

## 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

$$R_T = R_0 [1 + \alpha(T - T_0)] \quad (1)$$

where  $R_T$  and  $R_0$  are the values of the resistance at temperature  $T$  and  $T_0$ , respectively.  $T_0$  is often taken to be  $0^\circ\text{C}$ .  $\alpha$  is the temperature coefficient of resistivity. Pure metals have a small, positive value of  $\alpha$ , which means that their resistance increases with increasing temperature. From temperature measurements of  $R$  you can find  $\alpha$ . 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  $R_0$ , and the slope divided by  $R$  is the values of  $\alpha$ .

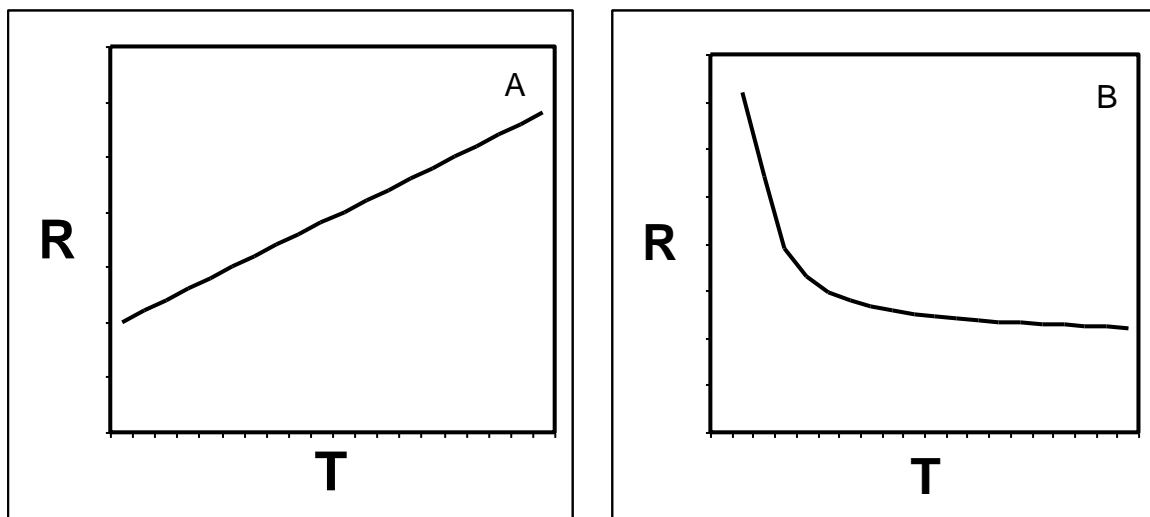


Fig. 1. Variation of resistivity with temperature of a metal (A) and a semiconductor (B).

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:

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

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

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

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.  $\beta$  can be found from the slope of that line.

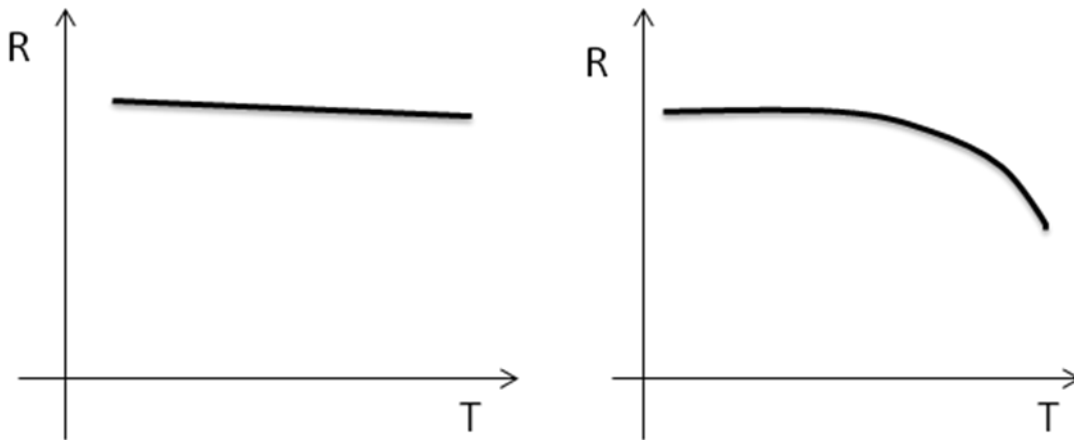


Fig. 2. Temperature dependence of resistance for an alloy (left) and a carbon resistor (right).

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  $0^\circ\text{C}$  and  $100^\circ\text{C}$ . 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



Table 2. Temperature coefficient of resistivity for selected materials

| Conductor                                | $\alpha$ [ $^{\circ}\text{C}^{-1}$ ] |
|------------------------------------------|--------------------------------------|
| Copper                                   | $4.29 \times 10^{-3}$                |
| Iron                                     | $6.41 \times 10^{-3}$                |
| Nickel                                   | $6.00 \times 10^{-3}$                |
| Platinum                                 | $3.93 \times 10^{-3}$                |
| Mercury                                  | $0.89 \times 10^{-3}$                |
| Chromel (alloy of chromium and aluminum) | $0.58 \times 10^{-3}$                |
| Nichrome (alloy of nickel and chromium)  | $0.40 \times 10^{-3}$                |

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  $\alpha$  and  $\beta$ .

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