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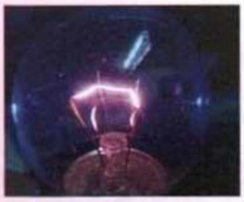

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Matter

Theme : Building on previous learning in classes VI and VII, in this class the theme aims at introducing children to the kinetic theory that will help them in understanding the difference in the three states of matter. The theory states that all matter is made of tiny particles that in an object are always in motion that may move slow or fast. In solids, the particles have less energy hence, do not move around freely. In liquids, they have relatively more energy and move freely within the container. The particles of gases have much more energy and move freely at high speeds. The increase or decrease in the movement of energy is the result of heating or cooling of an object. Heating an object increases the energy of particles whereas cooling decreases the energy of particles of an object.

In this chapter you will learn to

- distinguish the three states of matter in terms of movement of particles;
- relate the three states of matter with energy of movement of particles in them;
- describe the changes of state using kinetic theory :
  - Boiling
  - Melting
  - Evaporation
  - Sublimation
  - Freezing
  - Vaporization
  - Fusion
  - Condensation
  - Deposition
- identify appropriate observable parameters in experiments;
  - collect data and make careful observation;
- present the results in the form of tables;
- consider results using scientific knowledge and communicate these.

LEARNING OBJECTIVES

- Revising previous concepts learnt by children.
- Building on children's previous learning.
- Demonstrating matter in three states.
- Demonstrating change of state, solid to liquid, liquid to gas etc.
- Demonstrating the phenomenon of melting and boiling.
- Engaging children to undertake activities related to melting and boiling, condensation and freezing and make observations followed by discussion.
- Engaging children (individually/in groups) to observe change of state; solid to liquid, liquid to gas and record what is observed.
- Explaining the different terms like boiling, melting, freezing, condensation, sublimation etc. with examples from daily life.

- Observations of above mentioned phenomena in possible classroom situations (using different samples).
- Children observing solids and liquids (compare and contrast the physical characteristics).
- Encouraging children to prepare a comparison table of different states based on shape, texture and volume.
- Asking children to describe the interconversion of states using examples like water, naphthalene balls etc. and additional examples of all types of change of state.
- Engaging children in pairs or small groups in investigation of the related change of state due to addition of energy (heating or cooling) due to a substance.
- Engaging children (individually/in groups/in pairs) in the design of activities to show that melting or boiling occurs at a fixed temperature for a substance.

KNOWING CONCEPTS

- Kinetic theory of matter.
- Three states of matter in terms of movement of particles.
- Energy contents in the three states of matter.
- Change of state in matter using the kinetic theory:
  - Boiling
  - Melting
  - Evaporation
  - Sublimation
  - Freezing
  - Vaporization
  - Fusion
  - Condensation
  - Deposition
- Change of state diagrams (using the terms mentioned above).

MATTER

We have read in class VI, that matter is something which occupies space, has mass and can be perceived by our senses. *For example*, air, water, iron, hydrogen, oxygen, milk, oil, sugar, salt etc. all are matter. Actually, matter means all the living and non-living things of the universe.

Composition : In the past, Indian philosophers considered that matter was made up of five tatvas (or constituents) namely akash, vayu, tejas (or agni), jal and prithvi. Later on, Maharishi Kanada considered matter to be made up of **tiny particles** which he called **anu**.

Now it is established that matter is composed of tiny particles called **molecules**. A molecule can exist free in nature and it has all the properties of that substance.

Do You Know ?

1. A molecule, composed of atoms can exist independently and freely in nature.
2. A molecule composed of one atom is called monoatomic molecule (such as helium, neon, argon, etc.).
3. A molecule composed of two atoms is called a diatomic molecule (e.g. hydrogen molecule, oxygen molecule, nitrogen molecule, etc.) and a molecule composed of more than two atoms is called polyatomic molecule (e.g. water, ammonia, carbon dioxide etc.).

CHARACTERISTICS OF MOLECULES

The molecules of matter have the following characteristics :

1. They are very small in size.
2. They have spaces between them.
3. They are in constant motion as they possess kinetic energy.
4. They attract each other.

1. Molecules are very small in size : A molecule is of size nearly 10^{-10} metre. It is too small that it cannot be seen even with the help of a microscope.

ACTIVITY 1

To demonstrate that matter is composed of tiny particles.

Take a clean beaker. Pour 100 mL water in it. Now add three or four crystals of potassium permanganate in it. Stir the solution with a glass rod so that the crystals dissolve in water evenly. Note the colour of the solution. It is pink.

Then take four small beakers A, B, C and D. Empty the pink solution obtained above in beaker A. Pour 100 mL of water each in beakers B, C and D.

Next, take 10 mL of this solution in beaker A and pour it in the water of beaker B. What do you observe? You will observe that the solution turns pink though the colour becomes lighter. Again take 10 mL of this solution in beaker B and pour it in the water of beaker C. The solution turns pink though the colour is fainter. Again take 10 mL of the solution of beaker C and pour it in the water of beaker D. What do you see ? You will see that the solution is still pink but very faint in colour.

This experiment shows that there are millions of tiny particles in a crystal of potassium permanganate which evenly spread out in water. Each dilution spreads them further as the water molecules increase. Hence the pink colour becomes fainter.

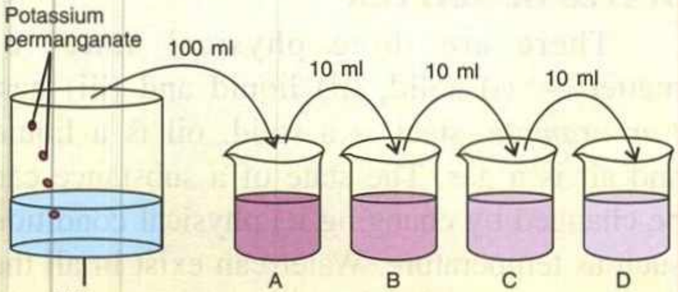
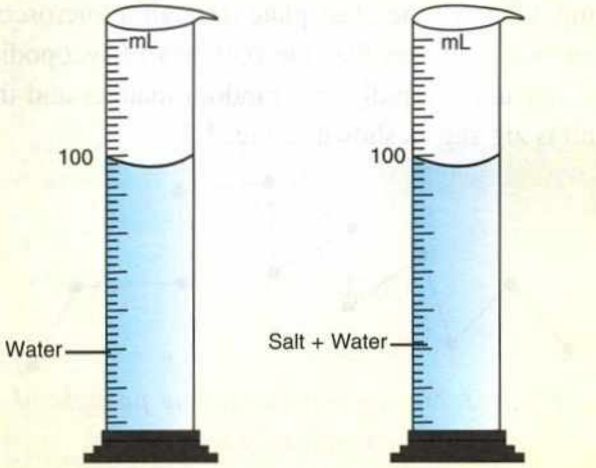


Fig. 1.1

2. The molecules of matter have spaces between them : The space between the molecules of matter is called inter-molecular space. It is less in solids, more in liquids and still more in gases. In other words, molecules are very closely packed in solids, less in liquids and least in gases.

ACTIVITY 2

Take 100 mL of water in a measuring cylinder. Add gently 20 grams of salt in water and stir it well so as to dissolve the salt evenly in water. You will notice that the level of water does not change (Fig. 1.2). It shows that the molecules of salt occupy the spaces between the molecules of water.



(a) Water alone (b) Salt added to water

Fig. 1.2 The molecules of salt occupy the spaces between the molecules of water

3. Molecules are in constant motion : The molecules of matter are not at rest, but they are constantly in motion. In solids, the molecules vibrate about their mean positions without leaving their positions. In liquids, the molecules are free to move within the boundary of the container. In gases, the molecules can move in a random manner everywhere in the space available to them.

ACTIVITY 3

Spray a perfume in a corner of a room. You will find that the smell of perfume spreads everywhere inside the room in a negligible time. This shows that the molecules of perfume are in random motion.

ACTIVITY 4

Take a beaker. Fill it partly with water. Add some lycopodium powder (yellow coloured dust powder also called jash powder) in the beaker containing water. Stir the contents of the beaker with a glass rod. Take out few drops of this suspension on a glass plate. Place it on the table and illuminate it with a table lamp. Observe the glass plate through a microscope. You will find that the fine particles of lycopodium powder move rapidly in a random manner and their path is zig zag as shown in Fig. 1.3.

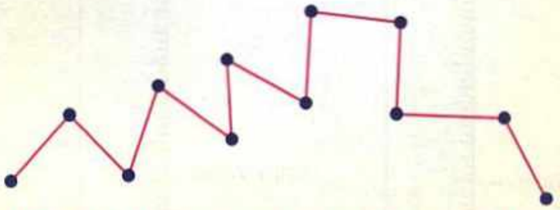


Fig. 1.3 Zig zag path of a fine particle of lycopodium powder

The reason is that the molecules of water are in random motion which collide with the suspended fine particles of lycopodium powder and make them to move in a zig zag path.

4. **Molecules attract each other :** The molecules of matter exert a force of attraction on each other. This force of attraction is called **inter-molecular force**.

The inter-molecular force is neither due to their masses (*i.e.* gravitational force) nor due to their charges (*i.e.* electrostatic force). This force is a strong attractive force. It is effective between the molecules only upto a separation of 10^{-9} metre. As the separation between the molecules becomes more than 10^{-9} metre, this force vanishes.

The force of attraction between the molecules of a solid is very strong, while it is less strong between the molecules of a liquid and negligible between the molecules of a gas.

The inter-molecular force of attraction between the molecules of the same substance is called **force of cohesion**, while the force of attraction between the molecules of two different substances is called **force of adhesion**. These forces are responsible in liquids for their property of surface tension and viscosity.

Do You Know ?

1. The liquids and gases can flow because the molecular forces of attraction in them are weak.
2. Adhesives have strong molecular forces of attraction.

ACTIVITY 5

Try to break a piece of coal into small particles. You will find it difficult to break it in minute particles. This shows that the particles of coal are bound by the strong forces of attraction amongst themselves.

STATES OF MATTER

There are three physical states of matter — (i) solid, (ii) liquid and (iii) gas. *For example*, steel is a solid, oil is a liquid and air is a gas. The state of a substance can be changed by changing its physical condition such as temperature. Water can exist in all the three states, viz, ice (solid state), water (liquid state) and steam (gaseous state).

Solids are rigid. They have a definite size (volume) and a definite shape.

Liquids are not rigid. They have a definite volume, but no definite shape. They take the shape of the vessel in which they are placed.

Gases are also not rigid. They have neither a definite volume nor a definite shape. They take the volume and shape of the container.

The properties which decide the state of a substance, *i.e.* solid, liquid or gas are :

1. Inter-molecular space.
2. Force of attraction between the molecules.
3. Kinetic energy of molecules due to their motion.

Solid : When inter-molecular force is very strong and kinetic energy is very less, the inter-molecular space is reduced and matter exists as a solid.

Liquid : When inter-molecular force between the constituent molecules is not much strong and kinetic energy is sufficient for the molecules to move to and fro, the inter-molecular space is increased and matter exists as a liquid.

Gas : When inter-molecular force is negligible and kinetic energy is very high, matter exists as a gas.

MOLECULAR MODEL OF SOLIDS

1. Each solid is made up of very tiny particles called molecules. These molecules are very small in size and they can be assumed to be like tiny rigid balls.
2. The separation between two molecules in a solid (*i.e.* inter-molecular spacing) is very small.
3. The molecules in a solid can only vibrate to and fro about their mean positions. They do not leave their positions.
4. The molecules in a solid are closely packed due to the strong attractive forces between them as shown in Fig. 1.4.

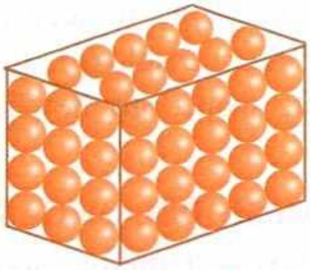


Fig. 1.4 Arrangement of molecules in a solid

Thus, the molecules in a solid are in fixed positions and due to the strong inter-molecular forces, they do not leave their positions, so a solid has a definite shape and a definite size (volume).

MOLECULAR MODEL OF LIQUIDS

1. Each liquid is made up of very tiny particles called molecules. These molecules are very small in size and they are not in a rigid arrangement.
2. The inter-molecular spaces in liquids are more than that in solids.
3. The liquid molecules can move about freely within the boundary of the vessel in which the liquid is kept.
4. The molecules in a liquid are less closely packed and their positions are not fixed as they are free to move within the boundary of the vessel as shown in Fig. 1.5. This is because the inter-molecular forces in a liquid are weak in comparison to that in solids.

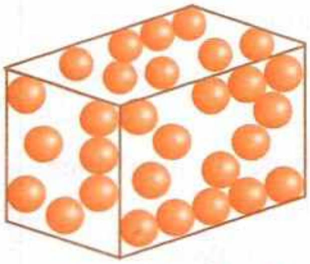


Fig. 1.5 Arrangement of molecules in a liquid

Thus, the liquid molecules can slide over one another due to which a liquid can flow. The inter-molecular forces, although weak, are sufficient to keep the molecules within the boundary of the vessel. So, liquids do not have a definite shape, but they have a definite volume.

MOLECULAR MODEL OF GASES

1. Like solids and liquids, gases are made up of very tiny particles called molecules. These molecules are very small in size and they can be assumed to be like rigid, homogeneous and perfectly elastic balls.
2. The separation between the molecules is quite large as compared to that in liquids and solids.
3. The molecules in a gas can move about freely in the space available to them.
4. The molecules in a gas are wide apart and their positions are not fixed because the inter-molecular forces in them are very weak. The arrangement of molecules in a gas is shown in Fig. 1.6.

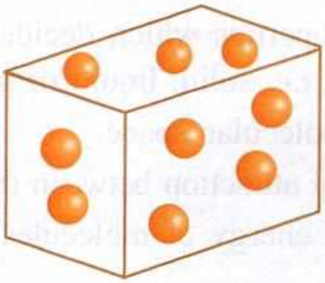


Fig. 1.6 Arrangement of molecules in a gas

Thus, the gas molecules are quite free to move here and there in the space available to them because of their weak inter-molecular forces. This is why, the gases have neither a definite shape nor a definite volume.

DISTINCTION BETWEEN SOLIDS, LIQUIDS AND GASES

Solids	Liquids	Gases
1. A solid has a definite shape and a definite volume.	1. A liquid has a definite volume, but not a definite shape.	1. A gas has neither a definite volume nor a definite shape.
2. The molecules in a solid are rigid.	2. The molecules in a liquid are non-rigid.	2. The molecules in a gas are rigid, homogeneous and perfectly elastic.
3. The molecules in a solid can only vibrate to and fro about their mean positions.	3. The molecules in a liquid can move within the boundary of the vessel.	3. The molecules of a gas can move freely in the available space.
4. The molecules remain fixed at their positions.	4. The molecules do not remain fixed at their positions.	4. The molecules do not remain fixed at their positions.
5. The inter-molecular forces are very strong.	5. The inter-molecular forces are less strong (moderate).	5. The inter-molecular forces are weak.
6. The molecules in a solid are closely packed.	6. The molecules in a liquid are loosely packed.	6. The molecules in a gas are wide apart.
7. A solid cannot flow.	7. A liquid can flow.	7. A gas can flow.

List of few solids, liquids and gases

Solids	Liquids	Gases
Ice	Water	Steam
Aluminium	Benzene	Air
Silver	Chloroform	Oxygen
Calcium	Oil	Hydrogen
Gold	Honey	Chlorine
Iron	Glycerine	Nitrogen
Sodium-chloride	Hydrochloric-acid	Ammonia
Sugar	Nitric acid	Sulphur dioxide
Wood	Alcohol	Nitric oxide
Plastic	Spirit	Helium
Wax	Dettol	Argon

CHANGE OF STATE

We know that matter exists in three different states, namely, solid, liquid and gas.

The process of change from one state to another state either by absorption or rejection of heat at a constant temperature is called change of state.

Change of solid into liquid or vice-versa :

When a solid is heated, it changes into its liquid at a fixed temperature. This process is called **melting** or **fusion**. The reverse happens when this liquid is cooled. The liquid freezes into solid at the same fixed temperature. This process is called **freezing**.

Change of liquid into gas or vice-versa :

When a liquid is heated, it changes into its vapour (or gas) at a fixed temperature. This process is called **boiling** or **vaporization**. The reverse happens when this vapour is cooled. The vapour condenses into liquid at the same fixed temperature. The process is called **condensation**.

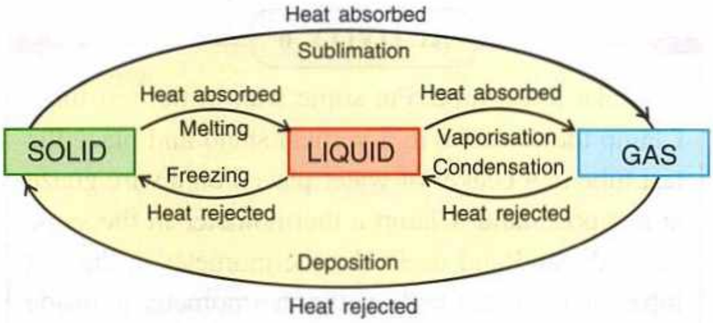


Fig. 1.7 Change of state

Change of solid into gas or vice-versa :

In some cases (like camphor, iodine), on heating, a solid directly changes to its vapour or gaseous state (without changing into liquid). This process is called **sublimation**. In the reverse process, the gas on being cooled directly changes into solid. This process is called **deposition**.

The above changes in state of matter are shown in Fig. 1.7.

It may be noted that the change of state of a substance occurs at a fixed temperature and during the process, the quantity of heat given to (or taken from) the substance, does not cause a change in its temperature. This heat is called latent heat (or hidden heat) because it is not manifested by any change in temperature.

MELTING

The change from the solid state to the liquid state on heating at a fixed temperature is called **melting**. The temperature at which a solid changes into liquid without further increase in temperature is called the **melting point of the solid**. *For example*, ice (solid) at 0°C melts to form water (liquid) at 0°C by the absorption of heat.

The process of melting can be demonstrated by the following activity.

ACTIVITY 6

Take a test tube. Put some wax in the test tube. Clamp the test tube in a vertical stand and place the test tube in a beaker of water placed on a wire guaze at a tripod stand. Clamp a thermometer in the same vertical stand and insert the thermometer in the test tube such that the bulb of the thermometer is inside the wax as shown in Fig 1.8. Heat the beaker over the flame of a burner and record the temperature of the wax after every minute. Record your observations.

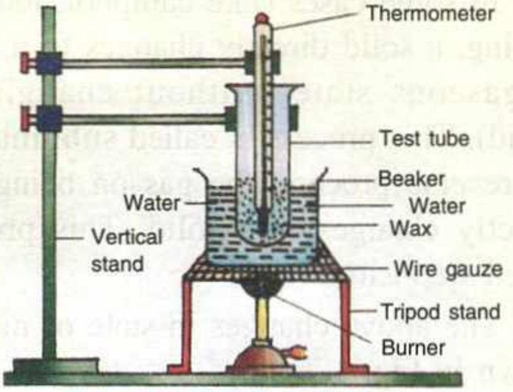


Fig. 1.8 Melting of wax

Observations :

Time (in minute)	Temperature of wax (in °C)
0	25
1	30
2	35
3	40
4	45
5	50
6	55
7	55
8	55
9	55
10	60
11	65
12	70

Conclusion : From the above observations, you will note that wax melts at 55°C during which heat is supplied, but temperature does not rise. Thus, the melting point of wax is 55°C. After the melting of the whole wax, the temperature begins to rise.

FREEZING

The change of state of a substance from the liquid state to its solid state on cooling (rejecting heat) is called ***freezing***.

Freezing occurs at a fixed temperature. During freezing the temperature of the liquid remains unchanged till all the liquid has changed into solid.

The temperature at which a liquid changes into solid without further decrease in temperature is called the **freezing point of the liquid**. *For example*, water (liquid) at 0°C freezes to form ice (solid) at 0°C, by releasing heat.

The process of freezing can be demonstrated by the following activity.

ACTIVITY 7

In activity-6 given above, when the temperature of melted wax reaches 70°C, remove the burner. Allow the beaker to cool and record the temperature of wax after every minute.

Observations :

Time (in minute)	Temperature of wax (in °C)
0	70
1	65
2	60
3	55
4	55
5	55
6	55
7	50
8	45
9	40
10	35
11	30
12	25

Conclusion : In the above observations, you will notice that the melted wax changes into solid wax *i.e.* it freezes at 55°C when the temperature does not fall further on cooling. After the wax has frozen completely, its temperature begins to fall again.

***Note* :** 1. The process of melting and freezing can also be demonstrated with powdered naphthalene or solid ice.

2. For a substance, the melting point and freezing point are the same. *For example*, melting point of wax is 55°C and freezing point of melted wax is also 55°C.

The melting point and the heat absorbed for change of state from solid to liquid, for some solids, are given in the following table.

Melting point and heat absorbed during melting for some substances

Substance	Melting point	Heat absorbed
1. Ice	0°C	336×10^3 J kg^{-1}
2. Wax	55°C	147×10^3 J kg^{-1}
3. Naphthalene	80°C	147×10^3 J kg^{-1}
4. Copper	1085°C	1806×10^3 J kg^{-1}

Do You Know ?

1. The amount of heat rejected during freezing of a substance is same as the amount of heat absorbed during melting for the same mass of the substance.
2. The amount of heat absorbed or rejected during the change of state for a unit mass of substance is called its **specific latent heat**. It is measured in joules per kilogram.
3. Water expands on freezing whereas wax, lead etc. contract on freezing.
4. Melting point of ice decreases with increase of pressure on it, but the melting point of wax increases with increase of pressure on it.
5. Melting point of ice decreases when salt is added to it. This mixture of salt added to ice is called freezing mixture. It is used for preparing Kulfies.

EXPLANATION OF MELTING BY MOLECULAR MODEL

In a solid, the molecules are closely packed *i.e.*, they have less inter-molecular spacing. The molecules only vibrate about their mean positions, so they have very little kinetic energy. They have strong molecular forces of attraction amongst them. On heating a solid, the kinetic energy of molecules increases due to which they begin to vibrate more violently. At a particular temperature (called the melting point), the molecules acquire sufficient kinetic energy to become far separated from each other by overcoming the forces of attraction between them. They become free to move within the substance *i.e.*, the state of substance becomes liquid. In this state, the heat energy absorbed by the substance does not change the temperature of the substance, but is utilized in doing work against the forces of attraction in increasing the separation between the molecules (*i.e.*, their potential energy increases).

VAPORIZATION OR BOILING

*The change from liquid state to gaseous (or vapour) state on heating at a constant temperature by absorption of heat is called **vaporization** or **boiling**.*

The temperature at which a liquid changes into vapour without further increase in temperature is called the **boiling point of the liquid**. *For example*, water (liquid) at 100°C changes to steam (gas) at 100°C by absorption of heat.

The vaporization of a liquid can be demonstrated by the following activity.

ACTIVITY 8

Take a beaker. Pour some water in the beaker. Place the beaker on a wire gauze placed over a tripod stand. Clamp a thermometer in a vertical stand and insert it in the beaker as shown in Fig. 1.9. Heat the beaker over the flame of a burner and record the temperature of water after every minute.

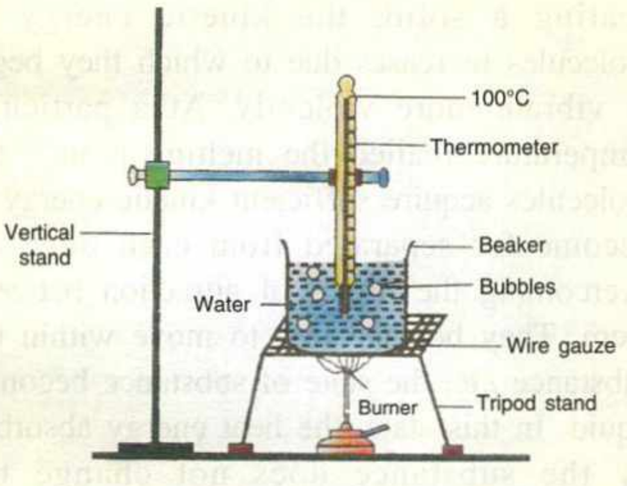


Fig. 1.9 Vaporization of water

You will notice that the temperature of water rises continuously till the water starts boiling at 100°C. Once the water starts boiling, its temperature does not rise any further, although the heat is still being supplied. Now the bubbles formed through the water are seen. At this temperature water begins to boil and changes into steam. Thus, the boiling point of water is 100°C.

Condensation : The change from vapour state to liquid state at a constant temperature on rejecting heat (or on cooling) is called **condensation**. The temperature at which vapour changes into liquid without any further decrease in temperature is called **condensation point of the vapour**. *For example*, steam (gas or vapour) at 100°C condenses to water (liquid) at 100°C on cooling (*i.e.* by rejecting heat).

Do You Know ?

1. For a substance, the boiling point and the condensation point are same. *For example*, boiling point of water is 100°C and condensation point of steam is also 100°C.

2. The amount of heat absorbed or rejected during the change from liquid to vapour state or from vapour to liquid state is same for the same mass of the substance.

3. All liquids expand on heating.

4. The boiling point of a liquid increases with the increase of pressure on it. This is why it is difficult to cook vegetables at the mountains where pressure is low but it is easy to cook vegetables in a pressure cooker in which pressure is increased by keeping the water vapour inside the cooker.

5. The boiling point of a liquid increases when impurities are added to it.

The boiling point and heat absorbed for change of state from liquid to vapour, for some liquids are given in the following table.

Boiling point and heat absorbed during vaporization of some liquids

Liquid	Boiling point	Heat absorbed for vaporization
1. Water	100°C	2260×10^3 J kg^{-1}
2. Alcohol	78·3°C	$856{\cdot}8 \times 10^3$ J kg^{-1}
3. Ether	35°C	$352{\cdot}8 \times 10^3$ J kg^{-1}

EXPLANATION OF VAPORIZATION BY MOLECULAR MODEL

In a liquid, the molecules move in all directions but within the boundary of the container. They exert small forces of attraction on each other. They have low kinetic energy. On heating (absorbing heat), the average kinetic energy of molecules of liquid increases. At a particular temperature (boiling point), the molecules acquire sufficient kinetic energy to overcome the forces of attraction between themselves and they become free to leave the liquid surface. This is called vaporization. Thus, a liquid changes into vapour at a particular temperature by the absorption of heat energy. The heat energy absorbed does not change the kinetic energy of the molecules, but is utilised in doing work against the forces of attraction in increasing the separation between the molecules *i.e.*, in increasing their potential energy.

EVAPORATION

Evaporation is another process by which a liquid changes into vapour. The change of state from liquid to vapour at all temperatures from the surface of a liquid is called evaporation. It is to be noted that :

1. Evaporation takes place at all temperatures, but vaporization takes place only at a fixed temperature which is the boiling point of the liquid.
2. Evaporation is a slow and gradual process whereas vaporization is a rapid and violent process.
3. Evaporation takes place only at the surface of the liquid whereas vaporization takes place over the entire liquid.
4. Evaporation has cooling effect, but vapourization does not produce cooling.

The process of evaporation can be demonstrated by the following activity.

ACTIVITY 9

Spray some water on the floor, you will find that after some time the floor dries up. It dries up because the water evaporates (*i.e.* it changes into vapour). Similarly, a wet cloth dries up after sometime due to evaporation of water from the cloth.

RATE OF EVAPORATION

The rate of evaporation of a liquid depends mainly on the following five factors :

(i) **The temperature of liquid :** A wet cloth dries up on a hot day much faster than on a cold day. Thus, the rate of evaporation is higher if the temperature of liquid is high.

(ii) **The area of the exposed surface :** A cloth dries up faster if it is spread out than if it is folded up. Thus, the rate of evaporation increases if the area of surface exposed increases.

(iii) **The nature of liquid :** Volatile liquids with low boiling point such as alcohol, spirit, ether etc. evaporate much faster than water. This is why volatile liquids are stored in tightly closed bottles.

(iv) **The flow of air above the liquid :** If air is blown above the liquid surface, it moves away the molecules of liquid from the surface with it, so the liquid evaporates more quickly. This is why to cool the milk, we blow air above it.

(v) **The presence of moisture or humidity :** In dry air, evaporation is faster than in humid air. This is why wet clothes dry faster in dry summer days than in rainy season.

EXPLANATION OF EVAPORATION BY THE MOLECULAR MODEL

In a liquid, the molecules are in motion within its boundary. They collide with each other. During the collision, some molecules below the surface of liquid acquire sufficient kinetic energy to overcome the force of attraction of other molecules and their intermolecular spacing increases. Such molecules move to the surface of the liquid and they absorb heat from the surroundings so as to escape out into the atmosphere with the atmospheric air molecules. This process is called evaporation.

Do You Know ?

1. More the temperature of a liquid, higher will be the rate of molecules escaping from its surface.

2. More the area of exposed surface, more will be the number of molecules escaping out of the surface.

3. In a volatile liquid, the force of attraction among molecules is negligible. So, they escape out more easily.

4. On blowing air, the air molecules take away the liquid molecules from the surface with them and other molecules of the liquid occupy their place. This increases the rate of evaporation.

5. In humid air, the water molecules present in the air near the surface of the liquid do not allow the molecules of the liquid to escape out easily. They decrease the rate of evaporation.

EVAPORATION PRODUCES COOLING

If a little alcohol (or spirit) is poured on the palm, it gives a soothing (or cooling) sensation. If some alcohol (or spirit) is poured on cotton (or wool) wrapped around the bulb of a thermometer, the reading of the thermometer falls. This shows that cooling is produced when a liquid evaporates. The reason for cooling in evaporation is that when a liquid changes into vapour, it requires heat. This heat is supplied by the surroundings of the liquid (such as palm or cotton wrapped around the thermometer in the above examples). This results in fall in temperature (or cooling) in the surroundings.

APPLICATIONS OF EVAPORATION

(1) In summer, water gets cooled in an earthen pot (surahi). The reason is that water seeps out on the surface through the pores in the pot and it evaporates. The heat required for evaporation is taken from water inside the pot which therefore gets cooled.

(2) Doctors advice to put the strips of wet cloth on the forehead of a patient having high fever. The reason is that water of the strips evaporates. During evaporation, water takes heat from the body of the patient and thus the temperature of his body decreases.

(3) We often pour tea in a saucer to cool it faster. In the saucer, the surface area of tea increases and evaporation becomes faster.

(4) Evaporation of sweat from our body helps to maintain the body temperature at 37°C (or 98·6°F). When sweat evaporates, it requires heat which it takes away from our body. As a result, temperature falls to keep the body at 37°C.

Difference between evaporation and boiling

Evaporation	Boiling
1. It is a slow process.	1. It is a rapid process.
2. It takes place at the surface of liquid.	2. It takes place through out the mass of liquid.
3. It takes place at all temperatures.	3. It takes place at a specific constant temperature which is called the boiling point of the liquid
4. The temperature of surroundings falls.	4. The temperature of surroundings remains constant.

UBLIMATION AND DEPOSITION (OR OLIDIFICATION)

Sublimation : Sublimation is the process y which a solid when heated, directly hanges into its vapour (gaseous state) vithout first changing into liquid.

Deposition or **solidification :** It is a rocess when a vapour (or gas) on cooling hanges directly into a solid without first hanging into liquid. These processes are hown in Fig. 1.10.

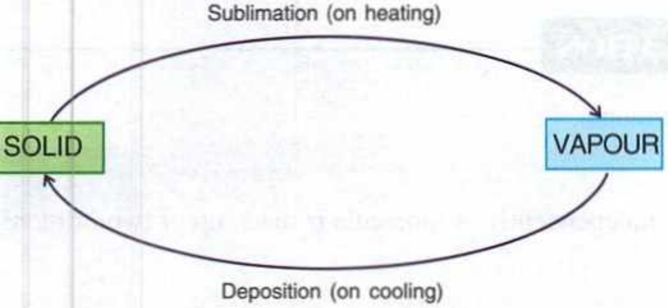


Fig. 1.10 Sublimation and deposition

For example, when ammonium chloride, odine, camphor, naphthalene and solid carbon lioxide (dry ice) are heated, they directly change nto their vapours and when their vapours are ooled, they change into their solids.

Note : 1. Carbon dioxide gas when ooled converts into solid carbon dioxide vhich is called dry ice.

2. Sometimes sublimation also takes lace without heating. *For example,* aphthalene balls (or moth balls) which we se to protect woolen clothes from insects, irectly changes into vapour and with time hey become small in size.

The process of sublimation and eposition (or solidification) can be easily emonstrated by the following activity.

ACTIVITY 10

Take some camphor or ammonium chloride. Powder it. Keep the powder in a china dish. Now cover the china dish with an inverted funnel as shown in Fig. 1.11. Then close the end of funnel with a piece of cotton.

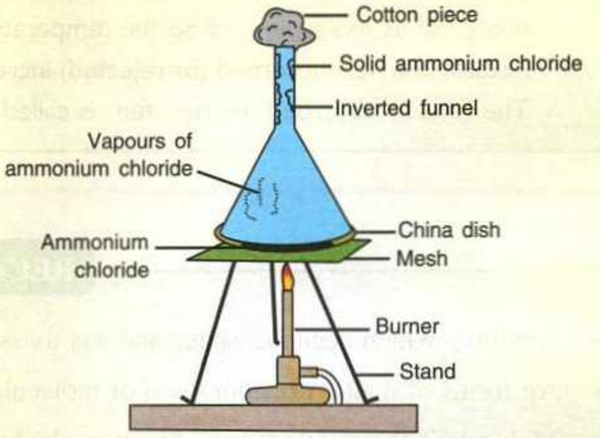


Fig. 1.11 Sublimation and deposition of ammonium chloride

Now, place the dish on a wire mesh kept on a tripod stand to heat it by a burner. You will notice that the fumes (*i.e.* vapours) of ammonium chloride are seen in the funnel above the dish. These vapours upon rising, get cooled and change to solid ammonium chloride which gets deposited on the inner walls of the funnel. Thus, ammonium chloride on heating changes directly from solid to vapour and these vapours on cooling directly change to solid ammonium chloride.

EXPLANATION OF SUBLIMATION BY THE MOLECULAR MODEL

In some solids, the inter-molecular forces of attraction are weak. In such solids, on heating, the molecules acquire sufficient kinetic energy to overcome the force of attraction and they become free to move. Thus, their inter-molecular separation becomes very large and they change to vapour directly.

Do You Know ?

1. The average kinetic energy of molecules of a substance is a measure of its temperature.
2. In general, when a substance absorbs heat, the average kinetic energy of its molecules increases due to which its temperature rises. But if the substance gives out heat, the average kinetic energy of its molecules decreases due to which its temperature falls.
3. During the change of state, when a substance absorbs or gives out heat, there is no change in average kinetic energy of its molecules and so the temperature of the substance does not change during the change of state. Actually the heat absorbed (or rejected) increases (or decreases) the average potential energy of its molecules. The heat so absorbed (or rejected) is called the latent heat or hidden heat.

RECAPITULATION

- Anything which occupies space and has mass is called matter.
- All forms of matter are composed of molecules.
- Molecule is the smallest unit of matter which can exist independently. A molecule is made up of two or more atoms of same type or of different types.
- A molecule of a substance has all its properties.
- Molecules in matter are always in a state of motion (translational or vibrational) and so they possess kinetic energy.
- On heating, the increase in temperature increases the kinetic energy of the molecules.
- The force of attraction between the molecules of same kind is called the force of cohesion, whereas the force of attraction between the molecules of different kinds is called the force of adhesion.
- The force of attraction between the molecules is also called inter-molecular force of attraction. The space between the molecules of matter is called inter-molecular space.
- In case of solids, inter-molecular space is the least and so inter-molecular force of attraction is maximum.
- In liquids, the inter-molecular space is more than in solids and the inter-molecular force of attraction is less than in solids.
- In gases, the inter-molecular spaces are maximum while the inter-molecular force of attraction is negligibly small.
- A substance can exist in three different states : solid, liquid and gas.
- The process of change from one state to the other state at a constant temperature is called change of state.
- The change from the solid state to the liquid state on heating at a fixed temperature is called melting and the change from the liquid state to the solid state on cooling at the same fixed temperature is called freezing.
- The constant temperature at which a substance changes from its solid state to the liquid state by absorbing heat is called its melting point. Similarly, the constant temperature at which a substance changes from the liquid state to the solid state by giving out heat is called its freezing point. The melting point and freezing point of a substance are same. The melting point of ice or the freezing point of water is 0°C.
- The heat absorbed by a substance during melting and the heat given out by it during freezing for the same mass without change in temperature, are same.

- Ice at 0°C absorbs 336×10^3 Joule per kilogram of heat to convert into water at 0°C while water at 0°C rejects 336×10^3 joule per kilogram of heat to convert into ice at 0°C.
- The change from the liquid state to the gaseous (or vapour) state on heating at a fixed temperature is called boiling or vaporization. The reverse process of change from the vapour state to the liquid state on cooling at the same fixed temperature is called condensation.
- The constant temperature at which a substance changes from the liquid state to its vapour state by absorbing heat is called its boiling point. The boiling point of water is 100°C.
- The heat absorbed by a liquid during vaporization and the heat given out by it during condensation of the same mass without change in temperature, are same.
- Water at 100°C absorbs 2260×10^3 Joule per kilogram of heat to change into steam at 100°C, while steam at 100°C changes into water at 100°C by giving out 2260×10^3 joule per kilogram of heat.
- The vaporization of a liquid can take place in the following different ways :
  (i) through boiling at a fixed temperature, and
  (ii) through evaporation at all temperatures.
- The change from the liquid state to the vapour state at all temperatures from the surface of a liquid is called evaporation. Evaporation is a slow process.
- Evaporation produces cooling.
- The rate of evaporation of a liquid depends on (i) the temperature of liquid, (ii) the area of the surface exposed, (iii) the nature of liquid, (iv) the wind or blowing air above the liquid surface, and (v) the presence of humidity.
- The process of change of a solid directly into gas (or vapour) at a fixed temperature without changing into liquid is called sublimation while the reverse process of change of vapour (or gas) directly into solid at a fixed temperature without changing into liquid is called deposition or solidification e.g. camphor, ammonium chloride etc. sublime when heated and solidify when cooled at a fixed temperature.

TEST YOURSELF

A. Objective Questions :

1. Write **true** or **false** for each statement :

   (a) The temperature of a substance remains unaffected during its change of state.

   (b) Ice melts at 100°C.

   (c) Water at 100°C has more heat than steam at 100°C.

   (d) Evaporation of a liquid causes cooling.

   (e) Water evaporates only at 100°C.

   (f) Boiling takes place at all temperatures.

   (g) Evaporation takes place over the entire mass of the liquid.

   (h) The process of a gas converting directly into solid is called vaporization.

   (i) At high altitudes, water boils above 100°C.

   (j) The melting point of ice is 0°C.

   Ans: True—(a), (d), (j)
   False—(b), (c), (e), (f), (g), (h), (i)

2. Fill in the blanks :

   (a) Evaporation takes place at .... temperatures.

   (b) .... process is just the reverse of melting.

   (c) .... is a process that involves direct conversion of a solid into its vapour on heating.

   (d) The temperature at which a solid converts into a liquid is called its ....

(e) The smallest unit of matter that exists freely in nature is called ....

(f) Molecules of a substance are always in a state of .... and so they possess ....

(g) Inter-molecular space is maximum in .... less in .... and the least in ....

(h) Inter-molecular force of attraction is maximum in ...., less in .... and the least in ....

Ans: (a) all (b) freezing (c) sublimation (d) melting point (e) molecule (f) motion, kinetic energy (g) gases, liquids, solids (h) solids, liquids, gases

3. Match the following :

Column A	Column B
(a) Molecules	(i) water boils
(b) 100°C	(ii) evaporation
(c) 0°C	(iii) changes from solid to gas
(d) At all temperatures	(iv) matter
(e) Camphor	(v) water freezes

Ans: (a)–(iv), (b)–(i), (c)–(v), (d)–(ii), (e)–(iii)

4. Select the correct alternative :

(a) The inter-molecular force is maximum in :

(i) solids (ii) gases
(iii) liquids (iv) none of the above.

(b) The inter-molecular space is maximum in :

(i) liquids (ii) solids
(iii) gases (iv) none of the above.

(c) The molecules can move freely anywhere in :

(i) gases (ii) liquids
(iii) solids (iv) none of the above.

(d) The molecules move only within the boundary in :

(i) liquids (ii) gases
(iii) solids (iv) none of the above.

(e) The temperature at which a liquid get converted into its vapour state is called its :

(i) melting point (ii) boiling point
(iii) dew point (iv) freezing point.

(f) Rapid conversion of water into steam is a example of :

(i) evaporation (ii) freezing
(iii) melting (iv) vaporization.

(g) Evaporation takes place from the :

(i) surface of liquid
(ii) throughout the liquid
(iii) mid-portion of the liquid
(iv) bottom of liquid.

(h) Boiling takes place from :

(i) the surface of the liquid
(ii) throughout the liquid
(iii) mid-portion of liquid
(iv) none of the above.

Ans: (a)–(i), (b)–(iii), (c)–(i), (d)–(i), (e)–(ii) (f)–(iv), (g)–(i), (h)–(ii

B. Short/Long Answer Questions :

1. Define the term matter. What is it composed of
2. State three properties of molecules of matter.
3. What do you mean by inter-molecular spaces ? How do they vary in different states of matter ?
4. What is meant by inter-molecular forces of attraction ? How do they vary in solids, liquids and gases ?
5. Which of the following are correct ?

(a) Solids have definite shape and definite volume.

(b) Liquids have definite volume but no definite shape.

(c) Gases have definite volume but no definite shape.

(d) Liquids have both definite shape and definite volume.

Ans: Correct : (a) and (b)

6. Discuss the three states of matter : solid, liquid and gas on the basis of molecular model.

7. What do you mean by 'the change of state' ? Write the flow chart showing the complete cycle of change of state.
8. Differentiate between melting point and boiling point, giving atleast one example of each.
9. Describe the process of condensation and sublimation with examples.
10. Explain the terms melting and melting point.
11. Describe an experiment to demonstrate that a substance absorbs heat during melting without change in its temperature.
12. Explain the terms vaporization and boiling point.
13. A liquid can change into vapour state
    (a) at a fixed temperature, and
    (b) at all temperatures
    Name the processes involved in the two cases.
14. Some ice is taken in a beaker and its temperature is recorded after each one minute. The observations are listed below :

Time (in minute)	Temperature (in °C)
0	0
1	0
2	0
3	0
4	0
5	0
6	3·8
7	7·6
8	11·4

From the above observations what conclusion do you draw about the melting point of ice ?

Ans: Melting point of ice = 0°C

15. Describe an experiment to demonstrate that water absorbs heat during boiling at a constant temperature.
16. State (a) the melting point of ice and (b) the boiling point of water.
17. What is evaporation ?
18. State three factors which affect the rate of evaporation of a liquid.
19. Wet clothes dry more quickly on a warm dry day than on a cold humid day. Explain.
20. Water in a dish evaporates faster than in a bottle. Give reason.
21. Why are volatile liquids such as alcohol and spirit stored in tightly closed bottles ?
22. A certain quantity of water is heated from 20°C to 100°C. Its temperature is recorded after each 1 minute. The observations are :

Time (in minute)	Temperature (in °C)
0	20
1	30
2	40
3	50
4	60
5	70
6	80
7	90
8	100
9	100
10	100
11	100
12	100

What conclusion do you draw from the above table about the boiling point of water ? Explain.

Ans: Boiling point of water = 100°C

23. Why is cooling produced on evaporation of a liquid ?
24. Explain with an example that when a liquid evaporates, it takes heat from its surroundings.
25. Give two applications of evaporation.
26. Explain why in hot summer days water remains cool in earthen pots.
27. A patient suffering from high fever is advised to put wet cloth strips on his forehead. Why ?
28. What do you mean by sublimation ? Explain with an example.
29. Why does the size of naphthalene balls decrease when left open ?
30. Describe an experiment to demonstrate the process of sublimation.

Project Work

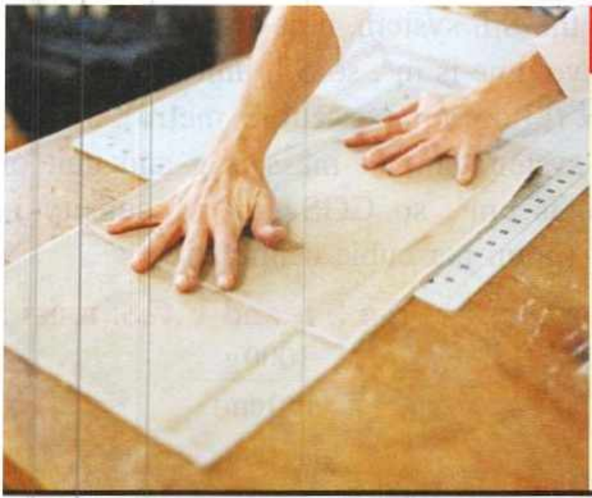
Take a beaker. Fill it half with water. Add two spoons of table salt in the water of beaker. Stir the contents of the beaker with a spoon. What do you observe ? Where do the particles of salt go ?

Taste few drops of the salt solution. You will find it salty. Now, heat the beaker over a gentle flame till the entire water of the beaker vapourizes. See the contents of the beaker. What is left in the beaker ? Taste it. Does it still taste salty ?

How is this residue left ?

Hint :

1. The particles of salt occupy space between the inter-molecular spacing of water.
2. On heating when the water vaporizes, the inter-molecular spacing of water increases till only the particles of salt are left behind.



