UNIT 9

Transfer of Heat

1 What is meant by the rate of flow of heat? Describe the factors on which the rate of flow of heat depends.

Ans. Rate of Flow of Heat

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

Explanation

Consider a solid block as shown in figure. 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.

Thus Rate of flow of heat $= \frac{Q}{t}$ ..... (i)

Factors

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

(i) 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

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

(ii) 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

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

(iii) Temperature Difference Between Ends

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

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

Combining the above factors, we get

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

$$\text{Rate of flow of heat } \frac{Q}{t} = \frac{K\,A(T_1 - T_2)}{L} \quad \text{... (ii)}$$

Here k is the proportionality constant called thermal conductivity of the solid. Its value depends on the nature of the substance and is different for different materials. From equation (ii), we find k as:

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

2 What are conductors and non-conductors? Give some of their uses.

Ans. Conductors

Those material which allow to pass the heat through them are called conductors e.g. all metals.

Non-Conductors

Those material which do not allow to pass the heat through them are called non-conductors. E.g., wood and plastics etc.

Uses of Conductors

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.

Uses of non-Conductors

(i) Insulators or bad conductors are used in home utensils such as handles of sauce-pans, hot

plates, spoons, etc. they are made up of wood or plastic.

(ii) Air is one of the bad conductors or best 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.

(iii) Materials such as trap air i.e. wool, felt, fur, feathers, poly styrine fibres glass are also bad conductors. Some of these materials are used for laggins to insulate water pipes, hot water cylinders, ovens, refrigerators, walls and roofs of houses.

(iv) Woollen cloth is used to make warm winter clothes.

Thermal conductivities of some common substances

Substance	$wm^{-1} K^{-1}$
Air (dry)	0.026
Aluminium	245
Brass	105
Brick	0.6
Copper	400
Glass	0.8
Ice	1.7
Iron	85
Lead	35
Plastic foam	0.03
Rubber	0.2
Silver	430
Water	0.59
Wood	0.08

3. What measures do you suggest to conseve energy in houses?

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

(i) Hot water tanks are insulated by plastic or foam lagging.

(ii) Wall cavities are filled with plastic foam or wool.

(iii) Ceiling of rooms is covered by insulating materials (false ceiling).

(iv) Double glazed window panes are used. These window panes have air between glass sheets that provides good insulation.

4. What is meant by convection? Explain the process of convection with the help of a simple experiment.

Ans. Definition

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

Experiment

Take a beaker and fill two-third of it with water. Heat the beaker by keeping a burner below it. Drop two or three crystals of potassium permanganate in the water. It will be seen that coloured streaks of water formed by the crystals move upwards above the flame and then move downwards from side way. These coloured streaks show the path of currents in the liquid. When the water at the bottom of the beaker gets hot, it expands becomes lighter and rises up. While the cold but denser water moves downward to take its place.

Crystals of potassium permanganate are used to show the movement of water on heating.

5. How convection current set up in air? Give some uses of convection current.

Ans. Convection Currents in Air

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.

Use of Convection Currents

(i) Convection currents set up by electric, gas or coal heaters help to warm our homes and offices.

(ii) Central heating systems in buildings work on the same principle of convection.

(iii) Convection currents occur on a large scale in nature. The day-to-day temperature changes in the atmosphere result for the circulation of warm or cold air that travels across the region.

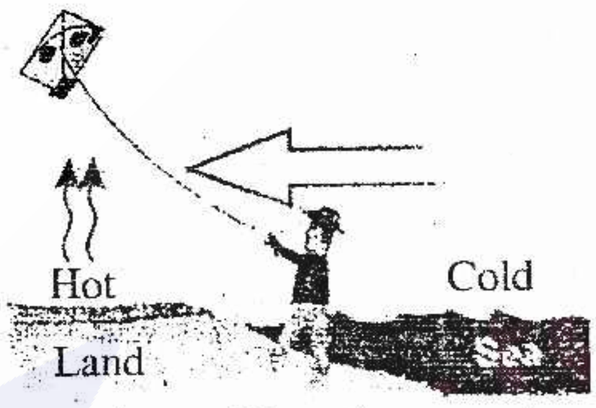
(iv) Land and sea breezes are also the examples of convection currents.

6 Why does sea breeze blow during the day while land breeze blow at the night?

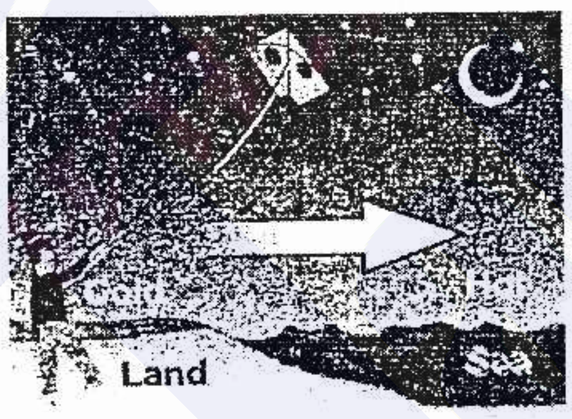
Ans. Land and sea Breezes

Land and sea breezes are the result of convection. 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.

