HEAT TRANSFER

1. HEAT TRANSFER

   Heat transfer is the propagation of heat from a body at high temperature to a body at lower temperature i.e Heat transfer means the movement of heat energy from one point towards to the another point due to the temperature difference. Normally heat travels from hot region to cold region.

   Example: Why does heat flows from a body at higher temperature to a body at lower temperature:

   Reason: A fast moving marble flows when it hits slower moving marbles. It gives up some of its kinetic energy to the slower ones. The same situation occurs in heat flow. Molecules with move kinetic energy that are in contact with energetic molecules give up by some of their kinetic energy to the less energetic ones. Thus the direction of heat flow is from hotter body to the colder body. The total heat energy before and after contact are the same.

   METHODS (WAYS) OF HEAT TRANSFER

   There are three ways or principle means of heat transfer:

   (i) Thermal conduction
   (ii) Thermal convection
   (iii) Thermal radiation.

   1. THERMAL CONDUCTION

      Thermal conduction is the process of heat transfer due to the vibration of particle about their mean position i.e conduction is the process in which heat flows from the hotter regions of a material to the colder region without their being any net movement of the material itself. Thermal conduction occurs in metals and the movement of heat takes place without any visible sign of movement of the particles in solid.

MECHANISM OF HEAT CONDUCTION IN METALS

Metals contain free electrons which are in thermal equilibrium with their atoms. In metals, there are electrons which are free to move about the whole of the lattice and collides with other particles which have the heat transfer from one point towards to the another point along the metals. Two mechanisms explain how heat is transferred by conduction.

(i) Lattice vibration i.e interatomic vibration
(ii) Motion of free electrons i.e collision between the particles

The conduction through solids occurs by a combination of the tow mechanism mentioned above.

- **Conduction by interatomic vibration**

  Atoms at a higher temperature vibrate move vigorously about their mean positions in the lattice that their colder neighbours. The vibration atoms transfer the energy to nearby atoms and cause them to vibrate move energetically as well. These in turns affect other atoms and thermal conduction occurs.

Note that:

1. PHONONS are particle like entities that carry the elastic wave during the propagation of heat in solids.
2. Conduction process by vibrations of atoms in very slow since atoms are move massive compared to the electrons; thus the increases in vibrations of atoms in fairly small.

- **Conduction by movement of electrons**

  Metals have free electrons which are not bound to any particular atoms and thus can freely move about the solid. If the temperature increases, the electrons on the hot side of solid move faster than those on the cooler side. As the electrons undergo series of collisions, the faster electrons give off some of their energy to the slower electrons. So heat energy is transmitted through the whole conductor.

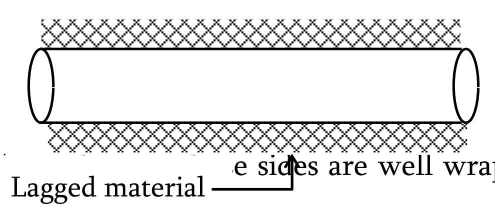
PARAMETER OF THERMAL CONDUCTION

1. **Conductor** – is the substance which allows heat energy to pass through it. Examples: All metals such as copper, Iron, Zinc, Aluminum, Lead, e.t.c.

2. **Bad conductor (insulator)** – Is the substance which does not allow heat energy to passing through it. Example: Rubber, wood, glass, waxy, cotton, e.t.c.

3. **Steady state condition** – Is an equilibrium point in which energy point in the bar maintains its temperature and that the rate of flow of heat through the bar is the same at all points. Under steady state conditions, the following points may be noted:-
   (i) The temperature at any point will remain constant with time.
   (ii) The temperature at two different points will be different.
   (iii) The rate of heat flows each section of the bar remain constant i.e $\frac{dQ}{dt} = \text{constant}$

4. **Lagging** – is the process of covering outer surface of conductor by lagged material (insulator) in order to prevent heat loss from the conductor to the surrounding.

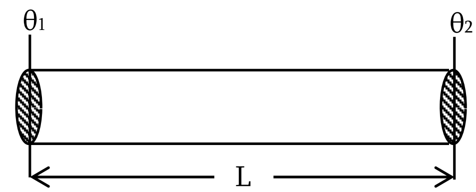


e sides are well wrapped with a good heat insulator is called a **Lagged**

5. **Unlagged bar** – is the conductor which does not covered by using insulating materials. For unlagged bar, the rate of heat flows is not constant since some of amount of heat energy is given out through the side of the conductor.

