OGUN DIGICLASS

CLASS: SECONDARY SCHOOL

SUBJECT: PHYSICS

TOPIC: HEAT/THERMAL ENERGY

HEAT/ THERMAL ENERGY

LEARNING OUTCOMES

- Explain temperature, expansion, change of state and vaporisation using the kinetic molecular theory.

- Solve simple problems involving linear, area and volume expansivity

CONCEPTS OF HEAT AND TEMPERATURE

- Heat energy is the energy that transferred from a hot object to a cooler object as a result of their difference in temperature.
- Heat is defined as a measure of the total kinetic energy of the molecules in a system.
- Temperature is the degree of hotness or coldness of an object.
- Temperature is defined as a measure of the average kinetic energy of the molecules of the system.

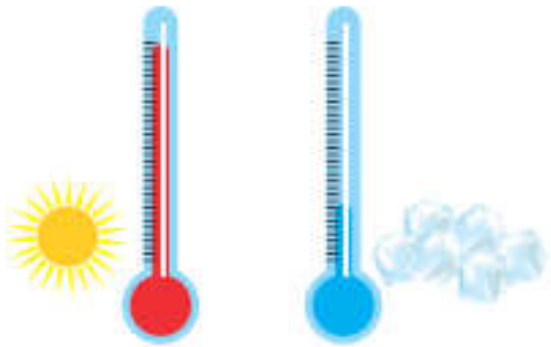
EFFECTS OF HEAT

- Change in temperature of the body
- Change of state of the body e.g melting, sublimation, vaporization
- Expansion/ contraction of the body
- Chemical change
- Change in physical properties of the body. (electrical resistance, manetic properties, conductivity, elasticity, density etc
- Change in pressure. (gas law)
- Thermionic emission.

Effects of Heat

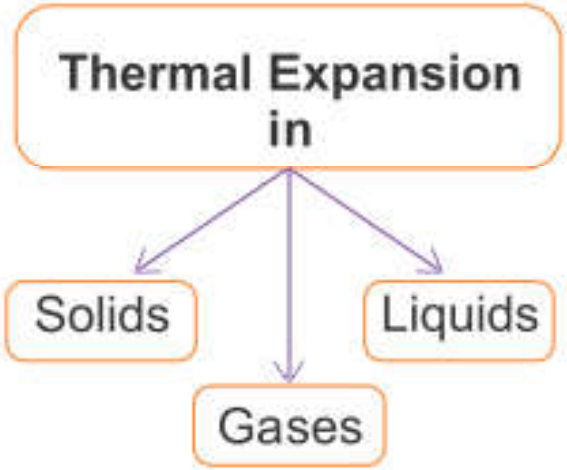
Change in temperature of body

When a body gains heat, temperature increases and when it is cooled temperature decreases.

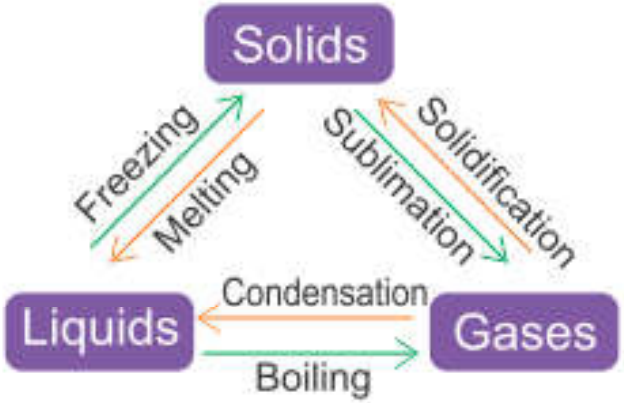


Change in shape of body

Length, volume and area of a substance increases, when heat is supplied to it. This is known as **thermal expansion.**