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.



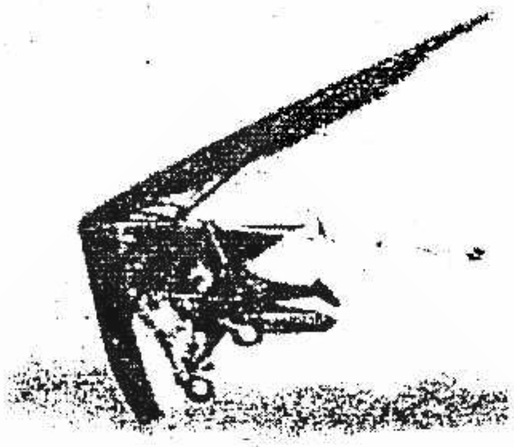
Sea breeze blows from sea to land in daytime



Land breeze blows form land to sea during night

7 What causes a glider to remain in air?

Ans. A gilder looks like a small aeroplane without engine. Glider pilots use upward movement of hot air currents 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 help them to stay in air for a long period.



A glider

8 How do thermals help birds to fly for hours without flapping their wings?

Ans. The birds stretch out their wings and circle in these thermals. The upward movement of air help 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 house 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 What is a lesile cube? How it helps us to find which surface is good emitter or good absorber.

OR

How various surfaces can be compared by a leslie cube?

Ans. Laslie Cube

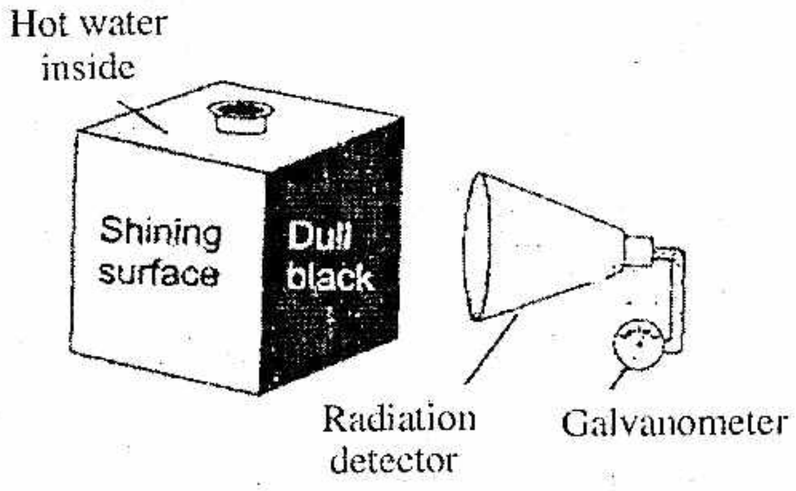
A leslie cube is a metal box having faces of different nature. The four faces of Leslie's cube may be as follows:

(i) A shining silvered surface

(ii) A dull black surface

(iii) A white surface

(iv) A coloured surface

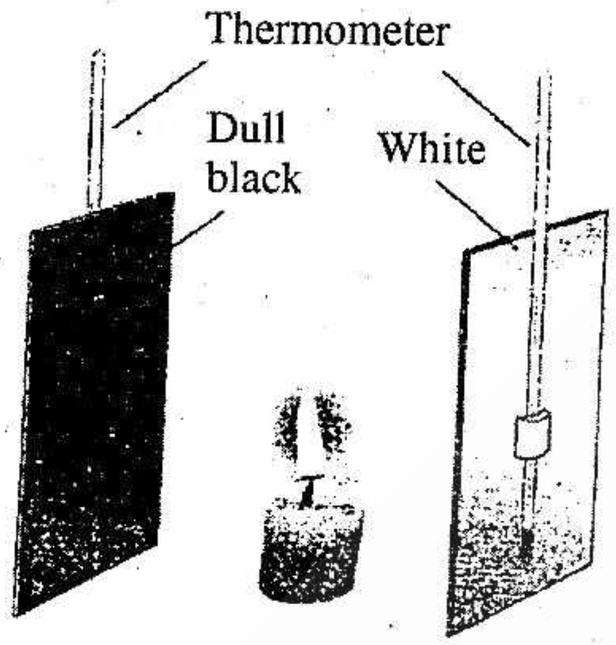


Radiation for Leslie's cube

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 a good emitter of heat.

