UNIT 9

TRANSFER OF HEAT

LONG QUESTIONS

9.2 CONDUCTION

Q.No.1 What is Conduction? Explain the process and write down it usage in our daily life.

Ans: "The mode of transfer of heat by vibrating atoms and free electrons in solids from hot to cold parts of a body is called conduction of heat".

OR

"Conduction is the process in which heat is transmitted from one body to another by the interaction of atoms and electrons".

Conduction Process

In solids, atoms and molecules are packed close together. They continue to vibrate about their mean position. When one end of the solid is heated then the atoms or molecules present at that end begin to vibrate more rapidly. They also collide with their neighboring atoms or molecules. In doing so, they pass some of their energy to neighboring atoms or molecules during collisions with them with the increase in their vibrations. These atoms and molecules in turn pass on a part of the energy to their neighboring particles. In this way some heat reaches the other parts of the solid. This is slow process and very small transfer of heat takes place from hot to cold parts in solids.

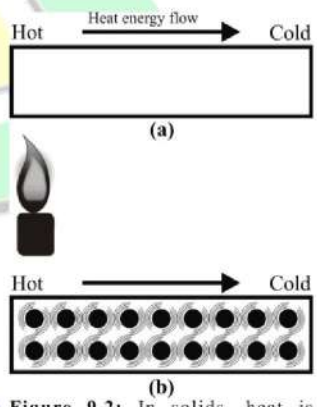

Figure 9.2: In solids, heat is transferred from one part to other parts from atoms to atoms or molecules to molecules due to collisions.

Speed of conduction in metals and non – metals

Metals have free electrons as shown in figure. These free electrons move with very high velocities within the metal objects. They carry energy at a very fast rate from hot to cold parts of the objects as they move. Thus, heat reaches the cold parts of the metal objects from its hot part much more quickly than non-metals.

Usage in household crockery

The handle of metal spoon held in hot water soon gets warm. But in case of wooden spoon handle does not get warm. Both the materials behave differently regarding the transfer of heat. Both metals and non-metals conduct heat. Metal are gradually better conductors than non-metals.

Q.No.2 On what factors conduction of heat depend? And define thermal conductivity.

(GRW 2015)

Ans: Conduction of heat occurs at different rates in different materials. In metals, heat flows rapidly as compared to insulators such as wood or rubber. Consider a solid block. One of its two opposite faces each of cross – sectional area A is heated to a

temperature T_1. Heat Q flows along its length L to opposite face at temperature T_2 in t seconds.

The amount of heat that flows in unit time is called the rate of flow of heat.

Thus Rate of flow of heat $= \frac{Q}{t}$

Dependence

It is observed that the rate at which heat flows through a solid object depends upon various factors.

- Cross sectional area of the solid
- Length of the solid
- Temperature difference between ends

Cross Sectional Area of the Solid

Larger cross sectional area A of a solid contains larger number of molecules and free electrons on each layer parallel to its cross sectional area and hence greater will be the rate of flow of heat through the solid.

Thus Rate of flow of heat $\frac{Q}{t} \propto A$

Length of the Solid

Larger is the length between the hot and cold ends of the solid, more time it will take to conduct heat to the colder end and smaller will be the rate of flow of heat.

Thus Rate of flow of heat $= \frac{Q}{t} \propto \frac{1}{L}$

Temperature Difference between Ends

Greater is the temperature difference $T_1 - T_2$ between the hot and cold faces of the solid, greater will be the rate of flow of heat.

Thus Rate of flow of heat $\frac{Q}{T} \propto (T_1 - T_2)$

Combining above factors, we get

$$\frac{Q}{t} \propto \frac{A(T_1 - T_2)}{L}$$

Rate of flow of heat $$\frac{Q}{t} = \frac{k\,A(T_1 - T_2)}{L}$$

Thermal Conductivity

Here k is the proportionality constant called thermal conductivity of the solid. Its value depends on the nature of the substance and it is different for different materials. Value of k can be found as:

$$k = \frac{Q}{t} \times \frac{L}{A}(T_1 - T_2)$$

The thermal conductivity of the substance can be defined as:

"The rate of flow of heat across the opposite faces of a meter cube of a substance maintained at a temperature difference of one Kelvin is called the thermal conductivity of that substance"

Use of Conductors and Non-Conductors **(LHR 2015)**

Q.No.3 Write down the uses of conductors and non – conductors.

Ans: In houses, good thermal insulation means lower consumption of fuel. For this, following measures may be taken to save energy.