2

Physical Quantities and Measurement

Theme : Previous learning demonstrated the measurement of the density of regular solids. In this class children will develop the ability to measure the density of an irregular solid and also of a given liquid. They will also understand that due to the difference in the value of densities of a solid and liquid, a piece of solid can float or sink in a liquid.

In this chapter you will learn to

- measure density of an irregular solid
- measure density of a liquid
- discuss the concept of floatation based on relative densities of solid and liquid
- express result of measurement in proper unit with proper symbol
- solve simple numerical problems based on formula of density
- compare densities of matter in three states, solid, liquid and gas
- make careful observations including measurements
- gather data using formal units
- make conclusions from collected data
- make predictions using scientific knowledge and effectively communicating the same.

LEARNING OBJECTIVES

- Revising previous concepts learnt by children.
- Building on children's previous learning.
- Demonstrating the process of measurement of density of an irregular solid.
- Demonstrating the process of measurement of density of a liquid.
- Engaging children in practical tasks involving measurement of density of an irregular solid and a liquid.
- Engaging children (in group/pairs/individually) in an investigation to find out which object floats in which liquid, given solids of different densities and liquids of different densities. This is to be followed by discussion.
- Guiding children to predict the result of the previous investigation and compare predictions with the outcomes.

KNOWING CONCEPTS

- Measurement of density of irregular solids using:
  - Eureka can • Measuring cylinder
- Measurement of density of fluids:
  - Basic concept
  - Concept of floatation and sinking of a substance (relate to density)
- Comparison of densities in the three states of matter.

DENSITY

Each body has a certain mass and a definite volume. The volume occupied by a body increases, if its mass is increased. Similarly, the mass of a body increases on increasing its volume. Further, it is found that

1. Equal masses of different substances have different volumes. *For example*, the volume of cotton is much larger than the volume of an equal mass of lead. This is because the particles of lead are closely packed while those of cotton are very loosely packed. In other words, lead is denser than cotton.
2. Equal volumes of different substances have different masses. *For example*, the mass of iron is much more than the mass of an equal volume of wood. This is because the particles of iron are more closely packed than those of the wood. In other words, iron is denser than wood.

Thus, to explain that equal volumes of different substances have different masses or equal masses of different substances have different volumes, we use a term called density. It is defined as follows :

The density of a substance is its mass per unit volume *i.e.*

$$\text{Density of a substance} = \frac{\text{Mass of the substance}}{\text{Volume of the substance}}$$

The density of a substance is represented by the symbol d. If mass of a substance is M and its volume is V, its density will be

$$\boxed{d = \frac{M}{V}}$$

UNIT OF DENSITY

$$\text{Unit of density} = \frac{\text{Unit of mass}}{\text{Unit of volume}}$$

In the S.I. system, unit of mass is kg and unit of volume is m^3, so S.I. unit of density i kg m^{-3} (kilogram per cubic metre). In th C.G.S. system unit of mass is g and unit o volume is cm^3, so CGS unit of density i g cm^{-3} (gram per cubic centimetre).

Relationship between S.I. and C.G.S. units :

$$1 \text{ kg m}^{-3} = \frac{1\,\text{kg}}{1\,\text{m}^3} = \frac{1000\,\text{g}}{(100\,\text{cm})^3}$$

$$= \frac{1}{1000} \text{ g cm}^{-3}$$

Thus,

$$1 \text{ kg m}^{-3} = 10^{-3} \text{ g cm}^{-3}$$

$$\text{or} \quad 1 \text{ g cm}^{-3} = 1000 \text{ kg m}^{-3}$$

Examples : 1. The mass of an iron cub of volume 10 cm^3 is equal to 78 g.

$$\text{Therefore, density of iron} = \frac{78\,\text{g}}{10\,\text{cm}^3}$$

$$= 7{\cdot}8 \text{ g cm}^{-3}.$$

2. The mass of 1 cm^3 of water is 1 g hence, density of water $= \frac{1\,\text{g}}{1\,\text{cm}^3} = 1$ g cm^{-3}.

3. A piece of copper of mass 8·9 kg ha volume 0·001 m^3. The density of coppe is $= \frac{8{\cdot}9\,\text{kg}}{0{\cdot}001\,\text{m}^3} = 8900$ kg m^{-3}.

Do You Know ?

1. The density of a substance does not change with any change in its shape or size.

2. Almost all substances expand on heating and contract on cooling, but their mass does not change. So, the density of a substance decreases with the increase in temperature and increases with the decrease in temperature. Exception is water which contracts on heating from 0°C to 4°C and expands on heating above 4°C. So the density of water increases from 0°C to 4°C and then decreases above 4°C (*i.e.* the density of water is maximum at 4°C which is equal to 1000 kg m^{-3}).

DETERMINATION OF DENSITY OF A REGULAR SOLID

1. First measure the mass M of the given regular solid by using a beam balance.
2. Now, to find the volume V of the given regular solid, use the following formula :

   Volume of a cube = $(\text{one side})^3$

   Volume of a cuboid

   $= \text{length} \times \text{breadth} \times \text{height}$

   Volume of a sphere = $\frac{4}{3}\pi\,(\text{radius})^3$

   Volume of a cylinder = $\pi\,(\text{radius})^2 \times \text{height}$

   (where $\pi = 3{\cdot}14$)

   The side of a cube or length, breadth and height of a cuboid or radius of a sphere or radius and height of a cylinder can be measured with the use of a metre ruler.

3. Knowing mass M and volume V, calculate density d of the substance of the given regular body by using the formula

   $$d = \frac{M}{V}$$

   For example, if mass of a cube of iron is

   $M = 210$ g

   One side of cube = 3 cm

   $\therefore$ Volume of cube $V = (\text{one side})^3$

   $= (3)^3 = 27\ \text{cm}^3$

   Density of iron $d = \frac{M}{V} = \frac{210\,\text{g}}{27\,\text{cm}^3}$

   $= 7{\cdot}78\ \text{g cm}^{-3}$

VESSELS FOR MEASURING VOLUME

In class VII, you have read that we use different vessels for measuring the volume of liquids. Some of the vessels are given below.

(i) **Measuring cylinder :** It is made up of glass or plastic and is graduated in millilitre (mL) with its zero mark at the bottom. The graduations then increase upwards as shown in Fig. 2.1. We have measuring cylinders available of different capacities, such as 50 mL, 100 mL, 200 mL, 500 mL etc. The capacity of a measuring cylinder is marked on it.

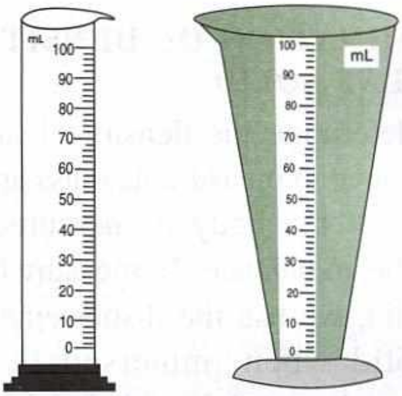


Fig. 2.1 Measuring cylinder

(ii) **Measuring beaker :** A measuring beaker is made up of glass, plastic or metal like aluminium. It is used to take out a fixed volume of liquids (say milk, oil, etc.) such as 50 mL, 100 mL, 200 mL, 500 mL, 1 litre from a large container. The capacity of a measuring beaker is marked on it.

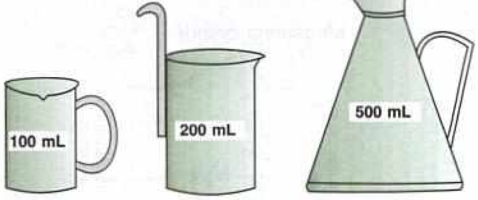


Fig. 2.2 Measuring beakers

(iii) **Eureka can :** A Eureka can is a glass (or polythene or metal) beaker with a side opening near its mouth which is known as spout. Thus, the beaker can contain a volume of liquid up to the spout. Any excess of liquid overflows through the spout. It is shown in Fig. 2.3.

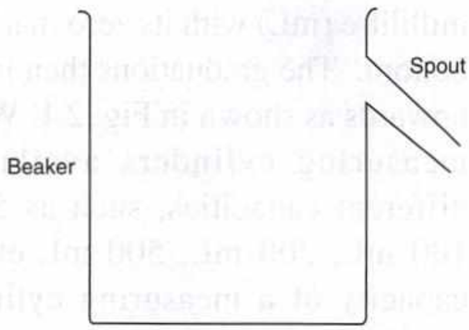


Fig. 2.3 Eureka can

DETERMINATION OF DENSITY OF AN IRREGULAR SOLID

To determine the density of an irregular solid, we have to measure its mass and volume. The mass of the body is measured with the help of a beam balance. To measure the volume of the solid, we use the displacement method *i.e.* a solid when immersed in a liquid, displaces volume of liquid equal to its own volume. The measurement of volume of an irregular body by displacement method can be understood by the following activities.

ACTIVITY 1

1. Measure the mass of the given solid using a common beam balance. Note the mass. Let it be M gram.
2. Take a measuring cylinder. Fill it partly with water as shown in Fig. 2.4 (a)

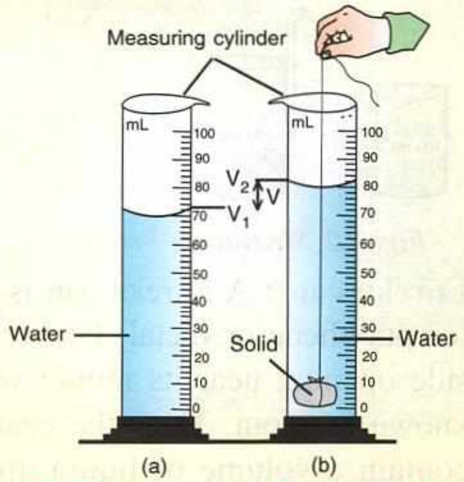


Fig. 2.4 Measurement of volume of a solid using a measuring cylinder

3. Note the level of water. Let it be V_1 mL.
4. Now, tie the given solid with a thread and gently lower the solid in water contained in the measuring cylinder as shown in Fig. 2.4 (b). Take care that no water splashes out. Note the level of water again. Let it be V_2 mL.
5. Find the difference, $V_2 - V_1$. It gives the volume V of the solid *i.e.*

$$V = (V_2 - V_1) \text{ cm}^3$$

6. Then, calculate the density of the solid by using the following formula:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{V} \text{ g cm}^{-3}$$

If $M = 78$ g, $V = 10$ cm^3, then

$$\text{Density} = \frac{78 \text{ g}}{10 \text{ cm}^3} = 7{\cdot}8 \text{ g cm}^{-3}.$$

Note : 1 mL = 1 cm^3.

ACTIVITY 2

1. Take an Eureka can. Place the Eureka can on the table with a measuring cylinder under its spout as shown in Fig. 2.5 (a). Pour water into the can until it starts overflowing through the spout. When the water has stopped dripping, remove the measuring cylinder. Empty it, dry it and again place it under the spout.
2. Now tie the given irregular solid by a thread. Immerse the solid gently into the water contained

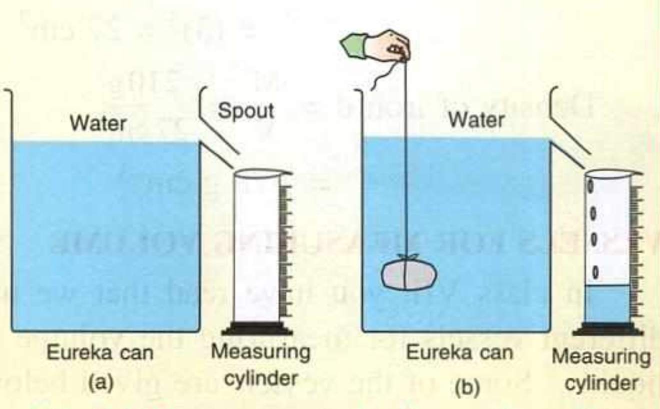


Fig. 2.5 Measurement of volume of a solid using Eureka can

in the Eureka can as shown in Fig. 2.5(b). The solid displaces water equal to its own volume which overflows through the spout and gets collected in the measuring cylinder. When water stops dripping out through the spout, note the volume of water collected in the measuring cylinder.

3. Dry the solid. Measure the mass M of the given solid with a beam balance.

   Let mass of solid M = 310 g

   Volume of solid V = volume of water collected in the measuring cylinder = 40 cm^3

   $$\text{Density } d = \frac{\text{Mass M}}{\text{Volume V}}$$

   $$= \frac{310\,g}{40\,cm^3} = 7{\cdot}75 \text{ g cm}^{-3}.$$

DETERMINATION OF DENSITY OF A LIQUID

To determine the density of a liquid (say milk, oil, etc.), its mass M is measured by a common beam balance and its volume V is measured by a measuring cylinder. Then density is calculated by using the relation $d = \frac{M}{V}$.

ACTIVITY 3

To determine the density of milk.

1. Take a beaker. Measure the mass of the empty beaker using a common beam balance. Let the mass be M_1 gram.
2. Now take a measuring cylinder and pour milk into it to a certain level say 50 mL. Thus, volume of milk V = 50 mL or 50 cm^3.
3. Transfer the milk into the empty beaker. Measure its mass again. Let the mass of beaker with milk be M_2 gram.
4. Find the difference $M_2 - M_1$ which gives the mass M of the milk. Thus, mass of the milk $M = (M_2 - M_1)$ gram. Let M = 51·5 gram.
5. Calculate the density of milk using the following formula :

   $$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{V}$$

   $$= \frac{51{\cdot}5\,g}{50\,cm^3} = 1{\cdot}03 \text{ g cm}^{-3}.$$

DENSITY BOTTLE

A density bottle is a specially designed bottle which is used to determine the density of a liquid. Fig. 2.6 shows a density bottle. It is a small glass bottle having a glass stopper at its neck. The bottle can store a fixed volume of a liquid. Generally the volume of bottle is 25 mL or 50 mL. The stopper has a narrow hole through it. When the bottle is filled with the liquid and stopper is inserted, the excess liquid rises through the hole and drains out. Thus, the bottle always contains the same volume of liquid each time when it is filled.

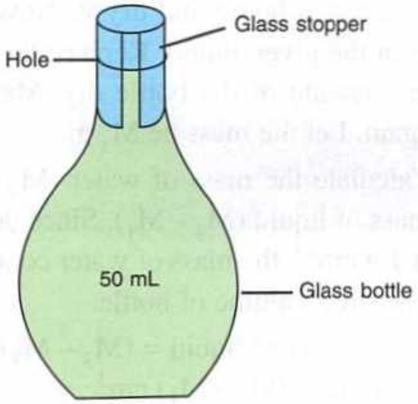


Fig. 2.6 Density bottle

Note : 1. Since the density of water is 1 g cm^{-3}, so the mass (in g) of water needed to fill the bottle completely, will give the volume (in mL) of bottle.

2. Nowadays, it is not named as specific gravity bottle.

DETERMINATION OF DENSITY OF A LIQUID USING THE DENSITY BOTTLE

To determine the density of a liquid using the density bottle, we have to measure the mass of liquid and mass of water taken in it by using the common balance, the mass of water in the density bottle gives the volume of liquid.

This can be understood by the following activity.

ACTIVITY 4

To determine the density of a liquid using a density bottle.

1. First wash the bottle and dry it. Then measure the mass of empty bottle using a beam balance. Let the mass be M_1 g.
2. Remove the stopper of the bottle and fill it with water. Replace the stopper. Wipe the outside of the bottle dry. Measure its mass again. Let the mass be M_2 g.
3. Empty the bottle and dry it. Now fill the bottle with the given liquid. Replace the stopper. Wipe the outside of the bottle dry. Measure its mass again. Let the mass be M_3 g.
4. Calculate the mass of water $(M_2 - M_1)$ and the mass of liquid $(M_3 - M_1)$. Since density of water is 1 g cm^{-3}, the mass of water contained in bottle gives the volume of bottle.

   Thus, mass of liquid = $(M_3 - M_1)$ g and volume of liquid = $(M_2 - M_1)$ cm^3

$$\therefore \text{ Density of liquid} = \frac{\text{Mass of liquid}}{\text{Volume of liquid}}$$

$$= \frac{(M_3 - M_1)\text{ g}}{(M_2 - M_1)\text{ cm}^3}$$

For example,

Mass of empty bottle $M_1 = 30$ g

Mass of bottle filled with water $M_2 = 60$ g

Mass of bottle filled with liquid $M_3 = 54$ g

The mass of liquid $M = 54 \text{ g} - 30 \text{ g} = 24 \text{ g}$

Volume of liquid $V = 60 - 30 = 30 \text{ cm}^3$

$$\text{Density of liquid} = \frac{M}{V} = \frac{24 \text{ g}}{30 \text{ cm}^3}$$

$$= 0{\cdot}8 \text{ g cm}^{-3}$$

RELATIVE DENSITY

The relative density of a substance is defined as the ratio of the density of the substance to the density of water. The symbol used for relative density is R.D. Thus,

Relative density of a substance

$$\text{R.D.} = \frac{\text{Density of the substance}}{\text{Density of water}}$$

For example, density of iron is $7{\cdot}8$ g cm^{-3} and density of water is 1 g cm^{-3}. Hence,

Relative density of iron

$$= \frac{\text{Density of iron}}{\text{Density of water}}$$

$$= \frac{7{\cdot}8 \text{ g cm}^{-3}}{1 \text{ g cm}^{-3}} = 7{\cdot}8$$

But density of a substance is the mass of 1 cm^3 of that substance, therefore we can also express the relative density of a substance as follows :

Relative density of a substance

$$= \frac{\text{Mass of } 1 \text{ cm}^3 \text{ of the substance}}{\text{Mass of } 1 \text{ cm}^3 \text{ of water}}$$

$$= \frac{\text{Mass of V cm}^3 \text{ of the substance}}{\text{Mass of V cm}^3 \text{ of water}}$$

$$= \frac{\text{Mass of any volume of the substance}}{\text{Mass of the same volume of water}}$$

Thus, *relative density of a substance can also be defined as the ratio of the mass of any volume of the substance to the mass of an equal volume of water.*

For example, if we say that the relative density of iron is 7·8, we mean that a piece of iron of any volume has mass 7·8 times that of an equal volume of water.

UNIT OF RELATIVE DENSITY

Relative density is just a number. It has no unit. It is a dimensionless quantity. It is a ratio of same quantities.

MEASUREMENT OF RELATIVE DENSITY OF A LIQUID

The relative density of a liquid is measured by using a density bottle. This can be understood by the following activity.

ACTIVITY 5

To determine the relative density of a liquid using a density bottle.

1. Take an empty dry density bottle. Find its mass M_1 g by using a beam balance.
2. Now fill the bottle completely with water and insert the stopper. The extra water overflows through the hole in the stopper. Dry the outer surface with a blotting paper and then measure the mass of bottle again on a beam balance. Suppose, the mass is M_2 g.
3. Now empty the bottle and dry it. Fill the bottle again completely with the given liquid, and insert the stopper. Again, the extra liquid, if any, will overflow through the hole in the stopper. Dry and measure the mass of bottle again. Suppose the mass now is M_3 g. Thus

Mass of empty bottle = M_1 g

Mass of bottle + water = M_2 g

Mass of bottle + liquid = M_3 g

Mass of water = $(M_2 - M_1)$ g

Mass of liquid = $(M_3 - M_1)$ g

Relative density of liquid

$$= \frac{\text{Mass of liquid}}{\text{Mass of equal volume of water}}$$

$$= \frac{(M_3 - M_1)\text{ g}}{(M_2 - M_1)\text{ g}} = \frac{M_3 - M_1}{M_2 - M_1}$$

For example, if $M_1 = 25$ g

$M_2 = 55$ g

$M_3 = 49$ g

$$\text{Then R.D. of liquid} = \frac{(49 - 25)\text{ g}}{(55 - 25)\text{ g}}$$

$$= \frac{24}{30} = 0{\cdot}8$$

Do You Know ?

1. Density bottle measures the relative density of a liquid.
2. Since density of water is 1 g cm^{-3}, so density of a substance in g cm^{-3}
   = relative density of the substance.
3. Since density of water is 1000 kg m^{-3}, so density of a substance in kg m^{-3}
   = 1000 × relative density of that substance.
4. Specific gravity usually means relative density with respect to water.

DENSITY OF A SUBSTANCE IN ITS DIFFERENT STATES

A substance can exist in three states (i) solid, (ii) liquid and (iii) gas. *For example*, ice, water and steam are the three states of the same substance, water. According to the molecular model, we have read that the molecules of a solid are closely packed, molecules of a liquid are loosely packed while those of a gas are very loosely packed. Therefore, a substance is highly dense in solid state, less

Density and Relative density of some common substances

Substance	Density		Relative density
	in g cm^{-3}	in kg m^{-3}	
Solid			
Cork	0·25	250	0·25
Wood	0·7	700	0·7
Ice	0·92	920	0·92
Glass	1·97	1970	1·97
Aluminium	2·7	2700	2·7
Iron	7·8	7800	7·8
Brass	8·4	8400	8·4
Silver	10·3	10300	10·3
Lead	11·5	11500	11·5
Liquid			
Turpentine oil	0·87	870	0·87
Alcohol	0·8	800	0·8
Water	1·0	1000	1·0
Milk	1·03	1030	1·03
Glycerine	1·26	1260	1·26
Mercury	13·6	13600	13·6

dense in liquid state and still less dense in gaseous state. Thus, the density of a substance in solid state is more than that in liquid state and density of a substance in liquid state is more than that in gaseous state.

Exception : The density of ice is less than water. The density of ice is 0·917 g cm^{-3}, that of water is 1·00 g cm^{-3} and that of steam is 0·00057 g cm^{-3}.

The table above gives the density and relative density of some common substances.

FLOATING AND SINKING

If we place a piece of cork and an iron nail on the surface of water, we notice that the cork floats while the nail sinks. This is because the density of cork is less than the density o water, while the density of iron (of which the nail is made up of) is more than the density of water. Thus, a body floats on a liquid if its density is less than the density of the liquid, while a body sinks in a liquid if its density is more than the density of the liquid.

Some examples :

1. A solid iron ball with a density of 7·86 g cm^{-3} will sink in water which has a density of 1·0 g cm^{-3}. The same iron ball will float in mercury which has a density of 13·6 g cm^{-3}.
2. A small cork will float on water because the density of cork is less than the

density of water, whereas an iron nail will sink in water because the density of iron nail is more than the density of water.

PRINCIPLE OF FLOATATION

When a body is completely or partially mmersed in a liquid, the following two forces ct on it :

(1) The weight of the body W acting vertically downwards. This force has a tendency to sink the body.

(2) The buoyant force of the liquid F_B acting vertically upwards. The buoyant force is equal to the weight of the liquid displaced by the immersed part of the body. This force has a tendency to move the body up. This is why buoyant force is also called upthrust.

Now there can be the following three possibilities :

Case 1 : The weight of the body W is greater than the buoyant force F_B. In this case, the resultant force on the body is $(W - F_B)$ which acts downwards. The body will sink in the liquid to the bottom under the influence of the resultant force $(W - F_B)$. This is shown in Fig. 2.7. This happens when the density of the solid is greater than the density of the liquid.

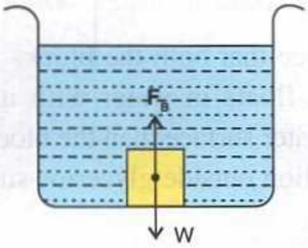


Fig. 2.7 When density of body is greater than the density of liquid, the body sinks

Case 2 : The weight of the body W is equal to the buoyant force F_B. In this case, the resultant force on the body is zero, *i.e.* the apparent weight of the body is zero. The body will float just inside the surface of liquid. This is shown in Fig. 2.8. This happens when the density of the solid is equal to the density of the liquid.

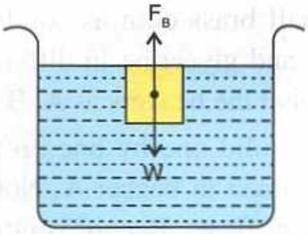


Fig. 2.8 When density of body is equal to the density of liquid, the body floats just inside the liquid surface

Case 3 : The weight of the body W is less than the buoyant force. In this case, the resultant force acts on the body upwards. The body will float partially above the surface of liquid. *Only that much portion of the body will immerse inside the liquid by which the weight of the liquid displaced F_B balances the total weight of the body.* This is shown in Fig. 2.9. This happens when the density of the solid is less than the density of the liquid. Now while floating, $F_B = W$, so apparent weight is zero.

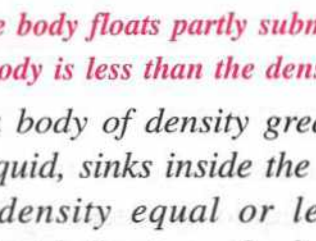


Fig. 2.9 The body floats partly submerged when density of body is less than the density of liquid

Thus, *a body of density greater than the density of liquid, sinks inside the liquid, while a body of density equal or less than the density of liquid, floats on the liquid.*

The dependence of a solid/liquid on its density to float/sink in a liquid can be understood by the following activity.

ACTIVITY 6

1. Take a cork, a piece of wood, an ice cube, an iron nail, a small brass coin as solids. Take water, turpentine and glycerine in different beakers as liquids. Label the beakers as A, B and C.
2. Place each solid one by one on the surface of liquid contained in beaker A. Note whether the solid sinks or floats. Record your observations.
3. Repeat step 2 with the liquid of beaker B and C respectively.

Beaker	Cork	Wood	Ice	Iron	Coin
Water	....	....	....	....	....
Turpentine	....	....	....	....	....
Glycerine	....	....	....	....	....

From the table of density of some substances, record the density of solids and liquids used above.

Density of solid		Density of liquid	
Cork	....	Water	....
Wood	....	Turpentine	....
Ice	....	Glycerine	....
Iron	....		
Brass	....		

Relate your observations of sinking or floating of a solid in a liquid with their densities. What do you conclude ?

Conclusion : ....

LAW OF FLOATATION

When a body floats in a liquid, the weight of the liquid displaced by its immersed part is equal to the total weight of the body. This is the law of floatation, *i.e.* while floating,

Weight of the floating body = Weight of the liquid displaced by its immersed part (*i.e.*, buoyant force).

In other words, according to the law of floatation, the apparent weight of a floating body is zero. A body floats with its major portion outside the surface of a liquid of higher density than that of a liquid of low density. This can be demonstrated by the following activity.

ACTIVITY 7

1. Take two identical small blocks of wood. Label them as A and B. Take water in a beaker labelled as P and glycerine in another beaker labelled as Q.
2. Place the wooden block A on the surface of water in beaker P and the wooden block B on the surface of glycerine in beaker Q (Fig. 2.10).

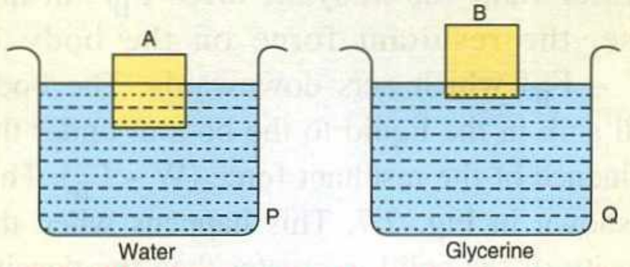


Fig. 2.10 Less portion of wood submerged in glycerine than in water, while floating

You will notice that both the blocks A and B float. The block A floats in water with its less portion outside the water surface than the block B which has its major portion outside glycerine surface.

Conclusion :

1. The density of wood is less than the density of water as well as the density of glycerine.
2. The density of glycerine is more than the density of water.

SOME APPLICATIONS OF FLOATATION

(i) **Floatation of an iron ship :** A nail made of iron sinks in water, but a ship made of iron does not. The reason is that a nail is solid and the density of iron is greater than that of water. The weight of the nail is more than the buoyant force of water on it. So the nail sinks in water. On the other hand, the ship is hollow and its empty space contains air. This makes the average density of ship less than that of water. Therefore, a ship floats on water.

(ii) **Floatation of man :** It is easier for a person to swim in sea water than in river water. The reason is that sea water contains salt and so its density is more than the density of river water. The weight of a man gets balanced by the less immersed part of his body in sea water as compared to that in river water. Thus, it is easier to swim in sea water than in river water.

(iii) **Floatation of ice on water :** A piece of ice floats on water with its $\frac{9}{10}$th part inside the water and only $\frac{1}{10}$th part of it outside the water. The reason is that the density of ice is 0·9 g cm^{-3} (or 900 kg m^{-3}) while the density of water is 1 g cm^{-3} (or 1000 kg m^{-3}). Hence, the weight of water displaced by $\frac{9}{10}$th part of ice immersed inside water becomes equal to the total weight of the ice piece.

(iv) **Submarine :** A submarine can be made to dive or to rise to the surface of water as and when desired. The reason is that a submarine is a water-tight boat which can travel under water like a ship (Fig. 2.11). A submarine is provided with water tanks. To make the submarine dive, the tanks are filled with water so that the average density of the submarine becomes greater than the density of sea water and it sinks. To make the submarine rise to the surface of water, these tanks are emptied. This makes the average density of the submarine less than the density of sea water, so the submarine rises up to the surface of water.

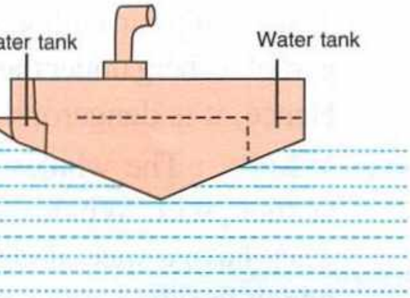


Fig. 2.11 A submarine

(v) **Icebergs :** Very huge and large pieces of ice floating on sea water, are called icebergs. They are dangerous for ships. The reason is that the density of ice is less than the density of sea water. The density of ice is 0·9 g cm^{-3} and the density of sea water is 1·02 g cm^{-3}. Hence, an iceberg floats in sea water with its large portion submerged inside the water and only a little portion of it is above the surface of water (Fig. 2.12).

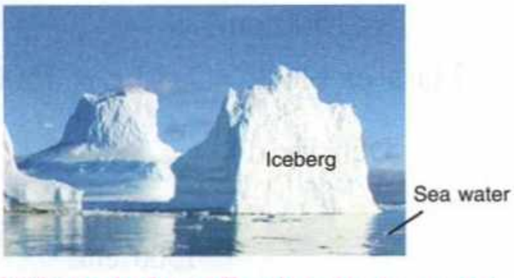


Fig. 2.12 An iceberg floating on sea water

Thus, a ship can collide with the invisible part of iceberg under the surface of water. Hence, it is dangerous for ships.

(vi) **Whales :** The whales can sink or rise at their will. Whales are sea animals. They have a special organ in their body which is called swim bladder. In order to come to the surface of water, they fill the bladder with air. This decreases the average density of the whale and so it rises to the surface. To dive into the sea, they empty the bladder. This increases the average density of the whale and it goes down.

(vii) **Balloons :** A hydrogen or helium filled balloon rises in air. The reason is that the density of these gases is less than the density of air. Therefore, the buoyant force experienced by the balloon due to air, becomes greater than the weight of the balloon. Hence, the balloon rises up under the influence of the net upward force.

SOLVED EXAMPLES

1. A block of glass is 30 cm long, 25 cm wide and has a thickness of 2 cm. Find its density if its mass is 7·5 kg.

Solution : Volume of glass block

$$= \text{length} \times \text{breadth} \times \text{thickness}$$
$$= 30\text{ cm} \times 25\text{ cm} \times 2\text{ cm}$$
$$= 1500\text{ cm}^3$$

Mass of block = 7·5 kg = 7500 g

$$\text{Density } d = \frac{M}{V}$$
$$= \frac{7500\text{ g}}{1500\text{ cm}^3} = 5\text{ g cm}^{-3}$$

2. A piece of iron of volume 30 cm^3 has mass of 234 g. Find the density of iron.

Solution : *Given,* mass M = 234 g

Volume V = 30 cm^3

$$\text{Density } d = \frac{M}{V}$$
$$= \frac{234\text{ g}}{30\text{ cm}^3} = 7{\cdot}8\text{ g cm}^{-3}.$$

3. The mass of 10 cm^3 of silver is 103 g. Find : (a) the density of silver in kg m^{-3} (b) relative density of silver. State th assumption made in part (b).

Solution : *Given,* mass M = 103 g and volume V = 10 cm^3

(a) $$\text{Density } d = \frac{M}{V}$$
$$= \frac{103\text{ g}}{10\text{ cm}^3} = 10{\cdot}3\text{ g cm}^{-}$$
$$= 10{\cdot}3 \times 1000\text{ kg m}^{-3}$$
$$= 10300\text{ kg m}^{-3}.$$

(b) Relative density of silver

$$= \frac{\text{Density of silver}}{\text{Density of water}}$$
$$= \frac{10300\text{ kg m}^{-3}}{1000\text{ kg m}^{-3}} = 10{\cdot}3$$

Assumption : The density of water is 1000 kg m^{-3}.

4. A piece of iron when immersed in wate taken in a Eureka can displaces 25 mL of water. Its mass is 195 g. Find the density of iron in kg m^{-3}.

Solution : *Given,* Mass of iron piece M = 195 g

= 0·195 kg

Volume of iron piece, V

= volume of water displaced

$$= 25\text{ cm}^3 = 25 \times 10^{-6}\text{ m}^3$$

Density of iron $d = \frac{M}{V}$

$= \frac{0{\cdot}195 \text{ kg}}{25 \times 10^{-6} \text{ m}^3}$

$= 7800 \text{ kg m}^{-3}$.

5. A block of silver displaces 200 mL of water in a measuring cylinder. If the density of silver is 10300 kg m^{-3}, find the mass of block.

***olution** : Given,* density of silver = 10300 kg m^{-3}

Volume of block V

= volume of water displaced

or $V = 200 \text{ cm}^3 = 200 \times 10^{-6} \text{ m}^3$

Since $d = \frac{M}{V}$

$\therefore$ Mass of block $M = V \times d$

$= (200 \times 10^{-6} \text{ m}^3) \times (10300 \text{ kg m}^{-3})$

$= 2{\cdot}06$ kg.

6. The mass of a copper piece is 44 g. A measuring cylinder contains water to a level of 12 mL. The water level rises to 17 mL mark when the copper piece is dipped in the measuring cylinder. Find : (i) the volume of copper piece, and (ii) the density of copper.

***olution** : Given :* Initial level of water $_1$ = 12 mL. Final level of water $V_2 = 17$ mL

Mass M = 44 g

Volume of copper piece $V = V_2 - V_1$

$= 17 - 12 = 5$ mL (or 5 cm^3)

Density of copper $d = \frac{M}{V} = \frac{44 \text{ g}}{5 \text{ cm}^3}$

$= 8{\cdot}8 \text{ g cm}^{-3}$

7. The mass of density bottle is 51·50 g when empty, 76·50 g when full of water and 71·85 g when full of an oil. Find : (a) capacity of density bottle, and (b) density of oil.

***Solution** : Given*, Mass of empty density bottle $M_1 = 51{\cdot}50$ g

Mass of bottle with water $M_2 = 76{\cdot}50$ g and mass of bottle with oil $M_3 = 71{\cdot}85$ g

(a) Mass of water in bottle $= M_2 - M_1$

$= 76{\cdot}50 - 51{\cdot}50 = 25{\cdot}00$ g

Since density of water is 1 g cm^{-3}, therefore, capacity of density bottle V = 25·00 mL.

(b) Mass of oil in bottle $M = M_3 - M_1$

$= 71{\cdot}85 - 51{\cdot}50 = 20{\cdot}35$ g

Density of oil d

$$= \frac{\text{Mass of oil M}}{\text{Volume of oil V}} = \frac{20{\cdot}35 \text{ g}}{25 \text{ cm}^3} = 0{\cdot}814 \text{ g cm}^{-3}$$

8. The mass of a density bottle is 35 g when empty, 65 g when filled with water, and 59 g when filled with alcohol. Find the relative density of alcohol.

***Solution** : Given*, Mass of empty density bottle $M_1 = 35$ g

Mass of bottle + water $M_2 = 65$ g

Mass of bottle + alcohol $M_3 = 59$ g

Relative density of alcohol

$$= \frac{\text{Mass of alcohol}}{\text{Mass of equal volume of water}}$$

$$= \frac{M_3 - M_1}{M_2 - M_1} = \frac{59 - 35}{65 - 35} = \frac{24}{30} = 0{\cdot}8$$

9. The table below gives the density of some solids and liquids. For each solid, list the name of liquids in which that solid will (a) float, (b) sink.

Solid	Density in kg m^{-3}	Liquid	Density in kg m^{-3}
1. Iron	7800	Mercury	13600
2. Wood	700	Water	1000
3. Cork	250	Glycerine	1260

(i) **Iron —** (a) floats on mercury
(b) sinks in water and glycerine.

(ii) **Wood —** (a) floats on mercury, water and glycerine
(b) sinks in none.

(iii) **Cork —** (a) floats on mercury, water and glycerine
(b) sinks in none.

RECAPITULATION

- Equal masses of different substances have different volumes.
- Equal volumes of different substances have different masses.
- The density of a substance is defined as the mass of a unit volume of that substance.
- If a body has mass M and volume V, its density d is given as $d = \frac{M}{V}$.
- Density = $\frac{\text{Mass}}{\text{Volume}}$, Mass = Volume × Density, Volume = $\frac{\text{Mass}}{\text{Density}}$.
- The S.I. unit of density is kg m^{-3} and the C.G.S. unit is g cm^{-3}.
- 1 g cm^{-3} = 1000 kg m^{-3}.
- The density of a substance is not changed by the change in its size or shape.
- The density of a substance decreases with increase in its temperature if the substance expands on heating. This decrease is more in gases, less in liquids and still less in solids for the same rise in temperature. However, the density of water increases when heated from 0°C to 4°C and then decreases when heated above 4°C.
- The density of a substance is more in its solid state, less in liquid state and still less in its gaseous state. Exception is ice whose density is less than the density of water.
- A density bottle is a specially designed bottle to store a fixed volume of liquid. It is used to find the density and relative density of a liquid.
- The relative density of a substance is defined as the ratio of the density of the substance to the density of water. Thus,

$$\text{Relative density of a substance} = \frac{\text{Density of the substance}}{\text{Density of water}}$$

- The relative density of a substance is the ratio of the mass of any volume of the substance to the mass of an equal volume of water.
- The relative density is just a number. It has no unit as it is a ratio of same quantities.
- When a body is partially or completely immersed in a liquid, it experiences an upward force due to the liquid which is called buoyant force or upthrust.
- The buoyant force is equal to the weight of the liquid displaced by the body.
- When a body is immersed in a liquid, the buoyant force on it depends on : (i) the volume of the body immersed in the liquid (larger the volume of the body immersed in a liquid, greater is the buoyant force). (ii) the density of the liquid in which the body is immersed (more the density of liquid, greater is the buoyant force).

- If the density of body is more than the density of liquid, the body sinks.
- If the density of body is equal to or less than the density of liquid, the body floats.
- A body floats with only that much portion of it submerged inside the liquid by which the weight of the liquid displaced (or buoyant force) balances the total weight of the body.
- According to the law of floatation, the weight of a floating body is equal to the weight of the liquid displaced by its submerged part (*i.e.*, buoyant force on it).
- The apparent weight of a floating body is zero.
- More the density of liquid, more is the portion of the floating body outside the surface of liquid.
- If a body floats in different liquids, its different volumes get submerged in different liquids, but in each liquid the weight of liquid displaced by the sumberged part of body (*i.e.*, buoyant force) remains same (equal to the weight on the body).

TEST YOURSELF

A. Objective Questions :

1. Write **true** or **false** for each statement :
   - (a) Equal volumes of two different substances have equal masses.
   - (b) The density of a piece of brass will change by changing its size or shape.
   - (c) The density of a liquid decreases with increase in its temperature.
   - (d) Relative density of water is 1·0.
   - (e) Relative density of a substance is expressed in g cm^{-3}.
   - (f) When a body is immersed in a liquid, the buoyant force experienced by the body is equal to the volume of the liquid displaced by it.
   - (g) A body experiences the same buoyant force while floating in water or alcohol.
   - (h) A body experiences the same buoyant force when it floats or sinks in water.
   - (i) A body floats in a liquid when its weight becomes equal to the weight of the liquid displaced by its submerged part.
   - (j) A body while floating, sinks deeper in a liquid of low density than in a liquid of high density.

   Ans: True—(c), (d), (g), (i), (j)
   False—(a), (b), (e), (f), (h)

2. Fill in the blanks :
   - (a) 1 kg is the mass of .... mL of water at 4°C.
   - (b) Mass = density × ....
   - (c) The S.I. unit of density is ....
   - (d) Density of water is .... kg m^{-3}.
   - (e) 1 g cm^{-3} = ... kg m^{-3}.
   - (f) The density of a body which sinks in water is .... than 1000 kg m^{-3}.
   - (g) A body sinks in a liquid A, but floats in a liquid B. The density of liquid A is .... than the density of liquid B.
   - (h) A body X sinks in water, but a body Y floats on water. The density of the body X is .... than the density of body Y.
   - (i) The buoyant force experienced by a body when floating in salt-water is .... that when floating in pure water.
   - (j) The weight of a body floating in a liquid is ....

   Ans: (a) 1000 (b) volume (c) kg m^{-3} (d) 1000 (e) 1000 (f) more (g) less (h) more (i) equal to (j) zero

3. Match the following :

Column A	Column B
(a) kg m^{-3}	(i) relative density
(b) No unit	(ii) sinks in alcohol
(c) Relative density	(iii) floats on water
(d) Iron	(iv) density
(e) Wood	(v) density bottle

Ans: (a)–(iv), (b)–(i), (c)–(v), (d)–(ii), (e)–(iii)

4. Select the correct alternative :

(a) The correct relation is

- (i) Density = Mass × Volume
- (ii) Mass = Density × Volume
- (iii) Volume = Density × Mass
- (iv) Density = Mass + Volume

(b) The relative density of alcohol is 0·8. Its density is

(i) 0·8 (ii) 800 kg m^{-3}

(iii) 800 g cm^{-3} (iv) 0·8 kg m^{-3}

(c) A block of wood of density 0·8 g cm^{-3} has a volume of 60 cm^3. The mass of block is

(i) 60·8 g (ii) 75 g

(iii) 48 g (iv) 0.013 g

(d) The density of aluminium is 2·7 g cm^{-3} and that of brass 8·4 g cm^{-3}. The correct statement is :

- (i) Equal masses of aluminium and brass have equal volumes
- (ii) The mass of a certain volume of brass is more than the mass of equal volume of aluminium
- (iii) The volume of a certain mass of brass is more than the volume of equal mass of aluminium
- (iv) Equal volumes of aluminium and brass have equal masses.

(e) A density bottle has a marking 25 mL on it. It means that :

- (i) the mass of density bottle is 25 g
- (ii) the density bottle will store 25 mL of any liquid in it
- (iii) the density bottle will store 25 mL o water, but more volume of liqui denser than water
- (iv) the density bottle will store 25 mL o water, but more volume of a liqui lighter than water.

(f) The correct statement is :

- (i) The buoyant force on a body is equa to the volume of the liquid displace by it.
- (ii) The buoyant force on a body is equa to the volume of the body.
- (iii) The buoyant force on a body is equal to the weight of the liquid displaced b it.
- (iv) The buoyant force on a body is alway equal to the weight of the body.

(g) A piece of wood floats on water. The buoyan force on wood will be :

- (i) zero
- (ii) more than the weight of the wood piece
- (iii) equal to the weight of the wood piece
- (iv) less than the weight of the wood piece.

(h) The weight of a body is more than the buoyant force experienced by it, due to a liquid. The body will :

- (i) sink
- (ii) float with its some part outside the liquid
- (iii) float just below the surface of liquid
- (iv) float with whole of its volume above the surface of liquid.

Ans: (a)–(ii), (b)–(ii), (c)–(iii), (d)–(ii), (e)–(ii), (f)–(iii), (g)–(iii), (h)–(i)

B. Short/Long Answer Questions :

1. Define the term density of a substance.
2. Name the S.I. unit of density. How is it related to g cm^{-3} ?
3. The density of brass is 8·4 g cm^{-3}. What do you mean by this statement ?

4. Arrange the following substances in order of their increasing density :

Iron, Cork, Brass, Water, Mercury.

5. How does the density of a liquid (or gas) vary with temperature ?

6. A given quantity of a liquid is heated. Which of the following quantity will vary and how ?

(a) mass, (b) volume or (c) density.

7. Describe an experiment to determine the density of the material of a coin.

8. Describe an experiment to determine the density of a liquid.

9. What is a density bottle ? How is it used to find the density of a liquid ?

10. Define the term relative density of a substance.

11. What is the unit of relative density ?

12. Distinguish between density and relative density.

13. Explain the meaning of the statement 'Relative density of aluminium is 2·7'.

14. How does the density of a body and that of a liquid determine whether the body will float or sink into that liquid ?

15. A cork piece floats on water surface while an iron nail sinks in it. Explain the reason.

16. Which of the following will sink or float on water ? (Density of water = 1 g cm^{-3})

(a) Body A having density 500 kg m^{-3}

(b) Body B having density 2520 kg m^{-3}

(c) Body C having density 1100 kg m^{-3}

(d) Body D having density $0{\cdot}85 \text{ g cm}^{-3}$.

Ans: Sink–(b) and (c), **Float–**(a) and (d)

17. State the law of floatation ?

18. The density of water is $1{\cdot}0 \text{ g cm}^{-3}$. The density of iron is $7{\cdot}8 \text{ g cm}^{-3}$. The density of mercury is $13{\cdot}6 \text{ g cm}^{-3}$. Answer the following :

(a) Will a piece of iron float or sink in water ?

