Experiment

17

Temperature Coefficient of Resistivity

1. Introduction

Resistance of any material varies with temperature. For temperature range that is not too great, this variation can be represented approximately as a linear relation

$$R_T = R_o [1 + \alpha(T - T_o)] \quad (1)$$

where R_T and R_o are the values of the resistance at temperature T and T_o, respectively. T_o is often taken to be either room temperature or 0^o C. α is the temperature coefficient of resistivity. Pure metals have a small, positive value of α, which means that their resistance increases with increasing temperature. From temperature measurements of R you can find α. To do this you will plot resistance values versus T, and approximate the results with a straight line. The intercept of this line with the resistance axis is R_o, and the slope divided by R_o is the values of α.

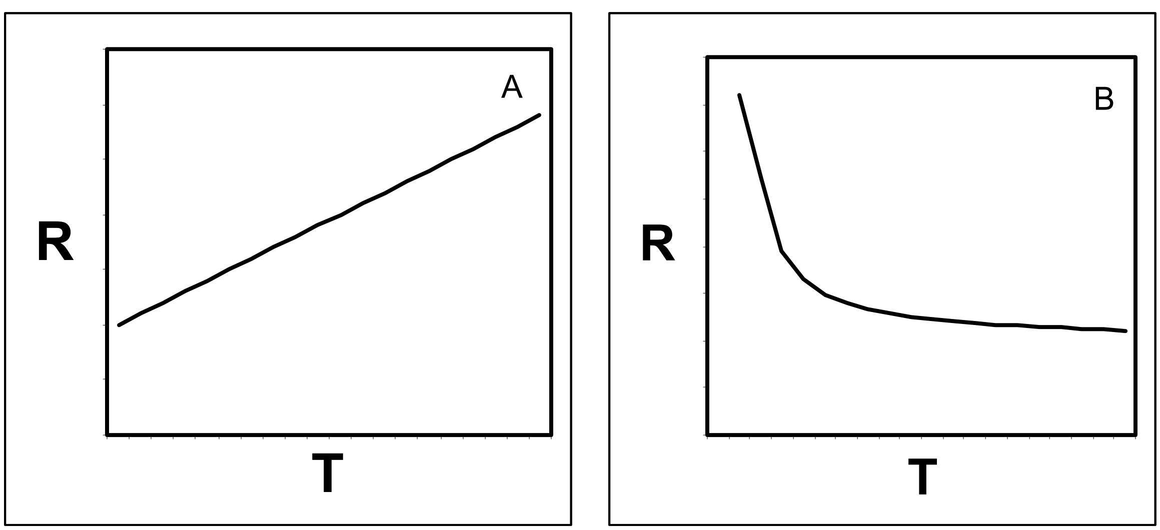

Fig. 1. Variation of resitivity with temperature of a metal (A) and a semiconductor (B).

There are materials in which resistance decreases with increasing temperature. A thermistor is an example of such a material. It is made of semiconductors, such as oxides of manganese, nickel and cobalt mixed in the desired proportion with a binder and pressed into shape. Thermistors are very sensitive to even small changes of temperature, therefore they are often used as thermometers (for example, you will use thermistors in Lab 23 to determine temperature of water). The change of resistance of a thermistor caused by temperature change is a nonlinear function and can be approximated by the following formula:

$$R_T = R_o \exp [\beta(1/T - 1/T_o)] \qquad (2)$$

where R_T and R_o are the resistance values at **absolute temperatures** T and T_o (<u>on the Kelvin scale</u>), β is a constant over a limited temperature range and characterizes a property of material. The unit of β is degree Kelvin. Equation 2 can be expressed as

$$\ln (R_T/R_o) = \beta(1/T - 1/T_o) \qquad (3)$$

When the resistance is measured at various temperatures and the $\ln(R_T/R_o)$ is plotted against $(1/T - 1/T_o)$, a straight line is formed. β can be found from the slope of that line.