- Hot water tanks are insulated by plastic or foam lagging
- Wall cavities are filled with plastic foam or wool
- Ceiling of room is covered by insulating materials (false ceiling)

- Double glazed window panes are used. These window panes have air between glass sheets that provides good insulation.
- Good conductors are used when quick transfer of heat is required through a body. Thus cookers, cooking plate, boiler, radiators and condensers of refrigerators etc. are made of metals such as aluminum or copper. Similarly metal boxes are used for making ice, ice cream etc.
- Insulators or bad – conductors are used in utensils such as handles of sauce – pans, hot plates, spoons etc. They are made of wood or plastic. Air is one of the bad conductors or good insulator. That is why cavity walls i.e. two walls separated by an air space and double glazed windows keep the houses warm in winter and cool in summer. Materials which trap air i.e. wool, felt, fur, feathers, polystyrene, and fiber glass are also bad conductors. Some of these materials are used for laggings to refrigerators, walls and roofs of houses. Woolen cloth is used to make warm winter clothes.

9.3 CONVECTION

Q.No.4 What is convection? Explain the process.

Ans: "Transfer of heat by actual movement of molecules from hot place to a cold place is known as convection".

Liquids and gases are poor conductors of heat. However, heat is transferred through fluids (liquids or gases) by another method called convection.

Process

A liquid or gas becomes lighter (less dens) as it expands on heating. Hot liquid or gas from the surroundings fills the place which in turns is heated up. In this way, all fluid is heated up. Therefore, transfer of heat through fluids takes place by the actual movement of heated molecules from hot to cold parts of the fluid.

Experiment

Get a two-third water filled beaker and heat it by using burner. Pour 2 to 3 drops of $KMnO_4$. The colour start appearing first upward, then flow downward showing a path of liquid current. You will note that the liquid current will be disappeared on displacing the burner, as heat lift up the water making it light however the cold water tend to move down on getting denser.

Convection Currents in Air **(LHR 2013, 2014, 2015)**

Q.No.5 What do you know about convection currents in Air? How land and sea breeze blow?

Ans: Gases also expand on heating, thus convection currents are easily set up due to the differences in the densities of air at various parts in the atmosphere.

Uses of Convection currents

- Convection currents set up by electric, gas or coal heaters help to warm our homes and offices.
- Central heating systems in buildings work on the same principle of convection.
- The day –to– day temperature changes in the atmosphere result from the circulation or warm or cold air that travels across the region. Land and sea breezes are also examples of convection currents.

Land and Sea Breezes

Land and sea breezes are the result of convection.

Sea Breeze

On a hot day, the temperature of the land increases more quickly than the sea. It is because the specific heat of land is much smaller as compared to water. The air above land gets hot and rises up. Cold air from the sea begins to move towards the land. It is called sea breeze.

Land Breeze

At night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and the cold air from the land begins to move towards the sea. It is called land breeze.

Gliding (LHR 2014, GRW 2015)

Q.No.6 What is Gliding? And what do you know about birds gliding?

Ans: A glider looks like a small aeroplane without engine. Glider pilots use upward movement of hot air current due to convection of heat. These rising currents of hot air are called thermals. Gliders ride over these thermals. The upward movement of air currents in thermals helps them to stay in air for a long period.

Birds Gliding

The birds stretch out their wings and circle in these thermals. The upward movement of air helps birds to climb up with it. Eagles, hawks and vultures are expert thermal climbers. After getting a free lift, birds are able to fly for hours without flapping their wings. They glide from one thermal to another, and thus travel through large distances and hardly need to flap their wings.

9.4 RADIATION

Q.No.7 Define Radiation. How does heat reach us from the sun? Explain Radiation.

Radiation

Radiation is the mode of transfer of heat from one place to another in the form of waves called Electromagnetic waves.

Energy from Sun

Our sun is the major source of heat energy. Heat reaches us neither by conduction nor by convection, because the space between the Sun and Earth's atmosphere is empty. This is a third mode called radiation by which heat travels from one place to another. It is through radiations that heat reaches us from the sun.

Example (Heat from Fireplace)

Heat does not reach us by conduction through air from a fireplace because air is a poor conductor of heat. Heat does not reach us by convection because the air getting heat from the fireplace does not move in all directions. Hot air moves upward from the fireplace. Heat from the fireplace reaches us directly by a different process in the form of waves called radiation. A sheet of paper or cardboard kept in the path stop these waves to reach us.