(b) Will a piece of iron float or sink in mercury ?

19. The diagram given below shows a body floating in three different liquids A, B and C at different levels.

(a) In which liquid does the body experience the greatest buoyant force ?

(b) Which liquid has the least density ?

(c) Which liquid has the highest density ?

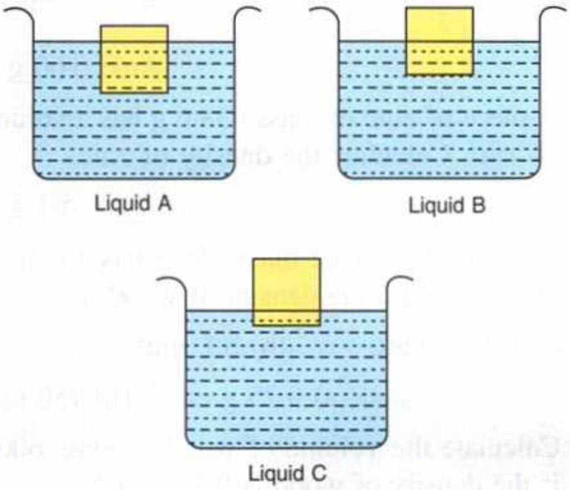


Fig. 2.13

Ans: (a) same in each, (b) A, (c) C

20. For a floating body, how is its weight related to the buoyant force ?

21. Why does a piece of ice float on water ?

22. Explain why an iron needle sinks in water, but a ship made of iron floats on water.

23. It is easier to swim in sea water than in river water. Explain the reason.

24. Icebergs floating on sea water are dangerous for ships. Explain the reason.

25. Explain why it is easier to lift a stone under water than in air.

26. What is a submarine ? How can it be made to dive in water and come to the surface of water ?

27. A balloon filled with hydrogen rises in air. Explain the reason.

C. Numericals :

1. The density of air is $1{\cdot}28 \text{ g litre}^{-1}$. Express it in : (a) g cm^{-3} (b) kg m^{-3}.

Ans: (a) $0{\cdot}00128 \text{ g cm}^{-3}$ (b) $1{\cdot}28 \text{ kg m}^{-3}$

2. The dimensions of a hall are 10 m × 7 m × 5 m. If the density of air is 1·11 kg m^{-3}, find the mass of air in the hall.

Ans: 388·5 kg

3. The density of aluminium is 2·7 g cm^{-3}. Express it in kg m^{-3}.

Ans: 2700 kg m^{-3}

4. The density of alcohol is 600 kg m^{-3}. Express it in g cm^{-3}.

Ans: 0·60 g cm^{-3}

5. A piece of zinc of mass 438·6 g has a volume of 86 cm^3. Calculate the density of zinc.

Ans: 5·1 g cm^{-3}

6. A piece of wood of mass 150 g has a volume of 200 cm^3. Find the density of wood in

(a) C.G.S. unit, (b) S.I. unit.

Ans: (a) 0·75 g cm^{-3}, (b) 750 kg m^{-3}

7. Calculate the volume of wood of mass 6000 kg if the density of wood is 0·8 g cm^{-3}.

Ans: 7·5 m^3

8. Calculate the density of a solid from the following data :

(a) Mass of solid = 72 g

(b) Initial volume of water in measuring cylinder = 24 mL

(c) Final volume of water when solid i completely immersed in water = 42 mL

Ans.: 4·0 g cm^{-3}

9. The mass of an empty density bottle is 21·8 g when filled completely with water it is 41·8 g and when filled completely with liquid it is 40·6 g. Find:

(a) the volume of density bottle

(b) the relative density of liquid.

Ans: (a) 20 mL, (b) 0·94

10. From the following observations, calculate the density and relative density of a brine solution.

Mass of empty density bottle = 22 g

Mass of bottle + water = 50 g

Mass of bottle + brine solution = 54 g

Ans: Density = 1·14 g cm^{-3}, relative density = 1·14

11. The mass of an empty density bottle is 30 g, it is 75 g when filled completely with water and 65 g when filled completely with a liquid. Find :

(a) volume of density bottle,

(b) density of liquid, and

(c) relative density of liquid.

Ans: (a) 45 mL (b) 0·77 g cm^{-3} (c) 0·77

Project Work

Collect some objects like cork, allpin, rubber, piece of wood, piece of plastic at your home. Take water, oil, milk, sugar solutions in separate beakers. Place each object one by one, on the surface of liquids taken into the beakers and see whether the object sinks or floats in that liquid. Record your observations and based on them, compare the densities of the objects and liquids.

3

Force and Pressure

Theme : A force is a push or pull upon an object resulting from the object's interaction with another object. Turning effect of a force is more if the distance between the point of application of force and the hinge on a door is more. It is given a special name — Moment of force. Pressure is defined as force per unit area. Solids, liquids and gases all exert pressure. Atmosphere also exerts pressure, activities are carried out to demonstrate that solid, liquid and gases exert pressure.

In this chapter you will learn to

- explain the turning effect of a force, with examples from daily life
- define moment of force
- express moment of force in proper units
- solve simple numerical problems based on moment of force
- define pressure
- express pressure in proper units
- solve simple numerical problems based on formula for pressure
- describe pressure exerted by a liquid
- demonstrate that liquids exert pressure
- describe pressure exerted by a gas
- describe atmospheric pressure
- express thoughts that reveal originality, speculation, imagination, a personal perspective, flexibility in thinking, invention or creativity
- present ideas clearly and in logical order.

LEARNING OBJECTIVES

- Revising previous concepts learnt by children
- Building on children's previous learning
- Demonstration of turning effect of force
- Explanation of turning effect and factors on which it depends
- Engaging children in task for calculation of turning effect
- Demonstration of pressure exerted by a force on an object
- Explanation: pressure depend on the area of surface on which the force acts
- Demonstration of pressure exerted by a liquid
- Demonstration of pressure exerted by a gas
- Explanation of pressure exerted by atmosphere
- Engaging children in tasks to show that:
  - (a) Pressure depends on area
  - (b) Liquids exert pressure
  - (c) Gases exert pressure

- Observation/experimentation/analysis
- Student led experiments (reasoning to be given by children individually)
- Investigate the effect on pressure when walking on flat shoes and pointed heels on our body support system
  For example: Children reasoning as to why is it easier to hammer a sharp pin respective to a blunt pin?

KNOWING CONCEPTS

- Turning effect of force (moment of force): concept, definition and calculation
- Pressure
  - Definition • Unit
  - Calculation of pressure in simple cases
  - Pressure exerted by liquids (Qualitative only)
  - Pressure exerted by gases — Atmospheric pressure (qualitative only)

FORCE

We have read that a body which does not change its position with respect to its surroundings is said to be at rest or stationary, whereas a body which changes its position with respect to its surroundings is said to be in motion or a moving body.

A force is a cause (push or pull) which tends to result in movement or change in size or shape of the body. A force when applied as push or pull on a stationary body which is free to move, can produce motion in it and if applied on a moving body, it can change the speed of motion of body (*i.e.* can speed up or slow down the moving body) or it can change both the speed and direction of motion. Similarly, the shape or size of a non-rigid body can also be changed by applying a force. However if an object does not move on application of force or its size and shape does not change, then in the language of Physics we say that force applied is not fruitful.

Examples :

1. A grass roller initially at rest when pulled, begins to move.
2. A fielder when catches a ball, stops the moving ball.
3. A moving car slows down on applying brakes on it.
4. A push on a swinging girl speeds up her swing.
5. A player when applies force by his hockey stick on the ball, the direction of motion of ball changes.

When force is applied as stretch or squeeze on a body which is not free to move, it changes the size or shape of the body.

Examples :

1. On stretching a rubber string, its length increases.
2. On squeezing a tube of gum, its shape changes.

Thus, we define force as below :

Force is that cause which changes the state of a body (either the state of rest or the state of motion) or changes the size or shape of the body.

Do You Know ?

1. The speed of a body is defined as the distance travelled by it in one second.
2. Speed up means more distance travelled in one second and slow down means less distance travelled in one second.

Note : 1. A force does not change the mass of the body on which it is applied.

2. We cannot see a force. However, we can see or feel the effect of a force.

3. A force is expressed by stating both its magnitude and direction.

4. A force is represented by an arrow →). The length of arrow is a measure of its nagnitude and the arrow head shows the irection.

UNIT OF FORCE

The S.I. unit of force is newton. The ymbol for newton is N. This unit is named fter the English scientist Sir Issac Newton ho did a lot of research work on force.

One newton is defined as the force which hen applied on a moving body of mass 1 kg in the direction of its motion, increases its speed by 1 m in one second.

We have read that our earth attracts each body towards it. The force of attraction exerted n a body by earth is called the weight of the ly or the force of gravity that acts on the body.

The force of gravity (or weight) of a body is different at different places on earth. At a place, the force of gravity on a body of mass 1 kg is called 1 kgf or 10 N. In other words, 1 N is the force of gravity at a place on 0·1 kg (100 g) mass. Thus, the unit of force kgf and N are related as :

$$1 \text{ kgf} = 10 \text{ N (nearly)}^*$$

In other words, one newton is the force hat we have to exert to hold a mass of 100 g n our palm (Fig. 3.1).

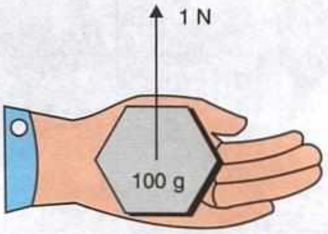


Fig. 3.1 Force of **1 N** *on a mass of* **100 g** *to hold it*

Do You Know ?

1. A body in which the inter-spacing between its constituent particles do not change when a force is applied on it, is called a rigid body and if it changes, the body is called a non-rigid body.

2. A force when applied on a rigid body can cause only change in motion of the body. But a force when applied on a non-rigid body can cause both change in its size or shape and motion in it.

TURNING EFFECT OF A FORCE

We have read above that if a force is applied on a stationary rigid body, it starts moving in a straight line in the direction of force as shown in Fig. 3.2. In Fig. 3.2, a ball moves on pushing.

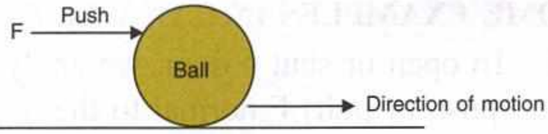


Fig. 3.2 A ball moves on pushing

Now if the body is not free to move, but it is pivoted at a point O and a force F is applied at a suitable point A, it begins to turn about the point O (Fig. 3.3). The vertical axis passing through the point O about which the body turns, is called the axis of rotation. In Fig. 3.3, on pushing, the wheel begins to turn about its pivoted point O.

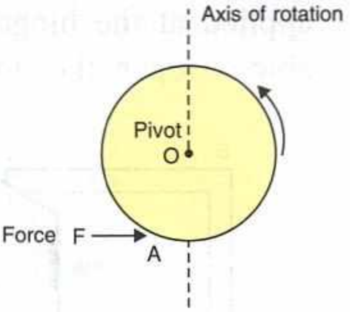


Fig. 3.3 Turning of a wheel about the pivot, on pushing

Similarly, when the handle of a door is either pushed or pulled, the door begins to turn about the hinges which hold the door at rest.

Precisely 1 kgf = 9·8 N

Thus, *a force (push or pull) has a turning effect on a body which is not free to move in a straight line, but is pivoted at a point about which it can turn.*

FACTORS AFFECTING THE TURNING OF A BODY

The turning effect of a force on a body depends on the following two factors :

1. **The magnitude of the force applied.** Larger the magnitude of force applied, more is the turning effect on the body.
2. **The perpendicular distance of the force from the pivoted point.** Larger the perpendicular distance of point at which the force is applied, from the pivoted point, more is the turning effect on the body.

SOME EXAMPLES IN DAILY LIFE

1. To open or shut a door, we apply a force (push or pull) F normal to the door at its handle P which is provided at the maximum distance from the hinges as shown in Fig. 3.4. We can notice that if we apply the force at a point Q (near the hinge R), much greater force is required to open the door and if the force is applied at the hinge R, we will not be able to open the door howsoever large the force may be. Thus, the handle P is provided near the free end of the door so that a smaller force at a large perpendicular distance, produces th required turning effect of force to open or shut the door.

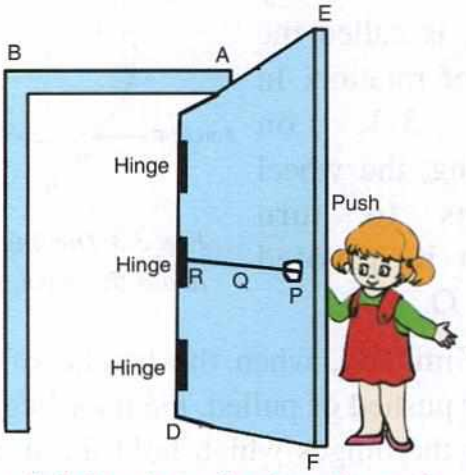


Fig. 3.4 Opening of a door by push

2. The upper circular stone A of a hand flour grinder is provided with a handl H near its rim (*i.e.* at the maximum distance from centre) so that it can easily be rotated about the iron pivot P at its centre by applying a small force at th handle H (Fig. 3.5).

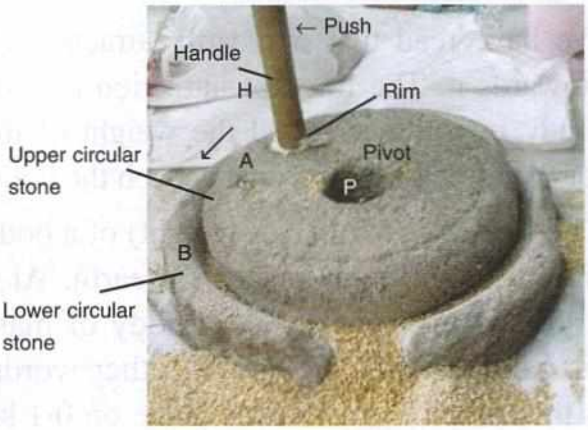


Fig. 3.5 Turning of a hand flour grinder

3. A potter's wheel has a wheel pivoted a the centre. The potter turns the wheel by means of a stick at the rim of the wheel as shown in Fig 3.6.

Fig. 3.6 Turning of a potter's wheel

4. A carpenter uses a drill machine which is provided with a handle so that by applying a less force at the end of handle, the drill can be turned easily (Fig. 3.7).

Fig. 3.7 Turning of a drill machine

5. To turn a steering wheel in a car or truck, the driver applies force at a point on the rim of the wheel as shown in Fig. 3.8.

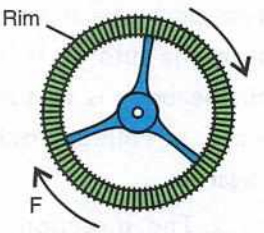


Fig. 3.8 Turning of a steering wheel

6. In a bicycle to turn the wheel, the force is applied on the pedal so that the distance of force from the axle of wheel is increased (Fig. 3.9).

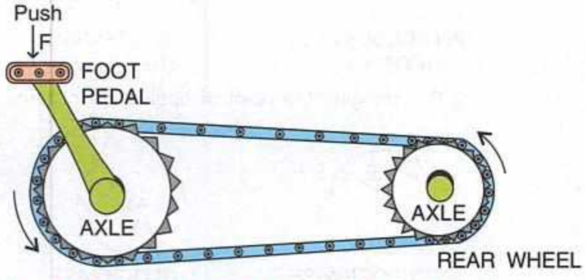


Fig. 3.9 Turning of wheel of a bicycle

7. A spanner used to tighten or loosen a nut, has a long handle to produce a large turning effect by a small force applied at the end of its handle as shown in Fig. 3.10.

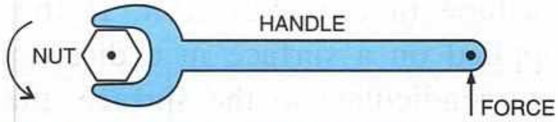


Fig. 3.10 Turning of a spanner

Conclusion : From the above examples, we conclude that the turning of a body about the pivot depends not only on the magnitude of the force, but it also depends on the perpendicular distance of the force from the point of rotation. Larger the perpendicular distance, less is the force needed to turn the body. Actually the turning effect on a body depends on the product of both the magnitude of force and the perpendicular distance of force from the pivoted point. This product is called the moment of force (or torque). In other words, a body turns (or rotates) about the pivoted point due to the moment of force.

MOMENT OF FORCE

> The moment of a force is equal to the product of the magnitude of the force and the perpendicular distance of the force from the pivoted point.

Consider a body which is pivoted at a point O. If a force F is applied on the body in the direction FP as shown in Fig 3.11, the force is unable to produce linear motion of the body in its direction because the body is not free to move, but this force turns (or rotates) the body about the point O, in the direction shown by the arrow in Fig. 3.11.

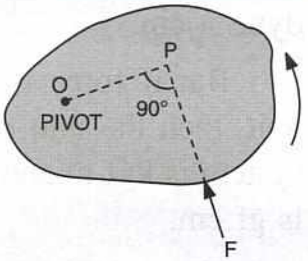


Fig. 3.11 Moment of a force

In Fig. 3.11, the perpendicular distance of the force F from the pivoted point O is OP. Therefore,

Moment of force about the point O

= Force × perpendicular distance of force from the point O

= F × OP

Note : For producing maximum turning effect on a body by a given force, the force is applied on the body at a point for which the perpendicular distance of the force from the pivoted point is maximum so that the given force may provide the maximum torque to turn the body.

UNIT OF MOMENT OF FORCE

Unit of moment of force

= unit of force × unit of distance

The S.I. unit of force is newton and that of distance is metre, so the S.I. unit of moment of force is **newton** × **metre**. This is written in short form as N m.

Note : The unit newton × metre (N m) of moment of force or torque is not written as joule (J).

The C.G.S unit of moment of force is dyne × cm.

But if force is measured in gravitational unit, then the unit of moment of force in S.I. system is kgf m and in C.G.S. system, the unit is gf cm.

These units are related as follows :

$$1 \text{ N m} = 10^5 \text{ dyne} \times 10^2 \text{ cm} = 10^7 \text{ dyne cm}$$

and $1 \text{ kgf m} = 9{\cdot}8 \text{ N m}$,

$1 \text{ gf cm} = 980 \text{ dyne cm}$

For example, Reena has to apply a minimum force of 1·5 N on the handle of the door of width 1·2 m to open it. This means that the minimum moment of force required to open the door is 1·5 N × 1·2 m = 1·8 N m. Now if she wants to open it by applying the force at the mid point between the handle and hinges, (*i.e.* at distance 0·6 m from the hinges) she will have to apply a force F such that

$$F \times 0{\cdot}6 \text{ m} = 1{\cdot}8 \text{ N m}$$

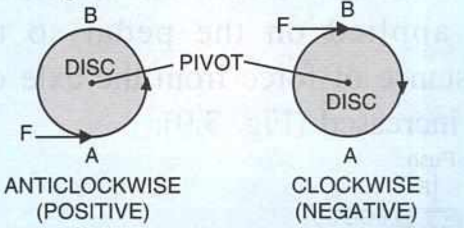
or $$F = \frac{1{\cdot}8 \text{ N m}}{0{\cdot}6 \text{ m}} = 3{\cdot}0 \text{ N}$$

Thus, on decreasing the distance of th applied force from the point of rotation, th magnitude of force increases.

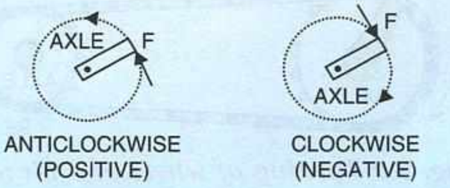
Do You Know ?

1. Conventionally, if the effect on the body is to turn it anticlockwise, moment of force is called anticlockwise moment and it is taken positive. If the effect on the body is to turn it clockwise, the moment of force is called clockwise moment and taken in negative.

2. The direction of rotation of a body can be changed either by changing the point at which the force is applied or by changing the direction of force applied as shown in Fig. 3.12.



(a) By changing the point of application of force



(b) By changing the direction of force

Fig. 3.12 Anticlockwise and clockwise moments

PRESSURE

Thrust : A force can be applied on surface in any direction. If the force i applied on a surface in a direction norma (perpendicular) to the surface, the force i called thrust. Thus, *the force acting normall* n *a surface is called* **thrust**. A body, when laced on a surface, exerts a thrust on the urface equal to its own weight.

The unit of thrust is same as that of the weight or force. Thus, the units of thrust are ilogram force (kgf), gram force (gf) and ewton (N). These units are related as :

$$1 \text{ kgf} = 1000 \text{ gf}$$
$$1 \text{ kgf} = 10 \text{ N (nearly)}$$
$$1 \text{ N} = 100 \text{ gf (nearly)}.$$

THE EFFECT OF THRUST

The effect of thrust depends on the area f the surface on which it acts. Smaller the area of the surface on which a thrust acts, larger is its effect. But the effect of a thrust is less on a larger area.

Examples :

(1) If you stand on loose sand, your feet will sink deeply into the sand. But when you lie on sand, your body does not sink much into the sand. In both the cases, the thrust exerted on the sand is same. The reason is that, when you stand, the thrust acts on a smaller area, so you sink more in the sand, and when you lie down, the same thrust acts on a larger area, so you sink less in the sand. (Fig. 3.13).

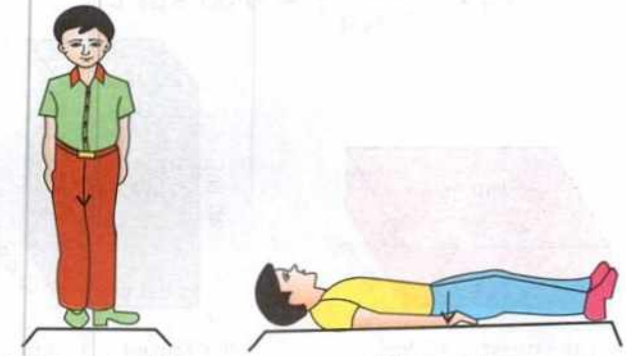
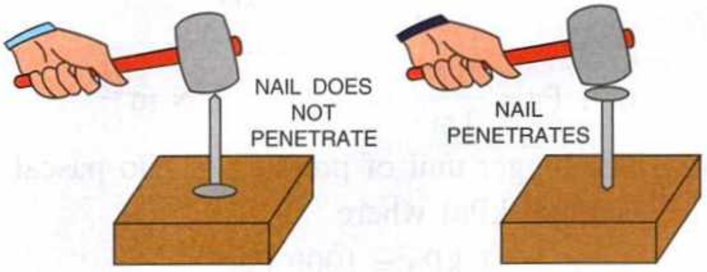

(a) Boy standing (more pressure)
(b) Boy lying (less pressure)

Fig. 3.13 Same thrust but different effects

(2) If you hammer a nail holding it with its flattened end resting on a wooden block [Fig. 3.14 (a)], you find it difficult to get the nail into the block. But if you hammer the nail holding its sharp end resting on the block [Fig. 3.14 (b)], the nail penetrates into the block easily. The reason is that when thrust acts on the flattened end, the effect of thrust is small but when the same thrust acts on the sharp end, the effect of thrust is more.



(a) Nail with its flattened blunt end on the block
(b) Nail with its sharp end on the block

Fig. 3.14 Effect of thrust is more on a smaller area than on a bigger area

The effect of thrust is expressed in terms of a quantity called pressure. More the effect of a given thrust on a surface, we say that the thrust exerts more pressure on the surface and if less is the effect of thrust on a surface, we say that the thrust exerts a less pressure on the surface.

DEFINITON OF PRESSURE

Pressure is defined as the thrust per unit area. Thus,

$$\text{Pressure} = \frac{\text{Thrust}}{\text{Area}}$$

It is denoted by the letter P.

If a thrust F acts on an area A, the pressure P is :

$$\boxed{P = \frac{F}{A}}$$

UNITS OF PRESSURE

(1) The S.I. unit of thrust (or force) is newton (N) and that of area is metre^2 (m^2), so the S.I. **unit of pressure is newton/metre^2** (symbol N/m^2 or N m^{-2}). This unit is also called **pascal** (symbol Pa) after the name of the scientist Blaise Pascal. Thus,

1 pascal is the pressure exerted by a thrust of 1 newton on a surface of area 1 metre^2. *i.e.*

$$1 \text{ pascal} = \frac{1 \text{ newton}}{1 \text{ metre}^2}$$

$$\text{or } 1 \text{ Pa} = \frac{1 \text{ N}}{1 \text{ m}^2} \text{ i.e. } 1 \text{ Pa} = 1 \text{ N m}^{-2}$$

(2) The bigger unit of pressure is kilo pascal (symbol kPa) where

$$1 \text{ kPa} = 1000 \text{ Pa}.$$

(3) If thrust is measured in kgf and area in cm^2, then pressure is expressed in unit kgf cm^{-2}.

(4) The atmospheric pressure is generally expressed in a unit atmosphere **(atm)** where

1 atm = 76 cm of mercury column
= $1{\cdot}013 \times 10^5$ Pa

FACTORS AFFECTING PRESSURE

The pressure on a surface depends on the following two factors :

1. On the area of the surface on which thrust acts,
2. On the magnitude of thrust acting on the surface.

1. Dependence of pressure on the area of surface :

When you stand on sand, a thrust equal to your weight acts on a smaller area and so exerts more pressure on sand, hence you sink more. But when you lie down on sand, the same thrust acts on a larger area and so exerts less pressure, hence you sink less Similarly, when you hammer a nail with its flattened end resting on a wooden block thrust exerted by you acts on a larger area so less pressure acts on the nail. Hence, it does not go into the block. But when you hammer the nail with its sharp end resting on the block, the same thrust acts on a smaller area, so more pressure acts on the nail. Hence, it easily prenetrates into the block.

Fig 3.15 (a) shows a block of mass 10 kg and dimensions 40 cm × 20 cm × 10 cm lying on a table top on its side 40 cm × 20 cm. The thrust exerted by the block on the table top is equal to the weight of the block *i.e.* 10 kgf. This thrust acts on an area A_1 = 40 cm × 20 cm = 800 cm^2. The pressure on the table top is

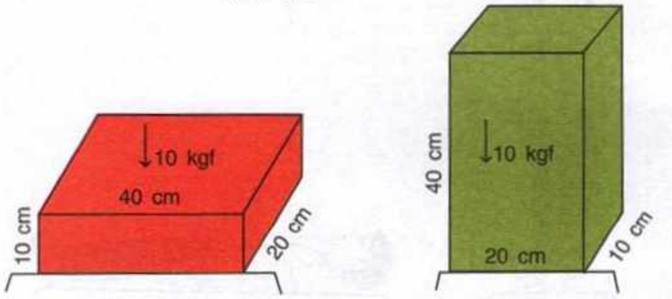
$$P_1 = \frac{10 \text{ kgf}}{800 \text{ cm}^2} = 0{\cdot}0125 \text{ kgf cm}^{-2}$$

Now if the block is turned so that it lies on its side 20 cm × 10 cm as shown in Fig 3.15 (b), the thrust exerted by the block on the table top is the same, equal to 10 kgf. But now, this thrust acts on an area

$$A_2 = 20 \text{ cm} \times 10 \text{ cm} = 200 \text{ cm}^2.$$

The pressure P_2 on the table top now is :

$$P_2 = \frac{10 \text{ kgf}}{200 \text{ cm}^2} = 0{\cdot}05 \text{ kgf cm}^{-2}$$



(a) Thrust = 10 kgf
Area = 800 cm^2
Pressure = $0{\cdot}0125$ kgf cm^{-2}

(b) Thrust = 10 kgf
Area = 200 cm^2
Pressure = $0{\cdot}05$ kgf cm^{-2}

Fig. 3.15 Lesser the area of surface, more is the pressure

Thus, pressure exerted by a body depends on the surface area on which the thrust of the body acts. *Smaller the surface area, more is the pressure exerted by the thrust and larger the surface area, lesser is the pressure exerted by the same thrust.*

This can also be demonstrated by the following activity.

ACTIVITY 1

Push a sharp pin into a piece of wood as shown in Fig 3.16 (a). Now try to push a nail with your thumb into the wood [Fig. 3.16 (b)]. You will not be able to push the nail into the wood but you will be able to push the pin into the wood. The reason is that the tip of the nail is of large area than the tip of the pin, so pressure exerted on nail is less than on the pin, hence pin gets inserted but the nail does not. Now, to insert the nail into the wood, hammer it as shown in [Fig. 3.16(c)]. You will find that the nail now gets inserted into the wood because thrust on it has increased the pressure.

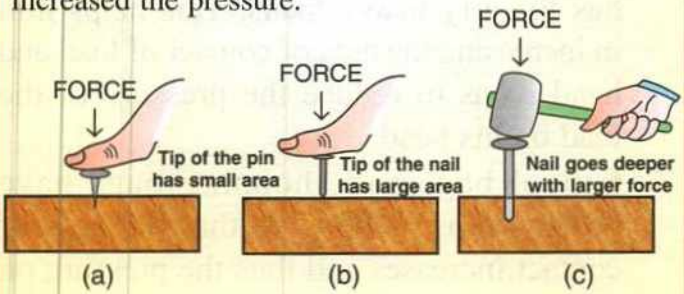
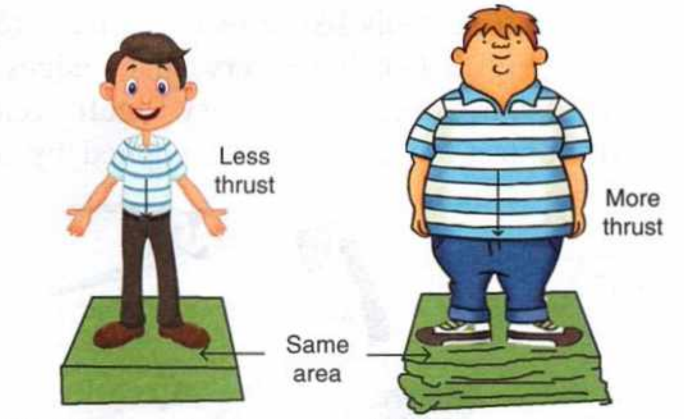


Fig. 3.16 Pressure increases when area decreases and force increases

2. Dependence of pressure on thrust (or force):

In Fig. 3.17 (a), a thin boy is standing on bricks kept on a bed. He exerts some pressure due to his weight. But in Fig. 3.17 (b), a fat boy is standing on the same bricks kept on the bed. In this case, the pressure exerted by the fat boy is more due to his excess weight. Thus, greater the thrust on a surface, more is the pressure on it while smaller the thrust on the same surface, less is the pressure on it.



(a) A thin boy standing on a bed (less pressure)

(b) A fat boy standing on a bed (more pressure)

Fig. 3.17 More the thrust, more is the pressure

This can be demonstrated by the following activity.

ACTIVITY 2

Take three identical blocks of solid wood X, Y and Z. Place these blocks on mud as shown in Fig 3.18. You will notice that the block X alone sinks less into the mud, but the blocks Y and Z placed one above the other, sink into the mud deeper.

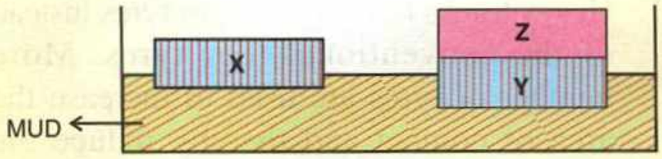


Fig. 3.18 X sinks less while Y and Z together sink more

EXAMPLES OF PRESSURE IN OUR DAILY LIFE

(A) Decrease in area increases the pressure

1. A nail or a board pin has one end pointed and sharp while the other end is blunt and flat. On applying force, the pointed end will exert greater pressure as the area of contact is small and hence, it will go deep into the given surface.

2. The cutting tools like a blade, knife, axe etc, (Fig. 3.19), have very sharp edges. The sharp edges have very small area of contact, so the pressure applied by a force is more.

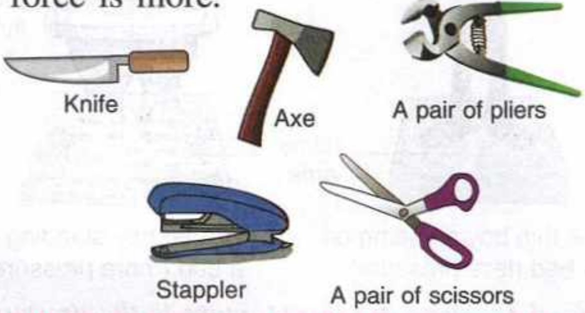


Fig. 3.19 Some cutting tools with sharp or pointed edges

3. The pointed heels of footwear exert more pressure on the ground than the regular flat heels. Therefore, a lady with pointed heel sandals finds it difficult to walk on a muddy road than on a tarred road.
4. The narrow heeled sandal of a girl hurts more than the broad heeled shoe of a boy. This is because more pressure is exerted by the girl than that exerted by the boy as her heel is more narrow than the heel of the shoe of the boy.

(B) Increase in area decreases the pressure

1. Heavy trucks have six to eight tyres instead of the conventional four tyres. More number of tyres are used to increase the area of contact and thereby reduce the pressure on the ground. If there are only four tyres in a heavy truck, due to less area the pressure applied by the truck will be more and hence its speed will get affected.
2. A camel can move more conveniently on sand as compared to a horse. The reason is that the camel has broader feet than that of a horse. The broader feet of the camel provide lesser pressure on the sand and it becomes easier for the camel to walk. In the case of a horse, the area of the feet is less, due to which the pressure is more and hence the feet show a tendency to sink inside th sand, making it difficult to walk.
3. Skiers use long flat skis to slide over th snow. The larger the area of contact, the lesser is the pressure on the snow. This helps the skier to slide comfortably without sinking in the snow.
4. Army tanks are usually very heavy and they exert large pressure on the ground, if they move on wheels. Hence they are made to move over the broad steel tracks called caterpillar wheels of tanks. These tracks are used to increase the surface area so as to reduce the pressure on the ground and hence avoid sinking of their wheels in the ground.
5. Foundation of buildings are kept wide so that the weight of the building may act on larger area. As a result, it will exert less pressure on the ground. This avoids sinking of buildings into the earth.
6. A porter wears turban on his head when he has to carry heavy loads. This helps him in increasing the area of contact of load and head so as to reduce the pressure of the load on his head.
7. School bags and shopping bags have broad straps or belts so that the area of contact increases and thus the pressure on the hand or shoulder is reduced.
8. Wide wooden sleepers are placed below the railway tracks (Fig 3.20) so that the pressure exerted by the rails on the ground becomes less.

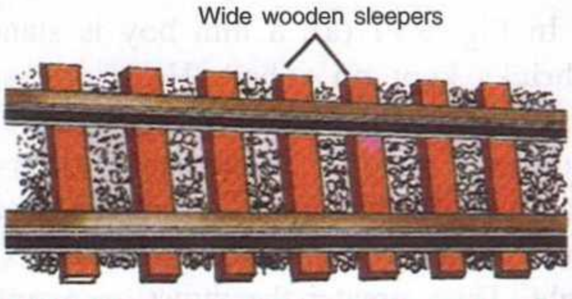


Fig. 3.20 Railway track having wide wooden sleepers

Difference between thrust and pressure

Thrust	Pressure
1. Thrust is the sum total of force acting perpendicular to a surface.	1. Pressure is the thrust acting per unit area.
2. It is independent of the area over which the force is applied.	2. It depends on the area on which the force acts.
3. It's S.I. unit is newton (N).	3. The S.I. unit is N m^{-2} or Pa.

LIQUID PRESSURE

A solid exerts pressure on a surface due to its own weight. Similarly, liquids have weight. They also exert pressure on the container in which they are kept. A solid exerts pressure only on the surface at its bottom. But a liquid exerts pressure not only on the surface of its container at the bottom, but also sideways, that is, in all directions. This can be demonstrated by the following activities.

ACTIVITY 3

A liquid exerts pressure at the bottom of its container.

Take a glass tube. Tie a balloon at its lower end. Hold it vertically straight as shown in Fig. 3.21 (a). Pour some water in the tube [Fig. 3.21 (b)]. You will notice that the balloon bulges out.

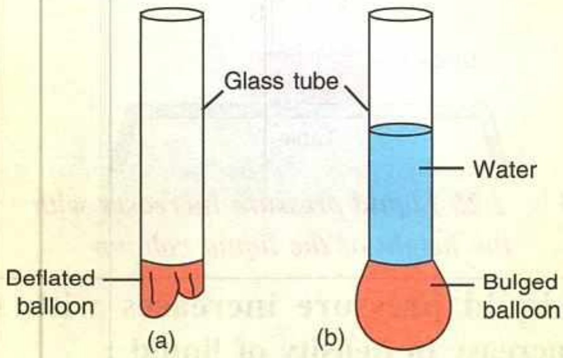


Fig. 3.21 Balloon bulges due to pressure of water column

Conclusion : The water column exerts a pressure on the balloon. The force on the balloon is equal to the weight of the water column which is called thrust. If W is the weight of water column and A the area of mouth of balloon, then

$$\text{Thrust} = W$$

and $$\text{Pressure} = \frac{\text{Thrust}}{\text{Area}} = \frac{W}{A}$$

ACTIVITY 4

A liquid also exerts pressure sideways on the walls of the container.

Take a glass tube closed at one end and having an opening in its side near the bottom. Tie a balloon at the side opening of the tube. Hold the tube vertically as shown in Fig 3.22 (a). Pour some water in the tube [Fig. 3.22 (b)]. You will notice that the balloon bulges out.

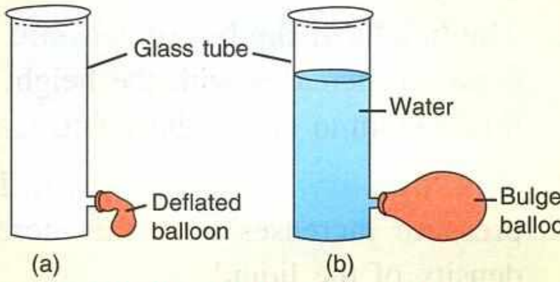


Fig. 3.22 Balloon bulges due to pressure of water on the sides of glass tube

This shows that liquids exert pressure sideways also on the walls of the container.

ACTIVITY 5

A liquid exerts pressure in all directions

1. Take a plastic mug and water in a bucket. Invert the mug and try to press it so as to immerse the mug into water. You will experience an upward push on your hand. This is because of the pressure exerted by water in the upward direction. Thus, liquids exert pressure in the upward direction also.

2. Take a balloon. Fill it with water. Tie its mouth. Make holes in it by inserting a pin at several places in all the directions. You will notice that water flows out through each hole (Fig. 3.23). This shows that water in the balloon exerts pressure in all directions.

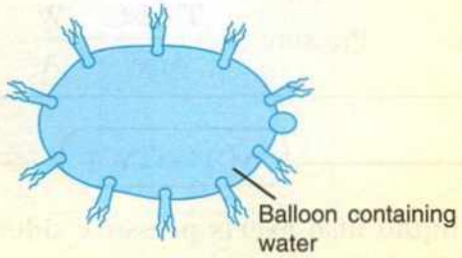


Fig. 3.23 Water inside a balloon exerts pressure in all directions

FACTORS AFFECTING LIQUID PRESSURE

The pressure at a point in a liquid depends on the following two factors :

1. **The height of the liquid column.** Liquid pressure increases with the height of the liquid column above the point.
2. **The density of the liquid.** Liquid pressure increases with the increase in density of the liquid.

1. Liquid pressure increases with the height of the liquid column :

This can be demonstrated by the following activities.

ACTIVITY 6

Take a glass tube open at both ends. Hold it vertically. Tie a balloon at its lower end. Pour some water in the tube. You will notice that the balloon bulges out as shown in Fig. 3.24 (a). Add some more water. You will find that the balloon bulges more [Fig. 3.24 (b)]. This shows that greater the height of the water column in the tube above the balloon, greater is the pressure exerted by it on the balloon. Thus, the liquid pressure at a point increases with the height of the liquid column above that point.

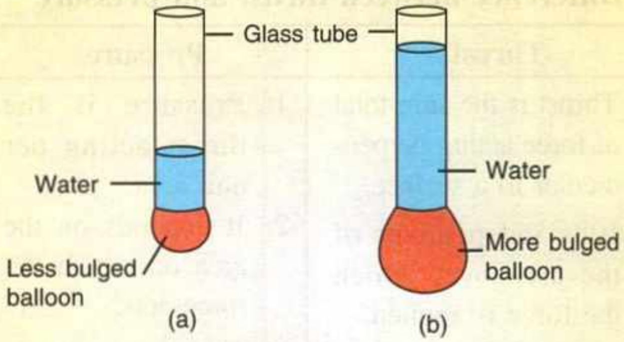


Fig. 3.24 Liquid pressure increases with the height of the liquid column

ACTIVITY 7

Take an empty tin cylinder. Make two holes in it, A near the top and B near the bottom. Close the holes A and B with an adhesive tape. Place the cylinder on a block kept on a table. Fill the cylinder with water. Remove the adhesive tape from the holes. You will notice that the water coming out from the upper hole A falls close to the cylinder and the water coming out from the lower hole B falls farther from the cylinder (Fig. 3.25). This shows that the liquid pressure at a point increases with the height of the liquid column above it.

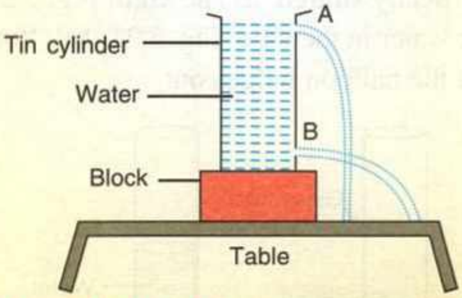


Fig. 3.25 Liquid pressure increases with the height of the liquid column

2. Liquid pressure increases with th increase in density of liquid :

This can be demonstrated by th following activity.

ACTIVITY 8

Take two identical glass tubes A and B open at both ends. Hold them vertical and tie a balloon at the lower end of each tube. Pour some water in the tube A. Now pour concentrated sugar solution in the tube B such that its height in the tube B is same as the height of water in the tube A as shown in Fig. 3.26. You will notice that the balloon attached with the tube B bulges more than that attached with the tube A. This shows that the same height of concentrated sugar solution exerts more pressure than water. Since the density of concentrated sugar solution is more than that of water, therefore we conclude that liquid pressure increases with the increase in density of the liquid.

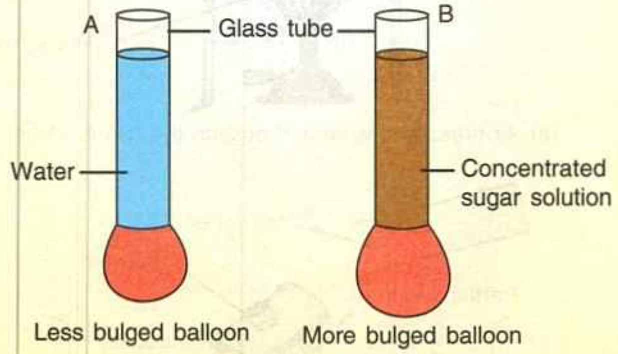


Fig. 3.26 Liquid pressure increases with increase in density of liquid

CONSEQUENCES OF LIQUID PRESSURE

Thickness of walls of a dam is increased towards the bottom : The reason is that the pressure at a point due to a liquid increases with the increase in height of the liquid column above it, so thickness of the walls of a dam is increased towards the bottom so as to withstand the increasing pressure of water (Fig. 3.27). The arrows in the figure show the increasing pressure towards the bottom of the dam.

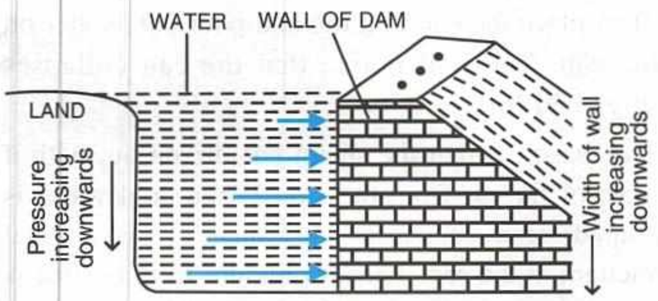


Fig. 3.27 Wall of a dam with its thickness increased towards the bottom

Do You Know ?

1. A liquid seeks its own level. The height of level of liquid in tubes of different areas of cross section always remains same, although volume of liquid is different in different tubes as shown in Fig 3.28. This is called hydrostatic paradox.

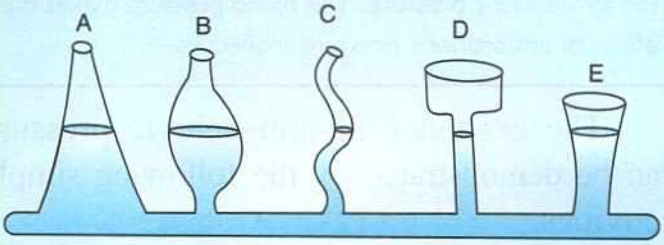


Fig. 3.28 A liquid seeks its own level

2. If a body is immersed in a liquid, the pressure of liquid on the bottom surface of body is more than at its top surface. Due to this difference in pressure, a force acts on the body (force = difference in pressure x area of surface of bottom) in the upward direction which is called **buoyant force** or **upthrust**.

3. Pressure at any point inside the sea/ocean is much greater than that at its surface. The pressure increases with the increase in depth. That is why deep sea-divers wear specially designed swim suits to counter such high pressure.

ATMOSPHERIC PRESSURE

Like liquids, gases also exert pressure. Our earth is surrounded by air to a height of about 200 kilometre. This envelope of air around the earth is called the **atmosphere**.