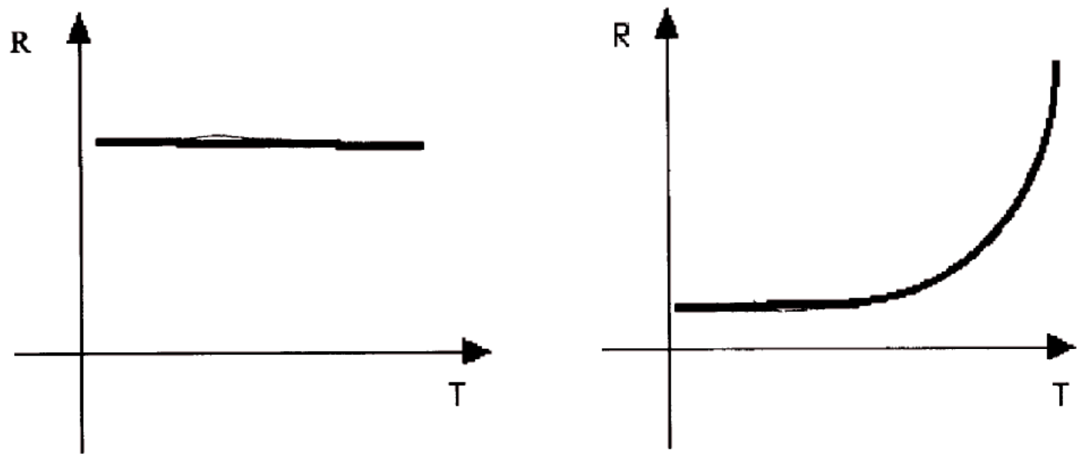

Fig. 2. Temperature dependence of resistance for an alloy (left) and a carbon resistor (right).

Some materials have very complicated temperature dependencies of resistance. For example, nichrome wire, used as a heating element in most space heaters, practically does not change its resistance in the temperature range between 0^o C and 100^o C. Fig. 2A illustrates this dependence, and it could be approximated by Eq. 1. For other materials, such as carbon resistors, R may be constant for a narrow temperature range and show a large effect beyond that range. Fig. 2B shows an exaggerated temperature dependence for this type of material.

2. **Procedure**

Open the plastic box with resistors and fill it with water. The resistors should be completely immersed in water. Close the box and secure the cover with electrical connections inside. Insert a thermometer, it should be immersed in water to the level indicated by a horizontal line. Connect the binding post of the terminal to an ohmmeter. Stir the water thoroughly and record the initial values of temperature and resistors in the box. Use the rotary switch to measure resistance of each of the resistors.

Turn the heater on by closing the switch on the top plate of the box. Increase the temperature by about 5 degrees. Keep stirring the water. Turn the heater off and continue stirring until water reaches thermal equilibrium. Record the resistance of each resistor in the box and the temperature. Repeat this procedure in approximately 5^o C intervals until you have at least 10 readings or the temperature reaches 90^o C. Do not increase the temperature above 90^o C. Record the data in Table 1.

To reduce the error use the same setting of the ohmmeter for the same resistors. Because the materials whose resistance you will measure have different values of R you will have to set the ohmmeter to ranges appropriate for each element. Remember to use the same ranges for each of the resistors.

Table 1. Results

Temperature [^{o} C]	Resistance [Ω] conductor 1	Resistance [Ω] conductor 2	Resistance [Ω] conductor 3	Resistance [Ω] conductor 4	Resistance [Ω] conductor 5

3. Report

Examine the data in Table I and identify the metals, the thermistor, the carbon resistor, and the alloy.

For the two metal resistors and the alloy use Equation 1 to determine the thermal coefficient of resistance, α. Plot normalized resistance, R_T/R_o, versus T and from the slope of the straight line drawn through the experimental points find α. I recommend that you use Excel or another software and a fitting routine to determine the slope. R_o is the value of the resistance at room temperature. Identify the metals by comparing the obtained results with the values in Table 2.

For the thermistor plot a graph of $\ln(R_T/R_o)$ versus $(1/T - 1/T_o)$ and find the slope of the straight line, which is the value of β in Eq. 3.

Table 2. Temperature coefficient of resistivity for selected materials

Conductor	α [(^{o} C)$^{-1}$]
Copper	4.29×10^{-3}
Iron	6.41×10^{-3}
Nickel	6.00×10^{-3}
Platinum	3.93×10^{-3}
Mercury	0.89×10^{-3}
Chromel (alloy of chromium and aluminum)	0.58×10^{-3}
Nichrome (alloy of nickel and chromium)	0.40×10^{-3}

For the carbon resistor plot R vs. T and determine the maximum temperature for which the resistance is approximately the same as at room temperature.

In the discussion section explain how you identified the materials and estimated the experimental errors. Estimate the precision of the constants α and β.

In the introduction use a collision model between electrons and nuclei to explain why resistance of pure metals increases with increasing temperature.