6. **Temperature difference** – is the difference in temperature between two opposite faces of cube or conductor.
$\Delta\theta = \theta_1 - \theta_2 \left(\theta_1 > \theta_2\right)$

7. **Temperature gradient** – Is the temperature difference per unit length of the conductor.
$$g = \frac{d\theta}{dx} = \frac{\text{temperature difference}}{\text{length of conductor}}$$

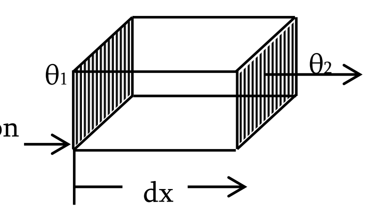


$$g = \frac{d\theta}{dx} = \frac{\theta_1 - \theta_2}{L}$$
S.I. unit of the temperature gradient is Km^{-1} or $^{O}Cm^{-1}$.

8. **Cross – sectional area, A** is the cross – sectional area of the conductor which allows heat to pass through it.

9. **Rate of heat flows** – is the amount of heat energy passing through the conductor per unit time through the given cross – sectional area of the conductor.

Expression of the rate of heat flows through a conductor.
Consider a slab of materials of cross – section area, A and thickness, dx subjected to a high temperature θ_1 on one side and lower temperature θ_2 on the other side.



Experimentally, it can be shown that, the quantity of heat energy passing through the conductor can be depends on the following factors:

(i) Cross – sectional area, A of a conductor (i.e $Q \alpha A$), the larger the area, the more thermal energy is transmitted.

(ii) Time taken (i.e $Q \alpha dt$). The longer the period of time, the move thermal energy is transmitted.

(iii) Temperature difference between the faces of slab ($Q \alpha \theta_1 - \theta_2$). If there is large temperature difference, the large amount of thermal energy flows.

(iv) Length or thickness of the conductor $\left(Q \alpha \frac{1}{dx}\right)$ on combining the factors above

$$dQ \alpha \frac{A(\theta_1 - \theta_2)dx}{dx}$$

$$dQ = \frac{-KA(\theta_1 - \theta_2)dx}{dx}$$

The rate of heat flows.

$$\frac{dQ}{dt} = \frac{-KA(\theta_1 - \theta_2)}{X} \text{ OR}$$

$$\frac{dQ}{dt} = KA\left(-\frac{d\theta}{dx}\right)$$

(This is called Fourier's law) in magnitude rate of heat flow is given by

$$\frac{dQ}{dt} = \frac{-KA(\theta_1 - \theta_2)}{X} = KA\frac{d\theta}{dx}$$

Where

$\frac{dQ}{dt}$ = Rate of heat flows

K = coefficient of thermal conductivity.

A = Cross – sectional area of a conductor.

$\frac{d\theta}{dx}$ = temperature gradient

Negative sign shows that temperature decreases as the length of conductor increases from the hot end.

The equation $\frac{dQ}{dt} = KA\frac{d\theta}{dx}$ is applicable under the following conditions:

(i) The steady state condition must be reached.

(ii) The conductor should be well lagged.

COEFFICIENT OF THERMAL CONDUCTIVITY

Qualitatively, thermal conductivity of a solid is a measure of the ability of the solid conductor heat through it.

Quantitatively, coefficient of thermal conductivity is defined as the rate of heat flows per unit cross – sectional area per unit temperature gradient.

$$K = \frac{dQ/dt}{A\, d\theta/dx}$$

S.I. unit of K is $Wm^{-1}K^{-1}$ or $Js^{-1}m^{-1}k^{-1}$ or $Cals^{-1}cm^{-1o}c^{-1}$.

Dimensional formula of

$$K = \frac{dQ/dt}{A\, d\theta/dx} = \frac{\left(ML^2T^{-2}\right)/T}{L^2\left(K/L\right)}$$

$$\left[K\right] = \left[MLT^{-3}K^{-1}\right]$$

********** END OF PREVIEW ************