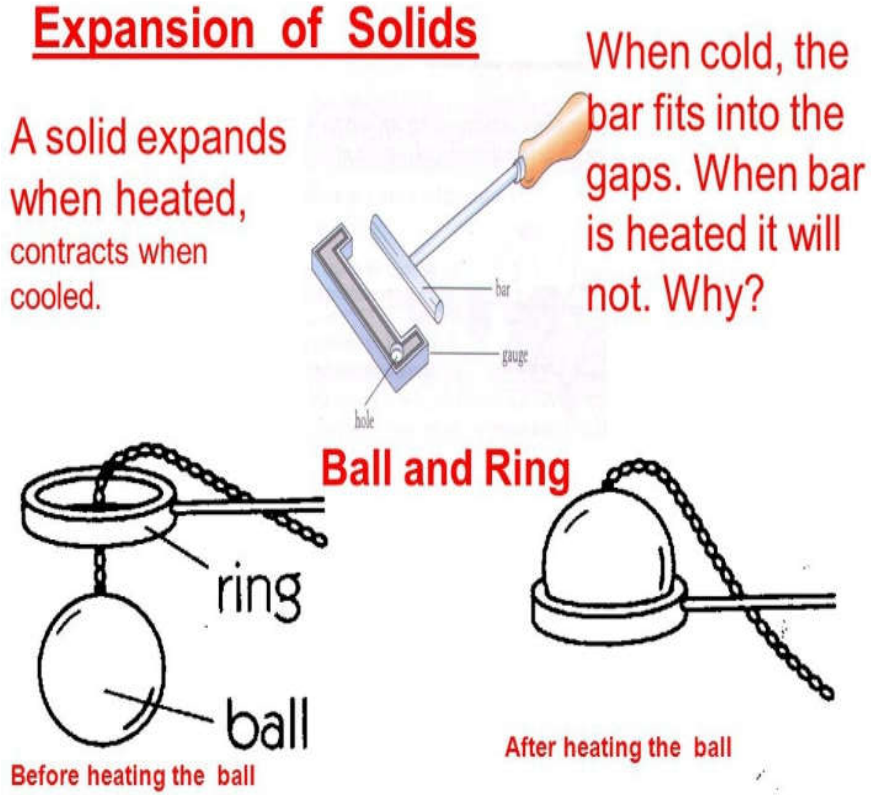


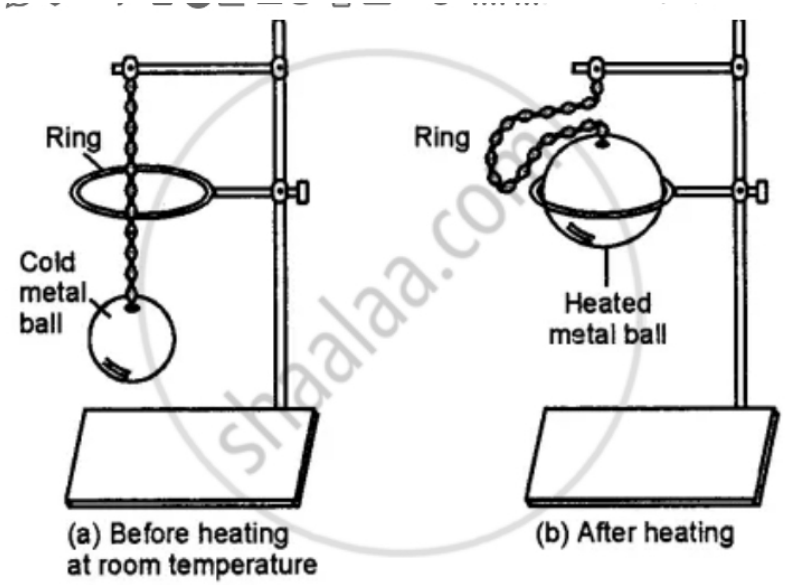
Change of state



THERMAL EXPANSION

- Thermal expansion is the increment in the average separation of the atoms or molecules of a substance (increase in size). Expansion occurs in solids, liquids and gases.



