Resistance and Ohm's Law

Goal: To test Ohm's law with a carbon resistor, measure resistances in series and parallel, and to measure the current-voltage characteristics of a light bulb.

Lab Preparation
For many conductors, especially metals, the current flowing through a device is proportional to the voltage difference applied to the device: the ratio of the voltage to the current is a constant. This is Ohm's law. This ratio for a particular device defines its resistance:

$$R = \frac{V}{I}$$

where R is measured in ohms (Ω). For many materials under ordinary lab conditions, the ratio is practically constant, and the device is said to be *ohmic*. In some situations the ratio $\frac{V}{I}$ of a device may vary with changes in the conditions of the measurement such as large changes in the applied voltage or temperature.

In this experiment you will test whether a carbon resistor (a common electronic component) obeys Ohm's law by measuring the current and voltage and calculating the ratio of $\frac{V}{I}$. If Ohm's law holds, the ratio should be a constant. According to Ohm's law, a graph of current as a function of voltage (an I vs. V curve) will form a straight line for a simple resistor. The slope of the line is the reciprocal of the resistance, $\frac{1}{R}$, which is called the conductance.

When two or more resistors are connected together, a single equivalent resistance can replace them. Most combinations of resistors can be broken down into two kinds: series and parallel (Figure 1).
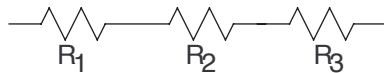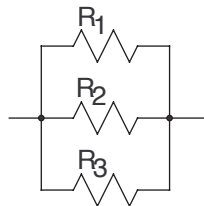

Figure 1a: Series   Figure 1b: Parallel

For two or more resistors connected in series, the same current must pass through each resistor. The equivalent resistance is the sum of the individual resistances:

$$R_{eq} = R_1 + R_2 + R_3 + ...$$

For two or more resistors in parallel, the same voltage drop is present across each resistor. The equivalent resistance is given by:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

The power dissipated by a resistor (or light bulb) is $P = VI$. The dissipated energy appears as heat and if the resistance is hot enough as visible light.

Procedure

I. Ohmic behavior.

    A. The resistors provided are made from a carbon-based composite material. Identify the values of the resistors provided by interpreting the color coded bands using the reference provided. Record these values along with the tolerances in a table.

    B. *Have your lab instructor check your circuit before closing the switch. When building circuits always try to arrange components as in the schematic to make wiring errors easier to spot. Add voltmeters last, since they usually can be added or subtracted from a circuit without significantly altering the currents and voltages present in the other components.*

       Build the circuit of Figure 2 with a 33 kΩ resistor. Connect to the battery pack's 6 V terminal. *Remember to have your lab instructor check your circuit.* Measure the current in μA (be very careful reading the ammeter) and the actual voltage drop across the resistor using the voltmeter. Record your values of V and I in a table that has columns for V, I and R. Calculate R.
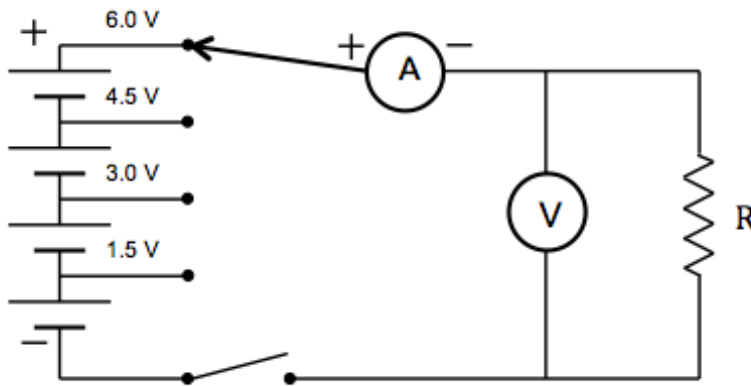

Figure 2

       Repeat this process for the battery pack hooked up to 4.5 V, 3.0 V, and 1.5 V. Does R have a constant value?

    C. Make a graph of I as a function of V (put I along the y-axis and V along the x-axis). Is the graph linear? If so, find the slope of the line and from the slope find the resistance. Check to see if this value is consistent with the value found in part A. Print out a copy of the graph to include in your report.

