how large the effect is. (It is incorrect to use the voltage from one circuit and the current from the other.)

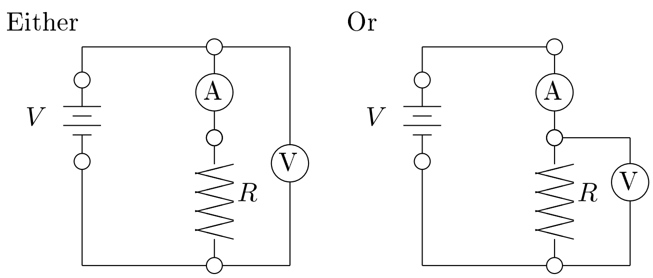

Figure 11.2.1: Determining Ohm's Law with a single resistor.

11.3 The Experiment

Please note Section 11.2 regarding the equipment as arranged in Figure 11.2.1. For one of your resistors arranged according to one of the circuits in Figure 11.2.1, measure the current (from the ammeter A) for several arbitrary and somewhat-evenly-spaced voltage values (as measured from V). Verify Ohm's Law by graphing the voltage V versus the current I and considering the equation of the best trendline. Repeat this for the second resistor. For at least one of your resistors, repeat this for the other configuration in Figure 11.2.1. Answer the first set of questions in Exercises 11.4.

Build the circuit in Figure 11.3.1 using your two resistors. Measure I from A for several V. Graph the voltages V_1, V_2, and V_t on the same graph, all versus the current I through the resistor. Consider the equations of the best trendlines. Answer Question 11.4.5, Question 11.4.6, and Question 11.4.7 about this data and graph.

Build the circuit in Figure 11.3.2 using your two resistors. Measure I from each A (I_1, I_2, and I_t) for several V. All on the same graph, plot the voltage V versus each current. Consider the equations of the best trendlines. Answer Question 11.4.9, Question 11.4.10, and Question 11.4.11 about this data and graph.

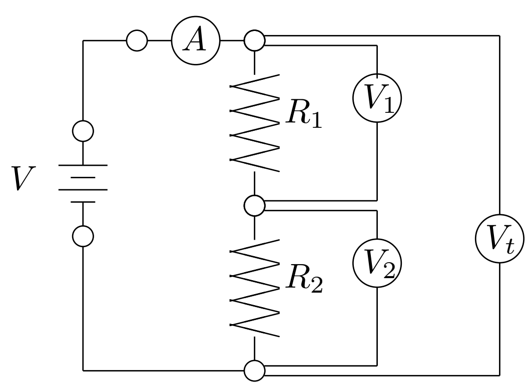

Figure 11.3.1: Using Ohm's Law with multiple resistors in series to find an equivalent resistance.

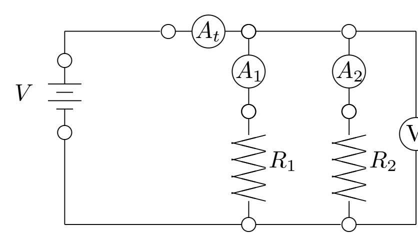

Figure 11.3.2: Using Ohm's Law with multiple resistors in parallel to find an equivalent resistance.

11.4 Questions

All of the following questions should be considered in your lab notebook and used to enhance the analysis of your report.
Regarding the individual resistors, answer the following questions:

1. Based on the color codes, do your resistor values agree with your graphs?

2. At the end of lab, the instructor will show you how to use the multimeter as an ohm-meter. Measure the resistance of your resistors and compare this value to the graphs.

3. Did the two configurations in Figure 11.2.1 give different values?

Regarding the series resistors, answer the following questions:

4. The series graph should have a plot of the individual resistors as well as the series combination. Do the individual series resistors on this graph agree with the individual values that you found on the plot in the first part? Are they too large or too small?

5. Use Ohm's Law to decide on the single equivalent resistor which could replace your two resistors without changing the current-voltage relationship.

6. Is the equivalent resistor larger than or smaller than the individual resistances?

7. Determine a relationship between your resistors, R_1 and R_2, and the equivalent resistance, R_{eq}.

Regarding the parallel resistors, answer the following questions:

8. The parallel graph should have a plot of the individual resistors as well as the parallel combination. Do the individual series resistors on this graph agree with the individual values that you found on the plot in the first part? Are they too large or too small?

9. Use Ohm's Law to decide on the single equivalent resistor which could replace your two resistors without changing the current-voltage relationship.

10. Is the equivalent resistor larger than or smaller than the individual resistances?

11. Determine a relationship between your resistors, R_1 and R_2, and the equivalent resistance, R_{eq}. (Hint: It may help to consider reciprocals of certain values; it may also help to look it up in your textbook.)

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