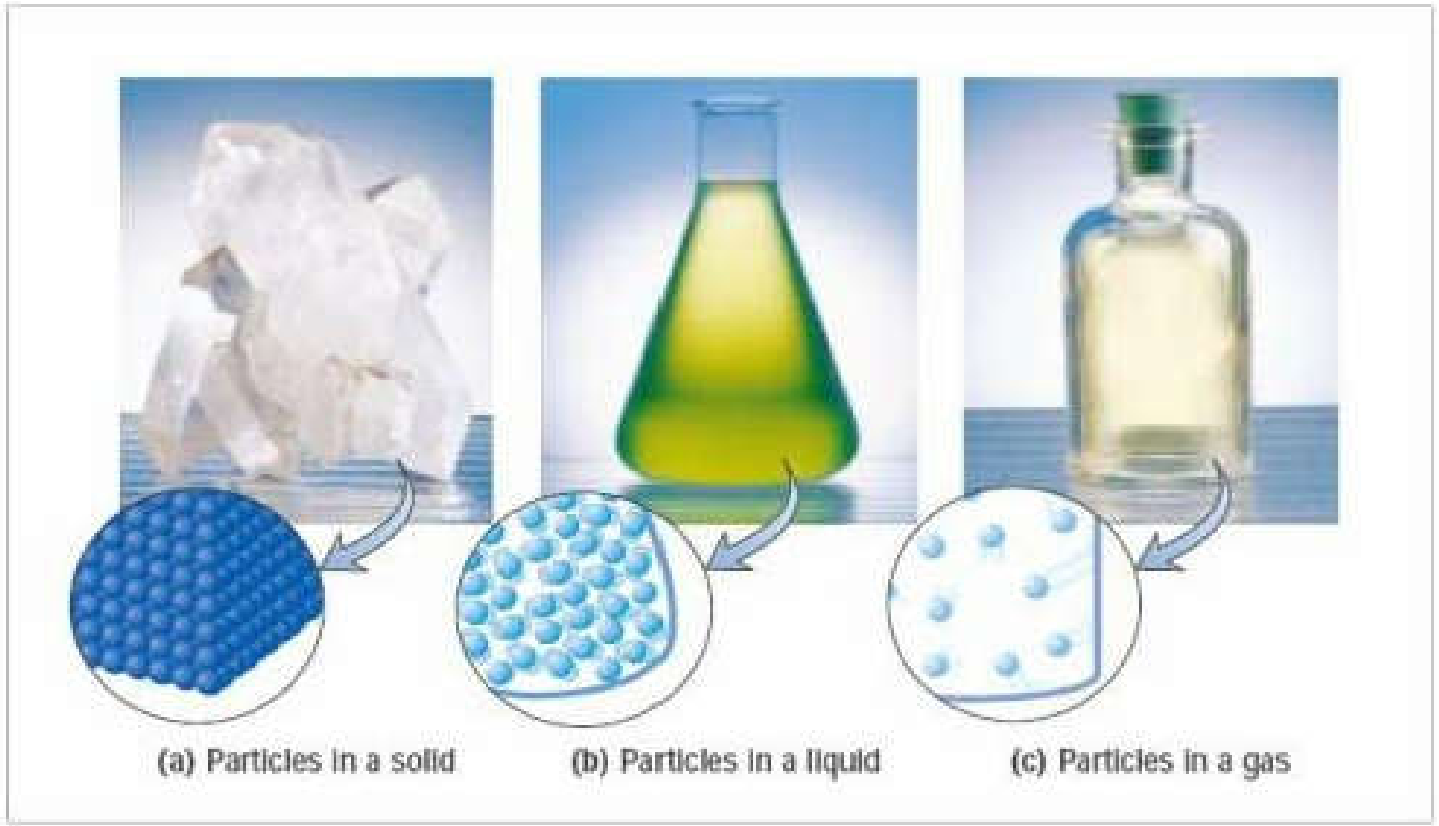


Describe an Experiment to Demonstrate the Thermal Expansion in ...