The rate at which various surfaces absorb heat also depends upon the nature of those surfaces. For example, take two surfaces, one is dull black and the other is a silver polished surface as shown in figure with a candle at the middle of the surface. It is found that:

A dull black surface is a good absorbed of heat as its temperature rises rapidly.



A comparison of absorption of radiation

A polished surface is poor absorber of heat as its temperature rises very slowly. The observations made from the set up are shown in the table given below:

Surfaces	Emitter	Absorber	Reflector
Dull black surface	Best	Best	Worst
Coloured surface	Good	Good	Good
White surface	Bad	Bad	Good
Shining silvered surface	Worst	worst	Best

It is also found that the transfer of heat by radiation is also affected by the surface of the body emitting or absorbing heat. 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.

10 What is green house? How does the temperature in a green house can be maintained?

Ans. Green House

The house whose walls and roof are made of transparent material such as glass or transparent polythere sheets is called Green house.

How Temperature is Maintained

Light from the sun contains thermal radiations (infrared) of long wavelengths as well as ultraviolet radiations of short wavelengths. Glass and transparent polythene sheets allow radiations of short wavelength to pass through easily but not long wavelengths of thermal radiations. Thus, a green-house becomes a heat trap. Radiations from the sun pass easily through glass and warms up the objects in a greenhouse. These objects and plant give out radiation 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.

11 Describe the application and consequence of radiations.

Ans. Application and consequences of Radiation

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. 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 gets hot quickly absorbing heat reaching it during a sunny day and also cools down quickly by giving out its heat to its surroundings. The bottom of cooking pots are made black to increase the absorption of heat from fire.

Like light rays, heat radiations 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 colured 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 radiation within them.

What is land breeze?

OR

Why land breeze blows from land to sea during night?

At night, the land cools faster than sea due to less specific heat than water. As a result the air above sea in warmer and rises up and the cold air from land begins to move towards the sea. It is called land breeze.

How do the land and sea breezes help to keep the temperature moderate in coastal areas.

During day time the sea breeze blows from the ocean towards the land while at night land breeze blows towards the sea. So they keep the temperature moderate in coastal areas.

What are thermals?

Due to convection current the hot air moves in the upward direction. These rising currents of hot air are called thermals.

What are thermal climbers? Give their examples.

Those birds which use the thermal for their flight are called thermal climbers. e.g. Eagles, hawks and vultures.

Write down the factors on which the rate of emission of radiations depends.

(i) Colour and texture of the surface.

(ii) surface temperature.

(iii) surface area.

Which surface is considered good emitter as well as good absorber.

Dull black surface is considered a good emitter as well as good absorber.

Why do we use white clothes in summer season?

While surface is a good reflector but bad absorber. That is why we use white clothes in summer.

Write the name of gases which are responsible for green house effect.

(i) Carbondioxide oxide

(ii) Water vapours

(iii) Methane gas

What is meant by global warming?

The earth temperature is increasing day-by-day due to high concentration of carbondioxide. This phenomena is called global warming.

In thermoflask, how heat is prevented to enter or leave the flask?

This is done by suitable measures to reduce the transfer of heat due to conductions, convection and radiation. i.e. by using insulator between the double of the flask and by making the inner surface good reflector. Thus, any thing kept in it, maintains its temperature for a long time.

EXERCISE

9.1 Encircle the correct answer from the given choices:

(i) In solids, heat is transferred by:

(a) radiation (b) conduction

(c) convection (d) absorption

(ii) What happens to the thermal conductivity of a wall if its thickness is doubled?

(a) becomes double

(b) remains the same

(c) becomes half

(d) becomes one fourth

(iii) Metals are good conductor of heat due to the

(a) free electrons

(b) big size of their molecules

(c) small size of their molecules

(d) rapid vibrations of their atoms

(iv) In gases, heat is mainly transferred by

(a) molecular collision (b) conduction

(c) convection (d) radiation

(v) Convection of heat is the process of heat transfer due to the:

(a) random motion of molecules

(b) downward movement of molecules

(c) upward movement of molecules

(d) free movement of molecules

(vi) False ceiling is done to

(a) lower the height of ceiling

(b) keep the roof clean

(c) cool the room

(d) insulate the ceiling

(vii) Rooms are heated using gas heaters by

(a) conduction only

(b) convection and radiation

(c) radiation only

(d) convection only

(viii) Land breeze blows from

(a) sea to land during night

(b) sea to land during the day

(c) land to sea during night

(d) land to sea during the day

(ix) Which of the following is a good radiator of heat?

(a) a shining silvered surface

(b) a dull black surface

(c) a white surface

(d) a green coloured surface

Answers

(i)	(b)	**(ii)**	(c)	**(iii)**	(a)	**(iv)**	(d)
(v)	(c)	**(vi)**	(c)	**(vii)**	(b)	**(viii)**	(c)
(ix)	(b)						

9.2. Why metals are good conductors of heat?

Ans. Metals have free electrons so they are good conductor of heat.