II. Series resistors.

Build the circuit in Figure 3. Use $R_1 = 33$ kΩ and $R_2 = 18$ kΩ and **6.0 V** on the battery pack. Measure the current and voltage and then calculate the combined series resistance. Compare your calculation with the equivalent resistance of R_1 and R_2 found using the given values above.
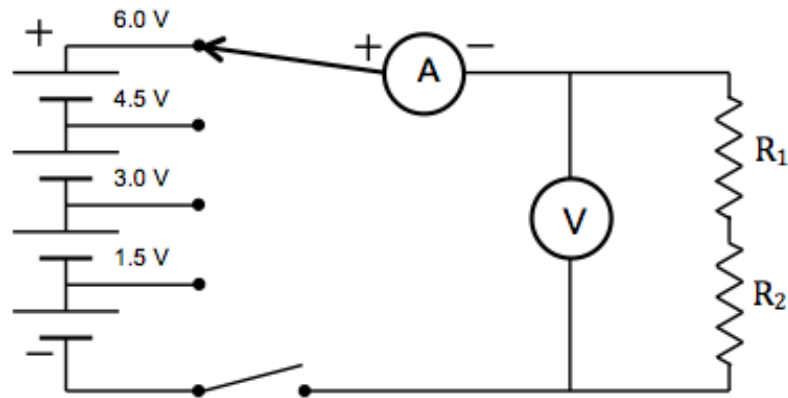

Figure 3

III. Parallel resistors.

A. Consider the circuit in Figure 4 (do not build yet). Use $R_1 = 33$ kΩ and $R_2 = 47$ kΩ and **3.0 V** on the battery pack. Predict the current flowing through the ammeter.
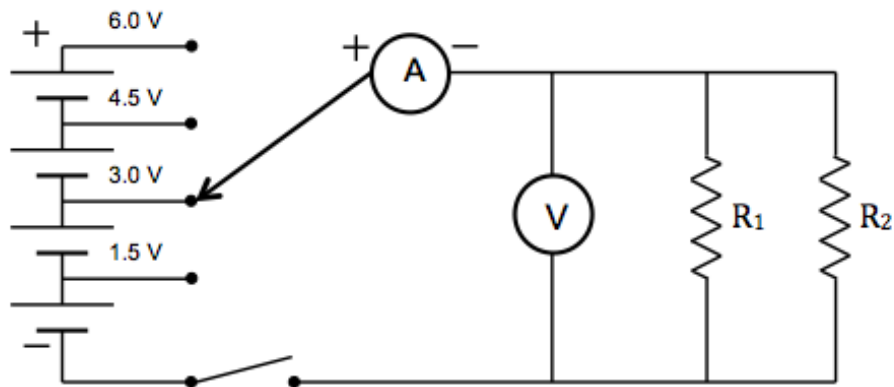

Figure 4

B. Build the circuit in Figure 4. Measure I and compare to your prediction.

C. Measure V. Find the equivalent resistance from your V and I measurements. Compare to the equivalent resistance found using the given values of R_1 and R_2.

D. Disconnect R_1 from the circuit. Does the voltmeter reading change significantly? Record the current now passing through R_2.

3

The voltages in this part of the experiment can cause an unpleasant shock. Do not touch exposed metal conductors while power is applied.

IV. <u>I-V characteristics of a light bulb.</u>
This circuit makes use of AC currents and voltages. The voltmeter must be set to measure AC volts (200 V range) and the ammeter must be an AC ammeter. **Do not** use the 200 μA DC ammeter of the previous circuits.

  A. *Have your circuit checked by the lab instructor before applying power.* Assemble the circuit shown in Figure 5. Be careful that the ammeter and voltmeter are not interchanged and that the Variac (variable transformer) is turned all the way down and the power is off.
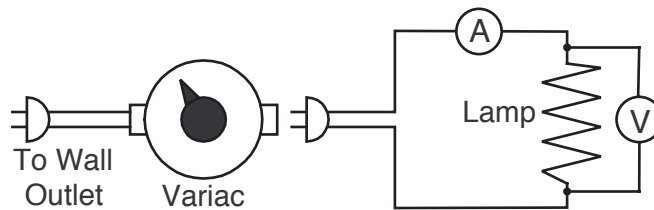

Figure 5

  B. Find the current for voltages varying from 0 to 120 volts in steps of approximately 10 volts. Adjust the Variac to control the voltage, but use the voltmeter to read the true voltage since the Variac scale is only approximate. Record your data (V and I) in a table (make an extra column for R).

  C. Make a graph of I as a function of V. Does this data form a straight line? Does the lamp obey Ohm's law? Print out a copy of the graph to include in your report.

  D. Calculate the lamp's resistance for each pair of (V,I) readings. What happens to the resistance as the temperature of the filament increases?

*When finished with your lab clean up your lab station. Make sure you put all of your wires away.

Homework
1. For part I check to see if the resistance found from the slope is within the accepted tolerance recorded from the colored band on the resistor.

2. For part III, which resistor carries the larger current when they are in parallel?

3. The volt is defined as 1 J/C. Prove that the product VI has units of watts.

4. Calculate the power consumed by the lamp at a voltage of 120 volts. The lamp used in this lab has a rated power of 40 Watts. How do these compare?