Physics 202 Lab 1: Electrical Conduction

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Theoretical Discussion

Electric potential and currents in conducting materials: When an electric potential V is applied across the two ends of a circuit, an electric field is induced in the circuit. Without this field, the conduction electrons within the circuit would randomly drift about, so that roughly equal numbers of them would move in any given direction. The induced electric field imparts a net drift velocity to the electrons so that they are more likely to travel anti-parallel (in the opposite direction) to the induced field direction than in the direction of the field[1]. This results in a current, or flow of charge, through the circuit. The greater the potential drop across the circuit, the larger the induced electric field and hence the larger the net drift velocity. Since the current is proportional to the net drift velocity, as the potential increases or decreases, so too does the current increase or decrease.

Resistance: The electrons in a conductor suffer many collisions while transiting the material. Some materials induce many more collisions than others, resulting in a smaller electron drift velocity and hence a smaller current, for a given potential drop through the material. These materials are said to have a relatively large resistance. A material for which very small electric potentials give rise to large currents is said to have a small resistance. The resistance of a circuit element is defined by the equation:

$$\boldsymbol{R} \equiv \frac{\boldsymbol{V}}{\boldsymbol{I}}$$

where R is the *resistance*, V is the potential drop across it, and I is the current flowing through it. In general, the resistance of a material depends on the voltage applied across it. If it does not, however, then the resistance is constant for all values of V, and the material is said to obey Ohm's Law. Such a material is called an *ohmic* material. Materials for which the resistance is not constant are called *non-ohmic*. In today's lab you will investigate both ohmic and non-ohmic materials.

Experimental Procedure

You will measure the current through a circuit element, as a function of the voltage drop across it, for two different types of elements;

- A resistor
  - Conducting material
  - Obeys Ohm's Law, so that the current is proportional to the potential for all values of the potential.

[1] The reason the drift velocity is anti-parallel to the field is because the electrons are negatively charged.

- A diode
    - Semi-conducting material
    - Does not obey Ohm's Law, so that the relationship between current and potential is non-linear.
    - Only conducts in one direction[2].

1. The resistor

a. Set up your circuit as shown in Figure 1 for the resistive circuit element. Use a 390 Ω resistor.

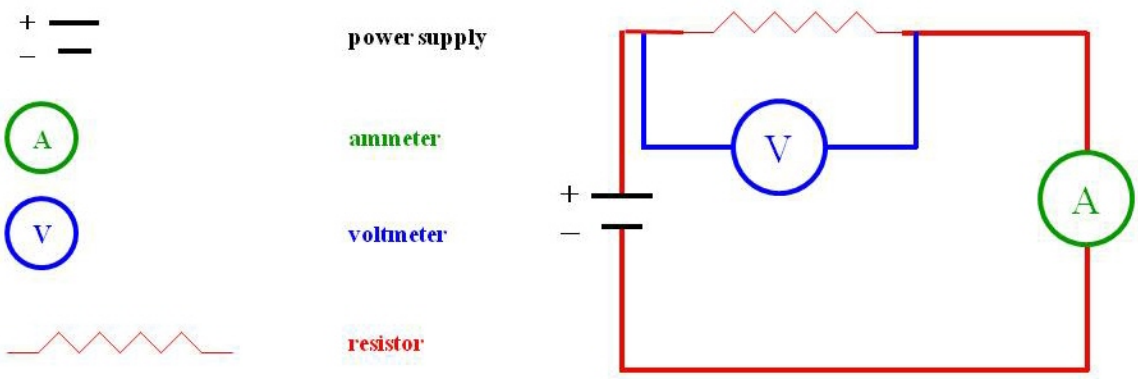

Fig. 1: Resistor Experimental Circuit Diagram

b. Vary the applied voltage between 2.0 and 10.0 V in 2.0 V steps. At each step, record the potential V and the current I.

c. Plot I vs. V. Note that this means that I is on the y-axis and V is on the x-axis.

d. Find the slope of this graph and use it to determine the resistance of the resistor R. Make sure you understand the mathematical relationship between the slope and R_{graph}.

e. Measure the resistance R_{meter} of the resistor using an Ohmeter.

f. Calculate the fractional discrepancy between the two values of R found in the previous two steps above. Note that we expect them to be very close to one another.

2. The diode

a. Set up your circuit as shown in Figure 2 for the diode circuit element.

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[2] Since a diode only conducts in one direction, for one of the cases in the procedure below, we expect that the current through the diode will be zero *no matter* what potential is placed across it.

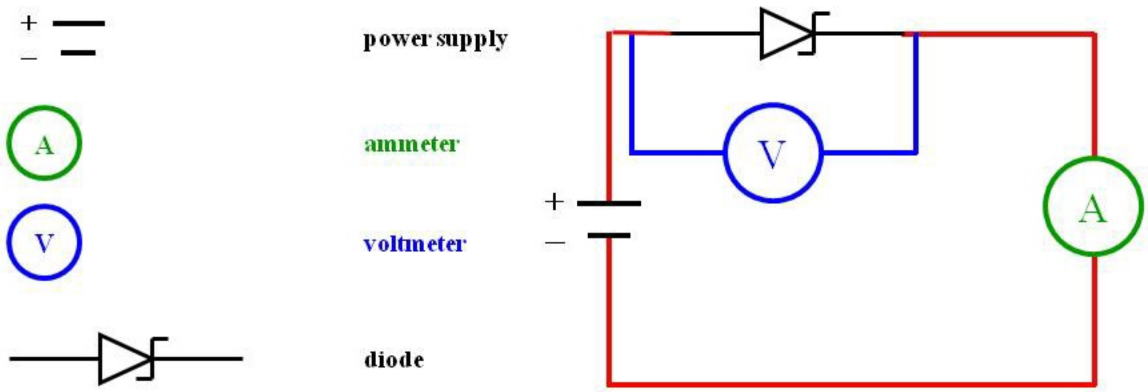

Fig. 2: Diode Experimental Circuit Diagram

b. Determine the direction of allowed current flow for the diode. You can do this by very slowly raising the potential across the diode. If you begin to see a large current before you reach 1.0 V potential, the diode is in the conducting position and you may skip to the next step. If you see no current across the diode, it is reversed biased and you should flip it around so that it points in the opposite direction. Then proceed to the next step.

c. Very slowly increase the voltage from 0 to 0.9 V in approximately 0.05 V steps. At each step, record the potential V and the current I. Be careful not to exceed the maximum permissible current on any given scale on your multimeter.

d. Plot, by hand, I vs. V for the forward biased case, in which the diode conducts electricity.

Fractional Discrepancies: The fractional discrepancy between any two quantities A and B, presumed to be independent measurements of the same quantity, is given by the ratio of the absolute value of their difference to the absolute value of their average. This ratio is expressed by the fraction

$$\delta = \frac{|A-B|}{\left(\frac{|A+B|}{2}\right)} = 2\frac{|A-B|}{|A+B|}$$