Exercise 23 Coefficient of linear expansion

1. Objectives:

Measure coefficient of linear expansion of metal rods.

2. Description:

Most solid rods' lengths will increase with increasing temperature. Their increments are proportional to their length at $0°\mathrm{C}$ and Celsius temperature. This relation is given by

$$L - L_0 = L_0 \alpha T \tag{1}$$

$$L = L_0(1 + \alpha T) \tag{2}$$

where L_0 is the length at $0°\mathrm{C}$

L is the length at $T°C$

α is coefficient of linear expansion of the object

T is Celsius temperature

When temperature change becomes smaller, α is closer to a constant. In this experiment, we suggest the temperature change is better not to over $50°C$, i.e.

$$\alpha = \frac{L - L_0}{L_0 T} \tag{3}$$

While there is larger temperature change, the relation between α and temperature T will be

$$\alpha = a + bT + cT^2 + \cdots\cdots \tag{4}$$

where *a*, *b* and *c* are constants. If L_1 and L_2 are lengths at temperatures T_1 and T_2 respectively, then we have

$$L_1 = L_0(1 + \alpha T_1) \tag{5}$$

$$L_2 = L_0(1 + \alpha T_2) \tag{6}$$

by eqs (5) and (6), we obtain

$$\frac{L_1}{L_2} = \frac{1+\alpha T_1}{1+\alpha T_2} \tag{7}$$

$$\alpha = \frac{L_2 - L_1}{L_1 T_2 - L_2 T_1} \tag{8}$$

Because the difference of L_1 and L_2 are very small, $L_2 \approx L_1$, we have

$$\alpha = \frac{\Delta L}{L_1 \Delta T} \tag{9}$$

where

$$\Delta L = L_2 - L_1 \quad \text{and} \quad \Delta T = T_2 - T_1$$

From eq. (9), the definition coefficient of liner expansion is the elongation per unit length of solid when temperature rises $1°\mathrm{C}$.

3. Material:

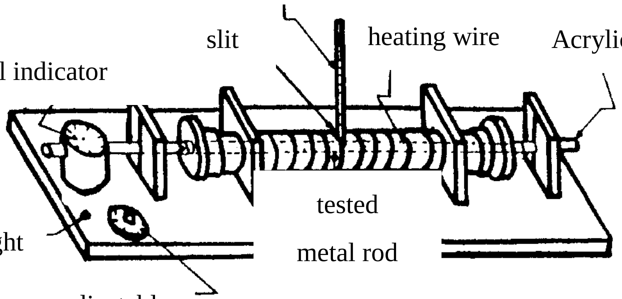
Coefficient of linear expansion analyzer, thermometer or mobile digital multimeter, K type temperature test cable, brass rod, aluminum rod, Acrylic base, fixing screws, dial indicator and metal round rack.

Table: Reference values of coefficient of linear expansion for metals (α , unit is $10^{-6}/°C$)

Metal	Gold	Silver	Copper	Brass	Iron	Aluminum	Stainless Steel	Lead
α	14.70	18.90	16.66	19.00	11.40	22.20	9.6	27.09

4. Procedure:

(1) Set up devices as plot 1 shown. Start experiment with recording room temperature and measure length of metal rod *L*.



Plot 1

(2) First, make sure there is no thermometer (or temperature test cable) in thermometer slit, then place tested metal rod into heating pipe. Make sure two ends of metal rod right reach sides of pipe, and screw tight to secure it with a hex key wrench.

(3) Place thermometer (or temperature test cable) slowly into thermometer slit.

(4) Active temperature adjustable knob and tune to proper temperature. Measure present temperature directly with a thermometer.

(5) Once temperature raised to 70°C, stop heating process. Only collect data when temperature starts to drop. Also take readings L_n from dial indicator and temperature T_n from thermometer.

(6) Record one data point (L_n，T_n) when temperature drops about 2°C to 5°C each time, till temperature is down to within 10°C of room temperature.

Attention: Temperature may decrease very fast in the beginning, and do not collect data in the first 5°C dropping.

(7) Draw ΔT as x-axis and ΔL as y-axis plot by eq. (9). Determine slope by least square error method and calculate linear expansion coefficient α of metal rod.

(8) Calculate the error percentage.

(9) Remove thermometer (or temperature test cable) slowly, redraw metal rod, place the second metal rod and put into thermometer slowly. Repeat steps (1) to (8).

(10) Replace to the third metal rod as step (9), and repeat steps described above.

5. Question:

(1) In this experiment, why do we start from decreasing temperature instead of increasing it?

(2) If we start from increasing temperature for this experiment, what difficulties we will encounter?

(3) Discuss the major sources of errors?

(4) During linear expansion coefficient α measurement process, what assumptions we used?