IMPORTANT: remember to reduce the voltage to zero and to turn the power off before you connect the wires to another lamp.

The neon lamp will not conduct electricity until you reach about 50 V, make several readings around this value, and then increase the potential in about 5-10 V increments.

Do not increase the potential above 100 V because the lamps will too bright.

Report

For each lamp plot voltage vs. current. Can the data be approximated by a straight line? Explain.

Calculate resistance for each lamp. Plot resistance versus voltage. Observe that resistance significantly increases for the tungsten filament, slightly decreases for carbon and follows an exponential decay for the neon lamp. Explain these dependencies.

Use Eq. 2 to estimate the temperature of the tungsten filament at the maximum potential. Assume that the thermal coefficient of resistivity for tungsten is 0.0045 $^{o}C^{-1}$, and T_o=20^{o}C.

In the introduction explain why the resistance of metals increases with increasing temperature.

In the conclusions suggest a mechanisms that would explain the observed decrease of the resistance of carbon filament with increased temperature. Repeat for the neon lamp.

must be reduced. For example, when that distance is reduced to less than 1 mm, the voltage required to start the discharge is reduced to a manageable value of less than 1000 V. Adjusting the pressure of the gas between the electrodes could further reduce this potential. This property is often used in voltage regulators.

<u>Procedure</u>

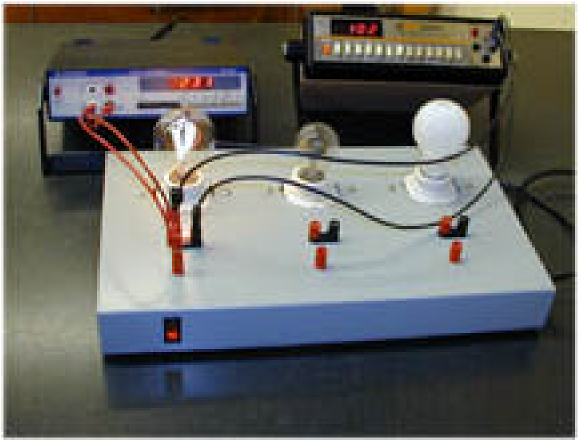

Fig. 1. Experimental setup with three light bulbs.

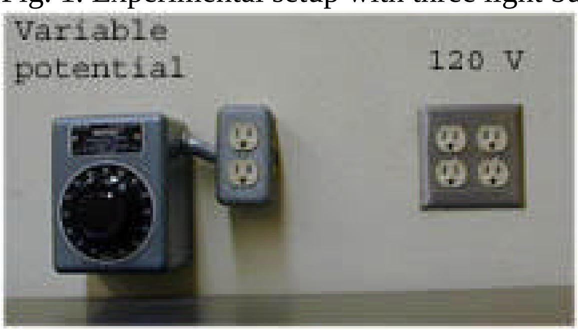

Fig. 2. Electrical outlets in rooms 364 and 361.

On the lab desks you will find metal boxes, each with three light bulbs, as shown in Fig. 1. The Victorian bulb on the left side of the box has a carbon filament, the lamp at the center, with two horizontal flat electrodes is the neon lamp, that on the right is the tungsten lamp. Make sure that the power switch on the front face of the box is in the OFF position. Next, plug in the power cord attached to the box into an outlet controlled by a variac, see Fig. 2. Connect an ammeter and a voltmeter to one of the lamps. The ammeter should be connected in series – connect the ammeter to the red posts on the box. The voltmeter should be connected in parallel, between the red and black posts, as shown in Fig. 1. Make sure that the instruments are set to measure **AC** current and potential, respectively. If you will use desktop multimeters, plug them into the 120 V outlets, not into the outlets of variable potentials! Ask the assistant to check the connections and only then turn the switch ON.

Increase the potential by rotating the large knob on the variac clockwise. For the carbon and the tungsten filament lamps initial increments should be small, about 1-2 volts, but after you exceed 10 V increase the step to about 5-10 V. Even if you turn the variac all the way to zero it will still provide some non-zero voltage, you make check it by increasing the sensitivity of the voltmeter. For each potential record the value of the current in proper units. For each lamp, you should record about twenty pairs of data points.

Experiment

27

Current and Resistance

Introduction

This is a simple experiment in which you will investigate the relationship between potential, current and resistance for three different materials. You will learn that not all materials follow the Ohm's law.

For a metallic resistor kept at a fixed temperature an increase in the voltage results in a corresponding increase in the current. This dependence is given by the Ohm's law:

$$V=IR \qquad (1)$$

Deviations from this linear relationship are expected when the temperature is increased. For metals, the temperature dependence of resistance in given by

$$R(T) = R(T_o)\,[1 + \alpha\,(T-T_o)], \qquad (2)$$

where $R(T_o)$ is resistance at room temperature T_o, R(T) is the resistance at temperature T, and α is thermal coefficient of resistivity. Different metals have different values of α. When the temperature of the conductor is increased due to thermal heating, V vs. I plot is no longer a straight line.

For semiconductors and isolators the voltage-current relationship is different from that given by Eq. 1. There are theoretical models that explain how the voltage changes with the current flowing through various gases, liquids and semiconductors. These models are complicated and their understanding is beyond the scope of this course. However, even without deep understanding of relevant theories you should be able to recognize different V(I) dependencies and identify mechanisms responsible for conductivity.

The first light bulb built by Thomas Edison had a carbon filament. Carbon is a semimetal and its resistance decreases slightly with increasing temperature. Thus, for a carbon resistor, when the temperature is increased, the plot voltage versus current slightly departs from a straight line. This property of carbon that allows it to maintain approximately the same value of resistance at various temperatures is utilized by the electronic industry which often uses this material to manufacture resistors.

Gases conduct electricity only after atoms become ionized. Ionized atoms and free electrons accelerate in the electric field, collide with other atoms, and in the course of these collisions secondary electrons and ions are formed. Motion of the electrons and ions is responsible for the flow of the current between the electrodes. For a given separation of the electrodes, d, the maximum voltage that can be applied without causing a discharge depends on the dielectric strength. The dielectric strength is for dry air is about 3 million V/m. If the applied electric field, E=V/d, exceeds the dielectric strength, the insulating properties break down and the medium begins to conduct. Of course, we do not want to work with potentials on the order of million of volts. To generate electric fields that would exceed the dielectric strength of the material and use reasonably low voltages, the distance between the electrodes