Air has weight. The weight of air exerts a thrust on earth. The thrust on unit area of the earth surface due to the column of air is called the **atmospheric pressure**. This is about 10^5 N m^{-2}. Thus, a thrust of 100,000 N acts on every 1 m^2 of the surface of objects on earth.

Do You Know ?

We all are under the atmospheric pressure (of about 10^5 Pa or 10^5 Nm^{-2}). The surface area of an average human body is 2 m^2. Therefore, a total thrust of about 200,000 N acts on our body by the atmosphere. However, we are not aware of this enormous thrust since the blood in the veins of our body also exerts a pressure (called the blood pressure) which is slightly more than the atmospheric pressure. This blood pressure makes the effect of atmospheric pressure ineffective.

The existence of atmospheric pressure can be demonstrated by the following simple activities.

ACTIVITY 9

Take a glass filled with water up to its brim and place a post card on top of it as shown in Fig. 3.29. Now press the palm of your one hand on top of the post card, then invert the water filled glass (keeping it tightly closed with the post card placed) upside down. Now gently remove your hand from the post card to release it. You will observe that the post card does not fall down from the glass although the pressure due to water column in the glass acts on it. The reason is that the atmospheric pressure acting upwards on the post card from outside the glass, overcomes the pressure on post card due to water in the glass.

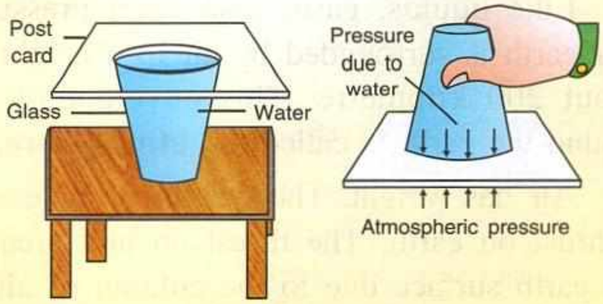
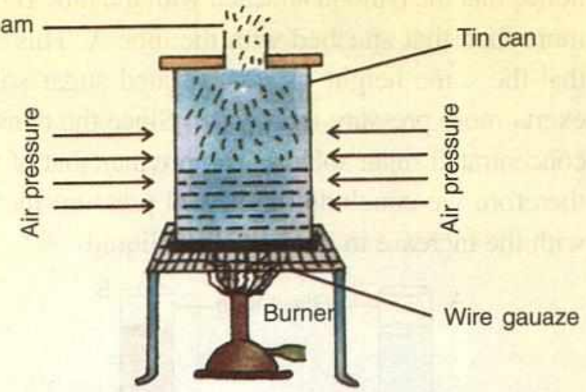


Fig. 3.29 Air exerts pressure

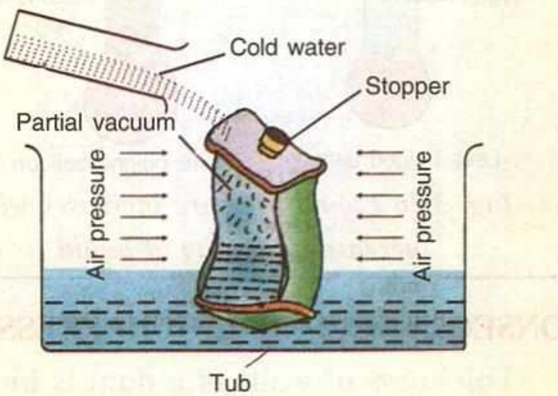
ACTIVITY 10

Crushing can experiment

Take a thin walled tin can provided with an airtight stopper. Remove the stopper. Fill the can partially with water. Heat the can over the flame of a burner till water begins to boil [Fig 3.30(a)]. Now the air pressure inside and outside the can is the same.



(a) Air pressure inside and outside the can is same



(b) Air pressure outside the can is more than that inside

Fig. 3.30 Crushing can experiment

When the steam starts coming out of the opening, put the stopper and remove the can from the burner. Then place the can in a tub and pour cold water on the can. You will notice that the can collapses [Fig. 3.30 (b)].

The reason is that the steam has driven out with it most of the air from the can. When cold water is poured, steam condenses into water, leaving a partial vacuum in the can. The air pressure from outside is now more than that from the inside. This excess air pressure from the outside exerts force due to which the can collapses.

STANDARD VALUE OF ATMOSPHERIC PRESSURE

At sea level on earth surface, the atmospheric pressure is 76 cm or 760 mm of mercury column which is equal to 1 atm or $1{\cdot}013 \times 10^5$ Pa.

Note : The atmospheric pressure decreases with increasing altitude *i.e.* as we go higher above the earth surface, the air pressure decreases.

SOME EXAMPLES IN DAILY LIFE TO SHOW THE EXISTENCE OF ATMOSPHERIC PRESSURE

Some of the examples in our daily life showing the effect of air pressure are given below:

1. When a drink is sucked with a straw (Fig. 3.21), the air of the straw goes into the lungs and thus air pressure in the straw decreases. The atmospheric pressure acting on the drink exerts force on the drink to move up into the straw and then into the mouth.

Fig. 3.31 Sucking a drink with a straw

2. When we blow air in a balloon, it bulges because of the pressure exerted by the air filled in it.
3. It is due to atmospheric pressure that ink gets filled into a fountain pen.
4. Water is drawn up from a well by a water pump because of the atmospheric pressure acting on water in the well.
5. A syringe gets filled with the liquid when its plunger is pulled up due to the atmospheric pressure acting on the liquid.
6. Rubber suckers are used as hooks in the kitchen and bathroom. They remain pressed against the wall due to the atmospheric pressure from outside.
7. It is difficult to take out oil from a sealed tin if only one hole is made in it. But if another hole is also made, the atmospheric pressure acts on the oil due to air entering in the tin through this hole and the oil then comes out of the tin through the other hole easily.
8. Lizards are able to move on the wall and stay wherever they desire. This is because their feet behave like suction pads, so they remain pressed against the wall due to the atmospheric pressure.
9. The astronauts and mountaineers have to wear special type of suits to protect themselves from adverse effects of low pressure prevailing at the great heights.
10. Nose bleeding often occurs at high altitudes. The reason is that the atmospheric pressure is low at high altitudes, but the pressure inside the human body does not change. Thus, the excess pressure inside the body compared to the atmospheric pressure, causes nose bleeding.

SOLVED EXAMPLES

1. Calculate the moment of force of 5 N applied on a body at a distance of 20 cm from a pivoted point.

Solution : *Given*, force $F = 5$ N,
distance $d = 20$ cm $= 0{\cdot}2$ m

$$\text{Moment of force} = \text{force } F \times \text{distance } d$$
$$= 5 \text{ N} \times 0{\cdot}2 \text{ m} = 1 \text{ N m}$$

2. The moment of force of 10 N about a pivot is 5 N m. Calculate the distance of force from the pivot.

Solution : *Given,* moment of force = 5 N m,
force $F = 10$ N

Let d metre be the distance of force from the pivot, then

$$\text{Moment of force} = \text{force } F \times \text{distance } d$$
$$5 \text{ N m} = 10 \text{ N} \times d$$
$$d = \frac{5 \text{ N m}}{10 \text{ N}} = 0{\cdot}5 \text{ m}$$

3. Julie can open a 2 m wide door by a minimum force of 2·5 N. Find the moment of force needed to open the door.

Solution : *Given,* force $F = 2{\cdot}5$ N, distance $d = 2$ m

$$\text{Moment of force} = F \times d$$
$$= 2{\cdot}5 \text{ N} \times 2 \text{ m} = 5{\cdot}0 \text{ N m}$$

4. A boy opens a nut by applying a force of 150 N using a wrench of length 30 cm. If he wants to open it by a force of 50 N, what should be the length of wrench ?

Solution : *Given*, force $F = 150$ N,
distance $d = 30$ cm $= 0{\cdot}3$ m

$$\text{Moment of force required} = F \times d$$
$$= 150 \text{ N} \times 0{\cdot}3 \text{ m} = 45 \text{ N m}$$

Now if force $F = 50$ N, moment of force needed = 45 N m, length d = ?

$$\text{Moment of force} = \text{force} \times \text{distance}$$
$$45 \text{ N m} = 50 \text{ N} \times d$$
$$d = \frac{45}{50} \text{ m} = 0{\cdot}9 \text{ m (or 90 cm)}$$

5. A solid block of weight 80 N and bas area 1·6 m² is placed on a surface. Calculate the pressure exerted on th surface.

Solution : *Given*, Thrust (F) = weight = 80 N
area $A = 1{\cdot}6 \text{ m}^2$

$$\text{Pressure} = \frac{\text{thrust}}{\text{area}} = \frac{80 \text{ N}}{1{\cdot}6 \text{ m}^2} = 50 \text{ Pa}$$

6. If a pressure of 50 Pa acts on an area o 4 m², calculate the thrust applied.

Solution : *Given*, Pressure $P = 50$ Pa, are $A = 4 \text{ m}^2$

$$\text{Since, pressure } P = \frac{\text{thrust } F}{\text{area } A}$$
$$\text{Thrust } F = \text{pressure } P \times \text{area } A$$
$$= 50 \times 4 = 200 \text{ N}$$

7. A force of 20 N acts normally on a body having area of cross section 10 cm² Calculate the pressure exerted by th body.

Solution : *Given*, thrust $F = 20$ N

$$\text{Area } A = 10 \text{ cm}^2 = \frac{10}{10000} \text{ m}^2$$
$$= 10^{-3} \text{ m}^2$$
$$\text{Pressure} = \frac{\text{Thrust}}{\text{Area}} = \frac{20 \text{ N}}{10^{-3} \text{ m}^2}$$
$$= 2 \times 10^4 \text{ N m}^{-2}$$

8. What is the magnitude of thrust required in newton to produce a pressure o 26500 Pa on an area of 100 cm² ?

Solution : *Given,*

$$\text{Area } A = 100 \text{ cm}^2 = \frac{100}{10000} \text{ m}^2 = 10^{-2} \text{ m}^2$$
$$\text{pressure } P = 26500 \text{ Pa}$$
$$\text{Since, } P = \frac{F}{A}$$
$$\text{Thrust } F = P \times A = 26500 \times 10^{-2} \text{ N}$$
$$= 265 \text{ N}$$

9. A normal force of 100 N can produce a pressure of 100000 Pa. Calculate the area in cm^2 on which the force shall act to exert the pressure.

Solution : *Given*, Thrust F = 100 N

pressure P = 100,000 Pa

Since $P = \frac{F}{A}$

$\therefore\ A = \frac{F}{P} = \frac{100}{100000}\ m^2 = \frac{1}{1000}\ m^2$

$= \frac{1}{1000} \times 10000\ cm^2 = 10\ cm^2$

10. A force of 10 N acts normally on a surface of area $0{\cdot}2\ m^2$. Find the pressure exerted on the surface.

Solution : *Given*, F = 10 N, $A = 0{\cdot}2\ m^2$

Pressure $P = \frac{F}{A} = \frac{10\ N}{0{\cdot}2\ m^2} = 50\ N\ m^{-2}$

11. The dimensions of heel of shoes of a girl weighing 45 kgf are 1·5 cm × 1 cm. Find the pressure exerted on the ground when she is standing on one heel.

Solution : *Given*, F = 45 kgf,

$A = 1{\cdot}5\ cm \times 1\ cm = 1{\cdot}5\ cm^2$

Pressure $P = \frac{F}{A} = \frac{45\ kgf}{1{\cdot}5\ cm^2} = 30\ kgf\ cm^{-2}$

12. A block of weight 5 kgf and dimensions 5 cm × 2 cm × 1 cm rests on a table in three different positions with its base as (i) 5 cm × 2 cm, (ii) 2 cm × 1 cm, (iii) 1 cm × 5 cm. Calculate the pressure exerted on the table in each case.

Solution : *Given*, In each case, F = 5 kgf

(i) In the first case,

$A = 5\ cm \times 2\ cm = 10\ cm^2$

Pressure $P = \frac{F}{A} = \frac{5\ kgf}{10\ cm^2} = 0{\cdot}5\ kgf\ cm^{-2}$

(ii) In the second case,

$A = 2\ cm \times 1\ cm = 2\ cm^2$

Pressure $P = \frac{F}{A} = \frac{5\ kgf}{2\ cm^2} = 2{\cdot}5\ kgf\ cm^{-2}$

(iii) In the third case,

$A = 1\ cm \times 5\ cm = 5\ cm^2$

Pressure $P = \frac{F}{A} = \frac{5\ kgf}{5\ cm^2} = 1\ kgf\ cm^{-2}$

13. A girl weighing 50 kgf wears sandals of pencil heel of area of cross section 1 cm^2, stands on a floor. An elephant weighing 2000 kgf stands on foot each of area of cross section 250 cm^2, on the floor. Compare the pressure exerted by them.

Solution : *Given*, for girl: Weight or force $F_1 = 50$ kgf

Area of both heels

$A_1 = 2 \times 1\ cm^2 = 2\ cm^2$

Pressure $P_1 = \frac{F_1}{A_1} = \frac{50\ kgf}{2\ cm^2} = 25\ kgf\ cm^{-2}$

For elephant, Weight = force $F_2 = 2000$ kgf

Area of four feet

$A_2 = 4 \times 250\ cm^2 = 1000\ cm^2$

Pressure $P_2 = \frac{F_2}{A_2} = \frac{2000\ kgf}{1000\ cm^2} = 2\ kgf\ cm^{-2}$

Now, $\frac{\text{Pressure exerted by girl}}{\text{Pressure exerted by elephant}} = \frac{P_1}{P_2}$

$= \frac{25\ kgf\ cm^{-2}}{2\ kgf\ cm^{-2}} = 12{\cdot}5 : 1$

Thus, the girl's pointed heel sandals exert 12·5 times more pressure than the pressure exerted by the elephant.

RECAPITULATION

- A force when acts on a rigid body which is free to move, can produce only the change in state of rest or motion.
- A force when acts on a non-rigid body which is free to move, can produce change in state of rest or motion as well as change in size or shape of the body.
- A force requires both its magnitude and direction to represent it.
- Force is represented by an arrow. The length of arrow is a measure of its magnitude and the arrow gives its direction.
- The S.I. unit of force is newton (symbol N) and its gravitational unit is kilogram force (kgf) where

  $$1 \text{ kgf} = 10 \text{ N (nearly)}.$$
- If a force is applied on a body which is pivoted at a point, the force can turn the body about that point. This is called the turning effect of force.
- The turning effect of a force depends on two factors : (i) the magnitude of force, and (ii) the perpendicular distance of force from the pivoted point. Greater the magnitude of force, more is the turning effect. Similarly greater the perpendicular distance of force from the pivoted point, more is the turning effect.
- The product of magnitude of force and the perpendicular distance of force from the pivoted point is called moment of force about the pivoted point, *i.e.*

  Moment of force = force (F) × perpendicular distance (d).
- The S.I. unit of moment of force is newton × metre (symbol N m).
- If a body turns towards the right, the moment of force is clockwise and negative but if the body turns towards the left, the moment of force is anticlockwise and positive.
- Thrust is a force that acts normally on a surface.
- Thrust exerted by a body on a surface is same howsoever it is placed.
- The effect of thrust depends on the area of the surface on which it acts.
- The units of thrust are kgf, gf and newton (N). They are related as :

  $$1 \text{ kgf} = 1000 \text{ gf}, \ 1 \text{ kgf} = 10 \text{ N (nearly) and } 1 \text{ N} = 100 \text{ gf (nearly)}$$
- Pressure is defined as the thrust per unit area *i.e.* Pressure $P = \dfrac{\text{Thrust F}}{\text{Area A}}$.
- Pressure on a surface depends on :

  (a) the area of the surface on which the thrust acts, (b) the magnitude of thrust acting on the surface.
- Smaller the surface area, more is the pressure exerted by the thrust.
- More the thrust on an area, more is the pressure.
- The pressure on a surface is increased by reducing the area of the surface and is reduced by increasing the area of the surface.
- The S.I. unit of pressure is newton per metre^2 (symbol N/m^2 or N m^{-2}) which is also called pascal (symbol Pa).
- Liquids and gases exert pressure in all directions. They exert pressure not only at the bottom, but also on the sides of the container in which they are kept.
- Pascal's law states that the pressure exerted by a liquid at a depth is same in all directions.

- The liquid pressure depends on the following two factors :
  - (a) the height of the liquid column. Liquid pressure at a point increases with the increase in height of the liquid column above that point.
  - (b) the density of the liquid. Liquid pressure increases with the increase in the density of liquid.
- The envelop of air up to a height of about 200 km around the earth is called the atmosphere.
- The weight of air exerts thrust on earth.
- The atmospheric pressure is the thrust on a unit area of the earth surface due to the column of air above it.
- At sea level the atmospheric pressure is equal to the pressure of 0·76 m of mercury column of air = 1 atm = $1{\cdot}013 \times 10^5$ Pa.
- Atmospheric pressure decreases with increasing height from the sea level.

TEST YOURSELF

. Objective Questions :

1. Write **true** or **false** for each statement :

(a) The S.I. unit of force is kgf.

(b) A force always produces both the linear and turning motions.

(c) Moment of force = force × perpendicular distance of force from the pivoted point.

(d) Less force is needed when applied at a farther distance from the pivoted point.

(e) For a given thrust, pressure is more on a surface of large area.

(f) The pressure on a surface increases with an increase in the thrust on the surface.

(g) A man exerts same pressure on the ground whether he is standing or he is lying.

(h) It is easier to hammer a blunt nail into a piece of wood than a sharply pointed nail.

(i) The S.I. unit of pressure is pascal.

(j) Water in a lake exerts pressure only at its bottom.

(k) A liquid exerts pressure in all directions.

(l) Gases exert pressure in all directions.

(m) The atmospheric pressure is nearly 10^5 Pa.

(n) Higher we go, greater is the air pressure.

Ans.: True—(c), (d), (f), (i), (k), (l), (m)
False—(a), (b), (e), (g), (h), (j), (n)

2. Fill in the blanks :

(a) 1kgf = ... N (nearly)

(b) Moment of force = ... × distance of force from the point of turning

(c) In a door, handle is provided .... from the hinges.

(d) The unit of thrust is ....

(e) Thrust is the .... force acting on a surface.

(f) Pressure is the thrust acting on a surface of .... area.

(g) The unit of pressure is ....

(h) Pressure is reduced if .... increases.

(i) Pressure in a liquid .... with the depth.

(j) The atmospheric pressure on earth surface is nearly ....

Ans.: (a) 10 (b) force (c) farthest (d) newton (e) normal (f) unit (g) pascal (h) area of surface (i) increases (j) 10^5 Pa

3. Match the following :

Column A	**Column B**
(a) Camel	(i) broad and deep foundation
(b) Truck	(ii) broad feet
(c) Knife	(iii) six or eight tyres
(d) High building	(iv) sharp cutting edge
(e) Thrust	(v) atm
(f) Moment of force	(vi) N
(g) Atmospheric pressure	(vii) N m

Ans.: (a)–(ii), (b)–(iii), (c)–(iv), (d)–(i), (e)–(vi), (f)–(vii), (g)–(v)

4. Select the correct alternative :

(a) S.I. unit of moment of force is :

(i) N (ii) N cm
(iii) kgf m (iv) N m

(b) To obtain a given moment of force for turning a body, the force needed can be decreased by :

(i) applying the force at the pivoted point
(ii) applying the force very close to the pivoted point
(iii) applying the force farthest from the pivoted point
(iv) none of the above.

(c) The unit of thrust is :

(i) kgf (ii) kg
(iii) g (iv) m s^{-1}

(d) The unit of pressure is :

(i) N × m (ii) kgf
(iii) N m^{-2} (iv) kgf m^2

(e) The pressure and thrust are related as :

(i) Pressure = Thrust
(ii) Pressure = Thrust × Area
(iii) Pressure = Thrust / Area,
(iv) Pressure = Area / Thrust

(f) A body weighing 5 kgf, placed on a surface of area 0·1 m^2, exerts a thrust on the surface equal to :

(i) 50 kgf (ii) 5 kgf
(iii) 50 kgf m^{-2} (d) 5 kgf m^{-2}

(g) The feet of lizards act like :

(i) moving pads (ii) drilling pads
(iii) suction pads (iv) none of the above

(h) Pressure exerted by a liquid is due to its :

(i) weight (ii) mass
(iii) volume (iv) area

(i) Pressure inside a liquid increases with:

(i) increase in depth
(ii) decrease in depth
(iii) decrease in density
(iv) none of the above

(j) The atmospheric pressure at sea level i nearly :

(i) 10 Pa (ii) 100,000 Pa
(iii) 100 Pa (iv) 10,000 Pa

(k) Nose bleeding may occur at a high altitud because :

(i) the atmospheric pressure decreases
(ii) the oxygen content of atmospher decreases
(iii) the atmospheric pressure increases
(iv) there are strong air currents at the hig altitude

Ans.: (a)–(iv), (b)–(iii), (c)–(i), (d)–(iii), (e)–(iii
(f)–(ii), (g)–(iii), (h)–(iii), (i)–(i), (j)–(i,
(k)–(i

B. Short/Long Answer Questions :

1. Define force. State its S.I. unit.
2. State two effects of a force when applied on body.
3. How does the effect of a force differ when it i applied on (a) a rigid body, (b) a non-rigi body ?
4. State the effect of force F in each of the followin diagrams (a) and (b).

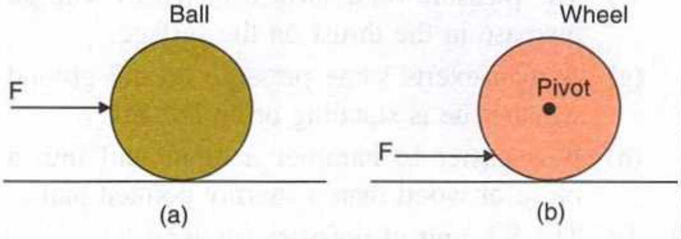


Fig. 3.32

5. Define the term moment of force.
6. State the S.I. unit of moment of force.
7. State two factors which affect moment force.
8. In Fig. 3.33 a force F is applied in a directi passing through the pivoted point O of the bod Will the body rotate ? Give reason to suppo your answer.

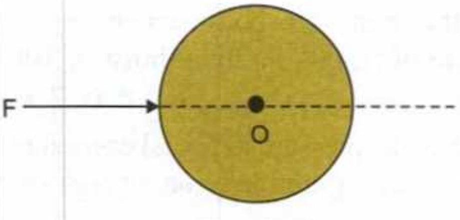


Fig. 3.33

9. Write the expression for the moment of force about a given axis of rotation.

0. State one way to decrease the moment of a given force about a given axis of rotation.

1. State one way to obtain greater moment of a given force about a given axis of rotation.

2. What do you mean by the clockwise and anti-clockwise moment of force ?

3. Explain the following :

   (a) The spanner (or wrench) has a long handle.

   (b) The steering wheel of a vehicle is of large diameter.

   (c) The hand flour grinder is provided with a handle near the rim.

   (d) It is easier to open the door by pushing it at its free end.

   (e) A potter turns his wheel by applying a force through the stick near the rim of wheel.

4. What is thrust ?

5. State the unit of thrust.

6. On what factors does the effect of thrust on a surface depend ?

7. Define the term 'pressure' and state its unit.

8. How is thrust related to pressure ?

9. Name two factors on which the pressure on a surface depends.

0. When does a man exert more pressure on the floor : while standing or while walking ?

1. Why do camels or elephants have broad feet ?

2. A sharp pin works better than a blunt pin. Explain the reason.

. Why is the bottom part of the foundation of a building made wider ?

24. It is easier to cut with a sharp knife than with a blunt one. Explain.

25. A gum bottle rests on its base. If it is placed upside down, how does the (i) thrust, (ii) pressure change ?

26. Explain the following:

   (a) Sleepers are used below the rails.

   (b) A tall building has wide foundations.

27. Describe an experiment to show that a liquid exerts pressure at the bottom of the container in which it is kept.

28. Describe a suitable experiment to demonstrate that a liquid exerts pressure sideways also.

29. Describe a simple experiment to show that at a given depth, a liquid exerts same pressure in all directions.

30. State two factors on which the pressure at a point in a liquid depends.

31. Describe an experiment to show that the liquid pressure at a point increases with the increase in height of the liquid column above that point.

32. Which fact about liquid pressure does the diagram in Fig. 3.34 illustrate ?

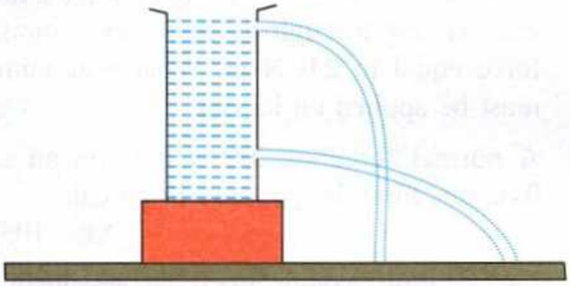


Fig. 3.34

33. Describe an experiment to show that liquid pressure depends on the density of liquid.

34. A dam has broader walls at the bottom than at the top. Give a reason.

35. What do you mean by atmospheric pressure ?

36. Write the numerical value of the atmospheric pressure on the earth surface in pascal.

37. We do not feel uneasy even under the enormous atmospheric pressure. Give a reason.

38. Describe a simple experiment to illustrate that air exerts pressure.

39. Describe the crushing tin can experiment. What do you conclude from this experiment ?

40. Give reasons for the following :
    (a) A balloon collapses when air is removed from it.
    (b) Water does not run out of a dropper unless its rubber bulb is pressed.
    (c) Two holes are made in a sealed oil tin to take out oil from it.

41. How does the atmospheric pressure change with altitude ?

C. Numericals :

1. Find the moment of force of 20 N about an axis of rotation at a distance of 0·5 m from the force. **Ans.** 10 N m

2. The moment of a force of 25 N about a point is 2·5 N m. Find the perpendicular distance of force from that point. **Ans.** 10 cm

3. A spanner of length 10 cm is used to unscrew a nut by applying a minimum force of 5·0 N. Calculate the moment of force required. **Ans. 0·5 N m**

4. A wheel of diameter 2 m can be rotated about an axis passing through its centre by a moment of force equal to 2·0 N m. What minimum force must be applied on its rim ? **Ans.** 2 N

5. A normal force of 200 N acts on an area of 0·02 m^2. Find the pressure in pascal. **Ans.** 10,000 Pa

6. Find the thrust required to exert a pressure of 50,000 pascal on an area of 0·05 m^2. **Ans.** 2500 N

7. Find the area of a body which experiences pressure of 50,000 Pa by a thrust of 100 N. **Ans.** 2×10^{-3} m

8. Calculate the pressure in pascal exerted by a forc of 300 N acting normally on an area of 30 cm^2 **Ans.** 10^5 P

9. How much thrust will be required to exert a pressur of 20,000 Pa on an area of 1 cm^2 ? **Ans.** 2

10. The base of a container measures 15 cm × 20 cm It is placed on a table top. If the weight of th container is 60 N, what is the pressure exerted b the container on the table top ? **Ans.** 2000 P

11. Calculate the pressure exerted on a surface o 0·5 m^2 by a thrust of 100 kgf. **Ans.** 200 kgf m

12. A boy weighing 60 kgf stands on a platform o dimensions 2·5 cm × 0·5 cm. What pressure i pascal does he exert ? **Ans.** $4{\cdot}8 \times 10^6$ P

13. Fig 3.35 shows a brick of weight 2 kgf an dimensions 20 cm × 10 cm × 5 cm placed i three different positions on the ground. Find th pressure exerted by the brick in each case.

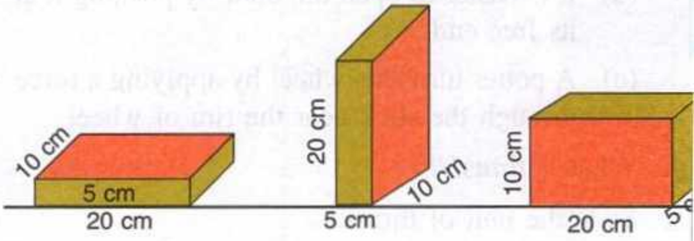


Fig. 3.35 Pressure exerted by a brick placed in three different positions

Ans. (a) $0{\cdot}01$ kgf cm^{-2} (b) $0{\cdot}04$ kgf cm
(c) $0{\cdot}02$ kgf cm

Project Work

Take a tray with dimensions about 40 cm × 30 cm × 10 cm. Fill it completely with wheat flour and level its surface plane.

(1) Lay down a brick A gently on the surface of flour. Write your observtion. Then place another identical brick B on brick A. What change do you observe ? Write and explain it.

(2) Remove both the bricks and level the surface plane again. Now lay down the brick A an place the brick B to stand vertical. Write your observations for the brick A and brick B Explain the difference in observation of both bricks when placed on flour.

4

Energy

Theme : Building on previous learning on energy, the emphasis in this class is on the introduction of gravitational potential energy to children. Look at a swinging bob of a pendulum. When it is at its extreme position (the highest point of its motion), it has gravitational potential energy. When it reaches its mean position (lowest point), it has maximum speed and it has high kinetic energy. In this case, one form of energy changes into other, according to the law of conservation of energy. Energy is the ability to do work. Work is said to be done when a force acting on an object changes the position of the object. For the special case when the object changes its position along the direction of the force, work is given by the product of the force and distance moved by the object. But different persons may take different time to do the same work. Rate of doing work is called power. So energy and power are two different physical quantities, having different units. In many situations, the focus is on the power and not energy. For e.g. the power of a motor which works is paid for the electricity consumed, is actually paid for the energy consumed.

In this chapter you will learn to

- define work;
- express work in proper unit;
- calculate work done in simple cases;
- define kinetic energy;
- express kinetic energy in proper units;
- solve simple problems based on kinetic energy;
- define potential energy;
- define gravitational potential energy;
- solve simple problems based on gravitational potential energy;
- describe energy transformation in daily life situation;
- distinguish between energy and power;
- plan an experimental investigation or demonstration using scientific processes;
- identify /select on the basis of attributes.

LEARNING OBJECTIVES

- Revising previous concepts learnt by children.
- Building on children's previous learning.
- Explaining concept of work done with examples from daily life.
- Calculating work done in simple cases and expressing result in proper unit.
- Explaining of kinetic energy and potential energy.
- Explaining of gravitational potential energy.
- Solving of problems on kinetic and potential energy.
- Demonstrating kinetic and potential energy using a simple pendulum.
- Engaging children in problem solving tasks on KE and PE.

- Explaining and discussing with children energy transformation in daily life situations / activities.
- Explaining the difference between energy and power.
- Citing examples of different applications of conservation of energy (roller coaster, Production of hydroelectricity etc.) with children making energy conversion diagrams and deduce that energy is conserved.

KNOWING CONCEPTS

- Concept of work.
- Unit of work (joule).
- Calculation of Work done in simple cases.
- Kinetic energy.
- Basic concept.
- Potential energy.
- Basic concept.
- Gravitational potential energy.
- Calculation of kinetic and potential energies from a set of given data (simple problems and assuming $g = 10\ m/s^2$).
- Energy transformation in common daily life situations.
- Difference between energy and power.

WORK

In everyday life, all of us do some work. We do work when we play, when we go to school, when we climb a staircase, when we pedal a bicycle, when we lift a load and so on.

In common language, we use the word work much casually. *For example*, if we push a wall, we say that work is done by us. While reading a book, we say that we are working. But actually no work is done in these activities (Fig. 4.1).

(a) No work is done in case of pushing a wall

(b) Reading is a kind of mental work; no work is done

Fig. 4.1 Examples when no work is done

In Physics, the word 'work' has a specia meaning. Work is said to be done only when body changes its position or moves or applying a force on it. No work is said to b done, if there is no motion produced in th body even when a force acts on it. Thus,

Work is said to be done if the force applied on a body moves it. If no motion take place, no work is said to be done.

For example, a cyclist pedalling a cycl does work, a horse pulling a cart does work an engine pulling a train does work, a coolie lifting a box does work, a boy climbing the stairs does work, a boy lifting a book doe work (Fig. 4.2).

Fig. 4.2 A boy lifting a book does work

When a crane picks up a car involved in n accident and takes it to a workshop, we say hat work is done.

In a school playground, while playing ootball, when a boy hits the ball and runs wards the goal, we say that work is done.

A boy climbing up stairs, does work Fig. 4.3).

Fig. 4.3 Work is being done when a boy is climbing the stairs

A person does no work if there is no hange in position or no motion even after he application of force. *For example*, a boy ushing a car or a heavy stone does no work f the car or stone does not move (Fig. 4.4), lthough he may get tired.

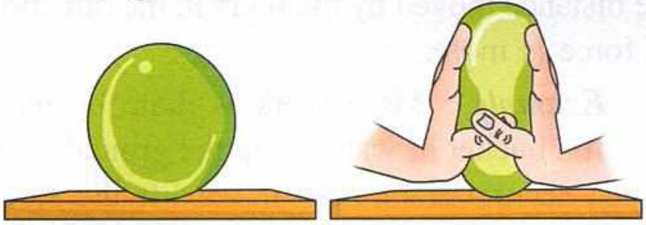
Fig. 4.4 A boy pushing a heavy stone does no work if the stone does not move

A person pushing against a wall also does o work since he is not able to move the wall. imilarly, a coolie does no work while standing with a heavy box on his head, as there is no motion, although he may get tired holding it (Fig. 4.5). But the coolie does work when he raises the heavy box to his head.

Fig. 4.5 A coolie standing with a box on his head, does no work

Work is also done by a force if the force applied on a body changes its size or shape.

For example, if a boy squeezes a toothpaste tube or gum tube or a rubber ball, he does work in changing the shape of the tube or ball (Fig. 4.6).



(a) Rubber ball (b) Rubber ball squeezed

Fig. 4.6 Work is done in changing the shape and size of a ball

Similarly, a boy does work in stretching a rubber string in which size of the string increases.

Thus, following two conditions must be fulfilled for work to be done :

(1) A force must act on the body.

(2) The force must produce change in position *i.e.*, motion of the body or change in size or shape of the body.

Factors affecting the amount of work done

Experimentally, it is found that the amount of work done by a force depends on the following two factors :

(1) The magnitude of the force applied, and

(2) The distance moved by the body in the direction of force.

(1) Dependence of the amount of work done on the magnitude of the force applied on the body : Work done is more if the force applied to move the body is more.

Example : More work is done by us if we lift a bucket full of water from the ground floor to the first floor than if we lift an empty bucket to the same height. The reason is that we have to apply a greater force to lift the bucket full of water than to lift the empty bucket.

(2) Dependence of the amount of work done on the distance moved by the body in the direction of force : Work done is more if the distance moved by the body in the direction of force is more.

Example : More work is done by us if we lift a bucket of water from the ground floor to the second floor than if we lift the same bucket from the ground floor to the first floor.

DEFINITION OF WORK

We define the work done as follows :

The work done by a force on a body is equal to the product of the force applied and the distance moved by the body in the direction of force i.e.,

Work done = Force × distance moved in the direction of force.

In Fig. 4.7, let a force F be applied on a body which moves it from position A t position B by a distance d in the direction o force, then the work done by the force on th body is

$$W = F \times d$$

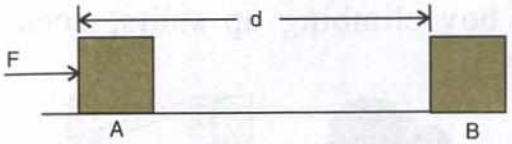


Fig. 4.7 Work done in motion of a body by a force

Obviously, if a force acts on a body an the body does not move, no work is done (*i.e.* $W = 0$ if $d = 0$).

Do You Know ?

The work done by a force is zero if the body moves in a direction perpendicular to the direction of force. *For example*, when a stone tied at the end of a string is whirled in a horizontal circular path, the motion of stone is always normal to the force of tension in the string as shown in Fig. 4.8. Therefore, the work done by the force of tension on the stone is zero.

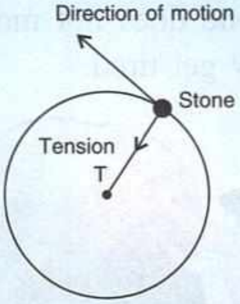


Fig. 4.8 No work is done by the force of tension on the stone

Similarly, in motion of earth around the sun, the force of attraction on earth by the sun is always normal to the direction of motion of earth, so no work is done by the gravitational force of sun on the earth.

Similarly, if a coolie moves on a plane road with luggage on his head, the work done by him against the force of gravity (*i.e.*, weight) is zero. Since, distance moved by him is normal to his weight.

Units of work

(1) We have read that the S.I. unit of orce is newton (N) and that of distance is ıetre (m). Hence, S.I. unit of work is ewton × metre (N m) or joule (symbol J). The unit joule has been named after the name f the scientist James Prescott Joule.

Definition of joule : Since,

$$1 \text{ joule} = 1 \text{ newton} \times 1 \text{ metre}$$

or $$1 \text{ J} = 1 \text{ N} \times 1 \text{ m}$$

i.e., one newton × metre is called one joule.

Thus, *one joule of work is said to be done f one newton force when acting on a body ıoves it by 1 metre in the direction of force.*

A bigger unit of work is kilo joule symbol kJ) and Mega joule (symbol MJ)

$$1 \text{ kJ} = 1000 \text{ J and } 1 \text{ MJ} = 10^6 \text{ J}$$

(2) If we measure the force in kgf nd the distance in metre, the unit of work is gf × m.

Since, $1 \text{ kgf} = 9{\cdot}8 \text{ newton}$

$$1 \text{ kgf} \times \text{m} = 9{\cdot}8 \text{ newton} \times \text{metre}$$
$$= 9{\cdot}8 \text{ joule.}$$

(Assuming that the force of gravity on a ass of 1 kg is 9·8 N).

In chapter 3, you have learnt that the unit f moment of force is newton × metre (symbol m). But it is not written as joule (J). Only or work and energy, the product, newton × ıetre is written as joule. This is to distinguish ıoment of force from work or energy.

NERGY

When work is done on a body, its energy ıcreases. In other words, the work done on e body is stored in it in the form of energy. ut if work is done by the body, its energy decreases. In other words, energy is spent when a body does work.

For example, a boy while playing football runs all over the field and he spends energy in doing work [Fig. 4.9]. He will continue to play football till he possesses energy.

A boy playing with football

Fig. 4.9 Energy is spent in doing work

Thus, we can define energy as follows :

Energy is the capacity of doing work.

Relationship between work and energy : It is experienced that more you run on a bicycle or more you run all around the playground, more you feel tired. The reason is that a lot of energy is spent in doing work by you. Thus, to do more amount of work, we need to spend more energy. Hence, we can say that there is a direct relationship between work and energy.

Similarly, *the work done on a body in changing its state is said to be the energy possessed by the body.*

For example, if a body is moved from the ground to a height, work is done on the body against the force of gravity and the body at the height is said to possess energy. Similarly, if a body initially at rest is made to move, work is done on the body and the body in motion is said to possess energy equal to the work done on the body.

UNIT OF ENERGY

Energy is measured in the same unit as work. Therefore, the S.I. unit of energy is joule (symbol J).

A body is said to possess an energy of one joule if it can do one joule work or if one joule work is done on it.

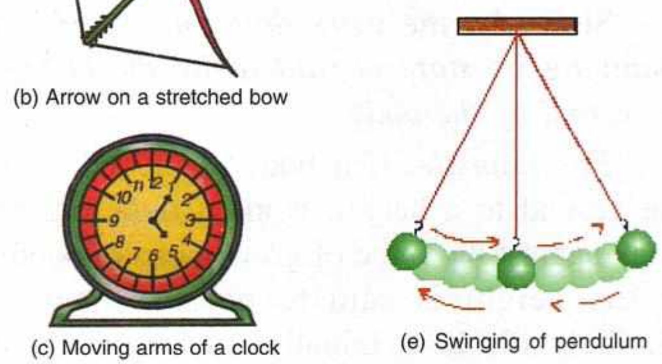
MECHANICAL ENERGY

The energy possessed by a body due to its state of rest or state of motion, is called ***mechanical energy***. Mechanical energy is found in two forms :

(1) Potential energy, and

(2) Kinetic energy.

The total mechanical energy of a body is the sum of its potential and kinetic energies. In Fig. 4.10, a car in motion, an arrow on a stretched bow, moving arms of a clock, a rock on a high hill and a swinging pendulum, all have mechanical energy.



(a) Car in motion

(d) Rock on a high hill

(b) Arrow on a stretched bow

(c) Moving arms of a clock

(e) Swinging of pendulum

Fig. 4.10 Bodies possessing mechanical energy

(1) Potential Energy (symbol P.E. or U)

Potential is a Latin word which mean 'to be able'. *The energy possessed by a bod due to its state of rest or position is calle* ***potential energy***. This is the energy stored i the body when work has been done by force in bringing the body to that state o rest or position (*i.e.*, the work done on th body has been stored in it in form o potential energy). *For example*, a stretche bow has potential energy stored in it whic is equal to the amount of work done i stretching the bow. When a spring i compressed, the work done in compressin the spring is stored in the spring in th form of its potential energy and th compressed spring is said to possess potentia energy. The energy of a stretched bow o compressed spring is also called elasti potential energy.

Similarly, when a body is taken from th earth's surface to a height, work has to b done on the body against the force of gravi on it. This work done is stored in the bod in form of its potential energy. This energ is also called **gravitational potential energy** Thus, the water stored in a dam ha gravitational potential energy. A rock lyin on top of a high hill has potential energy.

In Fig. 4.11(a), a boy does work i bending the branch of a tree. This work i stored in the branch of tree in form o potential energy. In Fig. 4.11(b), when th boy leaves the branch, it goes back. Th work needed for the return of the branch i now obtained from the potential energ stored in the branch when it was bent by th boy.

(a) The boy does work in bending the branch which is stored as potential energy

(b) The branch goes back for which energy is obtained from the potential energy

Fig. 4.11 Potential energy

SOME OTHER EXAMPLES OF POTENTIAL ENERGY

(1) A wound up watch spring has potential energy because of the wound up state of its coils. As the spring unwinds itself, it does work to move the arms of the watch.

(2) In Fig. 4.12, a compressed spring has potential energy because of its compressed state. If a ball is placed on a compressed spring [Fig. 4.12(a)] and the spring is released, the ball flies away as shown in Fig. 4.12(b). Thus, the spring does work on the ball to make it move.

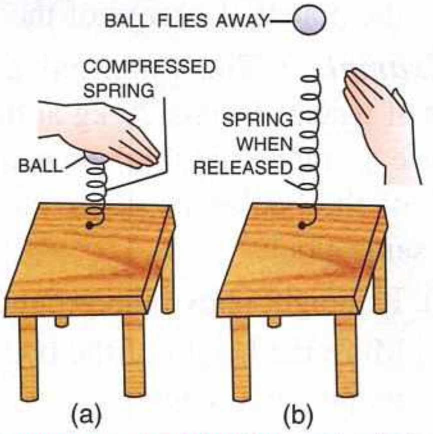


Fig. 4.12 A compressed spring has potential energy

Actually when a spring is compressed (or wound), some work is done on the spring which is stored in it in the form of potential energy.

(3) A stretched rubber band has potential energy. It does work in restoring itself to its original state. In Fig. 4.13, a pebble placed on the stretched rubber catapult, is thrown away when it is released to restore its original state.

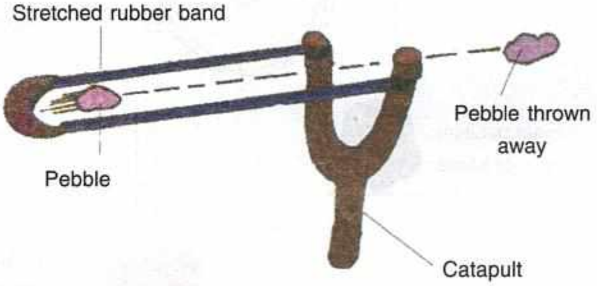


Fig. 4.13 A stretched rubber catapult has the potential energy

In stretching a rubber band, work is done. This work is stored in the rubber band in form of potential energy. This potential energy does work in moving the pebble.

(4) A stone placed at a height has potential energy stored in it. The stone has this energy because of its position at a height. In Fig. 4.14(a), the stone is dropped on a nail fixed on a piece of wood. It drives the nail into the wood as shown in Fig. 4.14(b) due to its potential energy.

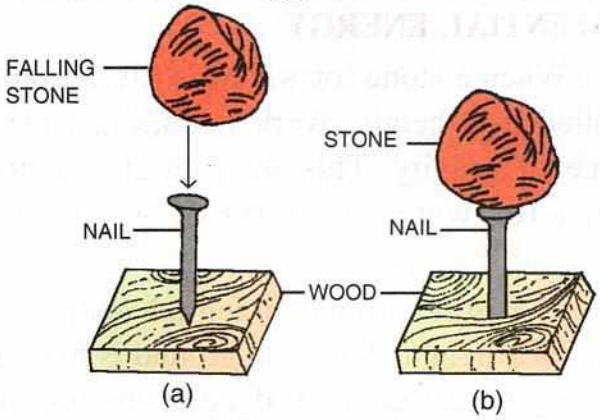


Fig. 4.14 A falling stone drives a nail into the wood

(5) In Fig. 4.15, a falling stone when reaches a pan attached at one end of a pulley, lifts up a weight at its other end because of its potential energy.

