Name Section #

Variation of Resistance

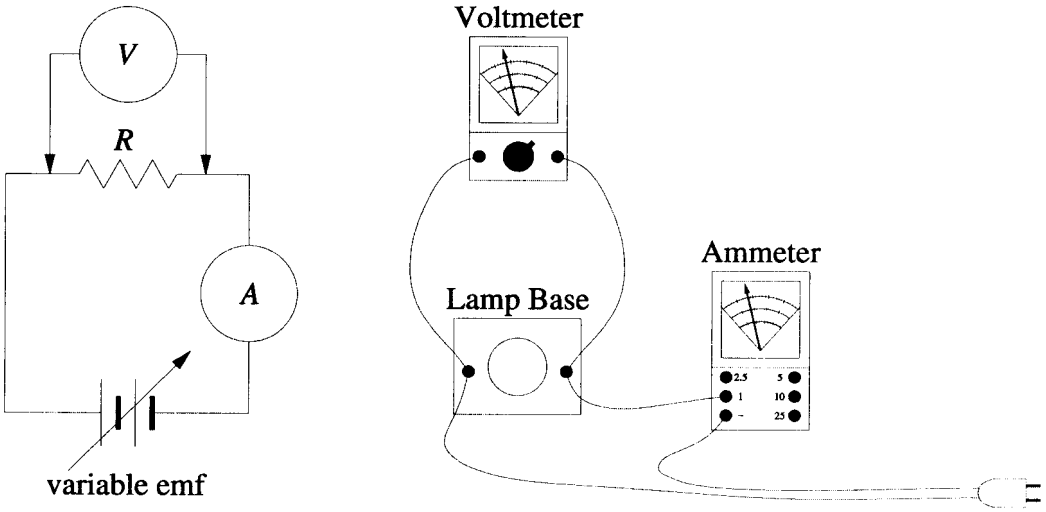
Purpose

You will examine the relationship between voltage and current where Ohm's law does not apply. A material obeys Ohm's law if the voltage and current are proportional when maintained at a constant temperature. That is, $V = RI$ and R is assumed to remain constant. (Power amplifiers and computers have internal fans to maintain a steady temperature.) No fans will be supplied and you will notice a marked increase in temperature as you increase the voltage across the carbon filament and tungsten filament bulbs in this experiment.

Theory

The valence (or conduction) electrons of a metal such as tungsten have sufficient energy so that they are not bound by the individual atoms and are free to move anywhere inside the metal. When a voltage is applied across the metal, some of the energy goes to increase the vibrational motion of the atoms (i.e., higher temperature) which interferes with the movement of the electrons. Hence increasing the voltage increases the resistance of a metal to current flow.

In the case of a non–metal such as carbon, all the electrons are bound to individual atoms and none may roam throughout the material. Applying a voltage across the carbon filament provides energy for some of the electrons to become free of the individual atoms, enabling them to move freely throughout the carbon. Such electrons are said to have entered the conduction band. Increasing the voltage increases both the temperature of the semiconductor and the number of electrons in the conducting band. Since the second effect is more important than the first, the resistance of the carbon filament should decrease.



Procedure

Connect the lamp base, voltmeter, and ammeter as shown in the above diagram. These should be connected via the power cord to the electric outlet which is connected to a variable voltage supply at the front of the room. Failure to make a proper circuit (such as interchanging the voltmeter

