Physics 2049C Laboratory 3
Ohm's Law and Resistor Circuits

Purpose

Part A. You will test Ohm's Law and apply it to a carbon resistor.

Part B. You will analyze a circuit with resistors in series and deduce the equivalent resistance of these resistors in the circuit.

Part C. You will analyze a circuit with resistors in parallel and deduce the equivalent resistance of these resistors in the circuit.

Apparatus

DC power supply, 340 Ω (or 350 Ω) rheostat, resistor board with three resistors, connecting wires, multi-scale ammeter, multi-scale voltmeter, linear graph paper (*supplied by student*).

I. Preliminary Discussion

Ohm's Law states that for an "ohmic" conductor, the voltage V across the conductor is directly proportional to the current I through the conductor.

$$V = I \cdot R \qquad (1)$$

where the constant of proportionality is known as the resistance R. This proportionality should be intuitively obvious, as the greater the voltage ("electrical pressure") across a conductor, the more current ("electrical flow") you can push through it. The linear relationship for an ohmic conductor only holds when the temperature is held constant, as the resistance of a conductor increases with temperature.

However, when a current flows through a conductor, energy is dissipated in the conductor as heat (this is known as Joule heating, given by $P = I^2R$). Therefore, if too much current flows through a resistor, the resulting heat will increase the resistance, and the resistor will behave non-linearly and therefore not according to Ohm's Law.

For this reason and because of a lack of experimental understanding among his contemporaries, Georg S. Ohm, a German physicist, was called a "charlatan" when he first published his law in 1827 (in *Mathematisch Berichte*) and it was not accepted until many years later.

II. Experiment

A. Measuring the Resistance of a Carbon Resistor Using Ohm's Law

- Wire the circuit as in Fig. 1, using one of the three carbon resistors for the unknown R_x.

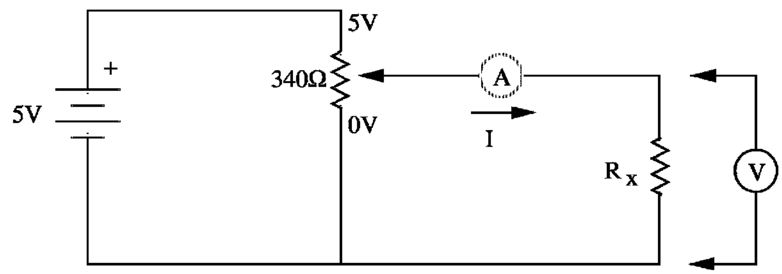

Figure 1

- The 340Ω rheostat is connected as a "voltage divider". By moving the rheostat wiper, the voltage across R_x can be varied from 0 to 5 V. With the voltmeter and ammeter connected as in Fig. 1, record the voltage across R_x and the corresponding current through the resistor for at least 5 different voltages across R_x.

- Plot the data on linear graph paper with current on the abscissa and voltage on the ordinate. Draw a "best fit" straight line through your data.

- From your V vs. I plot, determine the resistance of R and compare it to the value of the measured resistor given by the color code shown in Fig. 2.

(NOTE on Resistors: Black=0, Brown=1, Red=2, Orange=3, Yellow=4, Green=5, Blue=6, Violet=7, Gray=8, and White=9; Silver=10% and Gold=5%.)

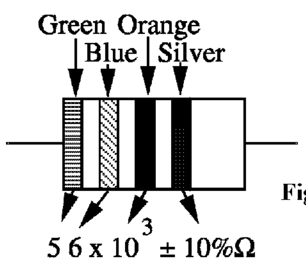

Figure 2

B. Analyzing Resistors Connected in Series in a Circuit

- Wire the circuit as in Fig. 3 with the three carbon resistor in series. You have only one ammeter and one voltmeter. The symbols in the figure show the different places in the circuit where you will insert the ammeter or connect the voltmeter.

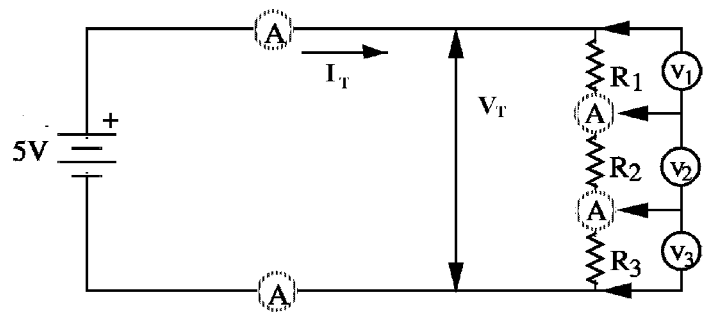

Figure 3

- Measure and record the voltage across each resistor and the total voltage V_T, across the series.

- Measure and record the current flowing through each resistor and through the series network. **(Remember, to measure current with an ammeter, the current must flow through the ammeter. Hence, you must open the circuit and insert the ammeter in series with a resistor, to measure its current.)**

- Using Ohm's Law to calculate the resistances, verify that the equivalent total series resistance equals the sum of the resistance in each element, or

$$R_T = R_1 + R_2 + R_3 \qquad (2)$$

- Verify that the total applied voltage equals the sum of voltage drops across each resistor, and that the current is constant, i.e. , the same current flows through each resistor connected in series.

$$V_T = V_1 + V_2 + V_3 \qquad (3)$$

$$I_T = I_1 = I_2 = I_3 \qquad (4)$$

C. Analyzing Resistors Connected in Parallel in a Circuit

- Now wire the three resistors in parallel as shown in Fig. 4. Again, you have only one ammeter. The symbols in the figure represent the different places in the circuit where you will insert the ammeter to make your measurements.

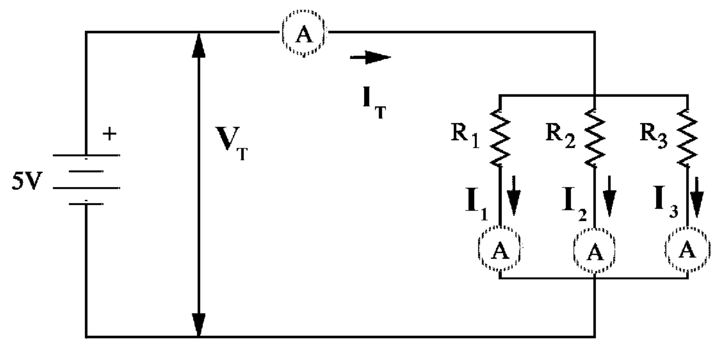

Figure 4

- Measure and record the voltage across each resistor, and V_T, the voltage applied to the parallel network. Measure and record the total current supplied by the source I_T and the current through each branch (each resistor) I_1, I_2, and I_3.

- Use Ohm's Law to calculate the resistances and verify that a parallel network of resistors satisfies the reciprocal equation

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \tag{5}$$

- Also verify that the sum of the individual currents in each branch of a parallel network is equal to the total current flowing into, or out of, the network and that the voltages across parallel elements are equal:

$$I_T = I_1 + I_2 + I_3 \tag{6}$$

$$V_T = V_1 = V_2 = V_3 \tag{7}$$