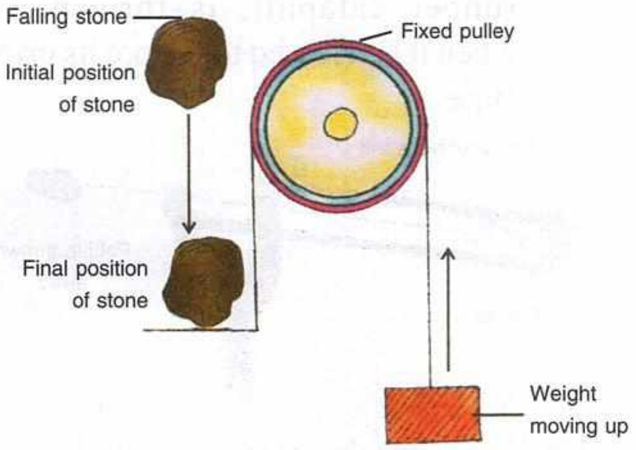


Fig. 4.15 A falling stone lifts a weight up

(6) Water at a height has potential energy stored in it. Thus, falling water from a height can be used to do work like turning a wheel.

Do You Know ?

The potential energy is of two forms: (i) Elastic potential energy, when the work done on the body changes its size or shape (ii) gravitational potential energy, when the work is done to move a body to a height above the earth surface.

EXPRESSION FOR THE GRAVITATIONAL POTENTIAL ENERGY

When a stone (or water) is lifted from the ground to a height, work is done against the force of gravity. This work is stored in the stone (or water) in form of gravitational potential energy.

The gravitational potential energy of a body at a height above the ground is measured by the amount of work done in moving it up to that height against the force of gravity acting on the body.

Let a body of mass m kg be moved from the ground to a height of h m. The minimum upward force required to move the body will be the force of gravity on the body acting vertically downward. If g is the force of gravity on a mass of 1 kg, the force of gravity on mass m kg will be mg N.

Force needed $F = mg$ N

Distance moved $d = h$ m

Work done W = force × distance moved

$= mg \times h$ Joule

This work done against the force of gravity, is stored in the body at height h in form of its gravitational potential energy.

Gravitational potential energy,

P.E. (or U) = mgh

The S.I. unit of potential energy is joule (symbol J).

Thus, the potential energy of a body in the raised position depends upon the following two factors :

(i) The mass of the body.

Greater the mass of the body, greater is the potential energy of the body.

Example : The potential energy of a bucket of water of mass 20 kg at the first floo of house is more (double) than the potential energy of the bucket of water of mass 10 kg at the same floor.

(ii) Its height above the ground.

More the height of the body, greater i its potential energy.

Example : The potential energy of a bucke of water of mass 10 kg at the second floor o house at height 6 m is more (double) than th potential energy of the same bucket of water o mass 10 kg at the first floor at height 3 m.

Kinetic energy (Symbol K.E. or K)

The energy of a body in motion is called ts kinetic energy. It is defined as follows :

Kinetic energy of a body is the energy possessed by it due to its state of motion.

Examples : (1) Fig. 4.16, shows that a fast moving stone has the capacity of breaking window pane when it strikes the pane. Thus, he fast moving stone has kinetic energy.

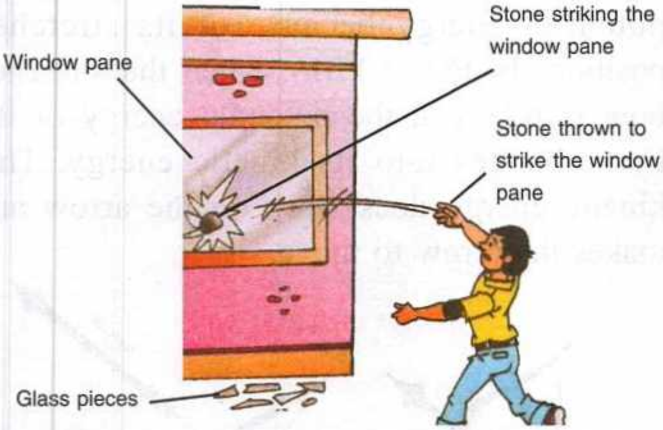


Fig. 4.16 A fast moving stone breaks a window pane due to its kinetic energy

(2) A falling hammer (*i.e.*, a hammer in motion) when strikes a nail fixed on a wooden block, moves it further down into the block. Thus the moving hammer has kinetic energy and it does work on the nail.

(3) A bullet fired from a gun, a rolling ball, an apple falling from a tree, blowing wind, flowing water, swinging pendulum, flying bird etc. all have kinetic energy.

If a body initially at rest is made to move, work is done on the body and the body in motion is said to possess kinetic energy. The kinetic energy of the body will be equal to the work done on the body.

Factors affecting the kinetic energy of a moving body :

The kinetic energy of a moving body depends on the following two factors :

(i) The mass of the body.

Greater the mass of the body, higher is its kinetic energy.

Example : The kinetic energy of a body of mass 10 kg moving with some speed is more (or double) the kinetic energy of another body of mass 5 kg moving with the same speed.

(ii) The speed of the body.

More the speed of the body, higher is its kinetic energy.

Example : If a boy increases his speed of motion from 2 m s^{-1} to 4 m s^{-1}, his kinetic energy will increase to four times the initial kinetic energy.

Expression for the kinetic energy

If a body of mass m is moving with a speed v, its kinetic energy is given as

$$\text{K.E.} = \frac{1}{2}\ mv^2$$

The unit of kinetic energy is joule (J).

The dependence of kinetic energy on speed can be demonstrated by the following activities.

ACTIVITY 1

Take a carrom board. Place all the coins in the middle of the board. Hit the coins by a striker. You will notice that more the effort applied to push the striker, more is the gain in kinetic energy of the striker. More the kinetic energy of the striker hitting the coins, longer is the distance covered by the moving coins.

ACTIVITY 2

While watching a cricket match, observe that when a batsman hits the ball with a little effort, the ball goes to a shorter distance while when he hits the ball hard, the ball goes to a greater distance to fetch him four or six runs.

Difference between potential energy and kinetic energy

Potential energy	Kinetic energy
1. It is the energy possessed by a body due to its state of rest or position.	1. It is the energy possessed by a body due to its state of motion.
2. It is the work done on the body to bring it to that state of rest or position.	2. It is equal to the work done in moving the body initially from rest.
3. It can change only in form of kinetic energy.	3. It can change in any form of energy (potential energy, heat energy, light energy etc).

CONVERSION OF POTENTIAL ENERGY INTO KINETIC ENERGY

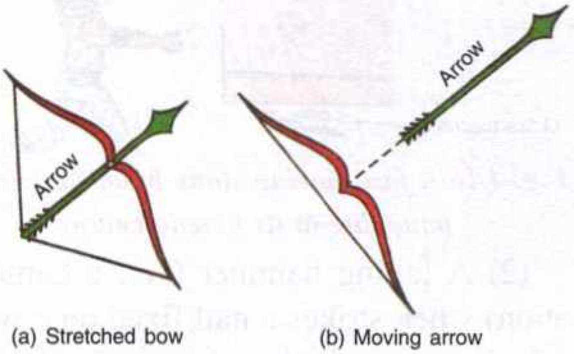
The potential energy changes into kinetic energy when it is put to use. In absence of friction, the sum of potential energy and kinetic enrgy remains constant at each instant. This is called the *law of conservation of mechanical energy.*

Examples : (1) A stone at a height has the potential energy due to its lifted or raised position. In Fig. 4.14, when the stone is dropped from that position, it begins to fall. The falling stone has the kinetic energy. Thus, the potential energy stored in the stone in its raised position changes into kinetic energy when the stone is falling. This kinetic energy does work on the nail as the stone strikes the nail and makes the nail to move into the wood.

(2) In Fig. 4.15, the potential energy possessed by the stone at a height changes into its kinetic energy when it falls. The kinetic energy of the falling stone does work in raising the weight upwards.

(3) A wound up watch spring has th potential energy because of its wound u state. As the spring unwinds itself, th potential energy changes into kinetic energy This kinetic energy does work in moving th arms of the watch.

(4) A stretched bow in Fig. 4.17(a) has potential energy because of its stretched position. In Fig. 4.17(b), when the stretched bow is released, the potential energy of th bow changes into its kinetic energy. Thi kinetic energy does work on the arrow and makes the arrow to move.



(a) Stretched bow (b) Moving arrow

Fig. 4.17 Potential energy of a stretched bow changes into its kinetic energy

(5) A compressed spring in Fig. 4.12(a has the potential energy in it due to its compressed state. In Fig. 4.12(b), when the compressed spring is released, the potential energy changes into its kinetic energy which does work on the ball placed on it and makes the ball to fly away.

(6) **Falling ball :** Consider a ball placed at a height. It will have only potential energy and no kinetic energy.

If the ball is released from the height, it falls down and the vertical height of the ball from the ground decreases. Therefore, the otential energy decreases and it changes to inetic energy due to which the speed of ball ncreases. During the fall, the ball has both he potential energy and the kinetic energy. As he ball reaches the ground, the potential nergy becomes zero and it changes entirely into kinetic energy.

Fig. 4.18 shows the conversion of potential energy into kinetic energy during the ertical free fall of a ball at various positions A, B and C.

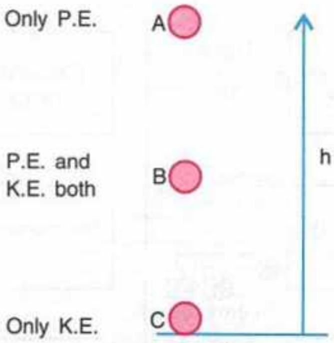


Fig. 4.18 Conversion of P.E. into K.E. during a vertical free fall

(7) **Production of hydroelectricity :** The water collected in a dam at a height has potential energy stored in it. When it is made to fall on a turbine, the potential energy changes to kinetic energy which is transferred to the turbine to rotate it (Fig. 4.19). By connecting the turbine to the armature of a dynamo, electricity (called the hydroelectricity) is produced.

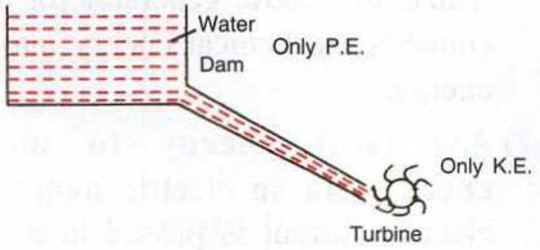


Fig. 4.19 Conversion of P.E. into K.E. of the water falling from a dam

(8) **Swinging pendulum :** Fig. 4.20 shows a simple pendulum suspended from a rigid support O. Its resting position is at A. When the bob of pendulum is slightly moved from A to B, its height increases, so at B, the bob has potential energy stored in it. On releasing the bob at B, it comes back to A during which the potential energy changes into kinetic energy. On reaching at A, whole of the potential energy changes into kinetic energy and due to this kinetic energy, the bob has the maximum speed with which it moves to the other side up to C, at the same vertical height h. In motion from A to C, kinetic energy changes into potential energy and at C, speed becomes zero. So it again returns to A. This motion continues.

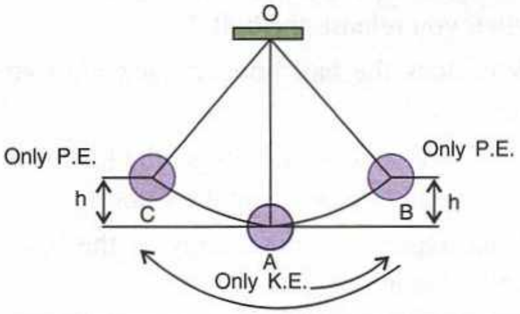


Fig. 4.20 Conversion of P.E. into K.E. in a swinging pendulum

Note : Here friction due to air has been neglected.

(9) **Roller coaster :** Fig. 4.21, the car on a roller coaster at position A has only potential energy (= E) and no kinetic energy. As the car comes to the positon B, whole of the potential energy changes into kinetic energy, so at B it has only the kinetic energy (= E) and no potential energy. Due to this kinetic energy, the car rises to the position C, during which the kinetic energy changes into potential energy and at C, it has the potential

energy (= E_1) and kinetic energy (= $E - E_1$). So the total sum of kinetic energy and potential energy is conserved. Note that the vertical height of C is less than that of A.

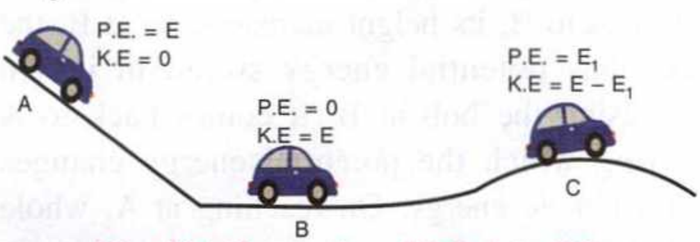


Fig. 4.21 Conversion of P.E. into K.E. in a roller coaster

ACTIVITY 3

Take a ping-pong ball. Release it from a height on a hard, smooth floor. You will observe that the ball after striking the floor bounces several times. Try to answer the following questions :

(a) What is the potential energy and kinetic energy when you release the ball ?

(b) Why does the ball bounce back after striking the floor ?

(c) From where does the ball get the kinetic energy for motion after striking the floor ?

(d) What happens to the energy of the ball when the ball stops bouncing ?

DIFFERENT FORMS OF ENERGY

Apart from mechanical energy, we have other forms of energy as well. These are solar energy, heat energy, light energy, sound energy, electrical energy, chemical energy, nuclear energy, etc. One form of energy can be converted into other useful forms of energy. Now we shall study some examples of transformation of one form of energy into other forms in our daily life.

SOME EXAMPLES OF TRANSFORMATION OF ENERGY

(1) Mechanical energy to electrical energy:

The water stored in the reservoir of a dam has the potential energy. When water falls its potential energy decreases and kineti energy increases. If the falling water i made to rotate a turbine near the botton of the dam, the kinetic energy of water i transferred to the turbine in the form o rotational kinetic energy due to which i rotates. The turbine rotates the armature o the generator connected to it and thus th kinetic energy gets transformed into th electrical energy by the generator.

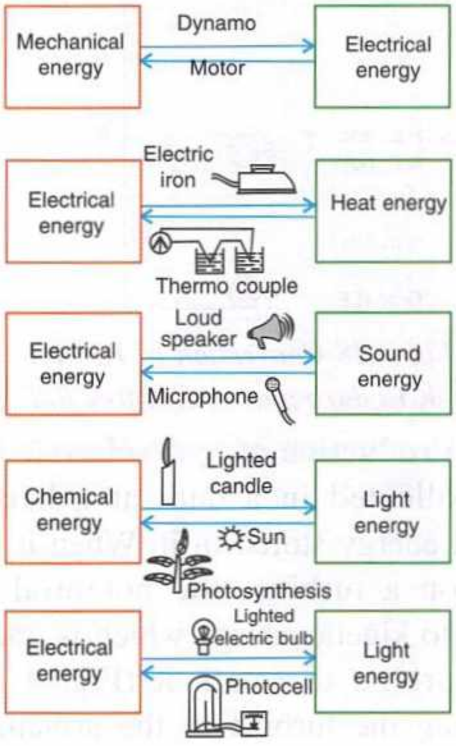


Fig. 4.22 Examples of energy conversion

Thus, an electric generator (or a dynamo) converts mechanical energy into electrical energy.

(2) Electrical energy to mechanical energy :

In an electric motor, when an electric current is passed in a coil freely suspended (or pivoted) in a magnetic field, a torque acts on the coil due to which it rotates. The shaft attached to the coil also rotates with it. Thus, the electrical energy changes into mechanical energy.

The electric motor is used in many home appliances such as electric fan, washing machine, mixer, grinder, etc. It is also used to run industrial machines.

(3) **Electrical energy to heat energy :** In electric appliances such as heater, oven, geyser, toaster, etc. electrical energy changes into heat energy when a current passes through their resistance wire (or filament).

(4) **Electrical energy to sound energy :** A loudspeaker when in use, receives electrical energy in the form of electrical signals from the microphone and changes it into sound energy.

In an electric bell when an electric current is passed, the electrical energy changes into sound energy.

(5) **Sound energy to electrical energy :** A microphone converts the sound energy into electrical energy in form of varying electric signals.

(6) **Light energy to chemical energy :** The light energy from the sun is absorbed by green plants and they change it in form of chemical energy during the process of photosynthesis.

(7) **Electrical energy to light energy :** When an electric bulb glows on passing an electric current through it, the electrical energy changes into heat and light energies.

(8) **Light energy to electrical energy :** In a photoelectric cell, the light energy gets converted into electrical energy.

In a solar cell, the light (or solar) energy changes into electrical energy.

(9) **Heat energy to mechanical energy :** In a steam engine, the chemical energy of coal first changes to heat energy of steam and then heat energy of steam changes into mechanical energy.

(10) **Mechanical energy to heat energy :** When water falls from a height, the potential energy stored in water at that height changes into kinetic energy of water during the fall. On striking the ground (or bottom), a part of the kinetic energy of water changes into heat energy due to which the temperature of water rises.

The moving parts of a machine get heated due to friction, thus a part of mechanical energy also changes into heat energy.

Do You Know ?

(1) Whenever mechanical energy changes to other forms, it is always in the form of kinetic energy and not in the form of potential energy i.e., the stored potential energy first changes to kinetic energy and then kinetic energy changes to the other forms.

(2) While transformation of energy from one form to the other desired form, the entire energy does not change into the desired form, but a part of it changes either to some other undesirable form (usually heat due to friction) or a part is lost to the surroundings due to radiation which is not useful. This conversion of energy to the undesirable (or non-useful) form is called dissipation of energy. Since this part of energy is not available to us for any productive purpose, so we call this energy as the degraded form of energy.

POWER

The power of a body is defined as the rate of doing work by the body.

If a body performs a work W in time t, the power spent by the body is :

$$\text{Power} = \frac{\text{Work done by the body}}{\text{Time taken}}$$

$$\text{or} \quad P = \frac{W}{t}$$

Note : (1) The symbol P is also used to represent pressure. But pressure and power are different quantities.

(2) Different persons may take different time to do the same work.

Power and energy (or work done) are related to each other. If a source of power P is used for time t, the energy spent or work done is P × t.

Thus, when a body does work or spends energy, we often come across the term 'power' spent by the body. All electrical appliances are rated with their power. When an appliance is in use, the electrical energy spent is given by the product of its power and time for which it has been used. We pay the cost for this electrical energy consumed.

For example, if we use an electrical motor of power 1·5 kW to lift water in the overhead tank, for 2 h the electrical energy spent is $1{\cdot}5\ \text{kW} \times 2\ \text{h} = 3\ \text{kWh}$ for which the cost is paid to the electricity board and we say that the power spent by the pump is 1·5 kW. If we say 9 W LED is glowing, we mean to say that while glowing, LED consumes 9 J of energy per second.

Unit of Power

The S.I. unit of work is joule (symbol J) and the S.I. unit of time is second (symbol s), so the S.I. unit of power is $= \frac{\text{joule}}{\text{second}} = \text{J s}^{-1}$.

The unit joule per second has been named as watt (symbol W) after the name o the scientist James Watt.

$$1\ \text{J s}^{-1} = 1\ \text{W}$$

The bigger units of power are kilowat (kw) and megawatt (MW) where

$$1\ \text{kW} = 1000\ \text{W, and}$$
$$1\ \text{MW} = 10^6\ \text{W}$$

Do You Know ?

(1) In mechanical engineering, we often use horse power (symbol H.P.) as the unit of power. It is related to watt as

$$1\ \text{H.P.} = 746\ \text{W}$$

(2) kWh (kilowatt hour) is the unit of energy where

$$1\ \text{kWh} = 3{\cdot}6 \times 10^6\ \text{J}$$

Factors affecting the power of a source

The power spent by a source depends on two factors :

(1) The amount of work done by the source, and

(2) The time taken by the source to do the said work.

If a machine (or a person) does a given amount of work at a faster rate *i.e.* in less time, more power is spent by it (or him).

Example : If a coolie A takes 1 minute to lift a load to the roof of a bus, while another coolie B takes 2 minute to lift the same load to the roof of the same bus, the work done by both the coolies is the same, but the power spent by coolie A is twice the power spent by coolie B because coolie A does work at double the rate (*i.e.*, in half the time) the coolie B works.

Difference between work and power

Work	Power
1. Work done by a force is equal to the product of force and distance moved in the direction of force.	1. Power of a source is the rate of doing work by it (*i.e.*, work done in one second).
2. Work done does not depend on time.	2. Power spent depends on the time in which work is done.
3. S.I. unit of work is joule (J).	3. S.I. unit of power is watt (W).

Difference between energy and power

Energy	Power
1. Energy of a body is its capacity to do work.	1. Power of a source is the rate at which energy is supplied or work is done by it.
2. Energy spent does not depend on time.	2. Power depends on the time in which energy is spent.
3. S.I. unit of energy is joule (J).	3. S.I. unit of power is watt (W).

SOLVED EXAMPLES

1. A force of 200 N moves a body through a distance of 2 m in the direction of force. Calculate the work done by the force.

olution : *Given*, F = 200 N, d = 2 m

Work done W = F × d

or W = 200 N × 2 m = 400 J

2. A machine moves a load of 520 N by a distance 5·2 m vertically up. Calculate the work done by the machine.

olution : *Given*, force needed F = load = 520 N,

Distance moved d = 5·2 m

Work done by the machine W = F × d

= 520 N × 5·2 m

= 2704 J

3. A coolie raises a box of mass 50 kg to a vertical height of 3 m. Calculate the work done by the coolie if force of gravity on 1 kg mass is 10 N.

Solution : *Given*, force F = mg

= 50 kg × 10 N kg^{-1}

= 500 N

d = 3 m

Work done W = F × d

= 500 N × 3 m = 1500 J

4. What is the potential energy of a stone of mass 10 kg that is lifted to a height of 8 m, if g = 10 N kg^{-1} ?

Solution : *Given*, m = 10 kg, g = 10 N kg^{-1}, h = 8 m

P.E. = mgh

= 10 kg × 10 N kg^{-1} × 8 m

= 100 N × 8 m

= 800 J

5. A body of mass 5 kg is taken from a height of 3 m to 6 m. Find the increase in the potential energy of the body. Take g = 10 N kg^{-1}.

Solution : *Given*, m = 5 kg, h_1 = 3 m, h_2 = 6 m, g = 10 N kg^{-1}

Increase in potential energy

$= mgh_2 - mgh_1$

$= mg\,(h_2 - h_1)$

= 5 × 10 × (6 – 3) J

= 150 J

6. A body of mass 4·0 kg falls from a height of 2·5 m. How much energy does it possess at any instant ? Take

$g = 10\ \text{N kg}^{-1}$.

Solution : *Given*, $m = 4{\cdot}0$ kg, $h = 2{\cdot}5$ m, $g = 10\ \text{N kg}^{-1}$

The energy possessed by the body at any instant will be equal to the initial potential energy at height h which is

$$\begin{aligned} U &= mgh \\ &= 4{\cdot}0\ \text{kg} \times 10\ \text{N kg}^{-1} \times 2{\cdot}5\ \text{m} \\ &= 100\ \text{J} \end{aligned}$$

7. A vessel containing 50 kg of water is placed at a height of 10 m above the ground. What is the potential energy stored in water ? Take $g = 10\ \text{N kg}^{-1}$.

Solution : *Given*, m = 50 kg, $g = 10\ \text{N kg}^{-1}$, h = 10 m

$$\begin{aligned} \text{Potential energy } U &= mgh \\ &= 50 \times 10 \times 10 \\ &= 5000\ \text{J} \end{aligned}$$

8. The mass of a body is 20 kg. It is moving with a speed of $10\ \text{m s}^{-1}$. What is its kinetic energy ?

Solution : *Given*, mass (m) = 20 kg, speed (v) = $10\ \text{m s}^{-1}$

$$\begin{aligned} \text{K.E.} &= \frac{1}{2}mv^2 \\ &= \frac{1}{2} \times 20 \times (10)^2\ \text{J} \\ &= 10 \times 100\ \text{J} = 1000\ \text{J} \end{aligned}$$

9. A bullet of mass 40 g has its kinetic energy equal to 200 J. Find the speed of the bullet.

Solution : *Given*, K.E. = 200 J,

$$\text{mass } m = 40\ \text{g} = \frac{40}{1000}\ \text{kg} = 0{\cdot}04\ \text{kg}$$

From the relation K.E. = $\frac{1}{2}$ mv²,

$$\text{Speed } v = \sqrt{\frac{2\ \text{K.E.}}{m}} = \sqrt{\frac{2 \times 200}{0{\cdot}04}}$$

$$= \sqrt{100 \times 100} = 100\ \text{m s}^{-1}.$$

10. Find the increase in kinetic energy of body of mass 500 g, when its spee increases from $2\ \text{m s}^{-1}$ to $4\ \text{m s}^{-1}$.

Solution : *Given*, $m = 500\ \text{g} = \frac{500}{1000}\ \text{kg} = 0{\cdot}5$ k

$V_1 = 2\ \text{m s}^{-1}$, $V_2 = 4\ \text{m s}^{-1}$

Increase in kinetic energy

$$\begin{aligned} &= \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 \\ &= \frac{1}{2}m(v_2^2 - v_1^2) \\ &= \frac{1}{2} \times 0{\cdot}5 \times [(4)^2 - (2)^2] \\ &= \frac{1}{2} \times 0{\cdot}5 \times 12 = 3\ \text{J} \end{aligned}$$

11. A boy has to do 300 J of work in tim 0·5 minute to lift a luggage to the roo of a bus. How much power does h spend ?

Solution : *Given*, W = 300 J,

$t = 0{\cdot}5\ \text{min} = 0{\cdot}5 \times 60\ \text{s} = 30\ \text{s}$

$$\text{Power } P = \frac{\text{Work } W}{\text{Time } t} = \frac{300\ \text{J}}{30\ \text{s}} = 10\ \text{W}$$

12. An electric heater of power 3 kW is use for 1 minute. Find the energy supplied b the heater.

Solution : *Given*, Power P = 3 kW = 3000 W, time t = 1 minute = 60 s

From relation $P = \frac{W}{t}$

$$\begin{aligned} \text{Energy supplied } W &= P \times t \\ &= 3000\ \text{W} \times 60\ \text{s} \\ &= 180000\ \text{J} \end{aligned}$$

3. A pump is used to lift 100 kg of water from a well 60 m deep, in 20 s. If force of gravity on 1 kg is 10 N, find :
   (a) work done by the pump
   (b) potential energy stored in the water
   (c) power spent by the pump
   (d) power rating of the pump. State the assumption if any.

Solution : *Given*, m = 100 kg, g = 10 N kg^{-1}

h = 60 m, t = 20 s

(a) Work done by the pump

$$= \text{force} \times \text{distance moved}$$

$$= \left(100\ \text{kg} \times \frac{10\ \text{N}}{\text{kg}}\right) \times 60\ \text{m}$$

$$= 60{,}000\ \text{J}$$

(b) Potential energy stored in water

$$= mgh = 100\ \text{kg} \times \frac{10\ \text{N}}{\text{kg}} \times 60\ \text{m}$$

$$= 60000\ \text{J}$$

(c) Power of the pump

$$P = \frac{W}{t} = \frac{60000\ \text{J}}{20\ \text{s}}$$

$$= 3000\ \text{W (or 3 kW)}$$

(d) Power rating of the pump = 3 kW.

Assumption : The pump is 100% efficient.

RECAPITULATION

- Work is said to be done if the force applied on a body, moves it. If no motion takes place, no work is said to be done. Work done is zero if the motion of body is normal to the force.
- The amount of work done depends on : (1) the magnitude of the force applied (greater the force applied, greater is the work done), and (ii) the distance moved in the direction of force (greater the distance moved, greater is the work done).
- The work done by a force on a body is equal to the product of the force and the distance moved by the body in the direction of force, *i.e.*

  Work done = Force × Distance moved in the direction of force

  or $W = F \times d$
- The S.I. unit of work is joule (J), where

  1 joule (J) = 1 newton (N) × 1 metre (m).
- One joule of work is said to be done if one newton force when acts on a body, moves it by 1 metre in the direction of force.
- Another unit of work is kgf × m where 1 kgf × m = 9·8 joule (precisely).
- The energy of a body is its capacity (or ability) to do work. The energy of a body in a state is equal to the work done on the body to bring it to that state.
- The S.I. unit of energy is joule (J), whether it is potential energy or kinetic energy.
- Mechanical energy is of two kinds : potential energy and kinetic energy.
- Potential energy of a body is the energy possessed by it due to its state of rest or position. This is equal to the work done on the body to bring it to that state of rest or position.
- Potential energy can be : (i) elastic potential energy (*i.e.* the energy stored when the size or shape of a body is changed) and (ii) gravitational potential energy (*i.e.* the energy when a body is taken to a height above the ground).

- The gravitational potential energy of a body in the raised (or lifted) position depends on two factors : (1) the mass of the body (greater the mass of the body, greater is the potential energy of the body), and (ii) the height of the body above the ground (greater the height of the body, greater is its potential energy).

  It is given as P.E. (U) = mgh

  where g is the force of gravity on a mass of 1 kg. Its value is nearly 10 N kg^{-1}.
- Kinetic energy of a body is the energy possessed by it due to its motion.
- Kinetic energy of a moving body depends on two factors : (i) on the mass of the body (greater the mass of the body, greater is its kinetic energy), and (ii) on the speed of the body (more the speed of the body, higher is its kinetic energy).

  Kinetic energy K.E. (or K) = $\frac{1}{2}$ mv^2.
- It is the kinetic energy which can change into any other form of energy such as heat, light etc. Potential energy does not directly change into any other form of energy except kinetic energy when it is put to use.
- The energy exists in different forms such as mechanical, heat, light, sound, electrical, chemical, solar, nuclear etc.
- One form of energy can be changed into other useful forms of energy.
- Power is defined as the rate of doing work or the energy spent in one second *i.e.* $P = \frac{W}{T}$ or energy spent = power × time.
- Power spent by a source depends upon time for which work is done. Power spent is more if same work is done in less time.
- The S.I. unit of power is joule per second (J s^{-1}) or watt (W).

TEST YOURSELF

A. Objective Questions :

1. Write **true** or **false** for each statement :

   (a) A coolie does no work against the force of gravity while carrying a luggage on a plane road.

   (b) The energy stored in water of a dam is kinetic energy.

   (c) The energy of a flying kite is kinetic energy.

   (d) Work done by a boy depends on the time in which he does work.

   (e) Power spent by a body depends on the time for which it does work.

   Ans. True—(a), (c), (e), **False**—(b), (d)

2. Fill in the blanks :

   (a) Work is said to be done by a force only when ....

   (b) Work done = Force × ....

   (c) The energy of a body is its capacity to d ....

   (d) The S.I. unit of energy is ....

   (e) The potential energy of a body is due to it .... and kinetic energy of a body is due to its ....

   (f) Gravitational potential energy U = mass force of gravity on unit mass × ....

   (g) Kinetic energy = $\frac{1}{2}$ × mass × ....

   (h) Power P = ... / time taken.

   (i) The S.I. unit of power is ....

   (j) I H.P. = ...W

   Ans: (a) the body moves (b) distance moved in direction of force (c) work (d) joule (e) state of rest or position, state of motion (f) vertical height (g) (speed) (h) work done (i) watt (j) 746

3. Match the following :

Column A	**Column B**
(a) A stone at a height	(i) power
(b) A moving ball	(ii) joule
(c) Energy	(iii) work done in 1 sec.
(d) Power	(iv) potential energy
(e) watt	(v) kinetic energy

Ans.: (a)–(iv), (b)–(v), (c)–(ii), (d)–(iii), (e)–(i)

4. Select the correct alternative :

(a) The S.I. unit of work is

(i) second (ii) metre

(iii) joule (iv) newton.

(b) No work is done by a force if the body

(i) moves in the direction of force

(ii) does not move

(iii) moves in opposite direction

(iv) none of these

(c) Two coolies A and B do some work in time 1 minute and 2 minute respectively. The power spent is

(i) same by both coolies

(ii) is more by coolie A than by B

(iii) is less by coolie A than by B

(iv) nothing can be said.

(d) The expression of power P is

(i) $P = mgh$ (ii) $P = \frac{1}{2} mv^2$

(iii) $P = F \times d$ (iv) $P = F \times \frac{d}{t}$

(e) 1 H.P. is equal to

(i) 1 W (ii) 1 J

(iii) 764 J (iv) 746 W

(f) When a boy doubles his speed, his kinetic energy becomes

(i) half (ii) double

(iii) four times (iv) no change.

(g) A boy lifts a luggage from height 2 m to 4 m. The potential energy will become

(i) half (ii) double

(iii) one-third (iv) one-fourth.

Ans.: (a)–(iii), (b)–(ii), (c)–(ii), (d)–(iv), (e)–(iv), (f)–(iii), (g)–(ii)

B. Short/Long Answer Questions :

1. Define work.
2. When does a force perform work ?
3. State two conditions when no work is done by a force.
4. In which of the following cases is work being done :
   (a) A boy pushing a heavy rock
   (b) A boy climbing up the stairs
   (c) A coolie standing with a box on his head
   (d) A girl moving on the road.
   Ans. (b), (d)
5. A coolie is moving on a road with a luggage on his head. Does he perform work against the force of gravity? Give reason for your answer.
6. The moon is revolving around the earth in a circular path. How much work is done by the moon ?
7. Write the expression for work done by a force.
8. State the S.I. unit of work and define it.
9. State two factors on which the work done on a body depends.
10. Define the term energy.
11. State the S.I. unit of energy.
12. Define 1 joule of energy.
13. How is work related to energy ?
14. What are the two kinds of mechanical energy ?
15. What is potential energy ? State its unit.
16. Give one example of a body that has potential energy, in each of the following :
    (a) due to its position at a height,
    (b) due to its elongated stretched state.

17. State two factors on which the potential energy of a body at a certain height above the ground depends.

18. Two bodies A and B of masses 10 kg and 20 kg respectively are at the same height above the ground. Which of the two has greater potential energy ?

19. A bucket full of water is on the first floor of your house and another identical bucket with same quantity of water is kept on the second floor. Which of the two has greater potential energy ?

20. Write the expression for the gravitational potential energy explaining the meaning of the symbols used.

21. A body of mass m is moved from ground to a height h. If force of gravity on mass of 1 kg is *g* newton, find : (a) the force needed to lift the body, (b) the work done in lifting the body and (c) the potential energy stored in the body.

22. Define the term kinetic energy. Give one example of a body which possesses kinetic energy.

23. State two factors on which the kinetic energy of a moving body depends.

24. Two toy-cars A and B of masses 200 g and 500 g respectively are moving with the same speed. Which of the two has greater kinetic energy ?

25. A cyclist doubles his speed. How will his kinetic energy change : increase, decrease or remain the same ?

26. Write the expression for the kinetic energy of a body explaining the meaning of the symbols used.

27. A ball of mass m is moving with a speed v. What is its kinetic energy ?

28. Name the form of energy stored in a wound up spring of a watch.

29. Can a body possess energy even when it is not in motion ? Explain your answer with an example.

30. Name the type of energy (kinetic or potential) possessed by the following :
    (a) A moving cricket ball.
    (b) A stone at rest on the top of a building.
    (c) A compressed spring.
    (d) A moving bus.
    (e) A bullet fired from a gun.
    (f) Water flowing in a river.
    (g) A stretched rubber band.

31. Give an example to show the conversion o potential energy to kinetic energy when put i use.

32. State the energy changes that occur in a watc spring while it unwinds.

33. Give reasons for the following :
    (a) No work is done if a man is pushing agains a wall.
    (b) Hammer drives a nail into the wood onl when it is lifted up and then struck.
    (c) A horse and a dog are running with the sam speed. Which one of them has more kinetic energy than the other ?
    (d) A teacher moving around in the class is doing work but a child standing and reading a book is not doing any work.

34. State the energy changes in the following while in use.
    (a) An electric bulb
    (b) An electric oven
    (c) A loud speaker
    (d) A microphone
    (e) An electric motor

C. Numericals :

1. A force of 30 N acts on a body and moves i through a distance of 5 m in the direction of force Calculate the work done by the force.
   Ans. 150 J

2. A man lifts a mass of 20 kg to a height of 2·5 m Assuming that the force of gravity on 1 kg mas is 10 N, find the work done by the man.
   Ans. 500 J

3. A body when acted upon by a force of 10 kg moves to a distance 0·5 m in the direction o force. Find the work done by the force. Ta 1 kgf = 10 N.
   Ans. 50 J

4. Two bodies of same masses are placed at height h and 2 h. Compare their gravitational potential energy.

Ans. 1 : 2

5. Find the gravitational potential energy of 2·5 kg mass kept at a height of 15 m above the ground. The force of gravity on mass 1 kg is 10 N.

Ans. 375 J

6. The gravitational potential energy stored in a box of weight 150 kgf is $1\cdot5 \times 10^4$ J. Find the height of the box. Take 1 kgf = 10 N.

Ans. 10 m

7. The potential energy of a body of mass 0·5 kg increases by 100 J when it is taken to the top of a tower from the ground. If force of gravity on 1 kg is 10 N, what is the height of the tower ?

Ans. 20 m

8. A body of mass 60 kg is moving with a speed 50 m s^{-1}. Find its kinetic energy.

Ans. $7\cdot5 \times 10^4$ J

9. A truck of mass 1000 kg, increases its speed from 36 km h^{-1} to 72 km h^{-1}. Find the increase in its kinetic energy. **Ans.** $1\cdot5 \times 10^5$ J

10. A car is moving with a speed of 15 km h^{-1} and another identical car is moving with a speed of 30 km h^{-1}. Compare their kinetic energy.

Ans. 1 : 4

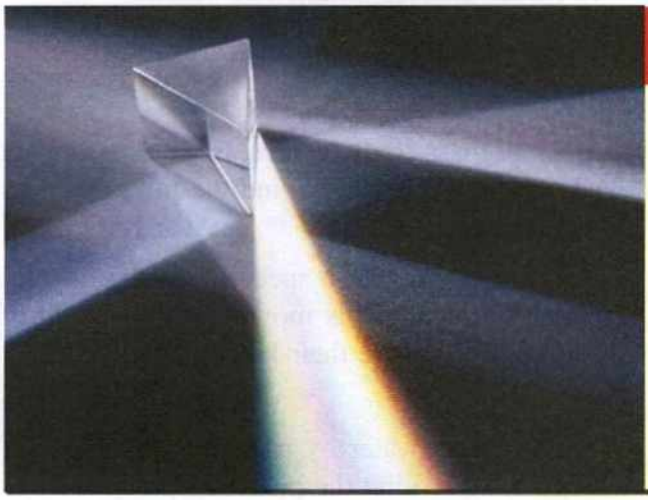
11. A pump raises water by spending 4×10^5 J of energy in 10 s. Find the power of pump.

Ans. 4×10^4 W

12. It takes 20 s for a girl A to climb up the stairs while girl B takes 15 s for the same job. Compare : (i) the work done and (ii) the power spent by them. **Ans.** (i) 1 : 1 (ii) 3 : 4

Project Work

Working in small groups (say, 5 students in each group), make a list of activities which they have seen with transformation of energy from one form to another, stating these changes.



5

Light Energy

Theme : An object lying at the bottom of a vessel filled with water usually appear to be at different depth than it actually is. This is due to bending of light rays when it travels from water to air. This phenomenon is called refraction. Light bends when it passes obliquely from one medium to the other. Due to refraction, a mirage is observed on a hot sandy desert. Atmosphere also refract the rays coming from the sun. This causes advanced sunrise and delayed sunset. Previous learning emphasized on reflection of light by a plane mirror. How images are formed by a curved (concave) mirror is now dealt upon along with rules used to construct ray diagrams.

In this chapter you will learn to

- define refraction;
- discuss examples of refraction;
- describe a spherical mirror;
- describe a concave and a convex mirror;
- define the terms, principal axis, centre and radius of curvature, focus and focal length for a spherical mirror;
- describe rules for making ray diagrams for spherical mirror;
- distinguish between real and virtual images;
- use a ray diagram to show formation of a real image by a spherical mirror;
- describe the characteristics of a real image formed by a spherical mirror;
- describe dispersion of white light by a prism into constituent colours;
- display a scientific attitude while making models;
- show a creative mind set while studying real world optical phenomena;
- Communicate logical reasoning and explanations effectively using scientific terms.

LEARNING OBJECTIVES

- Revising previous concepts learnt by children
- Building on children's previous learning
- Demonstrating the phenomenon of refraction
- Engaging children in pairs, individually or small groups in activities related to refraction
- Explaining refraction with suitable examples
- Demonstrating how concave and convex mirrors work
- Representing of concave and convex mirrors through diagrams
- Explaining the terms i.e. Focus, principal axis, centre of curvature, radius of curvature with the help of diagrams to children
- Engaging children in activities related to image formation by a concave mirror using ray diagram.
- Explaining real and virtual images
- Demonstrating the dispersion of white light into component colours

KNOWING CONCEPTS

- Refraction :
  - Definition
  - Examples of refraction
- Curved mirrors :
  - Convex
  - Concave
  - Reflecting surface (Convex and concave)
  - Uses of curved mirrors
  - Terms related to curved mirrors — Focus, principal axis, centre of curvature, radius of curvature
  - Rules for making ray diagrams of spherical mirrors
  - Real and virtual images
  - Ray diagrams with curved mirrors where real images are formed
- Dispersion of white light into constituent colours.

SPEED OF LIGHT IN DIFFERENT MEDIA

In class VII, we have read that light avels faster in air than in water or glass. The speed of light in air is 3×10^8 m s^{-1}, in water it is $2{\cdot}25 \times 10^8$ m s^{-1} and in glass it is only 2×10^8 m s^{-1}. In the language of Physics, we say that glass is optically denser than water and water is optically denser than air or air is optically rarer than both water and glass.

Thus, a medium is said to be denser if the speed of light in it decreases, while it is said to be rarer if the speed of light in it increases. But in no medium, it can be more than 3×10^8 m s^{-1}.

REFRACTION OF LIGHT

Light travels in a straight line path in a medium. But when a ray of light travelling in one transparent medium falls obliquely on the surface of another transparent medium, it travels in the other medium in a direction different from its initial path.

The change in direction of path of light when it passes from one optically transparent medium to another, is called ***refraction of light****.*

It has been experimentally observed that

(1) When a ray of light travels from a rarer to a denser medium (say, from air to water or from air to glass), it bends towards the normal as shown in Fig. 5.1.

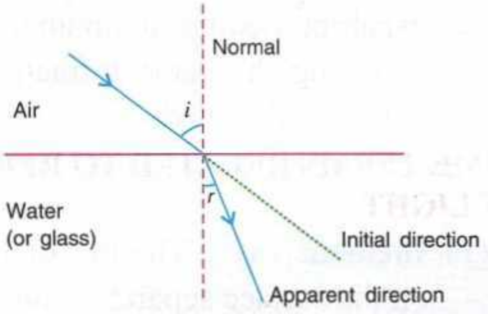


Fig. 5.1 A ray travelling from rarer to denser medium bends towards the normal

(2) When a ray of light travels from a denser to a rarer medium (say, from water to air or from glass to air), it bends away from the normal as shown in Fig. 5.2.

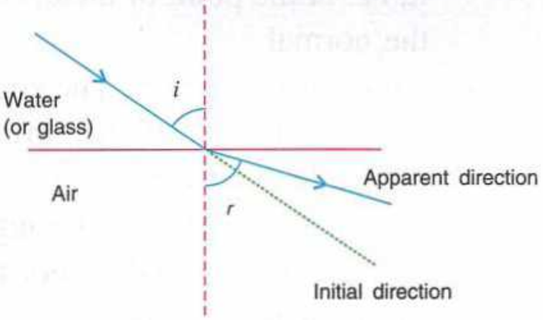


Fig. 5.2 A ray travelling from denser to rarer medium bends away from normal

(3) When a ray of light falls normally on the surface separating the two media, it passes undeviated (*i.e.*, along the same path) as shown in Fig. 5.3.

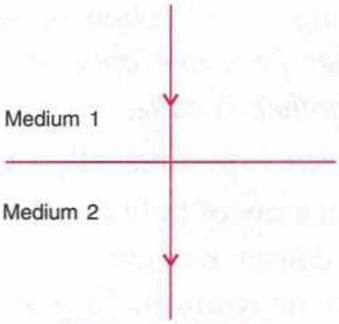


Fig. 5.3 A ray falling normally on the surface separating the two media, passes undeviated

Note : When a ray of light passes from one transparent medium to another transparent medium having the same refractive index, it also remains undeviated.

SOME TERMS RELATED TO REFRACTION OF LIGHT

1. **Incident ray :** The ray of light falling on the surface separating the two media, is called the **incident ray**.
2. **Refracted ray :** The ray of light travelling in the other medium in the changed direction, is called the **refracted ray**.
3. **Normal :** The perpendicular drawn on the surface separating the two media, at the point where the incident ray strikes it, *i.e.* at the point of incidence, is called the normal.
4. **Angle of incidence :** The angle between the incident ray and the normal is called the angle of incidence '*i*'
5. **Angle of refraction :** The angle between the refracted ray and the normal is called the angle of refraction '*r*'.

Fig. 5.4 shows a light ray AO passing from a rarer medium (air) into a denser medium (glass). XY is the surface separating the two media. AO is the incident ray, OB is the refracted ray. NOM is the normal at the point of incidence O, ∠AON is the angle of incidence $\angle i$ and ∠BOM is the angle of refraction $\angle r$. It is clear from the diagram that when the ray of light travels from air to glass, it bends towards the normal *i.e.*, instead of moving along its earlier direction shown by the dotted line OC, the ray bends towards the normal and moves along OB (*i.e.* $\angle r < \angle i$).