EXPANSION IN SOLIDS

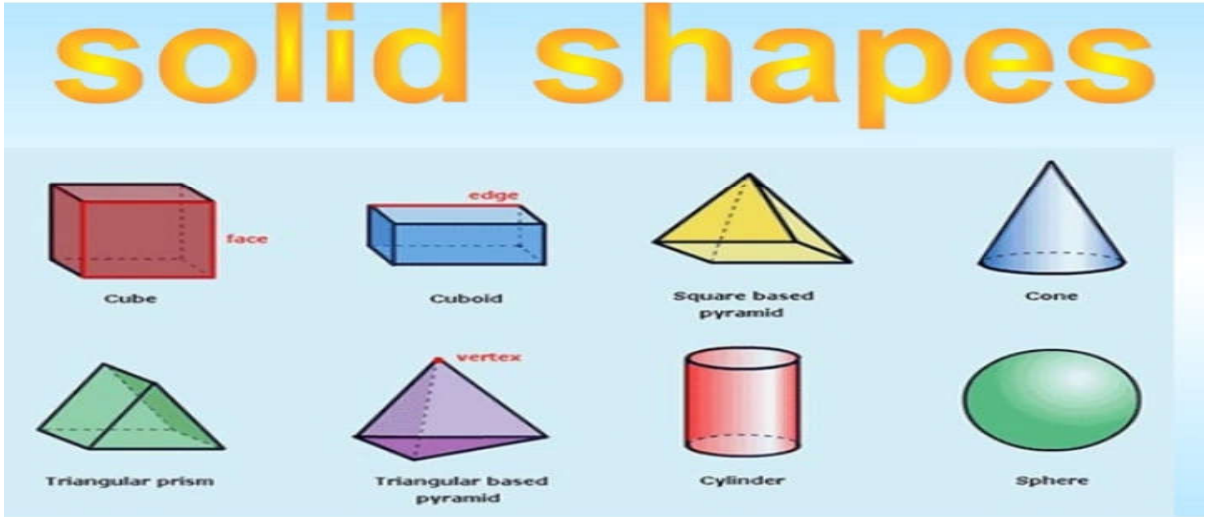
- According to the kinetic theory, when a solid object is heated, its atoms vibrate with high speed i.e its kinetic energy increases to overcome their intermolecular forces. The increase in speed causes an increment in the average separation of the atoms which makes it to occupy greater space (expansion in size).
- Solids expand when heated and contract when cooled e. g ball and ring; bar and gauge.

- The ***kinetic theory*** is a way to describe the ___motion___ of particles.
- It states that particles in all forms of matter, (S, L, G), are in constant motion, (either "__vibrating__", "__sliding__", or "__flying around__".)



TYPES OF SOLID EXPANSION

- There are three types of solid expansion, these are: linear expansion, superficial (area) expansion and cubic (volume) expansion. Different solids expand by different amounts when heated over the same temperature range due to their different coefficient of expansion or expansivity.



Solid shapes

LINEAR EXPANSIVITY

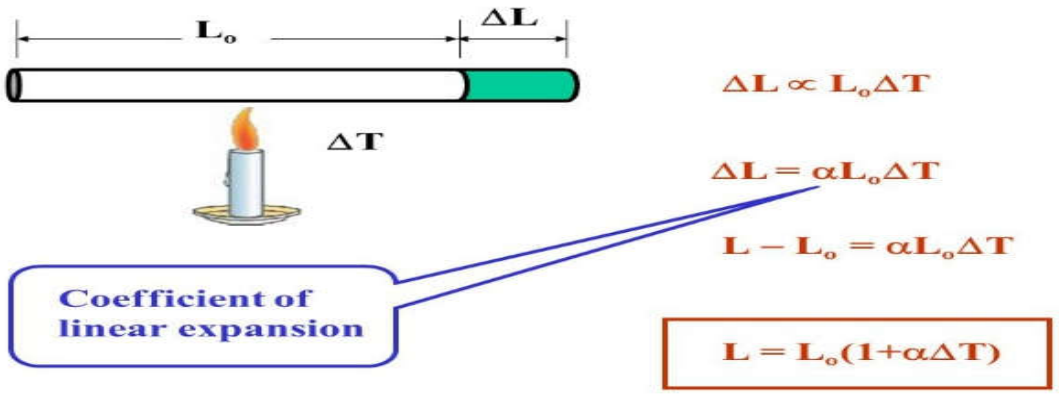
The linear expansivity α of a substance is defined as the increase in length per unit length per degree rise in temperature. In symbols,

$\alpha = L_2 - L_1$

---------- where $L_2 - L_1$ is the change or increase in length, L_1 is the original length, L_2 is final length.

$L_1 (\theta_2 - \theta_1)$

The unit is per kelvin (K^{-1})



EXAMPLE

If iron rails of 8m long are laid close up end to end when the temperature is 30 C, what gap will be provided between consecutive rails when the temperature rises to 60 C?(Take linear expansivity of iron = 1.2 x 10 K^{1}).

