Physics 102 Lab 3: Electrical Conduction

Dr. Timothy C. Black

Spring, 2005

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:

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

where R is the *resistance*, V is the potential drop across it, and I is the current flowing through it. The resistance of a material generally 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.
- 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.

Set up your circuit as shown in Figure 1 for each of the two circuit elements provided.

- **resistor**
  1. Vary the applied voltage between 1.0 and 5.0 V in 1.0 V steps. At each step, record the potential V and the current I.
  2. Plot I vs. V. Note that this means that I is on the y-axis and V is on the x-axis.
  3. 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.

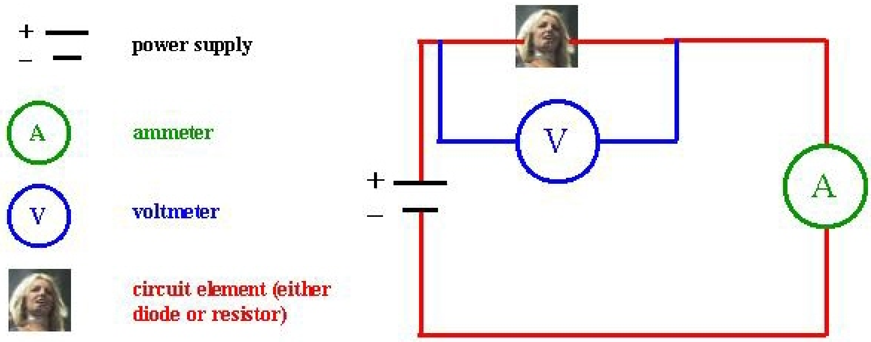

FIG. 1: Circuit diagram for investigating the relation between potential and current for various circuit elements

4. Measure the resistance of the resistor R using an Ohmeter.
5. Calculate the fractional discrepancy between the two values of R found in steps 3 and 4 above.

- **diode**

1. Very slowly increase the voltage from 0 to 1.0 V in approximately 0.1 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.
2. Reverse the polarity of the power leads (change + to − and *vice versa*) and repeat the previous step.
3. Plot by hand I vs. V for the 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 the difference to the absolute value of the average. This ratio is expressed by the fraction

$$\delta = \frac{|A-B|}{\frac{|A+B|}{2}} = 2\frac{|A-B|}{|A+B|}$$

---

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