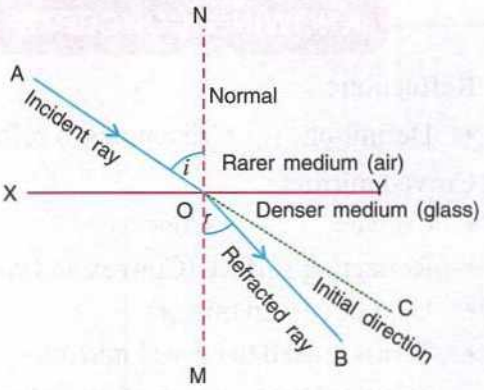


Fig. 5.4 Light ray in going from a rarer to a denser medium bends towards the normal

Fig. 5.5 shows a light ray AO passin from a denser medium (glass) to a rare medium (air). XY is the surface separating th two media. It is clear from the diagram tha the incident ray AO bends away from th normal and is refracted as OB (*i.e.* $\angle r > \angle i$).

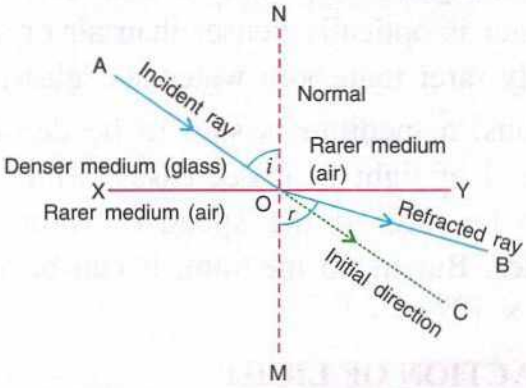


Fig. 5.5 Light ray going from a denser into a rarer medium bends away from the normal

LAWS OF REFRACTION (SNELL'S LAW)

Refraction of light obeys the followin two laws also known as Snell's laws o refraction.

1. The incident ray, the normal at the point of incidence and the refracted ray, all lie in the same plane.
2. For a given pair of media and given colour of light, the ratio of the sine of angle of incidence i to the sine of angle of refraction r is a constant *i.e.*,

$$\frac{\sin i}{\sin r} = \text{constant}$$

This constant is denoted by the symbol μ read as mew).

It is known as the refractive index of the second medium with respect to the first medium. It is given as

$$\mu = \frac{\text{Speed of light in first medium}}{\text{Speed of light in second medium}}$$

For example, if a ray of light travels from air to water, then the constant $\mu = \frac{\sin i}{\sin r}$ is the efractive index of water with respect to air.

It is given as

$$\mu = \frac{\sin i}{\sin r} = \frac{3 \times 10^8 \text{ m s}^{-1}}{2{\cdot}25 \times 10^8 \text{ m s}^{-1}} = \frac{4}{3} \text{ (or } 1{\cdot}33)$$

Similarly, if a ray of light travels from air to glass, then

$$\mu = \frac{\sin i}{\sin r} = \frac{3 \times 10^8 \text{ m s}^{-1}}{2 \times 10^8 \text{ m s}^{-1}} = 1{\cdot}5.$$

Note : The refractive index of air is 1. No medium can have refractive index less than 1.

EFFECTS OF REFRACTION

(1) The depth of water in a vessel when seen from air appears to be less

Consider a vessel containing water as shown in Fig. 5.6. Its real depth is AO. But when seen obliquely *i.e.* at an angle above O from air, its depth appears to be AI which is less than AO.

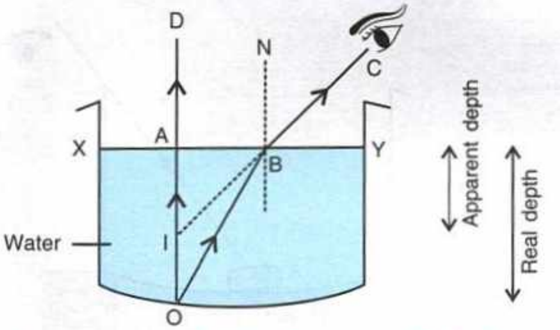


Fig. 5.6 Apparent depth of a vessel full of water

Reason : A ray of light OA from the point O at the bottom of vessel is incident normally on the water-air, surface XY. It travels straight along AD in air. Another ray OB incident from water on the surface XY, when passes to air, bends away from the normal BN, and goes along the path BC. The two refracted rays AO and BC when produced back, meet at I. Thus I is the image of O.

Thus to the observer in air, the depth of vessel appears to be AI instead of AO, due to refraction of light from water to air. The apparent depth AI is less than the real depth AO.

Do You Know ?

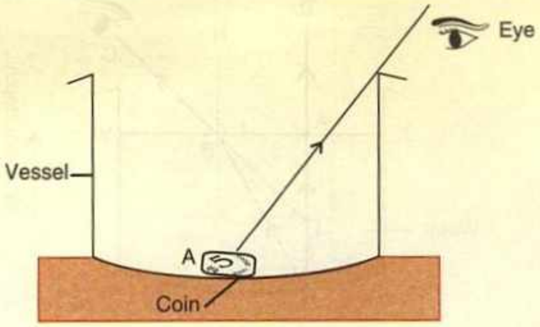
Real depth / Apparent depth = Refractive Index.

Since, refractive index of water is 4/3, so the apparent depth is $\frac{3}{4}$th the real depth.

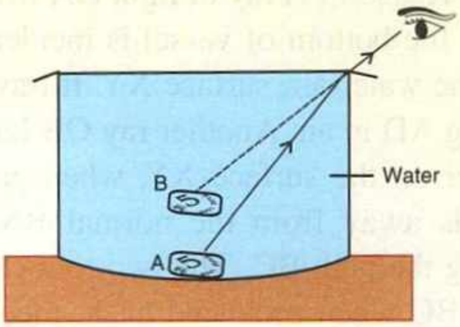
The change in depth due to refraction can be demonstrated by the following activities.

ACTIVITY 1

(1) Take a coin and an empty glass vessel. Place the coin in the vessel. Put the vessel on a table and step back till the coin is just out of your view. It is hidden from your eye by the edge of the vessel as shown in Fig. 5.7(a).



(a) Coin at the bottom not seen by the eye



(b) Coin seen when water is added to the vessel

Fig. 5.7 A coin in water appears to be raised

(2) Keep your eye in this position and ask your friend to pour water gradually in the vessel. You will find that when there is sufficient water in the vessel, the coin becomes visible because then, it appears to be slightly raised from position A to position B as shown in Fig. 5.7(b).

Explanation : In Fig. 5.7(a), when there is no water in the vessel, the coin is not visible because the ray of light from the coin travelling in a straight line does not reach the eye.

In Fig. 5.7(b), when water is poured in the vessel, the coin becomes visible because the ray of light from the point A of the coin, travelling in a straight line changes its direction (*i.e.* it bends) at the surface of water and reaches the eye. Thus, the light ray bends as it leaves water and enters air. The ray now appears to come from a point B instead of A. In other words, the coin appears to be raised from position A to position B.

ACTIVITY 2

(1) Take an empty beaker and a pencil. Place the pencil ABC obliquely in the beaker and look at it from the side. It appears straight as shown in Fig. 5.8(a).

(2) Now pour water in the beaker up to its brim. You will notice that now the pencil appears to be bent as ABD at the surface of water as shown in Fig. 5.8(b).

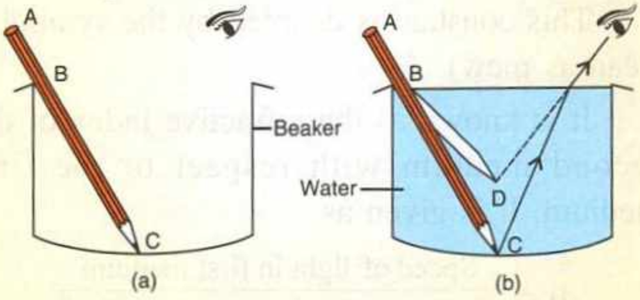


Fig. 5.8 The pencil in water appears to be bent

Explanation : The ray of light coming from the tip C of the pencil bends at the surface of water as it enters in air and it appears to be coming from the point D. In other words, it is due to refraction of light from water to air that the pencil ABC appears as ABD.

From the above, we conclude that when a light ray passes from one transparent medium to another, it bends. The direction in which light ray bends, depends upon whether light travels from a rarer medium to a denser medium or from a denser medium to a rarer medium.

EARLY SUNRISE AND LATE SUNSET

Before sunrise and after sunset, the upper atmospheric layers are warmer than the layers near the earth's surface. So the atmospheric layers near the earth's surface are denser than those above. When the sun is just below the horizon, the light from sun, while coming towards the earth, suffers refraction from a rarer to a denser layer and so it bends towards the normal at each refraction. Due to continuous bending of light rays at different sucessive layers, the sun can e seen even when its actual position is just elow the horizon as shown in Fig. 5.9. As a esult, sun is seen in advance, a few minutes efore it rises above the horizon in the morning.

Similarly, in the evening, sun is seen elayed by 3 to 4 minutes longer above the orizon after the sun set.

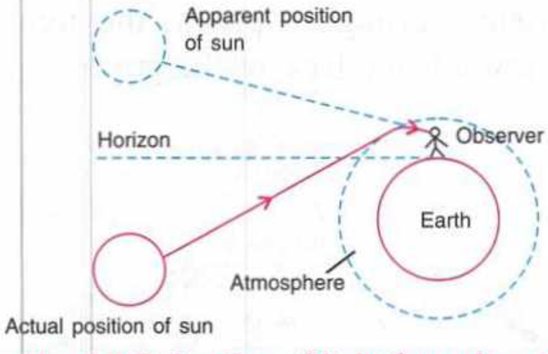


Fig. 5.9 Refraction of light from the sun in the atmosphere

MIRAGE IN A DESERT

Sometimes, in deserts, an inverted image f a tree is seen which gives a false impression f water under the tree. This is called a mirage.

The cause of mirage is the refraction of ight. In a desert, the sand becomes very hot during day-time and it rapidly heats the layers of air in contact with it. Therefore, the layers of air near the ground are warmer (and hence rarer) than the upper layers. In other words, the successive upper layers are denser than hose below them.

When a ray of light from sun after reflection from the top of a tree travels from a denser to a rarer layer, it bends away from the normal. As a result, in refraction at the surface of separation of successive layers, each time the angle of refraction increases and the angle of incidence of ray going from denser medium to rarer medium also increases, till a stage is reached when the angle of refraction becomes 90°. On further increase in angle of incidence, the ray of light travelling from a denser to a rarer layer, is not refracted, but it suffers reflection. This reflected ray now travels from the rarer to the denser layer, so it bends towards the normal, at each refraction. On reaching the eye of the observer, an inverted image of the tree is seen. Thus it gives a false impression of a pool of water in front of the tree (Fig. 5.10).

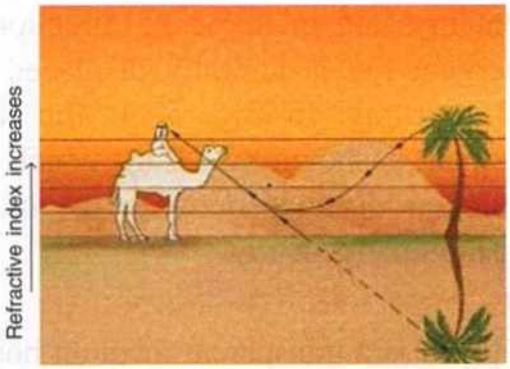


Fig. 5.10 Mirage in desert

REFRACTION OF LIGHT THROUGH A RECTANGULAR GLASS BLOCK

Fig. 5.11 shows a rectangular glass block PQRS. A light ray AB falls on the surface PQ. NBM is the normal at the point of incidence B to the surface PQ. At the surface PQ, the ray AB enters from air to glass, so it bends towards the normal NBM and travels along BC. At the surface RS, another refraction

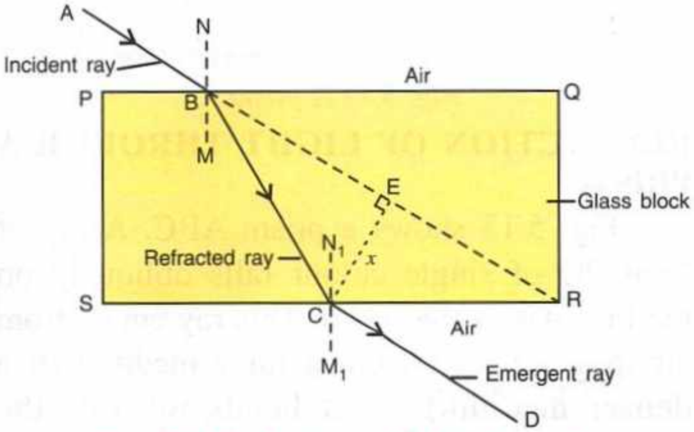


Fig. 5.11 Refraction of light through a rectangular glass block

occurs. N_1CM_1 is the normal at the point of incidence C to the surface RS.

The ray BC now enters from glass to air, so it bends away from the normal N_1CM_1 and travels along CD. The ray AB is called the incident ray, BC the refracted ray, and CD the emergent ray.

The emergent ray CD is parallel to the incident ray AB. Thus, both the incident and emergent rays are in the same direction, but the emergent ray is laterally displaced from the incident ray. In Fig. 5.11, the lateral displacement is shown by CE (x) which is the perpendicular distance between the incident ray and the emergent ray.

PRISM

A prism is a transparent medium bounded by five plane surfaces with a triangular cross section. Two opposite surfaces of a prism are identical and parallel triangles, while the other three surfaces are rectangular and inclined on each other as shown in Fig. 5.12.

In symbol form, it is represented by the triangle ABC.

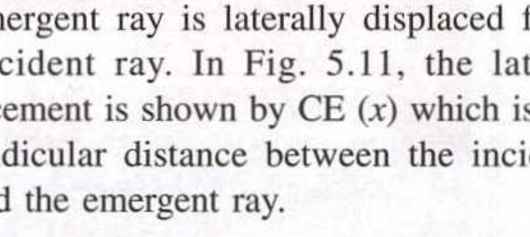


Fig. 5.12 A prism

REFRACTION OF LIGHT THROUGH A PRISM

Fig. 5.13 shows a prism ABC. A ray of light PQ of single colour falls obliquely on the face AB of the prism. This ray enters from air to glass (*i.e.*, from a rarer medium to a denser medium), so it bends towards the normal NQM to the face AB and travels along QR. At the face AC of the prism, another refraction occurs. The ray QR now enter from glass to air (*i.e.*, from a denser mediu to a rarer medium), so it bends away from th normal N′RM′ to the face AC and travel along RS. Thus, for the incident ray PQ, th refracted ray inside the prism is QR and th emergent ray outside the prism is RS. Thu on passing through a prism, the light ra bends towards the base of the prism.

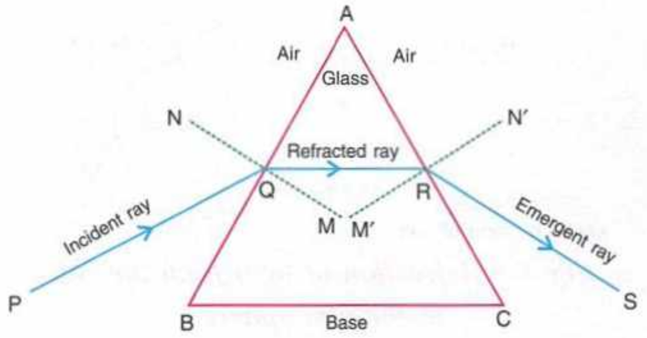


Fig. 5.13 Refraction of light through a prism

Do You Know ?

The emergent ray through a prism is not in direction of the incident ray, but it bends towards the base of the prism because in a prism, refraction occurs at two inclined surfaces. On the other hand, in a rectangular glass block, refraction of light occurs at two parallel surfaces, so the emergent ray is in direction of the incident ray, but laterally displaced.

DISPERSION OF WHITE LIGHT

Newton allowed white light from the su to enter a dark room through a small apertur in a window and placed a glass prism in th path of light rays. The light coming out of th

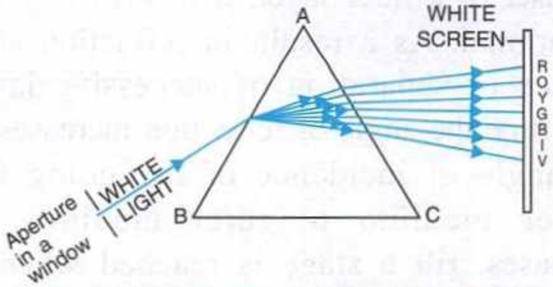


Fig. 5.14 Dispersion of light by a prism

rism was received on a white screen. On the creen, a coloured patch like a rainbow was ound as shown in Fig. 5.14. This patch was ermed as spectrum.

Starting from the side of the base of the rism, the colours in the spectrum on the creen are in the following order :

Violet (V), Indigo (I), Blue (B), reen (G), Yellow (Y), Orange (O), and ed (R). The order of colours in the spectrum an easily be remembered by the word IBGYOR. Thus, spectrum is the coloured and obtained on a screen on passing the hite light through a prism.

From the above experiment, Newton oncluded that white light is a mixture of even colours*.

Note that the prism does not produce olours, but it simply separates the colours hich already exist in white light.

Thus, if white light is passed through a rism, it splits into different colours. This is alled **dispersion of light**.

AUSE OF DISPERSION

In class VII, you have read that white ight of sun is composed of seven prominent olours, namely, violet, indigo, blue, green, ellow, orange and red. The speed of light of ll colours is same in air or vacuum, but it iffers in a transparent medium such as glass r water. In a transparent medium (such as lass or water), the speed of violet light is inimum and of red light is maximum. herefore, the refractive index μ of a ransparent medium is also different for lights f different colours.

Since, refractive index

$$= \frac{\text{speed of light in air}}{\text{speed of light in medium}},$$

the refractive index of a medium is maximum for the violet light and minimum for the red light. Therefore, when white light enters a prism, it splits into its constituent colours while refraction at the first surface of the prism. These colours get farther separated from each other on refraction at the second surface of prism.

Do You Know ?

In rainy season, sometimes after the rains, you see a rainbow in the sky, just opposite to the sun. It is due to dispersion of white light of sun by the rain drops which behave like small prisms.

The dispersion of white light can be demonstrated by the following activities.

ACTIVITY 3

To see dispersion of white light.

Take a thick cardboard sheet. Make a small hole in it. Allow the sun light to pass through it in a dark room. Place a prism in the path of sun light coming through the hole and then a white screen behind the prism as shown in Fig. 5.15.

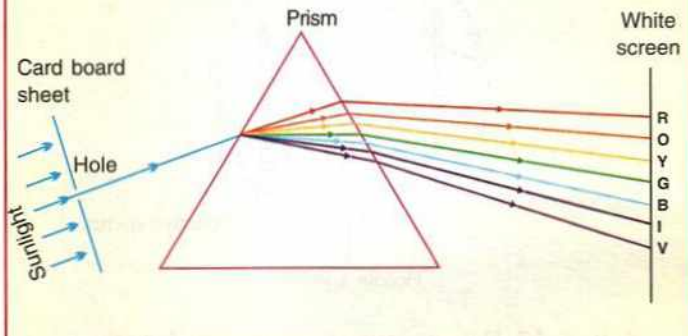


Fig. 5.15 Formation of spectrum by a prism

You will see that a band of colours is obtained on the screen with colours violet, indigo, blue, green, yellow, orange and red in order from the base of the prism upwards as shown in Fig. 5.15.

---

* *More precisely there are a number of colours mixed ith one another but the prominent colours are seven.*

ACTIVITY 4

Take a circular disc of cardboard and divide it into seven sectors. Then paint the sectors with the seven colours (violet, indigo, blue, green, yellow, orange and red) in order, as shown in Fig. 5.16.

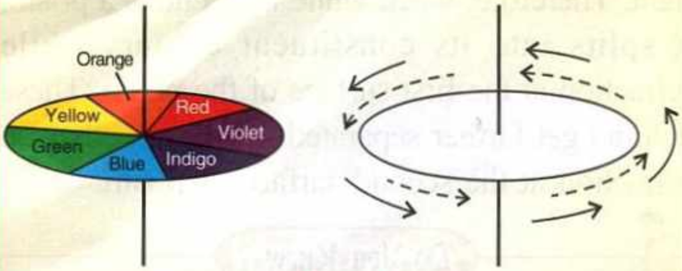


Fig. 5.16 A colour disc on rotation produces white colour

Rotate the disc rapidly. You will notice that the disc appears white.

This shows that seven colours violet, indigo, blue, green, yellow, orange and red being the constituent colours of white light, when combined produce the white colour effect.

SPHERICAL MIRRORS

Spherical mirrors are made by silvering the part AB of the hollow glass sphere as shown in Fig. 5.17.

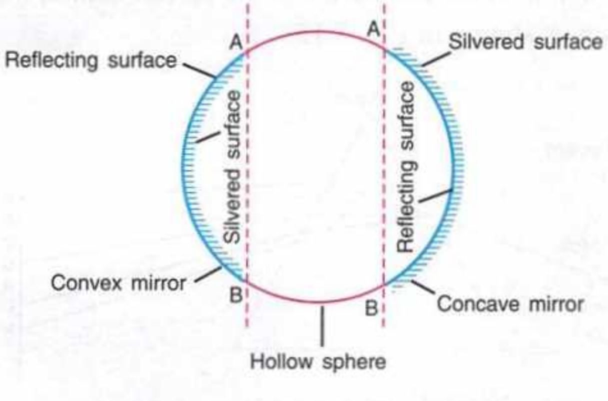


Fig. 5.17 Formation of a spherical mirror

The surface on which silvering is done, is called the silvered surface and the reflection of light takes place from the other surface which is called the reflecting surface.

Kinds of spherical mirrors

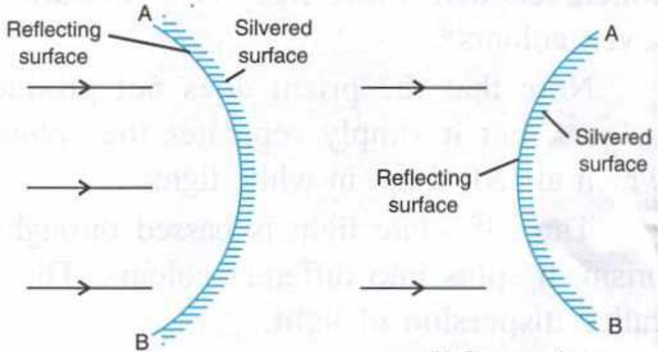
There are two kinds of spherical mirrors

(i) Concave mirror and

(ii) Convex mirror.

(i) Concave mirror : A concave mirror i made by silvering on the outer surfac of a hollow sphere such that th reflection takes place from the insid hollow (or concave) surface as show in Fig. 5.18 (a).

(ii) Convex mirror : A convex mirror i made by silvering on the inner surfac such that the reflection takes place fro the outer convexed (or bulged) surfac as shown in Fig. 5.18(b).



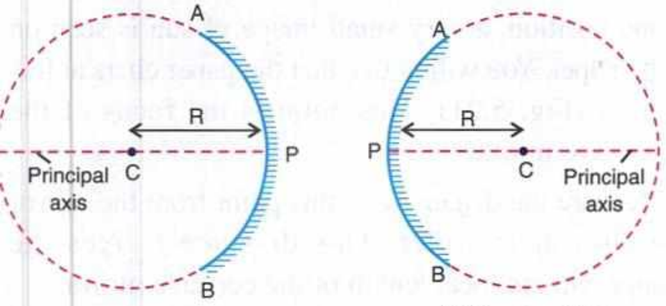
(a) Concave mirror (b) Convex mirror

Fig. 5.18 Concave and convex mirrors

SOME TERMS RELATED TO A SPHERICAL MIRROR

(1) Pole : The geometric centre of th spherical surface of the mirror i called the pole of the mirror. It is th mid point of the aperture AB o the mirror. It is represented by th symbol P in Fig. 5.19.

(2) Centre of curvature : The centre o curvature of a mirror is the centre o the sphere of which the mirror is part. It is represented by the symbol C in Fig. 5.19.



(a) Concave mirror (b) Convex mirror

Fig. 5.19 Pole, centre of curvature, radius of curvature and principal axis of a spherical mirror

Note : The normal at any point of the irror passes through the centre of curvature. other words, a line joining the centre of urvature to any point of the mirror, is normal n the mirror at that point.

(3) **Radius of curvature :** The radius of curvature of a mirror is the radius of the sphere of which the mirror is a part. Thus, it is the distance of the centre of curvature C from any point of the surface of mirror. In Fig. 5.19, this is represented by the symbol R.

(4) **Principal axis :** It is a straight line joining the pole of the mirror to its centre of curvature. In Fig. 5.19, the line PC represents the principal axis. It may extend on either side of the pole.

OCUS AND FOCAL LENGTH

In class VII, you have learnt about flection of light at a plane mirror. When a y of light is reflected from a plane mirror, it beys the following two laws of reflection :

(i) The angle of incidence *i* is equal to the angle of reflection *r*.

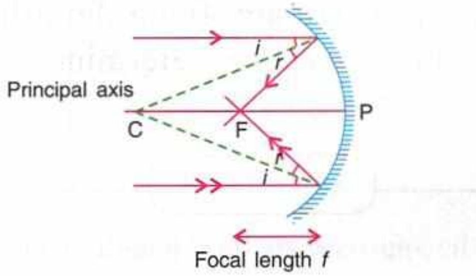
(ii) The incident ray, the reflected ray and the normal, all lie in the same plane.

The above laws of reflection of light hold rue for the spherical mirrors as well.

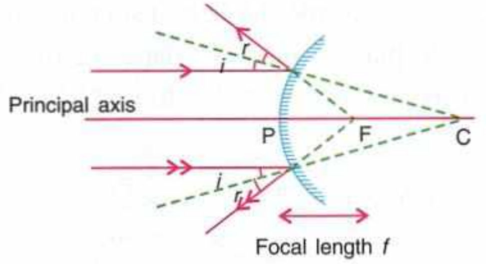
Focus : Fig. 5.20 shows the rays of light falling on a spherical mirror parallel to its principal axis. These rays are reflected by the mirror obeying the laws of reflection (*i.e.*, angle of incidence *i* = angle of reflection *r*). The normal at the point of incidence is obtained by joining this point to the centre of curvature C. The reflected rays are not parallel to each other, but they are converging towards a point in a concave mirror, while diverging from a point in a convex mirror.

In case of a concave mirror, the reflected rays meet at point F on the principal axis [Fig. 5.20(a)]. This point is called the focus of the concave mirror.

In case of a convex mirror [Fig. 5.20(b)], the reflected rays do not meet at any point, but they appear to come from a point F on the principal axis, behind the mirror. This point is called the focus of the convex mirror.



(a) Concave mirror



(b) Convex mirror

Fig. 5.20 Focus and focal length of a spherical mirror

The focus of a concave mirror is a point on the principal axis at which the light rays *incident parallel to the principal axis meet (converge) after reflection from the mirror.*

The focus of a convex mirror is a point on its principal axis at which the light rays incident parallel to the principal axis, appear to meet after reflection from the mirror.

The focus is represented by the letter F.

Note : The focus of a concave mirror is real, while that of a convex mirror is virtual.

Focal length : *The distance of the focus from the pole of the mirror is called the focal length of the mirror.* In Fig.5.20, the focal length of mirror is marked by the distance PF. Thus,

In Fig. 5.20, focal length f = PF.

It can be proved (by simple geometry) that

$$\text{Focal length} = \frac{1}{2} \times \text{Radius of curvature}$$

or Radius of curvature = 2 × Focal length.

The approximate focal length of a concave mirror can be determined by the following simple activity.

ACTIVITY 5

To find the approximate focal length of a concave mirror

Take the concave mirror and hold it such that it faces the sun. Now place a piece of paper in front of it and adjust its distance from the mirror such that at one position, a very small image of sun is seen on the paper. You will notice that the paper chars at this point (Fig. 5.21). This point is the focus of the concave mirror.

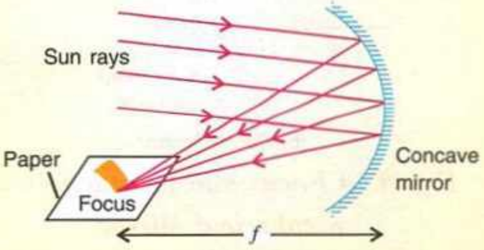


Fig. 5.21 Determination of approximate focal length of concave mirror

Measure the distance f of this point from the mirror with a metre ruler. This distance f gives the approximate focal length of the concave mirror.

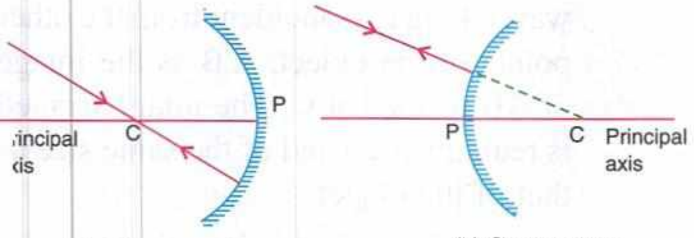
RULES FOR MAKING RAY DIAGRAM IN A SPHERICAL MIRROR

1. The object is kept in front of th reflecting surface on its left side.
2. The object is always kept on th principal axis such that it i perpendicular to the principal axis an its foot touches the principal axis.
3. For constructing a ray diagram, take a least two rays of convenience whos paths can be traced after reflection.

To construct the image of an object du to reflection by a spherical mirror, any tw of the following three rays can be draw according to our convenience.

Convenient rays :

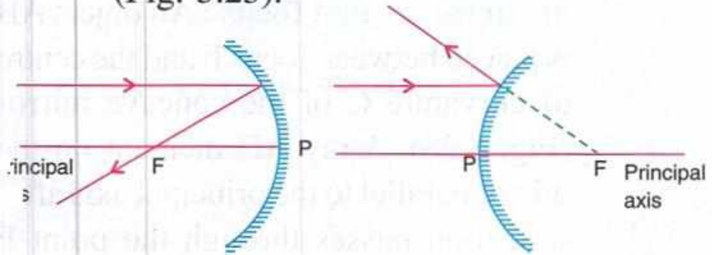
(i) **A ray passing through the centre o curvature is reflected along its ow path :** A line joining the centre o curvature to any point on the surfac of mirror is always normal to it. Thus a ray passing through the centre o curvature is incident normally on th spherical mirror. Its angle of incidenc is zero, therefore, the angle o reflection is also zero. It means tha the ray gets reflected back along it own path (Fig. 5.22).



(a) Concave mirror (b) Convex mirror

Fig. 5.22 A ray passing through the centre of curvature is reflected along its own path

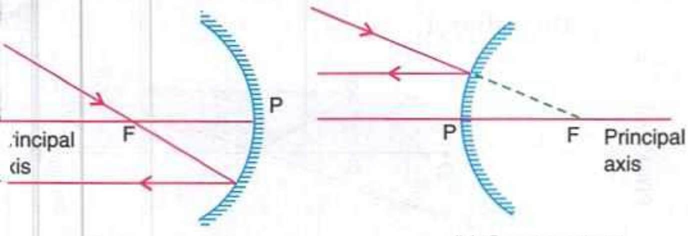
(ii) A ray parallel to the principal axis : A ray of light incident parallel to the principal axis, after reflection passes through the focus in case of a concave mirror or appears to come from the focus in case of a convex mirror (Fig. 5.23).



(a) Concave mirror (b) Convex mirror

Fig. 5.23 A ray parallel to the principal axis after reflection either passes or appears to pass through focus

(iii) A ray passing through the focus : A ray passing through the focus in case of a concave mirror or appearing to pass through the focus in case of a convex mirror, gets reflected parallel to the principal axis (Fi.g 5.24).



(a) Concave mirror (b) Convex mirror

Fig. 5.24 A ray passing through the focus or ppearing to pass through the focus, gets reflected parallel to the principal axis

To construct the image formed by a mirror, we take at least two rays incident on the mirror from a given point of the object. The point where the rays after reflection from the mirror, meet or appear to meet, gives the image of that point of the object.

REAL AND VIRTUAL IMAGE

If the reflected rays actually meet at a point, the image is real, but if the reflected rays appear to meet at a point when produced backwards, the image is virtual. A real image can be obtained on a screen, but a virtual image cannot be taken on a screen. A real image is inverted, but a virtual image is erect.

Distinction between real and virtual images

Real Image	Virtual Image
1. A real image is formed when the reflected rays actually meet at a point.	1. A virtual image is formed when the reflected rays meet on producing them backwards.
2. It is inverted.	2. It is erect or upright.
3. It can be obtained on a screen.	3. It cannot be obtained on a screen.

IMAGES FORMED BY A CONCAVE MIRROR

1. **When an object is at infinity :** When an object is at infinity, the image is formed at the focus. It is a real, inverted and highly diminished image (Fig. 5.25)

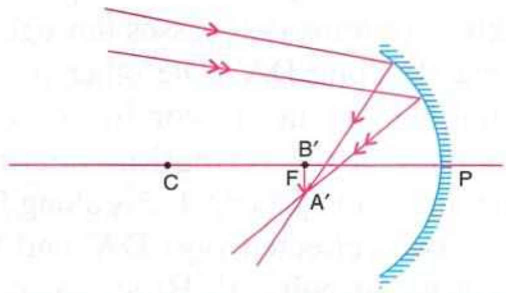


Fig. 5.25 A real, inverted and highly diminished image is formed when the object is at infinity

2. **When an object is beyond the centre of curvature :** An object AB is placed beyond the centre of curvature C of the concave mirror (Fig. 5.26). A ray AD is incident on the mirror parallel to the principal axis. This ray after reflection passes through the focus F along DA′. The other ray AE passing through the centre of curvature C after reflection retraces its path EA (*i.e.*, it gets reflected along EA). The two reflected rays DA' and EA intersect at A'. Thus, A' is the real image of the point A. When we take rays incident from other points of the object, we will find that A'B' is the image of AB which is between C and F. The image formed is real, inverted and smaller in size than the object.

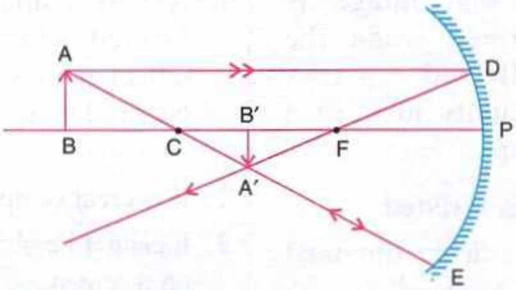


Fig. 5.26 A real, inverted and smaller image is formed between centre of curvature and focus

3. **When an object is at the centre of curvature :** An object AB is placed at the centre of curvature C of the concave mirror (Fig. 5.27). A ray AD incident on the mirror parallel to its principal axis after reflection passes through the focus F along DA'. The other ray AE incident on the mirror through the focus F after reflection becomes parallel to the principal axis along EA'. The two reflected rays DA' and EA' intersect at point A'. Hence, A' is the real image of the point A. In the same way, taking rays incident from the othe points of the object, A'B' is the imag of AB formed at C. The image forme is real, inverted and of the same size a that of the object.

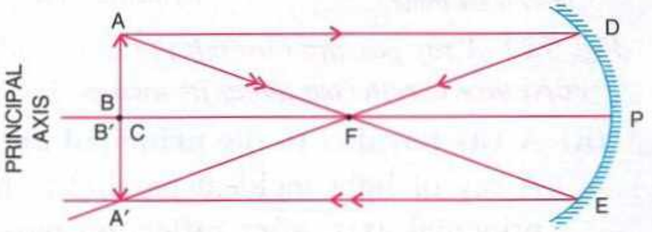


Fig. 5.27 A real, inverted image of the same size is formed at the centre of curvature

4. **When an object is between the centre of curvature and focus :** An object A is placed between focus F and the centr of curvature C of the concave mirro (Fig. 5.28). A ray AD incident on th mirror parallel to the principal axis afte reflection passes through the point along DA'. The other ray AE passin through the focus F after reflectio becomes parallel to the principal axi along EA'. The two reflected rays D and EA' intersect at A'. Thus, A' is th real image of A. In a similar way, takin rays incident from other points of th object, A'B' is the image of AB forme beyond C. The image thus formed i real, inverted and of bigger size tha the object.

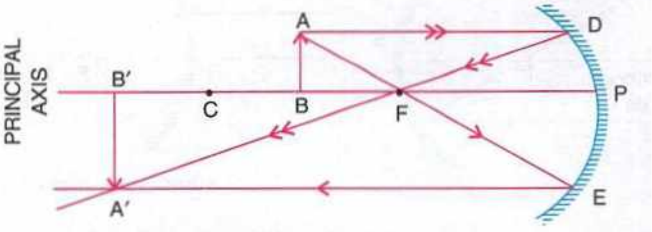


Fig. 5.28 A real, inverted and magnified image is formed beyond the centre of curvature

5. When an object is at the focus : When an object is at the focus, the image formed is at infinity. It is real, inverted and highly magnified (Fig. 5.29).

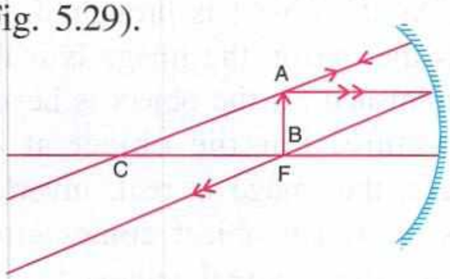


Fig. 5.29 A real, inverted and highly magnified image is formed at infinity

6. When an object is between the focus and pole : An object AB is placed between the pole P and focus F of a concave mirror (Fig. 5.30). A ray AD incident on the mirror parallel to the principal axis after reflection passes through the focus F along DF. The other ray AE passing through the centre of curvature C of the mirror after reflection retraces its path (*i.e.*, it gets reflected as EC). The two reflected rays DF and EC do not actually intersect, but they simply appear to diverge from a point A' behind the mirror. This is shown by the dotted lines. Thus, A' is the virtual image of A. In a similar way, taking rays incident from other points of the object, A'B' is the image of AB formed behind the mirror. The image formed is virtual, erect and of size bigger than the object.

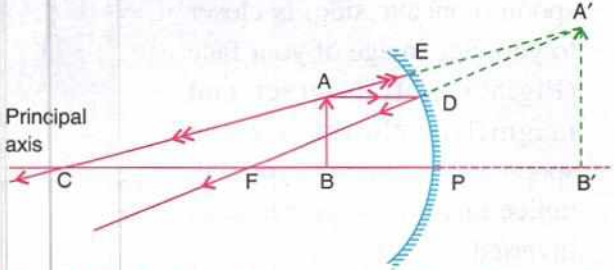


Fig. 5.30 A virtual, erect and bigger image is formed behind the mirror

Thus a concave mirror forms real as well as virtual images. The image is virtual if the object is very close to the mirror before its focus. For the object at focus or beyond it, the image is real. The virtual image is always magnified for each position of object between the pole and focus of mirror. The real image is magnified if the object is at focus or between focus and centre of curvature. It is of same size when object is at centre of curvature. But it is diminished when object is beyond centre of curvature.

Do You Know ?

The image formed by a mirror (both plane mirror and spherical mirror) shows lateral inversion (*i.e.*, the right side of object appears at left side of image or vice-versa).

Image formed by a concave mirror for different positions of the object

No.	Position of the object	Position of the image	Nature of the image
1.	At infinity	At focus (F)	Real, inverted and diminished
2.	Beyond the centre of curvature (C)	Between focus (F) and the centre of curvature (C)	Real, inverted and smaller than the object
3.	At the centre of curvature (C)	At the centre of curvature (C)	Real, inverted and of same size
4.	Between the centre of curvature (C) and focus (F)	Beyond the centre of curvature (C)	Real, inverted and bigger than the object
5.	At the focus (F)	Infinity	Real, inverted and highly magnified.
6.	Between the focus (F) and pole (P)	Behind the mirror	Virtual, erect and enlarged

Images Formed by A Convex Mirror

An object AB is placed in front of a convex mirror. A ray AD incident on the mirror parallel to the principal axis after reflection appears to diverge from the focus F along DA_1. The other ray AE passing towards the centre of curvature C, after reflection retraces its path EA as shown in Fig. 5.31. (*i.e.* it gets reflected back along EA).The two reflected rays DA_1 and EA do not actually meet, but they appear to meet at A' behind the mirror when produced backwards as shown by the dotted lines. Thus, A' is the virtual image of the point A. In a similar way, taking rays incident from the other points of the object, A'B' is the image of AB.

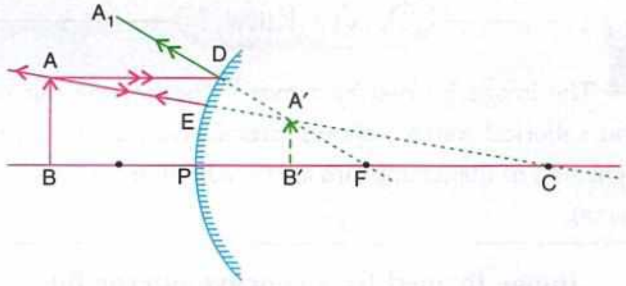


Fig. 5.31 A virtual, erect and smaller image is formed behind the mirror between F and P

As the object is brought closer to the convex mirror, the image moves towards the pole of mirror. Its size increases (but always remains smaller than the size of the object). It is virtual, erect and diminished, and is always formed between the pole and focus.

Position, size and nature of image formed by a convex mirror

No.	Position of the object	Position of the image	Size of the image	Nature of the image
1	At *infinity*	At *focus*	*Diminished* to a point	*Virtual* and *upright*
2.	At any other point	Between *focus and pole*	*Diminished*	*Virtual* and *upright*

Conclusion : (1) In a concave mirror, th image formed can be real or virtual, inverte or erect, diminished or of same size c enlarged, depending upon the position c object. As the object is brought from infinit towards the mirror, the image is real, inverte and diminished till the object is beyond centr of curvature. For the object at centre curvature, the image is real, inverted and same size. When object comes closer up t focus, the image is real, enlarged and inverte But if object comes still closer, the imag becomes virtual, erect and enlarged.

(2) In a convex mirror, the image forme is always virtual, erect, diminished and it i situated between the pole and focus, for eac position of the object in front of the mirro As the object moves closer to the mirror, th image shifts towards the pole and it increase in size. We can verify it by drawing ra diagrams for different positions of the objec

The formation of virtual images by concave and a convex mirror can b demonstrated by the following activity.

ACTIVITY 6

Take a polished steel spoon. The inside surface of the spoon is curved inwards and has a concave shape while the outside surface of the spoon is curved outwards and has a convex shape.

(1) Hold the spoon in such a way that the inside surface of the spoon (concave side) is closer to you. See image of your face (Fig.5.32). It is erect and magnified. Now move the spoon away from you, you will notice that the image becomes inverted.

Image in concave mirror

Fig. 5.32

(2) Now hold the spoon with its outside surface

towards your face. Observe the image. You will observe that the image is erect but diminished as shown in Fig. 5.33. If you move the spoon away from you, the image remains always erect and diminished.

Fig. 5.33

Do You Know ?

A real image formed by a mirror is always formed in front of the mirror, while a virtual image is formed behind the mirror.

USES OF A CONCAVE MIRROR

A concave mirror is put to the following ses :

(i) As a shaving mirror,
(ii) As a reflector,
(iii) As a doctor's head mirror,
(iv) To converge solar radiations in a solar cooker, and
(v) In flood lights as a reflector.

(i) Use of concave mirror as a shaving nirror : A concave mirror forms an erect and agnified image of an object placed close to . This fact enables us to use it as a shaving irror.

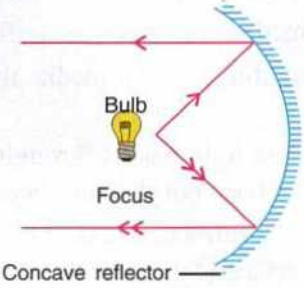


Fig. 5.34 Use of a concave mirror as a reflector

(ii) Use of concave mirror as a eflector : If a source f light is placed at the cus of a concave irror, we get a parallel m of reflected light ig. 5.34). This fact ables us to use it a reflector in rch, searchlight and headlight of a car and other vehicles. The source of light (bulb) is placed at the focus of the concave reflector.

(iii) Use of concave mirror as a doctor's head mirror : If a parallel beam of light is incident on a concave mirror, it converges the beam to a point called focus (Fig. 5.35). This fact enables us to use it as a doctor's head mirror to concentrate light on a small area to be examined, like nose, throat, ear, teeth, etc.

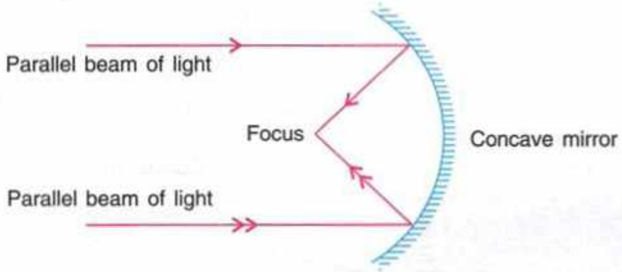


Fig. 5.35 Use of a concave mirror as a doctor's head mirror

(iv) Use of concave mirror in a solar cooker to converge the sun-rays : In a solar cooker a concave mirror is used to reflect the sun-rays so as to converge them on the cooking material placed at the focus of the concave mirror.

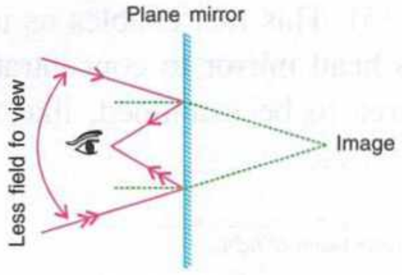
(v) Use of concave mirror in flood lights as a reflector : In flood lights, the source of light (*i.e.* bulb) is placed between the pole and focus of a concave mirror so as to obtain a diverging beam of light.