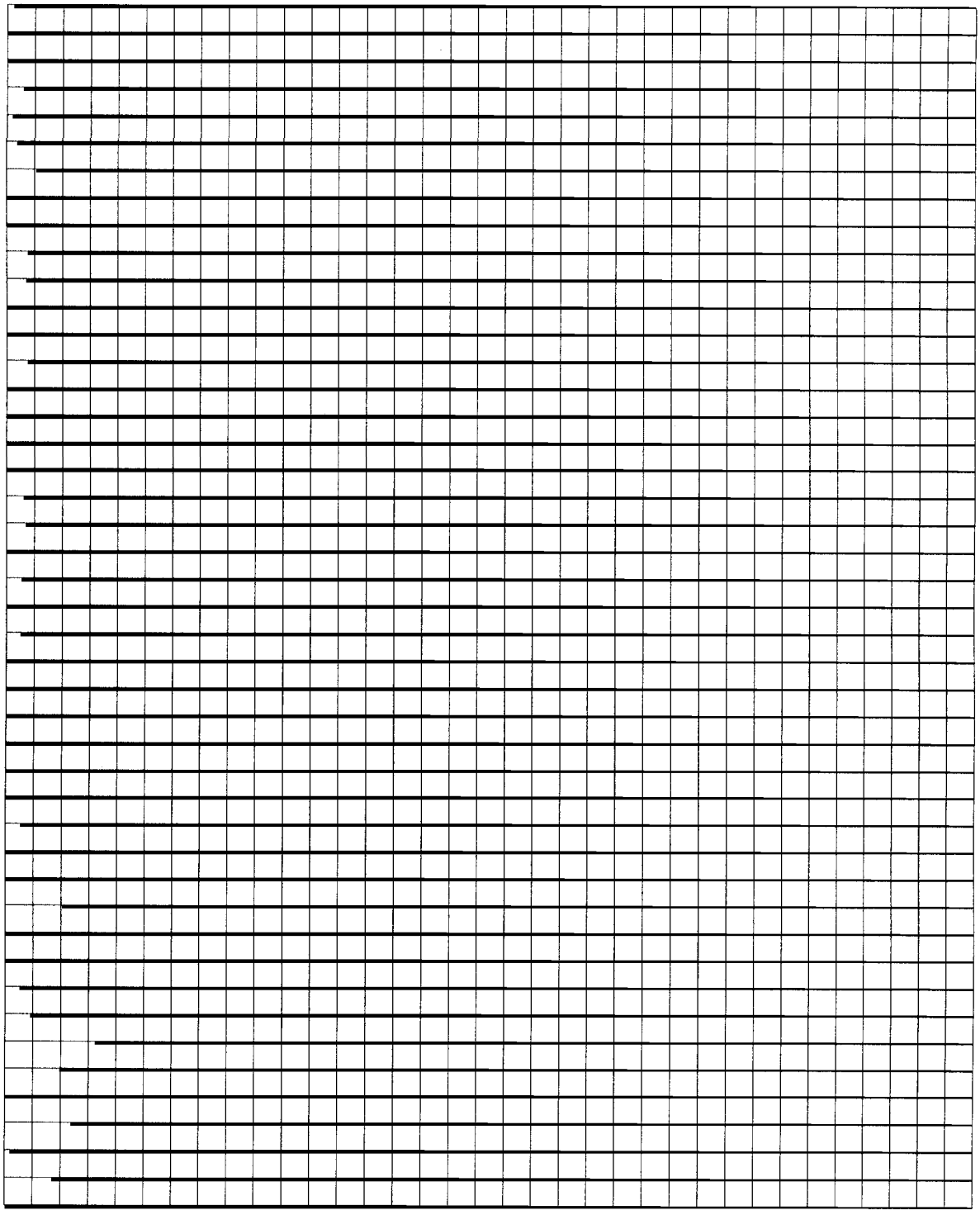
with the ammeter) may result in the destruction of the ammeter, a very expensive item to repair or replace. *If you are in doubt ask your teacher to check the connections.* You will be provided with two carbon filament bulbs and two tungsten filament bulbs. The voltage at the front of the room will be incremented in 12 steps from some minimum value to the maximum. For each step, read the ammeter and voltmeter on your desk to obtain the current and voltage for each of the four bulbs and enter your data in the Table.

Lamp #1: Carbon			Lamp #2: Carbon			Lamp #3: Tungsten			Lamp #4: Tungsten		
V (volts)	*I* (amps)	*R* (ohms)	*V* (volts)	*I* (amps)	*R* (ohms)	*V* (volts)	*I* (amps)	*R* (ohms)	*V* (volts)	*I* (amps)	*R* (ohms)