SOLUTION

$\alpha = 1.2 \times 10$ K^{1}, $L_2 - L_1 = ?$, $L_1 = 8m$, $\theta_2 - \theta_1 = 60 - 30 = 30$,

$$\alpha = \frac{L_2 - L_1}{L_1 (\theta_2 - \theta_1)};$$

$L_2 - L_1 = \alpha L_1 (\theta_2 - \theta_1) = 1.2 \times 10 \times 8 \times 30 = 2.88 \times 10^{3} m$

AREA (SUPERFICIAL) AND VOLUME (CUBIC) EXPANSIVITY

The area (superficial) expansivity (β) is given by

$$\beta = \frac{A_2 - A_1}{A_1(\theta_2 - \theta_1)}$$

Let $\theta = \theta_2 - \theta_1$

$\therefore \quad A_2 - A_1 = A_1 \beta \theta$

and $A_2 = A_1(1 + \beta \theta)$

THE VOLUME (CUBIC) EXPANSIVITY

$$\gamma = \frac{\text{change in volume}}{\text{volume at } 0\,^{\circ}\text{C} \times \text{change in temperature}}$$

$$= \frac{V_{100} - V_0}{V_0 \times 100} \text{ per K}$$

$$\gamma = \frac{l_{100} - l_0}{l_0 \times 100} \text{ per K}$$

$$\gamma = \frac{V_2 - V_1}{V_1(\theta_2 - \theta_1)}$$

γ = Cubic expansivity

V_1 = area of metal at temperature θ_1

V_2 = area of metal at temperature θ_2

RELATIONSHIP BETWEEN LINEAR, AREA (SUPERFICIAL) AND VOLUME (CUBIC) EXPANSIVITY

$$\alpha = \frac{L2-L1}{L1(\theta 2-\theta 1)} \quad Linear \quad Expansivity$$

$$\gamma = \frac{V2-V1}{V1(\theta 2-\theta 1)} \quad Cubic \quad Expansivity$$

$$\beta = \frac{A2-A1}{A1(\theta 2-\theta 1)} \quad Superficial \quad Expansivity$$

Comments

The effect of heat on matter:Linear, cubic, and superficial ...

$\beta = 2\ \alpha$

$\gamma = 3\ \alpha$

EXAMPLE

The linear expansivity of a material is $15 \times 10^{-5} K^{-1}$. If the initial area is $25m^2$,and then heated through 40^0C, calculate