USES OF A CONVEX MIRROR

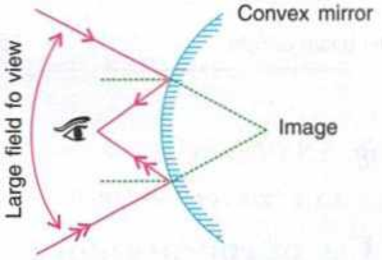
A convex mirror is put to the following uses :

(i) As a rear view mirror,
(ii) As a reflector in street lamps, and
(iii) As a vigilance or anti-theft mirror.

(i) Use of convex mirror as a rear view mirror : A convex mirror diverges the incident light rays and always forms a small and erect image between its pole and focus. This fact enables us to use it as a rear view mirror by a driver to see all the traffic behind him approaching the mirror. Fig. 5.36 shows that a convex mirror has a wider field of view than a plane mirror.



(a) Plane mirror



(b) Convex mirror

Fig. 5.36 Field of view of a convex mirror is wider than that of a plane mirror

(ii) Use of convex mirror as a reflecto in street lamps : The fact that a conve mirror diverges the light rays incident on i enables us to use it as a reflector in stre lamps. The light from a bulb placed in fro of a convex mirror diverges over a large are in the street as shown in Fig. 5.37.

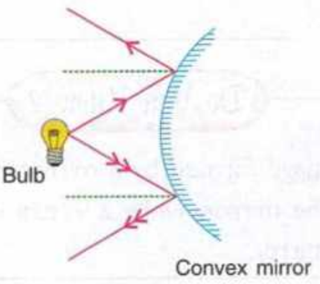


Fig. 5.37 Use of a convex mirror as a reflector in street lights

(iii) Use of convex mirror as a vigilanc mirror : In big showrooms and department stores, convex mirrors are used to have a vie on the customers entering in as well as goin out. The mirrors so used are called vigilan or anti-theft mirrors.

RECAPITULATION

- The change in direction of path of light when it passes from one transparent medium to another, is called the refraction of light.
- The speed of light in air is 3×10^8 m s^{-1}. In any other transparent medium (such as water, glass, etc.), the speed of light is less than that in air. The air is, therefore , optically rarer than any other transparent medium.
- When a ray of light travels from a rarer to a denser medium, it bends towards the normal.
- When a ray of light travels from a denser to a rarer medium, it bends away from the normal.
- When a ray of light falls normally on the surface separating the two media, the angle of incidence is zero, so it passes undeviated.
- Refraction takes place at the two parallel surfaces when light passes through a rectangular glass block. The emergent ray and the incident ray are in the same direction, but they are laterally displaced.
- When a light ray of single colour passes through a prism, refraction takes place at the two inclined surfaces of the prism and the light ray bends towards the third surface (called base) of the prism.
- When white light passes through a prism, it splits into seven colours namely, violet, indigo, blue, green, yellow orange and red (VIBGYOR) with violet colour towards the base of the prism. This coloured band is called spectrum of white light.

- The splitting of white light into the constituent colours is called dispersion of light.
- Prism does not produce colours, but it simply separates the colours which already exist in white light.
- The laws of reflection are : (a) The angle of incidence is equal to the angle of reflection. (b) The incident ray, the reflected ray and the normal lie in the same plane.
- These laws hold true for the spherical mirrors also.
- A spherical mirror is a part of a hollow sphere.
- Spherical mirrors are of two types : (a) concave and (b) convex.
- A concave mirror is made by silvering the outer surface of the sphere so that reflection takes place from the inner surface. A convex mirror is made by silvering the inner surface of the sphere so that reflection takes place from the outer surface.
- The pole of a mirror is the geometric centre of its spherical surface.
- The centre of curvature of a mirror is the centre of the sphere of which the mirror is a part.
- The radius of curvature of a mirror is the radius of the sphere of which the mirror is a part.
- The principal axis of a mirror is the straight line joining its pole and the centre of curvature.
- The focus of a concave mirror is a point on the principal axis at which the light rays incident parallel to the principal axis meet after reflection from the mirror.
- The focus of a convex mirror is a point on the principal axis at which the light rays incident parallel to the principal axis appear to meet after reflection from the mirror.
- The focal length of a spherical mirror is the distance of its focus from the pole.
- Focal length = $\frac{1}{2}$ × Radius of curvature. OR Radius of curvature = 2 × focal length.
- The image formed by a mirror is real if the rays after reflection from it actually meet at a point. A real image can be obtained on a screen. It is inverted.
- The image formed by a mirror is virtual if the rays after reflection from it do not actually meet at a point, but they meet when they are produced backwards. A virtual image can not be obtained on a screen.
- A ray passing through the centre of curvature is incident normally on the spherical mirror and so it gets reflected back along its own path.
- An incident ray parallel to the principal axis after reflection, passes (in a concave mirror) or appears to pass (in a convex mirror) through the focus of the mirror.
- A ray passing through the focus (in a concave mirror) or appearing to pass through the focus (in a convex mirror) is reflected parallel to the principal axis.
- In a concave mirror, the position and nature of the image formed, depends on the position of object. For the object situated beyond the focus, the image is always real and inverted, whereas for the object situated between the focus and the pole, the image is virtual, erect and enlarged.
- In a convex mirror, the image formed is always virtual, erect and diminished for each position of object. It is situated behind the mirror between its pole and focus.
- A concave mirror is used as a shaving mirror and as a reflector in torch, searchlight and headlight of a vehicle; and also as a doctor's head mirror.
- A convex mirror is used as a rear view mirror in front of a driver and as a reflector in street lamp.

TEST YOURSELF

A. Objective Questions :

1. Write **true** or **false** for each statement :

(a) Water is optically denser than glass.

(b) A ray of light when passes from glass to air, bends towards the normal.

(c) The speed of light is more in glass than in water.

(d) The depth of a pond when seen from above appears to be less.

(e) Light travels at a lower speed in water than in air.

(f) Light travels in the same straight line path while passing through different media.

(g) The angle formed between the normal and the refracted ray is known as the angle of incidence.

(h) At the point of incidence, a line drawn at right angles to the surface, separating the two media, is called the normal.

(i) Image is formed by a mirror due to refraction of light.

(j) Rays of light incident parallel to the principal axis pass through the focus after reflection from a concave mirror.

(k) A convex mirror is used as a shaving mirror.

(l) The focal length of a convex mirror is equal to its radius of curvature.

(m) A concave mirror converges the light rays, but a convex mirror diverges them.

(n) A virtual image formed by a spherical mirror is always erect and situated behind the mirror.

Ans. True – (d), (e), (h), (j), (m), (n),
False – (a), (b), (c), (f), (g), (i), (k), (l)

2. Fill in the blanks :

(a) Water is optically .... than air.

(b) Air is optically .... than glass.

(c) When a ray of light travels from water to air, it bends .... the normal.

(d) When a ray of light travels from air to glass it bends .... the normal.

(e) When white light passes through a prism, it ....

(f) The splitting of white light into it constituent colours is called ....

(g) A .... mirror is obtained on silverin the outer surface of a part of a hollow glas sphere.

(h) Radius of curvature of a spherical mirror i .... its focal length.

(i) The angle of incidence for a ray of ligh passing through the centre of curvature of spherical mirror is ....

(j) A .... mirror always forms a virtua image.

(k) A concave mirror forms a virtual image fo an object placed ....

Ans. (a) denser (b) rarer (c) away fro
(d) towards (e) disperses (f) dispersio
(g) concave (h) two times (i) 0° (j) conve
(k) between pole and focu

3. Match the following :

Column A	Column B
(a) White light	(i) convex mirror
(b) Refraction	(ii) concave mirror
(c) Virtual images	(iii) refraction
(d) Real images	(iv) spectrum
(e) Prism	(v) ray of light from glass to air

Ans. (a)–(iv), (b)–(v), (c)–(i), (d)–(ii), (e)–(iii

4. Select the correct alternative :

(a) The speed of light in air or vacuum is :

(i) 3×10^8 m s^{-1}

(ii) $2{\cdot}25 \times 10^8$ m s^{-1}

(iii) 332 m s^{-1}

(iv) $2{\cdot}0 \times 10^8$ m s^{-1}

(b) A ray of light moving from an optically rarer to a denser medium :

(i) bends away from the normal

(ii) bends towards the normal

(iii) remains undeviated

(iv) none of the above.

(c) The angle between the normal and refracted ray is called :

(i) angle of deviation

(ii) angle of incidence

(iii) angle of refraction

(iv) angle of emergence.

(d) The property of splitting of white light into its seven constituent colours is known as :

(i) rectilinear propagation

(ii) refraction

(iii) reflection

(iv) dispersion.

(e) The seven colours in the spectrum of sunlight in order, are represented as :

(i) VIBGYOR (ii) VIGYBOR

(iii) BIVGYOR (iv) RYOBIVG

(f) A ray of light passing through the centre of curvature of a spherical mirror, after reflection :

(i) passes through the focus

(ii) passes through the pole

(iii) becomes parallel to the principal axis

(iv) retraces its own path.

(g) If the radius of curvature of a concave mirror is 20 cm, its focal length is :

(i) 10 cm (ii) 20 cm

(iii) 40 cm (iv) 80 cm.

(h) The image formed by a convex mirror is :

(i) erect and diminished

(ii) erect and enlarged

(iii) inverted and diminished

(iv) inverted and enlarged.

(i) The image formed by a concave mirror is of the same size as the object, if the object is placed :

(i) at the focus

(ii) between the pole and the focus

(iii) between the focus and the centre of curvature

(iv) at the centre of curvature.

(j) A convex mirror is used :

(i) as a shaving mirror

(ii) as a head mirror by a dentist

(iii) as a rear view mirror by a driver

(iv) as a reflector in torch.

Ans. (a)–(i), (b)–(ii), (c)–(iii), (d)–(iv), (e)–(i), (f)–(iv), (g)–(i), (h)–(i), (i)–(iv), (j)–(iii)

B. Short/Long Answer Questions :

1. State the speed of light in (a) air, (b) water, and (c) glass.
2. How does the speed of light determine the optical density of a medium ?
3. Which is optically denser : water or air ? Give reason.
4. Out of air and glass, which is optically rarer ? Give reason.
5. What do you understand by refraction of light ?
6. Describe an experiment to show that a light ray bends when it passes from one transparent medium into another transparent medium.
7. Draw a ray diagram to show that the depth of a vessel containing water when seen from above, appears to be less than its real depth.
8. Define the following terms :

   Incident ray, Refracted ray, Angle of incidence, Angle of refraction.
9. A ray of light falls normally on a glass slab. What is the angle of incidence ?
10. A ray of light travels from a rarer medium to a denser medium. How will it bend ?

11. A ray of light travels from a denser medium to a rarer medium. How will it bend ?

12. The diagram given below in Fig. 5.38 shows a ray of light AO falling on a surface separating two media. Draw the refracted ray in each, case.

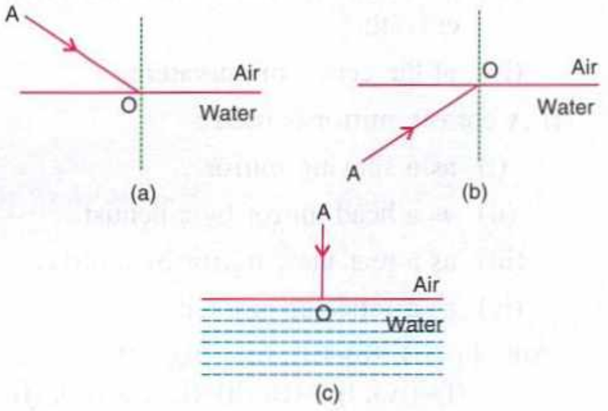


Fig. 5.38

13. Draw a diagram showing the refraction of a light ray from water to glass. Label on it the incident ray, the angle of incidence (*i*), and the angle of refraction (*r*).

14. The diagram in Fig. 5.39 shows a ray of light AO falling on a rectangular glass slab PQRS. Complete the diagram till the ray of light emerges out of the slab. Label on the diagram the incident ray, the refracted ray and the emergent ray.

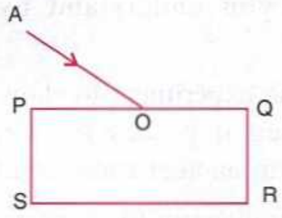


Fig. 5.39

15. Explain the following :

(a) A coin placed at the bottom of a vessel appears to be raised when water is poured in the vessel.

(b) A straight stick partly dipped in water obliquely, appears to be bent at the surface of water.

(c) The sun is seen before the sunrise and after the sunset.

16. What is a mirage ? Give a reason for its formatio

17. What is a prism ? Draw a ray diagram to sho the refraction of a light ray through a prism.

18. What do you mean by the term dispersion ?

19. A ray of white light falls on a prism. Draw a ra diagram to show that the prism disperses th white light.

20. In Fig. 5.40, AO is the ray of white light fallin on a prism PQR. Complete the diagram till th light emerges out from the prism and falls on th screen.

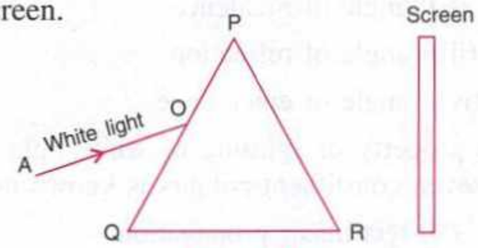


Fig. 5.40

21. What do you understand by the term spectrum Name the various colours present in the spectrur of sunlight.

22. You are given a disc divided into seven sector with colours violet, indigo, blue, green, yellow orange and red in them. What would be its colou when it is rotated rapidly ?

23. State the two laws of reflection of light.

24. What is a spherical mirror ?

25. State the two kinds of spherical mirrors an distinguish them with the aid of proper diagrams

26. Explain the following terms :

Pole, Centre of curvature, Radius of curvature Principal axis.

Show them on separate diagrams for each of th concave and convex mirrors.

27. What do you understand by the focus and foca length of a spherical mirror ? Show them o separate diagrams for each of a concave mirro and a convex mirror.

28. Draw suitable diagrams to illustrate how a bea of light incident parallel to the principal axis i reflected by :

(a) a concave mirror, and (b) a convex mirror.

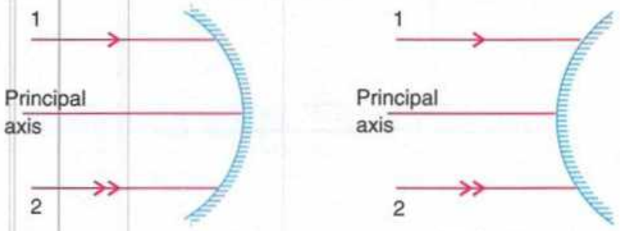
29. How is a spherical mirror used to converge beam of light at a point ? Name the type of mirro used.

30. How is a spherical mirror used to diverge a beam of light from a point ? Name the type of mirror used.

31. State the direction of incident ray which after reflection from a spherical mirror gets reflected along its own path. Give a reason.

32. How is the focal length of a spherical mirror related to its radius of curvature ?

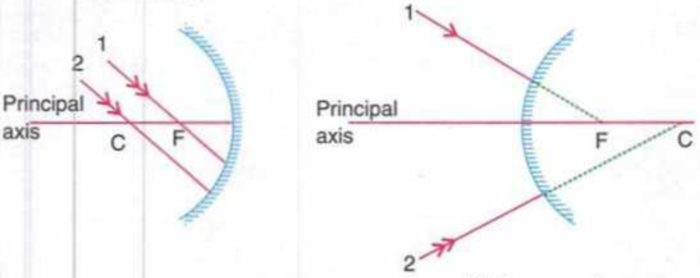
33. The diagrams (Fig. 5.41) given below show two parallel rays 1 and 2 incident on (a) a concave mirror, (b) a convex mirror. Draw the reflected rays and mark the focus by the symbol F.



(a) Concave mirror (b) Convex mirror

Fig. 5.41

34. Complete the following diagrams in Fig. 5.42 by drawing the reflected rays for the incident rays 1 and 2 if F is the focus and C is the centre of curvature.



(a) Concave mirror (b) Convex mirror

Fig. 5.42

35. Which are the two convenient rays that are chosen to construct the image formed by a spherical mirror for a given object? Explain with the help of suitable ray diagrams.

36. Draw a ray diagram to show the formation of the image of an object placed beyond the centre of curvature of a concave mirror. State the position, size and nature of the image.

37. Draw a ray diagram to show the formation of the image of an object placed at the centre of curvature of a concave mirror. State the position, size and nature of the image.

38. Draw a ray diagram to show the formation of image of an object placed between the focus and centre of curvature of a concave mirror. State the position, size and nature of the image.

39. Draw a ray diagram to show the formation of image of an object placed between the pole and focus of a concave mirror. State the position, size and nature of the image.

40. Draw a ray diagram to show the formation of the image of an object placed on the principal axis of a convex mirror. State the position, size and nature of the image. What happens to the image as the object is moved away from the mirror ?

41. Draw separate diagrams for the formation of virtual image of an object by
   (a) a concave mirror and
   (b) a convex mirror.
   State the difference of the two images.

42. Name the mirror which always forms an erect and virtual image. What is the size of the image as compared to that of the object ?

43. Name the mirror which forms an erect, virtual and enlarged image of an object. What is the position of object relative to the mirror ?

44. What is a real image ? Name the mirror which can be used to obtain the real image of an object. What should be the position of the object relative to the mirror ?

45. How can a concave mirror be used to obtain a virtual image of an object ? Draw a diagram to illustrate your answer.

46. State two uses of a concave mirror.

47. State two uses of a convex mirror.

48. A driver uses a convex mirror as a rear view mirror. Explain the reason with the help of a ray diagram.

49. State the kind of mirror used
   (a) by a dentist, and
   (b) as a street light reflector.

50. Name the kind of mirror used to obtain
   (a) a real and enlarged image,
   (b) a virtual and enlarged image,
   (c) a real and diminished image, and
   (d) a virtual and diminished image.

Project Work

You are given few mirrors labelled A, B, C, D, ... Identify them as plane, concave or convex mirror by looking your own face in each mirror one by one and recording the size and nature of image.

Mirror	Size of image	Type of mirror	Nature of image
A			
B			
C			
D			
E			

6

Heat Transfer

Theme : In both boiling and evaporation, matter changes from liquid to gas. But the two processes are quite different. When temperature of a matter increases, the particles of the matter gain energy and move with greater speed. In evaporation, the particles at the surface escape and form gas. Other particles, inside the liquid, do not have enough energy. So the process of evaporation occurs at the surface. It happens at all temperature. In boiling, all particles of the liquid are at the same temperature and are involved in the process. It happens in the whole volume of the liquid. And it happens at a fixed temperature, particular to a liquid. But before change of states takes place due to supply of heat, there is another effect which is commonly observed. That is the expansion of matter. Matters in all form, except some exceptions, expand on heating. In solids, the effect is less, in liquids more, and in gases maximum. Classification of expansion into three types-linear, superficial and volume are explained with examples from daily life.

In this chapter you will learn to

- compare and contrast boiling and evaporation;
- describe thermal expansion of matter;
- describe, linear, area (superficial) and volume expansion;
- compare expansivity in solids, liquids and gases;
- construct models based on scientific process;
- observe and cite multiple physical phenomena from one experiment;

LEARNING OBJECTIVES

- ➢ Revising and revisiting previous concepts learnt by children.
- ➢ Building on children's previous learning Demonstrating points of boiling and evaporation.
- ➢ Engaging children in tasks related to boiling and evaporation.
- ➢ Explaining the difference in boiling and evaporation.
- ➢ Demonstrating linear expansion, area expansion and volume expansion through conducting simple experiments for children.
- ➢ Explaining expansion with the help of examples from daily life activities.

KNOWING CONCEPTS

- ➢ Difference between boiling and evaporation.
- ➢ Thermal expansion:
  - Linear expansion • Volume expansion
  - Superficial expansion
  - Compare expansivity in solids, liquid, and gases.
  - Examples and real world applications

INTRODUCTION

In the earlier classes you have read that matter is composed of tiny particles called molecules. A molecule can exist freely in nature and it possesses the properties of the matter. It is very small in size (nearly 10^{-10} m) and cannot be seen even by a microscope. The molecules are in motion as well as they have the forces of attraction amongst them. Due to motion, the molecules have the kinetic energy and due to forces of attraction, they have the potential energy. The solid state would have the greatest potential energy and least kinetic energy. The gaseous state, on the other hand, would have the least potential energy and greatest kinetic energy. When a substance absorbs heat (or the substance is heated), the motion of its molecules becomes rapid, so their kinetic energy increases. When the substance is cooled (or it gives out heat), the motion of its molecules becomes slow and so their kinetic energy decreases. The total kinetic energy of molecules of the substance is called its internal kinetic energy and the total potential energy of molecules is called its internal potential energy. The sum of internal kinetic energy and internal potential energy is called the total internal energy or heat energy of the substance. Thus, heat is the internal energy of a substance. It is measured in the unit joule (symbol J)*.

When two bodies at different temperatures are kept in contact, heat flows from the body at higher temperature to the body at lower temperature. The average kinetic energy of the substance is a measure of temperature of the body. When there is a rise in average kinetic energy of molecules of a substance, its temperature increases and if there is fall in the average kinetic energy of molecules of substance, its temperature decreases.

However during the change in state of substance at a constant temperature, there wil be no change in the average kinetic energy o its molecules (as explained later on).

EFFECTS OF HEAT

Heat produces mainly the following thr effects :

1. Change in temperature of the body,
2. Change in state of the body, and
3. Change in size of the body.

1. Change in temperature of the body :

When a body is heated, its temperatur rises and when it is cooled, its temperatur falls. The change in temperature of the body depends on the following two factors :

(a) Quantity of heat imparted to (or rejected from) the body : When heat i imparted (or given) to the body, its temperatu rises while if heat is rejected (or taken) from the body, its temperature falls.

Reason : On heating, the molecules begin to move faster, so the average kinetic energy of molecules increases and so the temperature rises. On the other hand, on cooling, the average kinetic energy of molecules decreases, so the temperature falls.

(b) Material of the body : Some materials rise to high temperature while some to a low temperature even when same quantity of heat is imparted to them.

Reason : Different materials have different specific heat capacities (*i.e.*, different amount of heat required to raise the temperature of unit mass by unit rise in temperature).

2. Change in state of the body :

Matter exists in three different states,

---

* Other common unit of heat is calorie (symbol cal), where 1 cal = 4·2 J (nearly)

mely solid, liquid and gas.

The process of change from one state to nother at a constant temperature is called hange of state.

When a solid is heated, it changes into its quid at a fixed temperature. This process is alled **melting**. The reverse happens when liquid is cooled, the liquid freezes into olid at the same fixed temperature. This rocess is called **freezing**. *For example*, e at 0°C on heating melts into water at 0°C, hile water at 0°C on cooling freezes into ice t 0°C.

When a liquid is heated, it changes into its apour (or gas) at a fixed temperature. This rocess is called **vaporization or boiling**. The verse happens when vapour is cooled, e vapour condenses into liquid at the same xed temperature. This process is called **ondensation**. *For example*, water at 100°C on eating vaporizes into steam at 100°C, while eam at 100°C on cooling condenses into water t 100°C.

When a solid on heating changes directly to its vapour at a fixed temperature, the rocess is called **sublimation**. *For example*, amphor on heating, changes directly from olid to vapour. These vapour on cooling hange directly into solid state. This process called **solidification or deposition**.

The change of state from liquid to gas at ll temperatures is called evaporation. Thus, vaporation differs from boiling. Boiling is at fixed temperature while evaporation takes lace at all temperatures. *For example*, drying f clothes is due to evaporation of water. vaporation is a slow process, while boiling a rapid process. Fig. 6.1, shows the change different states of matter.

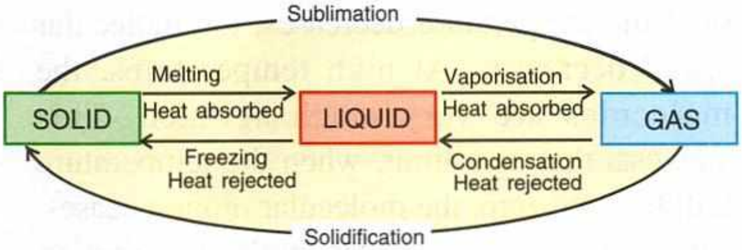


Fig. 6.1 Changes in state

During the change of state, the heat absorbed (or rejected) is called the latent heat or hidden heat because it is not manifested by any change in temperature. This heat when expressed for unit mass of a substance is called specific latent heat. The latent heat, instead of raising the temperature, is utilized to change the forces of attraction between the molecules of a substance. Since temperature remains constant, the absorbed (or rejected) heat has no effect on the speed or the average kinetic energy of the molecules. Thus during interconversion of states, the latent heat increases (or decreases) only the average potential energy of molecules whereas the average kinetic energy remains unchanged.

3. Change in size of the body :

When a body is heated, it expands and upon cooling, it contracts. This change in size of the body due to heating is called thermal expansion.

Generally all solids, liquids and gases expand on heating or contract on cooling. The reason is that on heating a substance, the average inter molecular separation between the molecules of the substance increases, while on cooling it decreases.

EFFECT OF TEMPERATURE ON MOLECULAR MOTION

We have read that the molecules of each substance possess kinetic energy by virtue of their continuous motion. When the motion becomes less rapid, the temperature decreases or if the temperature decreases, the molecular speed decreases. At high temperatures, the molecules are very much agitated. This suggests that as a limit, when the temperature will become zero, the molecular motion ceases. The temperature at which molecular motion completely ceases is known as the absolute zero on the Kelvin scale. Temperature lower than absolute zero is not possible.

CHANGE OF LIQUID INTO VAPOUR STATE

A liquid changes into vapour in two ways :

1. By evaporation at all temperatures, and
2. By boiling at a fixed temperature.

1. EVAPORATION

The change of liquid into its vapour at all temperatures from its surface is called evaporation.

If you place a drop of ether on your palm, you will notice that the ether disappears within a few seconds and the palm feels cold. The process causing this phenomenon is known as evaporation. This is essentially a surface phenomenon and takes place at all temperatures. The process of evaporation can be understood in terms of the molecular motion.

EXPLANATION OF EVAPORATION ON THE BASIS OF MOLECULAR MOTIONS

It is difficult to break a solid into its small pieces, but a liquid can easily break up into small drops. We conclude, therefore, that the mutual force of attraction between the liquid molecules is much less than that in the case of a solid. The attractive force between the liquid molecules is not strong enough to keep them in fixed positions. Therefore, the liquid molecules can move throughout the liquid. The molecules of a liquid on an average have a larger spee than the molecules of a solid. The relativ distance between the liquid molecules and th direction of their motion is found to be totall irregular. When a molecule, while in motio, reaches the surface of the liquid, it is pull inside by the Cohesive force of surroundin molecules of the liquid as there are no molecule on the other side of the surface. Thus, molecule are not allowed to leave the surface an therefore a liquid has a definite volume.

On the other hand, in a gas the molecule are very much farther apart than those of solid or liquid. There is a very small o negligible force of attraction between the ga molecules and therefore the molecules are fre to move about over the entire available spac This is why a gas has neither a fixed sha nor a fixed volume.

In a liquid, molecules while in motio collide with each other. Some molecules whic gain energy reach to the surface of liquid whil others which lose energy remain inside th liquid. Thus, the molecules on the surface o liquid have higher kinetic energy than thos inside the liquid. During evaporation, th molecules on the surface which have sufficien kinetic energy to do work against the force o attraction on them due to other molecule inside the liquid, escape out from the surfa into space. These escaping molecules form th vapour of the liquid. The process continue till all the liquid evaporates. The rate o evaporation depends on temperature of liqui wind, surface area and the presence o humidity.

Effect of temperature on the rate o evaporation : The rate of evaporatio ncreases with the increase in temperature of iquid. The reason is that the energy of the nolecules increases with increase in emperature. So more and more molecules ome to the surface of liquid, hence the rate f evaporation will increase with increase of emperature.

Effect of blowing air on the rate of vaporation : When air is blown above the urface of a liquid, the rate of evaporation ncreases. The reason is that the blowing air akes away with it the molecules of the liquid scaping out of its surface. To take their lace, other molecules move to the surface of he liquid.

Effect of increase in area of surface on he rate of evaporation : On increasing the rea of surface exposed to air, the rate of vaporation increases. The reason being that n increasing the area of surface, number of nolecules escaping out from the surface ncreases.

Effect of presence of humidity : In resence of humidity, the rate of evaporation ecomes slow because vapour molecules do ot find space to escape.

Cooling produced during evaporation: When a liquid evaporates, it produces cooling n its surroundings.

Reason : In the process of evaporation, a iquid changes to vapour and for this purpose ome heat is needed. If there is no external upply of heat, the liquid (e.g. ether) will draw he necessary heat from its surroundings (e.g. alm of your hand) and therefore it (palm) gets ooled.

2. BOILING

The change from the liquid state to the gaseous (or vapour) state, on heating at a constant temperature, is called boiling.

The temperature, at which the liquid changes into vapour without further increase in temperature, is called the boiling point of the liquid.

The boiling of a liquid can be demonstrated by the following activity.

ACTIVITY 1

Take a beaker. Pour some water in the beaker. Place the beaker on a wire guaze placed over the tripod stand. Clamp a thermometer in a vertical stand and insert it in the beaker as shown in Fig. 6.2. Heat the beaker over the flame of a burner and record the temperature of water after every minute.

You will notice that temperature of water rises continuously till the water starts boiling at 100°C. Once the water starts boiling, its temperature does not rise any further, although the heat is still being supplied. Now the bubbles formed throughout the water are seen. At this temperature, water begins to boil and changes into steam. Thus, the boiling point of water is 100°C.

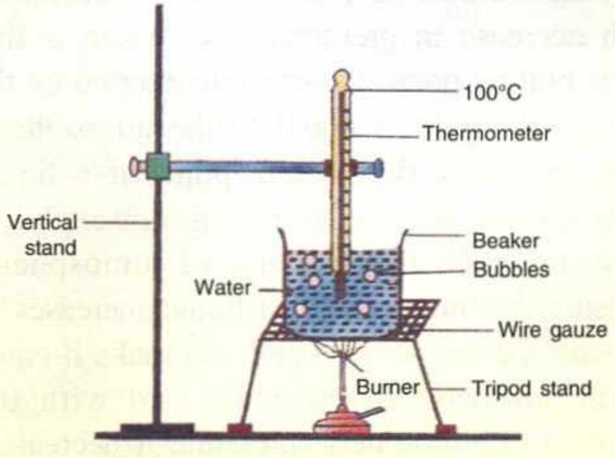


Fig. 6.2 Boiling of water

EXPLANATION OF BOILING BY MOLECULAR MOTION

When a certain liquid is heated, there is rapid formation of vapour from all parts of the liquid as indicated by visible bubbles. Heating of the liquid increases the average kinetic energy of the liquid molecules. When the molecules acquire sufficient kinetic energy to overcome the force of attraction of other molecules they escape out from the liquid in the form of vapour.

These molecules now start leaving the liquid, not only at the surface but also near the walls of the containing vessel. This is shown by the presence of bubbles on the walls of the vessel. The bubbles grow in size with further evaporation and move to the surface in quick succession. This causes agitation in whole of the liquid and this is called boiling. When the boiling starts, the temperature of the liquid does not increase any further. This temperature is known as the boiling point of the liquid.

Effect of pressure on the boiling point : The boiling point of a liquid increases with an increase in pressure and it decreases with decrease in pressure. The reason is that at the boiling point, the pressure exerted by the vapour of liquid is equal to the atmospheric pressure. Thus, the boiling point of a liquid depends on the surrounding atmospheric pressure. With the increase of atmospheric pressure, boiling point of a liquid increases to increase the vapour pressure and make it equal to the atmospheric pressure and with the decrease in atmospheric pressure, it decreases.

This is why at mountains where the atmospheric pressure is low, water boils at a temperature below 100°C and it become difficult to cook the vegetables. On the othe hand, in a pressure cooker by keeping th water vapours inside it, the surroundin pressure is increased, then water inside i boils at a temperature nearly 125°C, so th vegetables get readily cooked inside it.

Do You Know ?

One kg of water at 100°C absorbs $2{\cdot}26 \times 10^6$ J (or $5{\cdot}4 \times 10^5$ cal) of heat to convert into steam at 100°C.

DIFFERENCE BETWEEN EVAPORATION AND BOILING

In both processes evaporation an boiling, a liquid changes its state to th vapour or gaseous state. But they differ in th following respects :

1. Evaporation takes place at all temperature while boiling takes place at a fixe temperature called the boiling point o liquid.
2. Evaporation occurs only from th surface of liquid (*i.e.*, it is a surfac phenomenon) while boiling takes plac throughout the mass of liquid at the sam instant.
3. In evaporation, some molecules near the surface of liquid acquire sufficient kinetic energy by collisions with other liquid molecules to overcome the attractiv forces of the other molecules. Thus, absorbing heat from the surroundings, they escape out into space. On the othe hand, in boiling at a fixed temperature, the average kinetic energy of the liquid molecules become sufficient to overcome

the forces of attraction of other molecules and they start leaving the liquid throughout the mass of liquid. As a result, bubbles are formed. These bubbles move to the surface and boiling of liquid takes place.

4. In evaporation, heat is absorbed by the molecules at the surface of liquid from its surroundings so as to change to vapour state, while in boiling, heat is supplied externally at a fixed temperature.
5. Evaporation is a slow process while boiling is a rapid process.

THERMAL EXPANSION

It has been experimentally observed that when a substance (solid, liquid or gas) is heated, it expands and when it is cooled, it ontracts. We will now consider the thermal xpansion in solids, liquids and gases separately.

Do You Know ?

Exceptions of thermal expansions are :

1. Water from 0°C to 4°C.
2. Silver iodide from 80°C to 141°C.
3. Silica below – 80°C.

They contract on heating and expand on cooling in the given range of temperature.

THERMAL EXPANSION IN SOLIDS

A solid has a definite shape. When a solid is heated, it expands in all directions. ence the length, area and volume all ncrease on heating a solid. The increase in length of a solid is called linear expansion. The increase in area is called superficial expansion and increase in volume is called cubical expansion.

Explanation of thermal expansion of solids on the basis of molecular motion

On heating a solid, the average kinetic energy of molecules of the solid increases. They start vibrating about their mean positions with a large amplitude. The result is that their mean positions change such that the inter-molecular separation between the molecules increases, thus the solid expands equally in all directions.

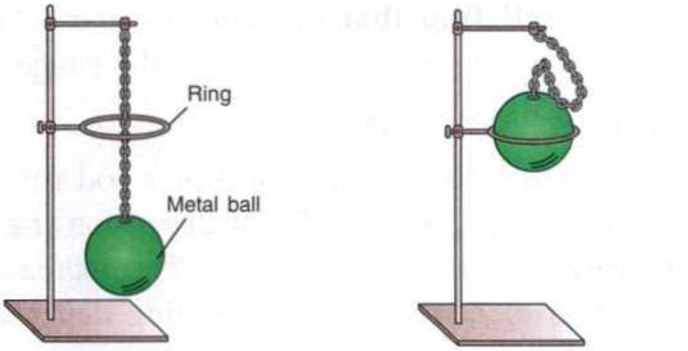
Demonstration of thermal expansion of solids

The thermal expansion in solids can be demonstrated by the following experiments.

Experiment (1) :

(i) Take a ball and ring set-up. This is shown in [Fig. 6.3(a)]. It consists of a metal ball and a ring. The metal ball just slips through the ring when both are at the room temperature.

(ii) Now heat the ball on a burner, and place it over the ring. You will notice that the ball does not pass through the ring [Fig. 6.3(b)]. The reason is that on heating, the ball expands and becomes bigger in diameter than the ring.



(a) Before heating, the ball passes through the ring (b) After heating, the ball does not pass through the ring

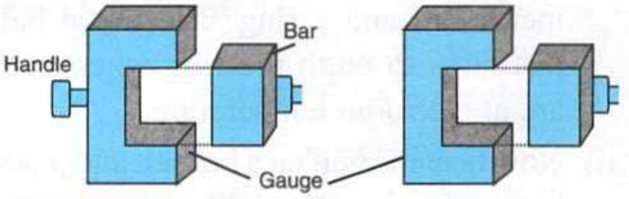
Fig. 6.3 Ball and ring set-up to show thermal expansion of a solid

(iii) Now allow the ball to cool by itself and after some time again place it over the ring. You will notice that the ball now passes through the ring. This is because on cooling, the ball contracts.

Experiment (2) :

(i) Take a bar and gauge set-up as shown in [Fig. 6.4(a)]. It consists of a metal bar and a metal gauge attached with a handle. The bar just fits into the gauge when both are at the room temperature.

(ii) Now heat the bar and try to fit it into the gauge. You will find that it does not fit into the gauge now [Fig. 6.4(b)]. This is because the bar expands on heating and becomes longer than the gap provided in the gauge.



(a) Before heating, the bar fits into the gauge

(b) after heating, the bar does not fit into the gauge

Fig. 6.4 Bar and gauge set-up to show thermal expansion in solids

(iii) Now allow the bar to cool by itself. You will find that the bar contracts on cooling and again fits into the gauge.

LINEAR EXPANSION

When a solid in the form of a rod (or a wire) is heated, only the linear expansion (*i.e.*, increase in length) is effective. The increase in length of a metal rod on heating depends on the following three factors :

(i) Original length of the rod,

(ii) Increase in temperature, and

(iii) Material of the rod.

(i) Dependence on the original length of the rod : If we heat two rods o the same metal – one short and th other long, to the same temperature we will find that the long rod expand more than the short rod. Thus, longe the rod, greater is the increase in it length.

(ii) Dependence on the increase in temperature : If we heat tw identical rods (of the same metal an of the same length), one at a highe temperature than the other, we fin that the rod heated to the highe temperature expands more than the rod heated to the lowe temperature. Thus, more the increas in temperature of rod, greater is th increase in its length.

(iii) Dependence on the material of the rod : If we heat two rods of same length, but one of copper and the other of iron at the same temperature, we find that the copper rod expands more than the iron rod. The increase in length of copper rod is nearly 3/2 times the increase in length of the iron rod. Thus, the increase in length of a rod depends on the material of the rod.

Do You Know ?

(I) A bimetallic strip which consists of two rods of same lengths but of different materials (say, one of iron and other of copper) rivetted together, is commonly used in a thermostat. A thermostat is a device used to control temperature by closing and opening the circuit. Thermostat is used in electrical gadgets like refrigerator, electric iron, oven, geyser, etc.

(2) The increase in length of a rod on heating does not depend whether it is hollow or solid. If we heat two rods of the same metal and of the same length, but one hollow and the other solid, to the same rise in temperature, we find that both the rods expand to the same extent.

If L_0 is the length of a rod at 0°C and its length at t °C is L_t, the increase in length is given as

$$L_t - L_0 = L_0 \alpha t$$

where α is called the coefficient of linear expansion which depends on the material of rod *i.e.*, α is different for different substances. Its unit is per °C.

The value of coefficient of linear expansion of some metals is given in the following table.

Coefficient of linear expansion of some solids

Substance	Coefficient of linear expansion ($\times 10^{-6}$ per °C)
Aluminium	24
Brass	19
Copper	17
Steel	13
Iron	12
Invar	0·9

Note : 1. Invar is an alloy which almost does not expand on heating. This is why the pendulum of a clock is made up of Invar.

2. Pyrex glass also expands negligibly on heating.

Linear expansion of solids can be demonstrated by the following activities.

ACTIVITY 2

To show linear expansion.

Take a metal rod and set up an apparatus as shown in Fig. 6.5. Fix one end of the rod and keep the other end free but it touches a pointer. Now heat the rod. You will see that the pointer starts moving up with the expansion of the metal rod. The metal rod elongates along the free end which pushes the pointer upwards.

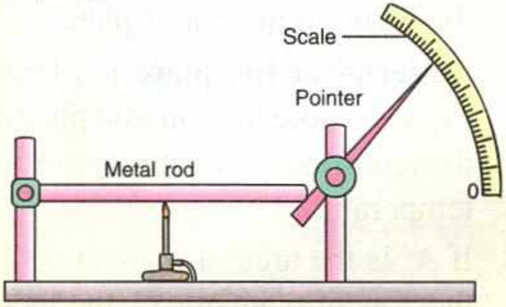


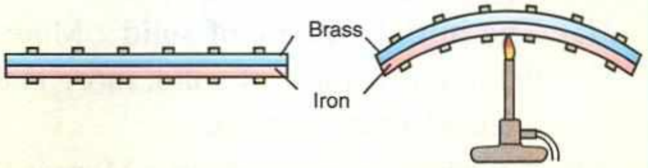
Fig. 6.5 A metal rod expands on heating

ACTIVITY 3

To show bending of a bimetallic strip

Take a composite bar (a bimetallic strip) as shown in Fig. 6.6(a). The bar is made of brass and iron of equal length and rivetted together. Heat the bar and observe. You will notice that the bar bends.

The reason is that brass expands more than iron on heating. The coefficient of linear expansion of brass is about twice that of iron. Thus, when the composite bar is heated, it acquires a curved shape as shown in the Fig. 6.6(b).



(a) Before heating (b) After heating

Fig. 6.6 Different metals on heating expand by different lengths.

Superficial expansion of solids

When a metal plate is heated, its length and breadth, both increase. This increases the area of the plate.

Experimentally it is observed that the increase in area of a metal plate depends on:

(i) **The initial area of the plate :** Larger the initial area of plate, more is the increase in its area on heating.

(ii) **The increase in temperature :** More is the rise in temperature, more will be the increase in area of plate.

(iii) **Material of the plate :** A brass plate expands more than an iron plate of same dimensions for the same rise in temperature.

If A_0 is the area of plate at 0°C and A_t the area of plate at t°C, the increase in area is given as

$$A_t - A_0 = A_0 \beta t$$

where β is the coefficient of superficial expansion which is different for different solids/materials.

Cubical expansions of solids

When a solid is heated, it expands in all directions *i.e.*, its length, breadth and thickness increase. Thus, the volume of the solid too increases.

Experimentally it is observed that the increase in volume of a solid depends on :

(i) **The initial volume of solid :** More is the initial volume of solid, more is the increase in its volume.

(ii) **The rise in temperature :** More is the rise in temperature, more is the increase in its volume.

(iii) **The material of the solid :** A brass bal increases in volume more than an irc ball of same radius for the same rise ir temperature.

If V_0 is the volume of a solid at 0°C an V_t the volume at t°C, then increase in volum is given as :

$$V_t - V_0 = V_0 \gamma t$$

where γ is called the coefficient of cubic expansion of a solid. It is different fo different materials.

Relationship between α, β and γ :

The three coefficients α, β and γ ar related as $\beta = 2\alpha$ and $\gamma = 3\alpha$

or $\alpha : \beta : \gamma = 1 : 2 : 3$

Some Applications of Thermal Expansior of Solids in Daily Life

1. **Construction of a bridge :** I the construction of a bridge, stee girders are used. One end A of the girdı is fixed in concrete, but the other enı B is not fixed into concrete (or pillar) It is supported on rollers as shown ir Fig. 6.7 so that if there is any rise (o fall) in temperature during summer (o winter), girder may expand (or contract without affecting the pillar and bridge.

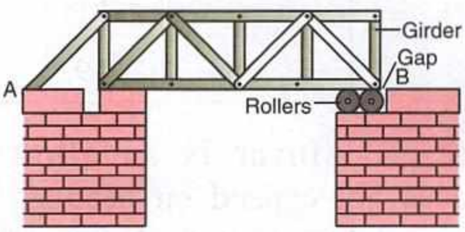


Fig. 6.7 In a bridge one end of a girder is kept on rollers for expansion or contraction

2. **Railway tracks :** The rails of railwa tracks are made up of steel. Whil

laying the railway tracks on wooden or concrete planks, a small gap is left between the successive lengths of rail as shown in Fig. 6.8. The reason is that in summer due to considerable rise in atmospheric temperature, each rail tends to increase in its length, so a gap is left between the two rails, otherwise the rail will bend sideways.

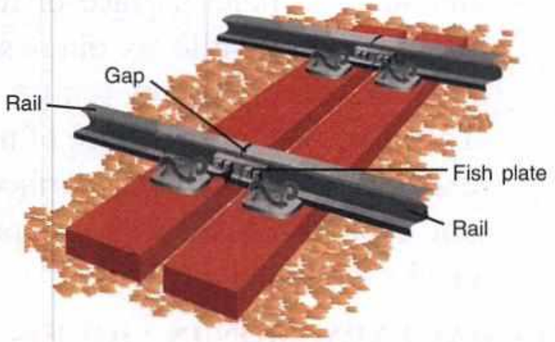
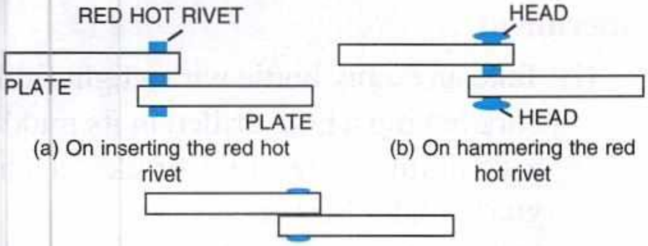


Fig. 6.8 Gap between the two rails for expansion in summer

3. **Riveting :** For joining two steel plates, they are placed one above the other and holes are drilled through them. The rivets (small steel rods) are heated red hot and then they are inserted in holes of the plates [Fig. 6.9(a)]. On heating, the rivets become soft, so their ends are easily hammered as heads. [Fig. 6.9(b)]. Now the rivets are allowed to cool [Fig. 6.9(c)]. On cooling, they contract but they cannot regain their original size as they have been hammered so they bring the plates closer and firmly grip them together making the joints water-proof (or steam-proof). Such riveting is used in joining steel girders, boiler plates, etc.