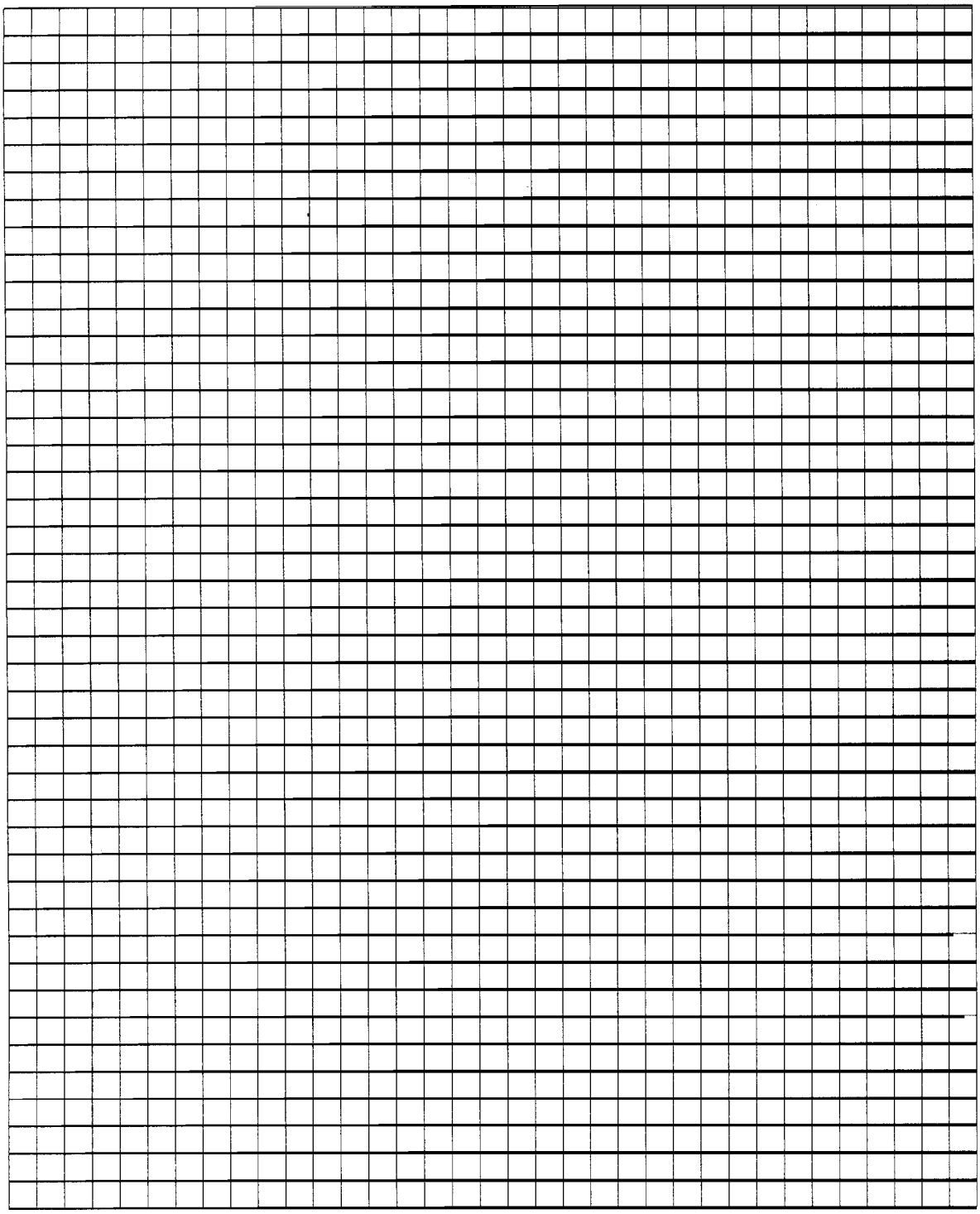
Use a single set of axes to plot the voltage (ordinate) versus the current (abscissa) for each of the 4 bulbs. Connect the data points with straight line segments. The slope of each such segment is an approximation for the bulb's resistance over that region of voltage and an even rougher approximation for the resistance at the starting voltage. Determine the value of the slope for each segment and enter this number under the column for resistance. For example; if the slope of the straight line segment between 18–20 V is 200 Ω while the slope between 20–22 V is 180 Ω, then enter 200 Ω as the approximate value of the bulb's resistance for 18 V and 180 Ω as its resistance for 20 V.

When you have completed the Table plot the resistance as ordinate versus the voltage as abscissa for each of the four bulbs using a single set of axes. The plot for each bulb should be a best line fit. Remember to answer the questions at the end of the lab.

Graphs of V versus I for 2 Carbon Bulbs and 2 Tungsten Bulbs



Graphs of R versus V for 2 Carbon Bulbs and 2 Tungsten Bulbs



Questions

What value should the slope of each of the *R versus V* graphs be if the bulbs obeyed Ohm's Law?

Determine the slope for each of your graphs and enter the values in the Table below.

	Lamp #1: Carbon	Lamp #2: Carbon	Lamp #3: Tungsten	Lamp #4: Tungsten
Slope of the *R* vs. *V* graph				

Are the slopes of the carbon bulbs similar? What about those the tungsten bulbs? Comment as to whether these slopes support the assertions made in the *Theory* section.

The relationship between resistance and temperature is given by $R = R_0 [1 + \alpha (T - T_0)]$ where R_0 is the resistance when T_0 is 20 °C or 293 K. R is the resistance when the temperature is T. For tungsten $\alpha = 0.0045\,\mathrm{K}^{-1}$, while for carbon $\alpha = -0.005\,\mathrm{K}^{-1}$. Assume the resistance obtained for the lowest voltage (when the bulb was at room temperature) to be R_0. Calculate the temperature of the tungsten filament in the larger 100–watt bulb when the potential difference across it is: (a) 15 V, and (b) 30 V. Do the same for the carbon filament.