1. The increase in area.
2. The cubic expansivity.

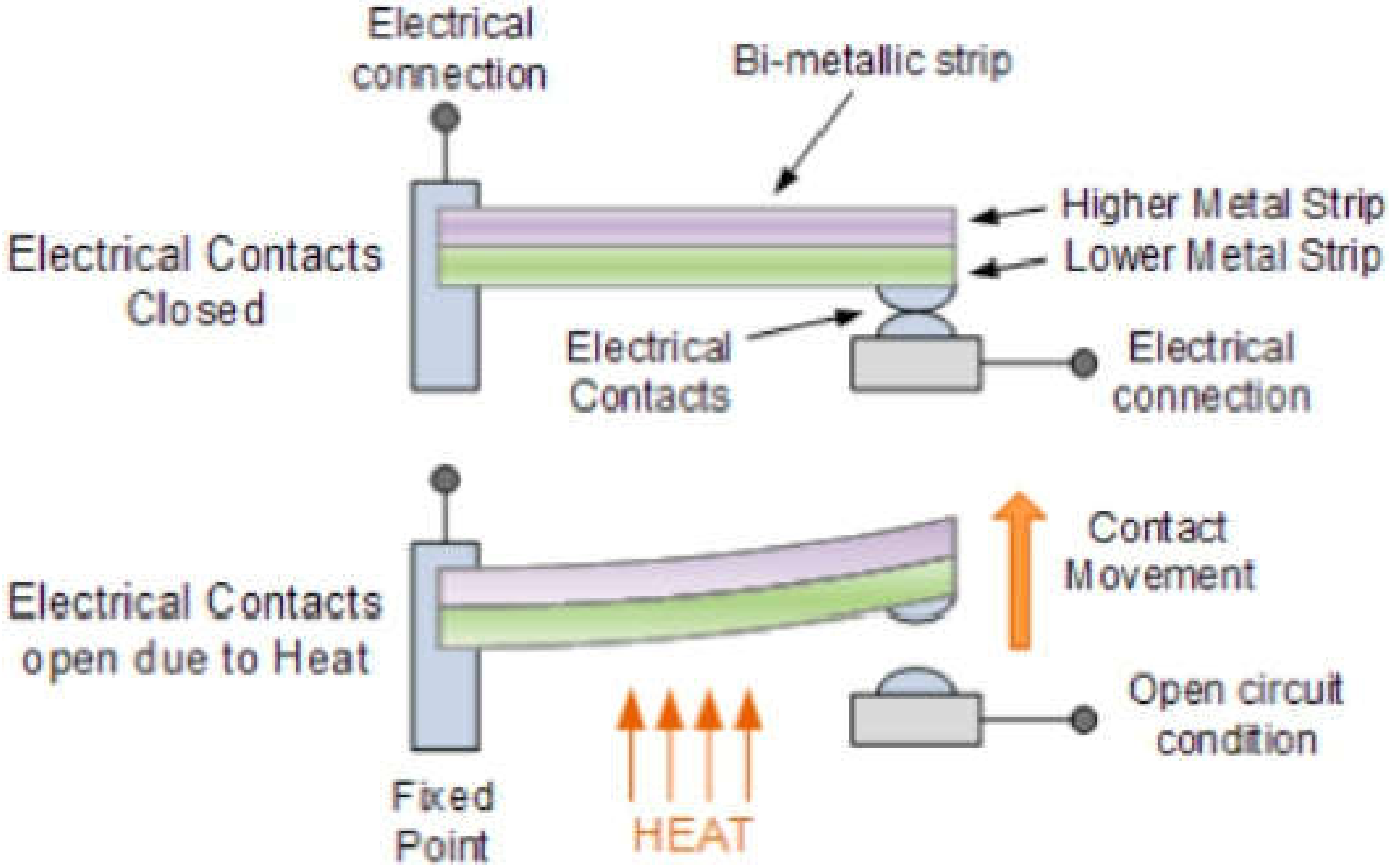
SOLUTION

I $A_2 - A_1 = \beta A_1 \theta = 2 \alpha A_1 \theta = 2 \text{ X } 15 \text{ X } 10 \quad \text{X } 25 \text{ X } 40 = 0.3 m^2$

2 Cubic expansivity $\gamma = 3 \alpha = 3 \text{ x } 15 \text{ X } 10 \quad = 4.5 \text{ x } 10^{4} K^{1}$

ADVANTAGES OF THERMAL EXPANSION OF SOLIDS

- Used in making bimetallic strip which is used in thermostat, bimetallic thermometer, electric fire alarm
- Removal of a tight glass stopper
- Red-hot rivets in ship building
- Expansion of metals used in fitting of wheels on rims
- In the construction of steel bridge where one end is fixed and the other end rest on rollers


Electrical connection
Bi-metallic strip
Higher Metal Strip
Lower Metal Strip
Electrical Contacts Closed
Electrical Contacts
Electrical connection
Contact Movement
Electrical Contacts open due to Heat
Open circuit condition
Fixed Point
HEAT

DISADVANTAGES OF THERMAL EXPANSION OF SOLIDS

Expansion of glass ; It can make thick glass tumblers break when hot liquids are poured into them

Railway lines : Expansion can cause railway line laid without gaps to buckle when subjected to changes in temperature.

Sagging of telegraph wires : Telegraphic lines and overhead wires when held firmly at their ends without allowing them to sag. Tight stretched wires snap under high temperature condition.

Balance wheel of clocks and watches : It affects the elasticity of the springs thus causing the watch to loose time

Expansion in buildings : The galvanized iron sheets used in the roof of the building make creaking noises when being heated by the sun

CRACKED ROAD

Illustrative Example

- Thermal expansion of long continuous sections of rail tracks is the driving force for rail buckling. This

6. JAR LIDS AND POWER LINES

- It is an everyday experience that tight metal lids are easy to remove after passage of hot water over them.
- Sagging of electrical power lines is another example of thermal expansion.

Applications of Thermal Expansion

ASSIGNMENT

1. A brass is 2m long at a certain temperature. What is its length for a temperature rise of 100K, if the expansivity of brass is $18 \times 10^{-5} K^{-1}$

2. The linear expansivity of a cube is $12 \times 10^{-5} K^{-1}$. If the length of each side is 10 cm, find

   the area of one face of the cube and the volume of the cube when its temperature is raised by 30K .

3. A solid metal cube of side 10cm is heated from 10^0C to 60^0C. If the linear expansivity of the metal is $1.2 \times 10^{-5} K^{-1}$ calculate the increase in it's volume.