The Effect of Temperature on Resistance

Introduction:
We have already become quite familiar with a quantity called resistance. Resistance was defined according to the relationship below:

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

For a manufactured resistor, you discovered that R was constant over the entire range of voltage and current values for which you collected data (i.e., the slope of your V vs. I graph was constant). Since just about everything that you could put into a circuit offers some resistance, we can broaden our definition of a 'resistor' to include anything you put into the circuit—a wire . . . a motor . . . even a hot dog! With this broader definition of a resistor, let's ask this question: "Is there anything that does affect the resistance of a resistor?"

As it turns out, the *temperature* of the resistive device can play a very interesting role in how the resistance behaves. Your mission is to answer this question: "How does the temperature affect electrical resistance?"

Background to your experimental approach:
You'll find three sample resistive materials that look similar to each other (see Figure 1): a wire, a manufactured resistor, and a piece of superconducting tape. Each of these three resistive materials has four jumper wires (A→D) soldered on to make various voltage and current measurements. Wires A and D will go to the power supply (with an ammeter wire in series in this loop; wires B and C will go to the voltmeter to measure the voltage drop across the testing material. Figure 2 shows a diagram of the circuit that you will build. The bolded line in Figure 2 represents the resistive material that you are testing.

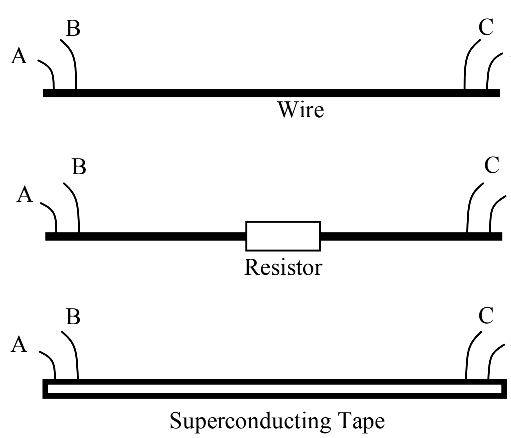

Figure 1. A 45-cm-length sample of wire, resistor with leads, and superconducting tape will serve as your sample resistive materials.

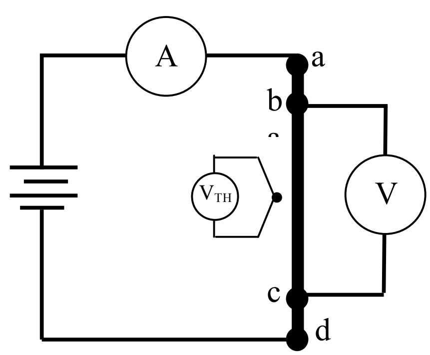

Figure 2. Schematic diagram of the circuit used to measure voltage and current (for resistance determination) and thermocouple voltage (for temperature).

You will alter the temperature by lowering your sample closer and closer toward a bath of liquid nitrogren. (CAUTION: SINCE THIS LIQUID NITROGEN IS 77 K (-196 °C), IT IS EXTREMELY IMPORTANT THAT YOU DO NOT TOUCH THIS LIQUID. YOU MUST WEAR GOGGLES WHEN WORKING WITH LIQUID NITROGEN.)

Figure 3 shows a diagram of the setup. Begin by lowering one of the samples, say the piece of wire, from a height of about 20 cm above a liquid nitrogen bath. At several heights above the liquid, the sample is held in place and the voltage and current are recorded from the voltmeter and ammeter respectively. At the same instant, the temperature will also need to be recorded. Unfortunately, we do not have a thermometer that measures temperatures as cold as we will encounter in this lab. Instead we will use a device called a thermocouple. This device is attached to the wooden frame that holds the sample. The thermocouple is then attached to a second voltmeter. You will record this second voltmeter reading and changes in these voltages and temperatures at a later time.

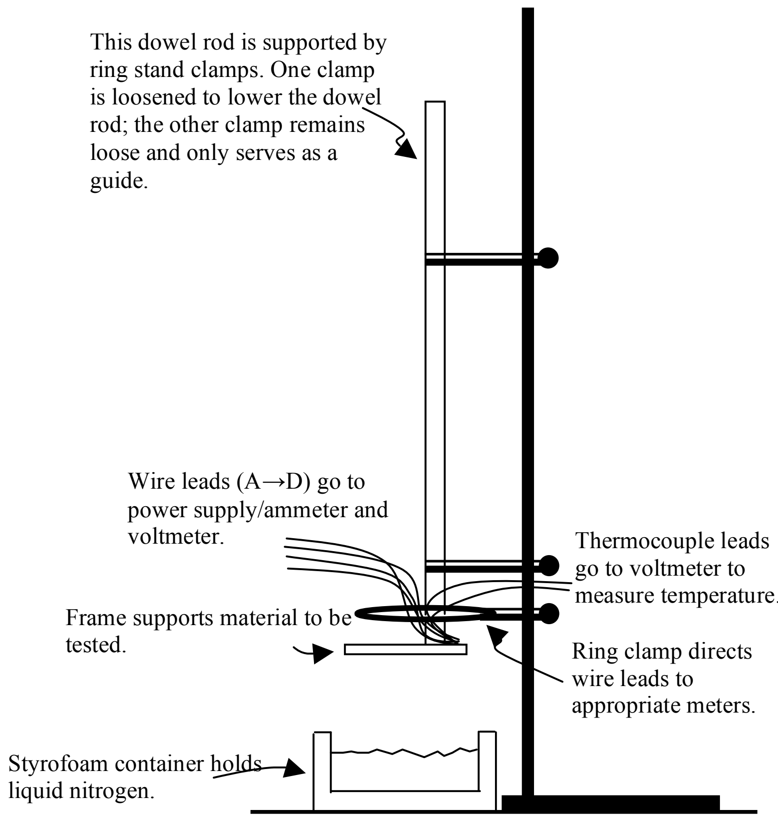

Figure 3. Equipment setup to cool sample and determine the resistance and temperature.

Since you already know that R = V/I, you can use the first voltmeter and ammeter measurements to calculate the resistance and the second voltmeter to determine the temperature. If you collect enough data over the entire range of temperatures from about 0 °C down to the temperature of liquid nitrogen, you should be able to answer the question at hand: "How does temperature affect resistance?"

Assessment

Your goal is to carry out an experiment that will lead you to understand how temperature affects electrical resistance for the objects that you test. You will write up your work in the form of a lab write-up. Your write-up should include the following elements: (1) a description of your purpose; (2) a description of your experimental design/equipment used; (3) data collected organized in tables; (4) graphs of resistance as a function of temperature for each material tested; and (5) a concluding statement and an answer to your research question.