ACTIVITY 9

AIM

To observe and explain the effect of heating on a bi-metallic strip.

APPARATUS AND MATERIAL REQUIRED

A iron-brass bi-metallic strip with an insulating (wooden) handle; heater/burner.

DESCRIPTION OF THE DEVICE

A bi-metallic strip is made of two bars/strips of different metals (materials), but of same dimensions. These metallic bars/strips (A and B) are put together lengthwise and firmly rivetted. An insulating (wooden) handle is also fixed at one end of the bi-metallic strip. A bi-metallic strip can be made by selecting metals (materials) with widely different values of coefficients of linear thermal expansion.

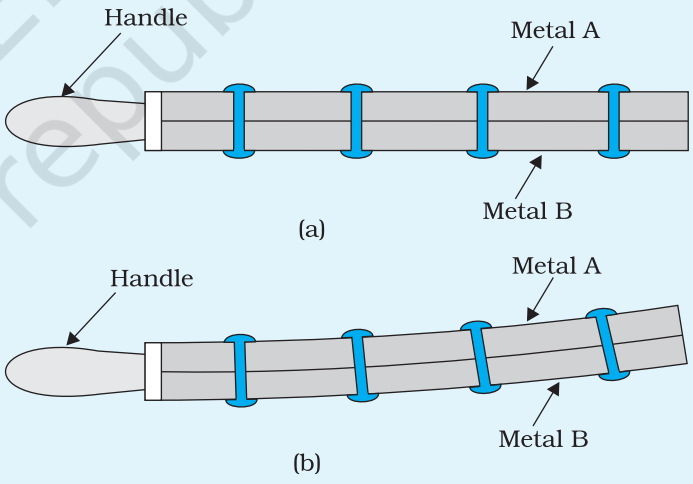

Fig. A 9.1: *A bi-metallic strip in (a) straight, and (b) bent positions*

The bi-metallic strip is straight at room temperature, as shown in position (a) of Fig. A 9.1. When the bi-metallic strip is heated, both metallic pieces expand to different extents because of their different linear thermal expansivities, as shown in position (b) of Fig. A 9.1. As a result, the bimetallic strip appears to bend.

PRINCIPLE

The linear thermal expansion is the change in length of a bar on heating. If L_1 and L_2 are the lengths of rod/bar of a metal at temperatures t_1°C and t_2°C (such that $t_2 > t_1$), the change in length

$(L_2 - L_1)$ is directly proportional to the original length L_1 and the rise in temperature $(t_2 - t_1)$.

(A 9.1) Then, $(L_2 - L_1) = \alpha L_1 (t_2 - t_1)$

(A 9.2) or $L_2 = L_1 [1 + \alpha (t_2 - t_1)]$

(A 9.3) and $\alpha = (L_2 - L_1)/(t_2 - t_1)$

where α is the coefficient of linear thermal expansion of the material of the bar/rod.

The coefficient of linear thermal expansion (α) is the increase in length per unit length for unit degree rise in temperature of the bar. It is expressed in SI units as K^{-1}.

PROCEDURE

1. Light a burner or switch on the electric heater.
2. Keep the bi-metallic strip in the horizontal position by holding it with the insulated handle and heat it with the help of burner/ heater. Note which side of the bi-metallic strip is in direct contact of heat source.
3. Observe the effect of heating the strip. Note carefully the direction of the bending of the free end of the bi-metallic strip, whether it is upwards or downwards?
4. Identify the metal (A or B) which is on the convex side of the bi-metallic strip and also the one which is on its concave side. Which one of the two metals/materials strips have a larger thermal expansion? (The one on the convex side of the bi-metallic strip will expand more and hence have larger linear thermal expansion).
5. Note down the known values of coefficient of linear thermal expansion of two metals (A and B) of the bi-metallic strip. Verify whether the direction of bending (upward or downward) is on the side of the metal/material having lower coefficient of linear thermal expansion.
6. Take the bi-metallic strip away from the heat source. Allow the strip to cool to room temperature.
7. Repeat the Steps 1 to 6 to heat the other side of the bi-metallic strip. Observe the direction of bending of the bi-metallic strip. What change, if any, do you observe in the direction of bending of the strip in this case relative to that observed earlier in Step 3?

RESULT

The bending of a bi-metallic strip on heating is due to difference in coefficient of linear expansion of the two metals of the strip.

PRECAUTIONS

The two bars (strips) should be firmly rivetted near their ends.

DISCUSSION

The direction of bending of the bi-metallic strip is towards the side of the metal which has lower value of linear thermal expansion.

SELF ASSESSMENT

1. You have been given bars of identical dimensions of following metals/materials along with their α - values, for making a bi-metallic strip:

   Aluminium ($\alpha = 23 \times 10^{-6}\ K^{-1}$); Nickel ($\alpha = 13 \times 10^{-6}\ K^{-1}$)

   Copper ($\alpha = 17 \times 10^{-6}\ K^{-1}$); Invar ($\alpha = 0.9 \times 10^{-6}\ K^{-1}$)

   Iron ($\alpha = 12 \times 10^{-6}\ K^{-1}$); Brass ($\alpha = 18 \times 10^{-6}\ K^{-1}$)

   which pair of metals/materials would you select as best choice for making a bi-metallic strip for pronounced effect of bending? Why?

2. What would be the effect on the bending of the bi-metallic strip if it is heated to a high temperature?

3. Name a few devices in which bi-metallic strips are generally used as a thermostat?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

Design fire alarm circuit using a bi-metallic strip.