9.3. Explain why:

(a) A metal feels colder to touch than wood kept in a cold place?

(b) Land breeze blows from land towards sea?

(c) Double walled glass vessel is used in thermos flask?

(d) Deserts soon get hot during the day and soon get cold after sunset?

Answer

(a) A good absorber is also a good emitter. Metals are good absorber as well good emitter. While wood bad emitter as well as absorber. So metals lose heat quickly than wood, so, it feels colder to touch.

(b) At night land cools faster than the sea, because the air above the sea is warmer, rises up and the cold air from the land begins to move towards sea.

(c) Double wall glass vessel is used in thermoflask because between these two walls air is present which is insulator so the loss heat due to conduction and convection is minimized.

(d) In deserts, the specific heat capacity of sand is very low so during day time their temperature rises quickly while at night they lose the heat quickly so they get cold.

9.4. Why conduction of heat does not take place in gases?

Ans. For conduction the heat is transmitted by the collision of molecules and molecules do not leave their places. But in gases molecules move freely. So in gases heat does not take place in gases.

9.5. What measures do you suggest to conserve energy in houses?

Ans. See Long Question No.3

9.6. Why transfer of heat in fluids takes place by convection?

Ans. In fluids heat is transferred by convection because in liquids molecules move freely and after getting the heat they moves in the upward direction and new molecules to the source of heat.

9.7. What is meant by convection current?

Ans. In liquids and gases when molecules get heat they rise up and cooler molecules take their place and move down ward so this continuous flow of molecules from colder to hotter region is called convection current.

9.8. Suggest a simple activity to show convection of heat in gases not given in the book.

Ans. Activity:

Take a glass box with two holes in its top. Place a burning candle below the one hole and smoking sticks on the other hole. After some time you will see the current of smoke moving toward the hotter region. This shows the convectional current in gases.

9.9. How does heat reach us from the sun?

Ans. From the sun heat reaches to us by the process of radiation.

9.10. How various surface can be compared by a Leslie cube?

Ans. See Long Question No.9

9.11. What is greenhouse effect?

Ans. In the green house, the rays having longer wave length cannot pass easily through the walls of the green house and warm the gases inside the house. This increase in temperature of the green house is called green house effect.

9.12. Explain the impact of green-house effect in global warming.

Ans. Carbon dioxide and water in the earth's atmosphere absorb heat and causes the green house effect. 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 green-house effect. This phenomenon is known as global warming. This has serious implications for the global climate.

PROBLEMS

9.1. The concrete roof of a house of thickness 20 cm has an area 200m^3. The temperature inside the house is 15°C and outside is 35°C. Find the rate at which thermal energy will be conducted through the roof. The value of k for concrete is 0.65 Wm^{-1} K^{-1}.

Sol. $A = 200\ m^2$

$L = 20\ cm \quad = 0.2\ m$

$T_1 = 35°C \quad = 35 + 273$

$\Rightarrow \quad 308k$

$T_2 = 15°C \quad = 15 + 273$

$\Rightarrow \quad 288k$

$K = 0.65\ wm^{-1}\ k^{-1}$

Rate of flow of heat = ?

$$\text{Rate of flow of heat} = \frac{K.A(T_1 - T_2)}{L}$$

$$\text{Rate flow of heat} = \frac{0.65 \times 200(308 - 288)}{0.2}$$

$$= \frac{0.65 \times 200 \times 20}{2}$$

Rate of flow of heat = 13000 watt or 13000 Js^{-1}

9.2. How much heat is lost in an hour through a glass window measuring 2.0 m by 2.5m when inside temperature is 25°C and that of outside is 5°C, the thickness of glass is 0.8 and the value of k for glass is 0.8 Wm^{-1} K^{-1}?

Sol. $A = 2 \times 2.5 \quad \Rightarrow \quad 5.0\ m^2$

$T_1 = 25°C = 25 + 273 = 298k$

$T_2 = 5°C = 5 + 273 = 278\ k$

$K = 0.8\ Wm^{-1}\ k^{-1}$

$L = 0.8\ cm \quad \Rightarrow \quad 0.008m$

$$\frac{Q}{t} = \frac{kA(T_1 - T_2)}{L}$$

$$\frac{Q}{t} = \frac{0.8 \times 5(298 - 278)}{0.008}$$

$$= \frac{0.8 \times 5 \times 20}{.008} = 10000\ Js^{-1}$$

So, the heat lost in an hour's time 1h = 3600 sec

$= 10000 \times 3600$

$= 36 \times 10^6\ J$

Heat lost = 3.6×10^7 J