Dependence of Rate of Radiation

Radiations are emitted by all bodies. The rate at which radiations are emitted depends upon various factors such as

- Color and texture of the surface
- Surface temperature
- Surface area

Heat absorbing and Radiating

All the objects, lying inside a room including the walls, roof and floor of the room are radiating heat. However, they are also absorbing heat at the same time.

Radiation of heat

When temperature of an object is higher than its surroundings then it radiating more heat than it is absorbing. As a result, its temperature goes on decreasing till it becomes equal to its surroundings. At this stage, the body is giving out the amount of heat equal to the amount of heat it is absorbing.

Absorption of heat

When temperature of an object is lower than its surroundings, then it is radiating less heat than it is absorbing. As a result, its temperature goes on increasing till it becomes equal to its surroundings. The rate at which various surfaces emit heat depends upon the nature of the surface.

Q.No.8 What is Leslie cube? How various surfaces can be compared by Leslie cube? (GRW 2014)

Leslie Cube

A Leslie cube is a metal box having faces of different nature as shown in figure. The four faces of Leslie's cube may be as follows:

- A shining silvered surface
- A dull black surface
- A white surface
- A coloured surface

Hot water is filled in the Leslie's cube and is placed with one of its face towards a radiation detector. It is found that black dull surface is good emitter of heat. The rate at which various surfaces absorb heat also depends upon the nature of those surfaces.

Example

Take two surfaces, one is dull black and the other is silver polished surface with a candle at the middle of the surface. It is fount that:

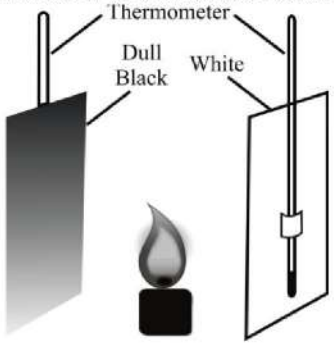

Figure 9.16: A comparison of absorption of radiation.

Black Surface

A dull black surface is a good conductor of heat and its temperature rises rapidly.

Polished Surface

A polished surface is poor absorber of heat as temperature rises very slowly. It is also found that the transfer of heat by radiation is also affected by the surface area of the body emitting or absorbing heat.

Area of the surface

Larger is the area, greater will be the transfer of heat. It is due to this reason that large numbers of slots are made in radiators to increase their surface area.

Greenhouse Effect **(LHR 2013, GRW 2013)**

Q.No.9 What do you know about greenhouse effect? Also explain the global warming.

Light from the Sun contains thermal radiations (infrared) of long wavelengths as well as light and ultraviolet radiations of short wavelength. Glass and transparent polythene sheets allow radiations of short wavelength to pass through easily but not long wavelengths of thermal radiations. Thus, a greenhouse becomes a heat trap. Radiations from the Sun pass easily through glass and warms up the objects in a greenhouse. These objects and plants give out radiations of much longer wavelengths. Glass and transparent polythene sheets do not allow them to escape out easily and are reflected back in the greenhouse. This maintains the inside temperature of the greenhouse. Greenhouse effect promises better growth of some plants. Carbon dioxide and water also behave in a similar way to radiations as glass or polythene.

Global Warming

Earth's atmosphere contains carbon dioxide and water vapors. It causes greenhouse effect and thus maintains the temperature of the Earth. During the recent years, the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the Earth by trapping more heat due to greenhouse effect. This phenomenon is known as global warming.

9.5 APPLICATION AND CONSEQUENCES OF RADIATIONS

Q.No.10 Explain the application and consequences of Radiations.

Different objects absorb different amounts of heat radiations falling upon them reflecting the remaining part. The amount of heat absorbed by a body depends upon the colour and nature of its surface.

Black Surface

A black and rough surface absorbs more heat than a white or polished surface. Since good absorbers are also good radiators of heat. Thus, a black coloured body quickly absorbing heat reaching it during a sunny day and sunny day and also cools down quickly by giving out its heat to its surroundings. The bottoms of cooking pots are made black to increase the absorption of heat from fire.

White and Polished Surface

Like light rays, heat radiators also obey laws of reflection. The amount of heat reflected from an object depends upon its colour and nature of the surface. White surfaces reflect more than coloured or black surfaces. Similarly, polished surfaces are good reflectors than rough surfaces and reflection of heat radiations is greater from polished surfaces. Hence, we wear white or light coloured clothes in summer which reflect most of the heat radiation reaching us during the hot day. We polish the interior of the cooking and hot pots for reflecting back most of the heat within them.