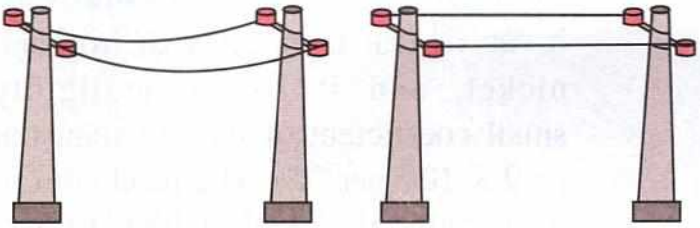
(a) On inserting the red hot rivet

(b) On hammering the red hot rivet

(c) On cooling the rivet

Fig. 6.9 Riveting

4. **Electric cables and telephone wires :** The electric cable in an overhead power transmission line and the telephone wires between two poles may break in winter due to contraction and may sag in summer due to expansion. Therefore, while putting up the wires between two poles, care is taken that in summer, they are kept slightly loose so that they may not break in winter due to contraction and while laying them in winter, they are kept tight so that they may not sag too much in summer due to expansion (Fig. 6.10).



(a) Electric wires in summer

(b) Electric wires in winter

Fig. 6.10 In summer electric wires are kept loose while in winter they are kept tight

5. **Fitting the steel rim on a horse cart wheel :** The wooden wheel of a horse cart is fitted with a steel rim to make it strong and smooth. To ensure a tight fit of steel rim over the wooden wheel, the rim is made slightly smaller in diameter than the wooden wheel. Then to fit the

rim, it is first heated uniformly along its circumference till its diameter becomes slightly more than that of the wooden wheel. The rim is then slipped over the wooden wheel before allowing to cool. On cooling, the rim contracts and makes a tight fit over the wooden wheel as shown in Fig. 6.11.

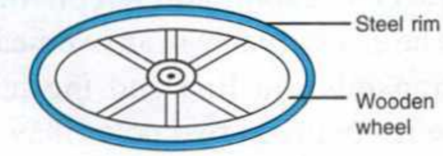


Fig. 6.11 Steel rim fitted over the wooden wheel

6. **Glassware used in kitchen :** The glassware used in kitchen are generally made up of pyrex glass. The reason is that the pyrex glass has a very low coefficient of cubical expansion, so the glassware on being heated, do not expand much and therefore they do not crack.
7. **Pendulum of a clock is made of invar :** Invar is an alloy of iron and nickel, and it has a negligibly small coefficient of linear expansion (= 9×10^{-7} per °C). The pendulum of invar helps the clock neither to lose time in summer due to expansion, nor to gain time in winter because of contraction.
8. **Loosening a glass stopper or a metal screw cap :** A glass stopper on a bottle is loosened by warming the neck of the bottle. The reason is that on warming the neck of the bottle, the neck expands and the glass stopper in it gets space to loosen.

   If there is a metal screw cap on the nec of a glass bottle, the screw cap is heated On heating, the screw cap expands an it gets loosened.
9. **Cracking of thick glass tumbler :** When a hot liquid is poured into a thic glass tumbler, it cracks. The reason i that glass is a poor conductor of heat When hot liquid is poured into tumbler, the inner surface of tumble becomes hot, while its outer surfac remains at the room temperature Therefore, the inner surface of tumble expands, while its outer surface doe not expand. This unequal expansio cracks the tumbler.

THERMAL EXPANSION IN LIQUIDS

Like solids, liquids also usually expan on heating. Liquids expand much more than the solids when heated. Liquids do not hav a definite shape, but they have a definit volume, therefore the liquids have only cubical expansion.

Exception : Water contracts on heatin it from 0°C to 4°C and then beyond 4°C o further heating, it expands. This is calle anomalous behavior of water.

The cubical expansion of a liquid o being heated can be demonstrated by th following simple experiment.

Experiment :

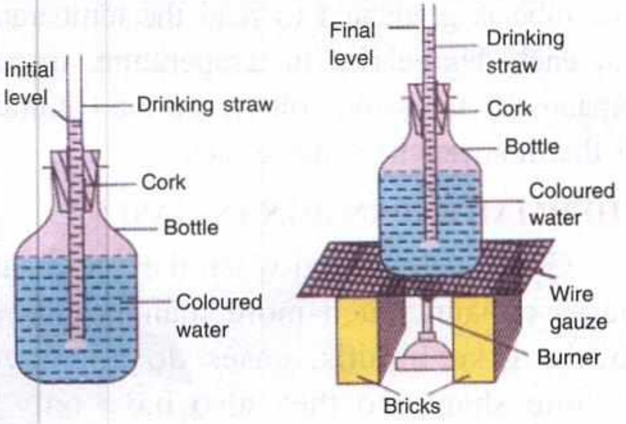
(i) Take an empty bottle with a tight fittin cork having a hole drilled in its middle a drinking straw, two bricks, a wi guaze and a burner.

(ii) Fill the bottle completely with wat and add few drops of ink in it to ma it coloured for easy contrast.

(iii) Fix the cork in the mouth of the bottle and pass the drinking straw through the cork. Put some molten wax around the hole so as to avoid the leakage of water.

(iv) Pour some more water into the drinking straw so that water level in the straw can be seen. Mark the water level in the straw as shown in Fig. 6.12(a).

(v) Place the bottle on the wire gauze kept over the two bricks as shown in Fig. 6.12(b). Heat the bottle using a burner.



(a) Before heating (b) After heating

Fig. 6.12 Thermal expansion of liquid

(vi) Look at the level of water in the straw.

You will notice that as the water is eated more and more, the level of water in e drinking straw rises. This shows that water xpands on heating.

Do You Know ?

When a liquid contained in a vessel is heated, first the vessel will get the heat so it will expand due to which the level of liquid will fall. Thereafter when heat reaches the liquid, it will expand, so the level of liquid will rise. Since liquids expand more than solids, the liquid level rises above its initial level. Thus, the real expansion of liquid is more than the observed expansion.

Explanation of thermal expansion of liquid by molecular motion

In a liquid, the molecules are free to move anywhere within the liquid. When a liquid is heated, the average kinetic energy of its molecules increases. As a result, the molecules begin to move more vigorously thereby increasing the inter-molecular separation. Thus, the liquid expands on heating.

Factors affecting the cubical expansion of a liquid

The cubical expansion of a liquid depends on the following three factors :

(i) Original volume of the liquid :

Larger the volume of liquid taken, more is the increase in its volume, on heating.

(ii) Rise in temperature :

Greater the rise in temperature of a liquid, more is the increase in its volume.

(iii) Nature of liquid :

Equal volumes of different liquids when heated to the same temperature, undergo different increases in their volumes.

If V_0 is the volume of liquid at 0°C and V_t the volume of liquid at t°C, then increase in volume of liquid is given as

$$V_t - V_0 = V_0 \gamma t$$

where γ is the coefficient of cubical expansion of liquid.

Different liquids have different cubical expansions

Experimentally it is observed that equal volumes of different liquids when heated to the same temperature, expand by different amounts. This can be easily demonstrated by the following activity.

ACTIVITY 4

Take four identical glass bottles each fitted with a narrow glass tube through a cork at its mouth. Fill them up to the same level with different liquids say water, kerosene, alcohol and benzene. Place them in a common water bath containing boiling water as shown in Fig. 6.13.

After some time, you will notice that different liquids rise to different levels. Benzene expands the most, then alcohol and kerosene, water expands the least.

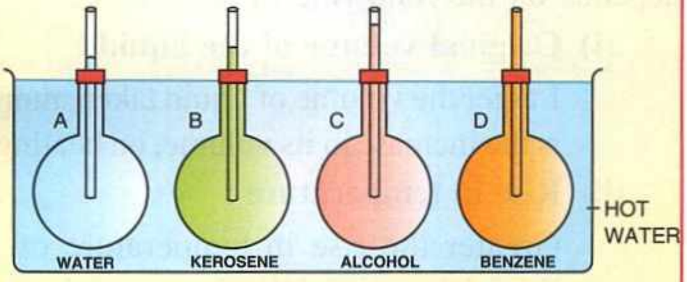


Fig. 6.13 Expansion of different liquids

The table given below gives the coefficient of cubical expansion of some common liquids.

Coefficient of cubical expansion of some liquids

Liquid	Coefficient of cubical expansion γ (× 10^{-4} per °C)
Mercury	1·8
Paraffin oil	7·64
Turpentine	10
Ethyl alcohol	10·9
Benzene	12·5

Water does not have a fixed coefficient of cubical expansion. Its value varies with rise in temperature.

Application of thermal expansion of liquid in daily life

Thermal expansion of liquids is used in th working of a mercury thermometer. We hav read that a mercury thermometer consists of capillary tube with one end closed and cylindrical bulb at the other end. The bulb i filled with mercury. Mercury is a shiny liqui so its level can be seen easily in the capilla tube. When the bulb of the thermometer is ke in contact with a hot body, mercury expand The level of mercury rises in the capillary tu The tube is graduated to read the temperatu For each degree rise in temperature, mercur expands by the same volume, so the calibratio of thermometer becomes easier.

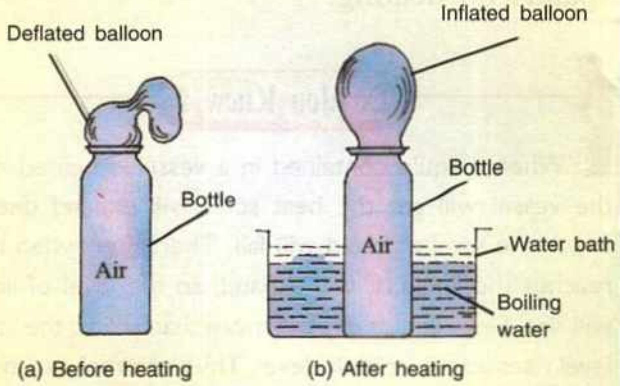
THERMAL EXPANSION IN GASES

Gases also expand when they are heated Gases expand much more than liquids an solids. Like liquids, gases do not have definite shape, so they also have only th cubical expansion.

Thermal expansion of gases can b demonstrated by the following simple activit

ACTIVITY 5

(i) Take an empty bottle. Actually, the empty bottle contains air. Attach a rubber balloon to



(a) Before heating (b) After heating

Fig. 6.14 Thermal expansion of air

its neck as shown in Fig. 6.14(a). Initially, the balloon is deflated.

(ii) Place the bottle in a water bath containing boiling water which heats the air contained in the bottle. After some time you will notice that the balloon gets inflated as shown in Fig.6.14(b). This shows that on heating, the air enclosed in the bottle expands and fills the balloon, hence the balloon gets inflated. Thus air expands on heating.

Do You Know ?

A gas is heated by keeping either its volume or pressure constant. In both cases, the expansion is same (*i.e.*, increase in pressure when volume is kept constant or increase in volume when pressure is kept constant, are same).

Explanation of thermal expansion in gases by the molecular motion

In a gas, molecules have more inter-molecular spacing amongst them. On heating, he average kinetic energy of molecules of gas ncreases and they begin to move violently in ll space available to them for motion. As a esult, the inter-molecular separation further ncreases, so they expand.

VARIATION OF DENSITY WITH TEMPERATURE

When a substance is heated, its volume increases while its mass remains same, therefore, the density of a substance (being the ratio of mass to its volume), decreases with the increase in temperature.

In case of solids, when temperature increases, increase in volume is very small and therefore, the decrease in density is not appreciable. But in case of liquids and gases, as temperature increases, volume increases by an appreciable amount and therefore decrease in their density is quite considerable.

Exception : Water contracts on heating from 0°C to 4°C, so the density of water increases on heating it from 0°C to 4°C. On further heating above 4°C, the density of water decreases. Thus, water has maximum density (= 1000 kg m^{-3}) at 4°C.

Do You Know ?

If an iron washer as shown in Fig. 6.15 is heated, its mass will remain unchanged. Its internal diameter, its external diameter, its thickness and its volume all will increase but its density will decrease.

Fig. 6.15

RECAPITULATION

- Matter is any substance which occupies space and has mass.
- The three states of matter are (i) solid, (ii) liquid and (iii) gas.
- Matter is composed of large number of molecules.
- A molecule is the smallest particle which can exist freely in nature by itself and it retains the properties of the substance.
- In a liquid, the molecules are not rigid, the inter-molecular spacing is more than that in solids, the inter-molecular forces are weak and the molecules are free to move within the boundary of the container, so the liquid has a definite volume, but it does not have a definite shape.

- In gases, the molecules are not rigid, the inter-molecular spacing is more than that in solids and liquids, the inter-molecular forces are the weakest, thus molecules are free to move anywhere in space. So a gas has neither a definite volume nor a definite shape.
- In evaporation, a liquid changes into vapour or gas at all temperatures.
- Evaporation is a surface phenomenon that occurs at all temperatures.
- In evaporation, some molecules near the surface of liquid acquire sufficient kinetic energy by collisions with the other molecules, to reach the surface. These molecules absorb heat from the surroundings to escape out in space.
- In boiling at a fixed temperature, by absorbing heat from an external source, all molecules throughout the liquid acquire sufficient kinetic energy to overcome the force of attraction of other molecules, so they escape out from the liquid in form of vapour.
- When a solid, liquid or gas is heated, it expands.
- The expansion of a substance when heated is called thermal expansion.
- A solid on being heated expands in length, area as well as in volume. Thus, a solid undergoes linear expansion, superficial expansion and cubical expansion.
- The increase in length of a solid in form of a rod, on heating, depends on : (i) its original length, (ii) the rise in temperature, and (iii) the material of the rod. Longer the rod, greater is the increase in its length. More the rise in temperature of rod, more is the increase in its length. Equal lengths of rods of different materials expand by different lengths, when heated to the same temperature.
- The increase in length is given as $L_t - L_0 = L_0 \alpha t$
- The increase in area of a plate is given as $A_t - A_0 = A_0 \beta t$
- The increase in volume of a solid is given as $V_t - V_0 = V_0 \gamma t$
- The coefficients of linear expansion α, superficial expansion β and cubical expansion γ are related as
$$\alpha : \beta : \gamma = 1 : 2 : 3.$$
- According to molecular motion, the molecules of a solid on heating start vibrating about their mean positions with greater amplitude. This changes the mean positions of the molecules so as to increase the inter-molecular spacing and so the solid expands on heating.
- Some solids such as invar, pyrex glass, quartz have negligible expansion on heating.
- Liquids expand more than solids when heated.
- Liquids have only cubical expansion.
- The increase in volume of a liquid is given as $V_t - V_0 = \gamma V_0 t$ where γ is the coefficient of cubical expansion of liquid.
- Different liquids of same volume expand by different amounts when heated to the same rise in temperature e.g. benzene expands much more than water.
- Water contracts on heating from 0°C to 4°C and then it expands on further heating above 4°C.
- Thermal expansion of liquids is used in the working of a mercury thermometer.
- Gases expand much more than solids and liquids, when heated. They also have only cubical expansion.
- On heating, density of solids, liquids and gases decreases.
- Water has maximum density at 4°C which is equal to 1000 kg m^{-3}.

TEST YOURSELF

. Objective Questions :

1. Write **true** or **false** for each statement :

(a) Evaporation is rapid on a wet day.

(b) Evaporation takes place only from the surface of a liquid.

(c) All molecules of a liquid take part in the process of evaporation.

(d) Temperature of a liquid rises during boiling or vaporization.

(e) All molecules of a liquid take part in boiling.

(f) Boiling is a rapid phenomenon.

(g) All solids expand by the same amount when heated to the same rise in temperature.

(h) Telephone wires are kept tight between the two poles in winter.

(i) Equal volumes of different liquids expand by different amounts when they are heated to the same rise in temperature.

(j) Solids expand the least and gases expand the most on being heated.

(k) A mercury thermometer makes use of the property of expansion of liquids on heating.

(l) Kerosene contracts on heating.

Ans: True—(b), (e), (f), (h), (i), (j), (k)
False—(a), (c), (d),(g), (l)

2. Fill in the blanks :

(a) Boiling occurs at ....

(b) Evaporation takes place at ....

(c) The molecules of liquid .... heat from surroundings in evaporation.

(d) Heat is .... during boiling.

(e) Cooling is produced in ....

(f) A longer rod expands .... than a shorter rod on being heated to the same temperature.

(g) Liquids expand .... than the solids.

(h) Gases expand .... than the liquids.

(i) Alcohol expands .... than water.

(j) Iron expands .... than copper.

Ans: (a) a fixed temperature, (b) all temperatures, (c) absorb (d) absorbed, (e) evaporation, (f) more, (g) more, (h) more (i) more (j) less

3. Match the following :

	Column A		**Column B**
(a)	Blowing air increases	(i)	increase in inter-molecular separation
(b)	Increase in pressure increases	(ii)	pendulum of a clock
(c)	Thermal expansion	(iii)	cooking utensils
(d)	Invar	(iv)	boiling point
(e)	Pyrex glass	(v)	evaporation

Ans: (a)–(v), (b)–(iv), (c)–(i), (d)–(ii), (e)–(iii)

4. Select the correct alternative :

(a) In evaporation :

(i) all molecules of liquid begin to escape out

(ii) only the molecules at the surface escape out

(iii) the temperature of liquid rises by absorbing heat from surroundings.

(iv) the molecules get attracted within the liquid.

(b) The rate of evaporation of a liquid increases when :

(i) temperature of liquid falls

(ii) liquid is poured in a vessel of less surface area

(iii) air is blown above the surface of liquid

(iv) humidity increases.

(c) During boiling or vaporization :

(i) all molecules take part

(ii) temperature rises

(iii) no heat is absorbed

(iv) the average kinetic energy of molecules increases.

(d) The boiling point of a liquid is increased by:

(i) increasing the volume of liquid

(ii) increasing the pressure on liquid

(iii) adding ice to the liquid

(iv) decreasing pressure on liquid.

(e) Two rods A and B of the same metal, but of length 1 m and 2 m respectively, are heated from 0°C to 100°C. Then :

(i) both the rods A and B elongate the same

(ii) the rod A elongates more than the rod B

(iii) the rod B elongates more than the rod A

(iv) the rod A elongates, but the rod B contracts.

(f) Two rods A and B of the same metal, same length, but one solid and the other hollow, are heated to the same rise in temperature. Then :

(i) the solid rod A expands more than the hollow rod B

(ii) the hollow rod B expands more than the solid rod A

(iii) the hollow rod B contracts, but the solid rod A expands

(iv) both the rods A and B expand the same.

(g) A given volume of alcohol and the same volume of water are heated from the room temperature to the same temperature then :

(i) alcohol contracts, but water expands

(ii) water contracts, but alcohol expands

(iii) water expands more than alcohol

(iv) alcohol expands more than water.

(h) The increase in length of a metal rod depends on :

(i) the initial length of the rod only

(ii) the rise in temperature only

(iii) the material of rod only

(iv) all the above three factors.

(i) The correct statement is :

(i) Iron rims are cooled before they ar placed on the cart wheels.

(ii) A glass stopper gets tightened o warming the neck of the bottle.

(iii) Telephone wires sag in winter, b become tight in summer.

(iv) A little space is left between two rai on a railway track.

Ans.: (a)–(ii), (b)–(iii), (c)–(i), (d)–(ii), (e)–(iii, (f)–(iv), (g)–(iv), (h)–(iv), (i)–(i

B. Short/Long Answer Questions :

1. What is matter ? What is it composed of ?
2. Name the three states of matter and distinguis them on the basis of their (i) volume, an (ii) shape
3. Distinguish between liquid and vapour (or ga states of matter on the basis of the followin factors :
   (a) Arrangement of molecules
   (b) Inter-molecular separation
   (c) Inter-molecular force, and
   (d) Kinetic energy of molecules
4. What is evaporation ? Explain it on the basis molecular motion.
5. Do all the molecules of a liquid take part i evaporation ? If not, explain your answer.
6. No heat is supplied to a liquid during evaporatio How does then the liquid change into its vapour
7. Comment on the statement 'evaporation is surface phenomenon'.
8. Why is cooling produced when a liqui evaporates ?
9. Give reason for the increase in rate of evaporati of a liquid when
   (a) air is blown above the liquid
   (b) surface area of liquid is increased
   (c) temperature of liquid is increased.

0. What is boiling ? Explain it on the basis of molecular motion.

1. Why does bubbles appear when a liquid is heated ?

2. What is the change in average kinetic energy of molecules of a liquid during boiling at its boiling point ?

3. How is the heat energy supplied to a liquid used during boiling at a fixed temperature ?

4. Name two ways of changing liquid state to the vapour state and distinguish them.

5. What do you understand by thermal expansion of a substance ?

6. Give *two* examples of the substances which expand on heating.

7. Describe an experiment to demonstrate the thermal expansion in solids.

8. State three factors on which depend the linear expansion of a metal rod on heating.

9. Two iron rods – one 10 m long and the other 5 m long, are heated to the same rise in temperature. Which will expand more ?

. Two identical rods of copper are heated to different temperatures – one by 5°C and the other by 10°C. Which rod will expand more ?

1. One rod of copper and another identical rod of iron are heated to the same rise in temperature. Which rod will expand more ? Give reason.

. Two identical rods – one hollow and the other solid, are heated to the same rise in temperature. Which will expand more ?

3. In the ball and ring experiment, if the ball after heating is left to cool on the ring for some time, the ball again passes through the ring. Explain the reason.

. Explain the following :
   (a) The telephone wires break in winter.
   (b) Iron rims are heated before they are fixed on the wooden wheels.
   (c) Gaps are left between the successive rails on a railway track.
   (d) A glass stopper stuck in the neck of a bottle can be removed by pouring hot water on the neck of the bottle.
   (e) A cement floor is laid in small pieces with gaps in between.

25. Why is one end of a steel girder in a bridge kept on rollers instead of fixing it in a pillar ?

26. A metal plate is heated. State three factors on which the increase in its area will depend.

27. A cubical metal solid block is heated. How will its volume change ?

28. Describe an experiment to show that liquids expand on heating.

29. State one application of thermal expansion of liquids.

30. Describe an experiment to show that air expands on heating.

31. An empty glass bottle is fitted with a narrow tube at its mouth. The open end of the tube is kept in a beaker containing water. When the bottle is heated, bubbles of air are seen escaping into water. Explain the reason.

32. Which of the following will expand more, when heated to the same temperature : (a) solid (b) liquid or (c) gas ?

33. Describe an experiment to show that same volume of different liquids heated to same rise in temperature expand by different amounts.

34. 100 ml of each of the following liquids is heated from 10°C to 50°C. Which will expand more : (a) water (b) benzene (c) alcohol ?

35. Water is heated from 0°C to 4°C. Will it expand ?

36. What do you mean by anomalous behavior of water ?

37. How does the density of a substance (solid, liquid and gas) change on heating ?

38. An iron washer is heated. State the effect on its (i) mass, (ii) internal diameter, (iii) external diameter, and (iv) density.

Project Work

To prepare a model of fire alarm.

1. Take a bimetallic strip made of brass and iron, two vertical stands, a metal rod, a dry cell, an electric bell, a spirit lamp and some connecting wires.
2. Clamp one end (say, A) of the bimetallic strip AB on one vertical stand such that the metal brass that expands more is kept on the outer side as shown in Fig. 6.15.
3. Clamp the metal rod on the other vertical stand and place it such that the rod is just below the free end (say, B) of the bimetallic strip. The bimetallic strip is attached such that the end B of the strip does not touch the rod, but it is just about to touch.

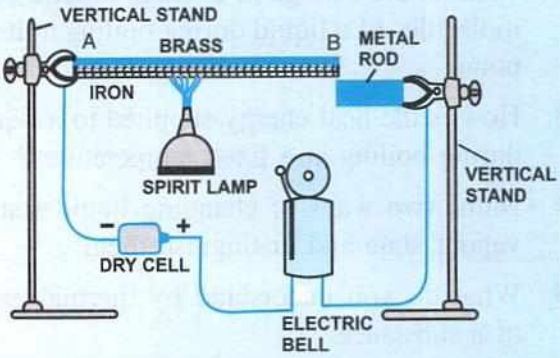
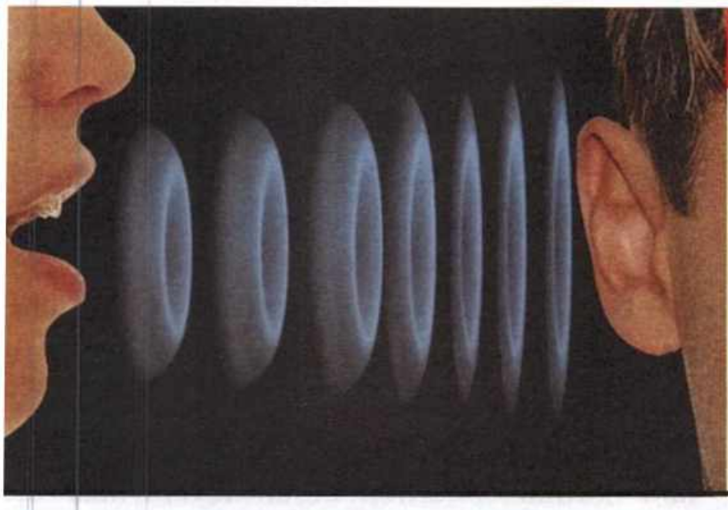


Fig. 6.15 A model of fire alarm

4. Connect one terminal of the cell to the clamped end A of the bimetallic strip and the other terminal of the cell to the electric bell and then to the metal rod.
5. Burn the spirit lamp and place it just below the bimetallic strip. You will notice that on heating the bimetallic strip, the bell rings. The reason is that on heating, the bimetallic strip expands. Since brass expands more than iron, it bends inwards and the end B comes in contact with the metal rod. This completes the circuit and the bell rings.



7

Sound

Theme : In the previous classes children were made aware about and enabled to understand that a sound wave is characterised by its frequency and amplitude. Parameters that focus on loudness and pitch; and are commonly used to characterise sound produced by different sources, were also highlighted. The loudness depends on the amplitude, hence when the amplitude of sound is large, sound is loud. Pitch is related to the frequency so when the frequency is high, the pitch is high or the sound is shrill. In this class the theme focuses on showing how sound produced by different musical instruments have different pitch and loudness.

In this chapter you will learn to

- relate pitch and frequency;
- understand pitch and frequency in relation to working of musical instruments (wind, membrane and string);
- explain mono tone;
- relate loudness and amplitude;
- state the unit of loudness in decibels.

LEARNING OBJECTIVES

- Revising and revisiting previous concepts learnt by children.
- Building on children's previous learning.
- Explaining terms related to pitch and frequency.
- Demonstrating the relation between pitch and frequency.
- Demonstration of pitch and frequency of some common musical instruments.
- Demonstrating monotone sound.
- Demonstrating the relation between loudness and amplitude.
- Explaining units of loudness i.e. decibel.
- Engaging children in tasks/ activities related to pitch, loudness, frequency and amplitude.
- Engaging children in the design of musical toys.

KNOWING CONCEPTS

- Pitch and frequency.
- Pitch and frequency in relation to working of musical instruments (wind, membrane and string).
- Monotone.
- Loudness and amplitude.
- Unit of loudness in decibels.

INTRODUCTION

In class VII, we have read that sound is a form of energy which produces a sensation of hearing in our ears. Sound is produced when a body vibrates. Thus, each source of sound is a vibrating body.

For example, take a rubber band and cut it to get a string. Now stretch the string, keeping its one end in your mouth under the teeth and the other end in your hand as shown in Fig. 7.1. When you pluck the string from the middle, you see that the string starts vibrating and a feeble sound is heard.

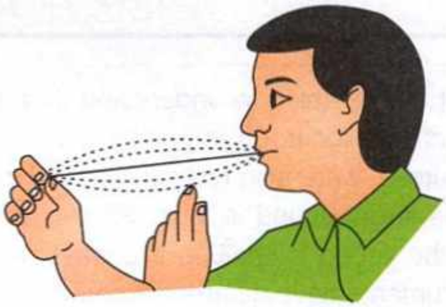


Fig. 7.1 A vibrating string produces sound

Sound needs a medium for its propagation. It cannot travel in vacuum. This is why two persons cannot hear each other on the moon or in space where there is no atmosphere. Sound can travel in solids, in liquids as well as in gases. Its speed is more in solids, less in liquids and still less in gases. The speed of sound in iron is nearly 5000 m s^{-1}, in water it is nearly 1500 m s^{-1} and in air it is nearly 330 m s^{-1}.

When a body vibrates, the particles of the medium also start vibrating. During vibrations, the kinetic energy of particles changes into potential energy and potential energy into kinetic energy. This is why sound is a form of energy.

PROPAGATION OF SOUND IN AIR

When a source of sound vibrates, it creates a periodic disturbance in the medium near it (*i.e.*, the condition of mediu changes). The disturbance then travels in th medium in form of waves. This can b understood by the following example.

Example : Take a vertical metal stri with its lower end fixed. Push its upper en to one side and then release it. As it vibrates *i.e.* moves alternately to the right and left producing sound. Fig. 7.2(a) shows th steady (or mean position) of the metal stri and normal condition of air layers near th strip.

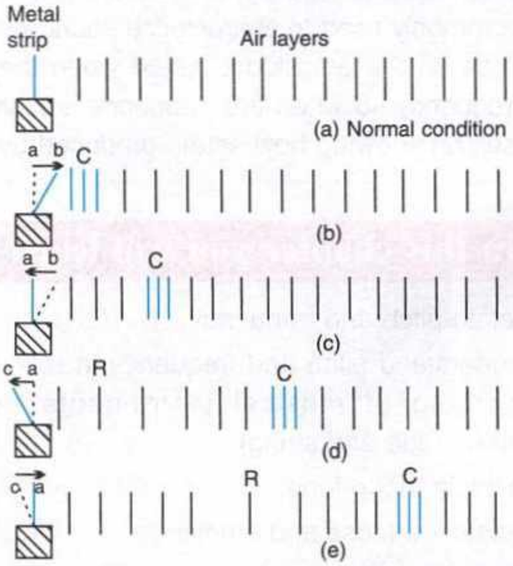


Fig. 7.2 Propagation of sound in air

As the strip moves to the right from a to b in Fig. 7.2(b), it pushes the particles o air layer in front of it. So, the particles of air in this layer come closer to each other *i.e.*, air in that layer gets compressed (or compression is formed at C). The particles of this layer while moving towards right, pushes and compresses the layer next to it, which then compresses the next layer and so on. Thus, the disturbance moves forward in form of compression. The particles of the medium o not move with the compression.

As the metal strip starts returning from to a in Fig. 7.2(c) after pushing the particles ear the strip, the compression C moves orward and the particles of air near the strip eturn back to their normal positions due to he elasticity of the medium.

When the strip moves to the left from a o c in Fig. 7.2(d), it pulls the layer of air near t towards left and thus produces a space of ery low pressure on its right side. The air ayers on the right side of the strip expand in his region thus forming the rarefied layers. This region of low pressure is called a arefaction R.

By the time the strip returns from c to ts mean position a in Fig. 7.2(e), the arefaction R moves forward and air layers ear the strip return back to their normal osition due to the elasticity of the medium.

In this manner, as the strip moves to the ight and left repeatedly, the compression and refaction regions are produced one after the ther, which carry the disturbance along it with a definite speed depending on the nature f the medium.

One complete to and fro motion of the trip forms one compression and one arefaction which together constitute one wave. This wave in which the particles of the medium vibrate about their mean positions, in he direction of propagation of sound, is called longitudinal wave. Thus, sound travels in air in form of longitudinal waves. These ongitudinal waves can be produced in solids, n liquids as well as in gases.

Thus, due to propagation of wave in a medium, the particles of the medium vibrate about their mean positions (without leaving their positions) and they transfer the energy with a constant speed from one place of medium to other places.

TERMS RELATED TO A WAVE

(1) **Amplitude :** The maximum displacement of a particle of medium on either side of its mean position, is called the amplitude of wave. It is denoted by the letter *a*. Its S.I. unit is metre (m).

(2) **Time period :** The time taken by a particle of medium to complete its one vibration is called the time period of the wave. It is denoted by the letter T. Its S.I. unit is second (s).

(3) **Frequency :** The number of vibrations produced by a particle of the medium in one second is called the frequency of the wave. It is also defined as the number of waves passing through a point in one second. It is denoted by the letter *f*. Its S.I. unit is second^{-1} or hertz (symbol Hz).

The frequency of a wave is equal to the frequency of vibrations of its source. It is the characteristic of its source which produces the sound. It does not depend on the amplitude of vibration or on the nature of medium through which the wave propagates.

Relationship between time period (T) and frequency (*f*) : If T is the time period of a wave, then by definition

In time T, the number of waves = 1

∴ In 1 second, number of waves (or frequency) $f = \frac{1}{T}$

Thus, frequency = $\frac{1}{\text{Time period}}$

or time period = $\frac{1}{\text{frequency}}$

(4) **Wavelength :** The distance travelled by the wave in one time period of vibration of particle of medium is called its wavelength. It is denoted by the letter λ (lambda). Its S.I. unit is metre (m). It depends on the nature of medium through which the wave travels.

In a longitudinal wave, the distance between two consecutive compressions or between two consecutive rarefactions is equal to one wavelength (λ).

REPRESENTATION OF A WAVE

A wave while propagating in a medium can be represented by the following two graphs :

(1) Displacement-time graph, and

(2) Displacement-distance graph.

(1) **Displacement-time graph :** Fig.7.3 shows the variation of displacement of a particle of the medium with time at a given position, when a wave propagates through the medium. It is called displacement-time graph. Th amplitude is represented by the letter and time period is represented by th letter T in Fig. 7.3.

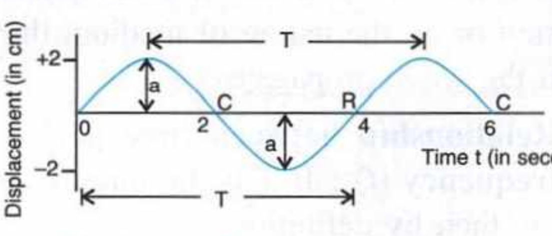


Fig. 7.3 Displacement – time graph of a particle in a wave

In Fig. 7.3, the amplitude of wave i 2 cm and its time period is 4 s (*i.e* frequency is 0·25 Hz).

(2) **Displacement-distance graph** Fig. 7.4 shows the variation o displacement of particles of the mediu at different positions with distance a the same time. Here amplitude of wav is shown by the letter a and wavelength is shown by the letter λ.

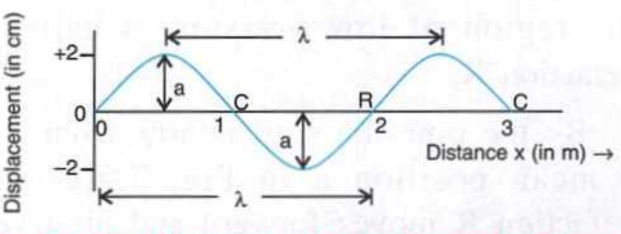


Fig. 7.4 Displacement – distance graph of a wave

For example in Fig. 7.4, amplitude c wave is 2 cm and its wavelength is 2 m.

Do You Know ?

(1) In a longitudinal wave, in Fig.7.3 and 7.4, the displacement on + Y axis shows the motion of medium particles in the direction of propagation of wave while the displacement on – Y axis shows the motion of medium particles in direction opposite to the propagation of sound.

(2) If the particles of medium vibrate normal to the direction of propagation of wave, the wave is called transverse wave.

(3) Sound waves produced in strings are transverse waves.

CHARACTERISTICS OF SOUND

A sound wave is characterized by it amplitude and frequency. Depending upon th amplitude and frequency of the sound wave, wo sounds can be distinguished from one nother by the following three different haracteristics :

(1) Loudness,

(2) Pitch (or shrillness), and

(3) Quality (or timbre or wave form).

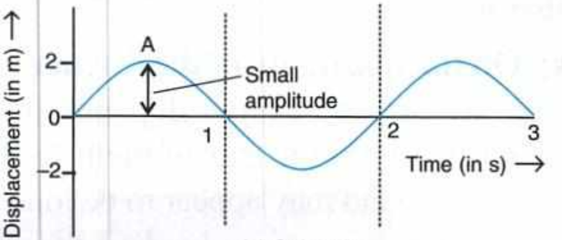
The above characteristics of a given sound an be known from the wave pattern of that ound.

(1) Loudness :

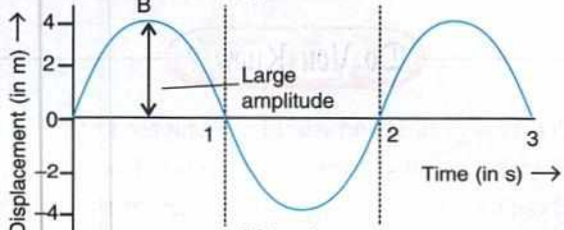
Loudness is the characteristic of sound y virtue of which a loud sound can be istinguished from a faint sound, both having he same frequency and same wave form.

The loudness of a sound depends on the mplitude of vibration of the vibrating body roducing sound. Greater the amplitude of ibrations, louder is the sound produced.

Fig. 7.5 shows two waves A and B of ame frequency and same wave form, but the mplitude of wave A is 2 m while that of the ave B is 4 m. Thus, the amplitude of wave B s greater than that of A, hence the sound B is ouder than sound A.



(a) Soft note



(b) Loud note

Fig. 7.5 Soft and loud sound

Examples : (i) If you gently pluck the string of a sitar or a guitar, a soft (or faint) sound is heard. But if you pluck the string hard, it gets displaced more from its rest position *i.e.*, its amplitude of vibration increases and so a loud sound is heard.

(ii) If you strike the drum gently, a faint sound is heard. But if you strike it hard, you hear a loud sound.

(iii) If you gently strike a tuning fork on a rubber pad, you will hear the feeble (or soft) sound, but if you strike it hard on the rubber pad, a loud sound is heard.

Similarly, if the key of a piano is hit harder or a pipe is blown harder, we put more energy in the vibrating system due to which the amplitude of vibration is increased and a loud sound is produced.

The dependence of loudness on amplitude of vibrations can be demonstrated by the following activity.

ACTIVITY 1

Producing a faint and loud sound by a drum.

Take a drum, a pencil and a stick. First beat the drum gently with the pencil. You will hear a faint sound. The reason is that the membrane of drum vibrates with small amplitude.

Now you beat the drum hard with the stick (Fig. 7.6), so that the membrane of drum vibrates with a large amplitude. You will now hear a loud sound.

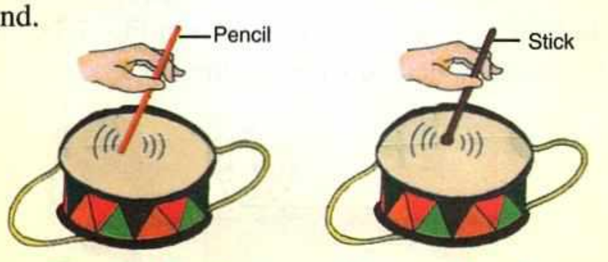


Fig. 7.6 Producing a faint and loud sound by a drum

Factors affecting the loudness of sound : The loudness of sound depends on the following factors :

(i) On the amplitude of wave : When a body vibrates with greater amplitude, it sends forth a greater amount of energy and hence the energy received by the eardrum is large, so the sound heard is louder. This can be understood by the following activity.

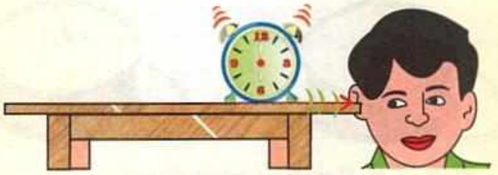
ACTIVITY 2

Take a drum. Place a ping-pong ball on the membrane of the drum. Beat the membrane gently with the drum stick. A feeble sound is heard and the ball moves up to a small height showing that the amplitude of vibration is small. Now beat the membrane harder with the drum stick. The drum produces a louder sound and the ball jumps higher showing that the amplitude has increased.

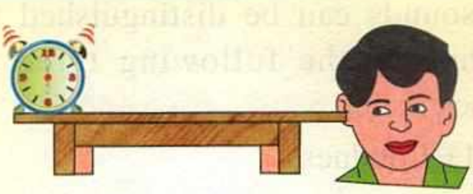
(ii) On the distance of source of sound : If the listener is close to the source of sound, he hears it quite louder, but if he is far away, the sound becomes feeble. If he moves further away from the source, a stage may reach when the sound becomes inaudible. Thus, closer the source, louder is the sound. This can be demonstrated by the following activity.

ACTIVITY 3

Place a clock on one end of a long table and bring your ear near the clock as shown in Fig. 7.7(a). You will hear the ticking sound of the clock.



(a) Loud sound



(b) Feeble sound

Fig. 7.7 Loudness decreases with increase of distance of source

Now move the clock on the table away from you. You will notice that the ticking sound of clock becomes feeble and a stage comes when you will not be able to hear the sound [Fig. 7.7(b)].

(iii) On the surface area of the vibrating body : A large vibrating area sends fort a greater amount of energy, so th amplitude of vibration is large. Henc larger the surface area of the vibratin body, louder is the sound heard.

If you take two drums, one small and th other big, and beat them one by one to produc vibrations in them, you will notice that th sound produced by the big drum is louder tha that produced by the small drum.

In temples, you must have noticed that bell with a big case produces a louder soun than that with a small case.

(iv) On the sensitivity of the listener : Th loudness of a sound depends on th sensitivity of the ears of the listener. given sound may appear to be loud to listener, but not so loud to the oth

Do You Know ?

The energy of sound reaching a unit area of surface in each second is called intensity of sound. The intensity of sound can be measured, but loudness cannot be measured. Intensity of sound does not depend on the sensitivity of the ears of the listener. However larger the intensity, louder is the sound. Thus, loudness depends on intensity.

listeners. To a partially deaf listener, a louder sound will appear to be feeble.

Relationship between loudness and amplitude of a wave : The loudness of sound is directly proportional to the square of amplitude of wave. It implies that on doubling the amplitude of wave, the loudness becomes $(2)^2 = 4$ times. If amplitude of wave is tripled, the loudness become $(3)^2 = 9$ times and so on. Thus

Loudness ∝ $(\text{amplitude})^2$

or $L \propto a^2$

Fig. 7.8 shows two waves A and B The amplitude of wave A is 2 cm and that of B is 3 cm, but both waves are of same frequency. The ratio of loudness of B and A is

$$\frac{\text{Loudness of wave B}}{\text{Loudness of wave A}} = \frac{(3\text{ cm})^2}{(2\text{ cm})^2} = \frac{9}{4}$$

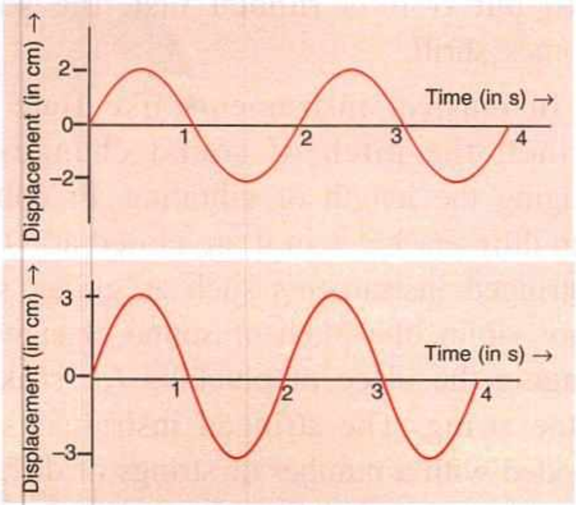


Fig. 7.8 Two waves of different amplitudes

Unit of loudness — decibel (dB)

The loudness of sound is measured on a special scale called the decibel scale. Note hat 1 dB = one-tenth of bel where bel is the unit of level of loudness, named after the cientist Alexander Graham Bel, who invented one of the most useful devices, viz, telephone.

The minimum loudness of sound audible at frequency 1 kHz is considered to be the zero level of sound in decibel (*i.e.*, zero dB). It is taken to be the reference level. When the loudness increases 10 times, the level of sound is said to be 10 dB. When the loudness becomes 100 times, its level is 20 dB, when the loudness becomes 1000 times, its level is 30 dB and so on.

The table below gives the level of sound in dB produced by some objects.

Level of sound produced by some objects

Object producing sound	Level (in dB)	Loudness
1. Minimum audible	0	Very much faint
2. Leaves rustling	10	Very faint
3. Recording studio	20	Very faint
4. Whisper	30	Faint
5. Normal conversation	50	Moderate
6. Vacuum cleaner	60	Moderate
7. Vehicle	80	Loud
8. Diesel engine	90	Very loud
9. Heavy hammering machine	110	Painful
10. Police car siren	120	Painful
11. Rocket take off	140	Much painful

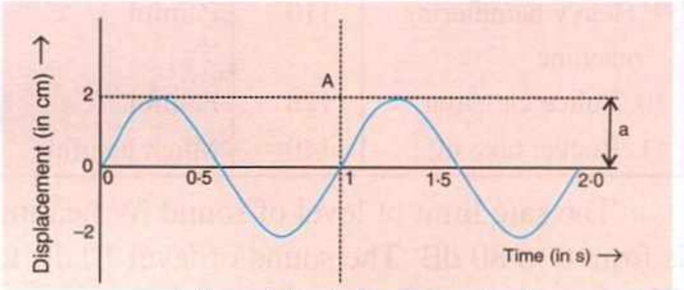
The safe limit of level of sound for hearing is from 0 to 80 dB. The sound of level 10 dB to 30 dB has soothing sensation. A constant hearing of sound of level above 120 dB can cause headache and permanent damage to the ears of the listener. Such sound is called **noise**.

(2) Pitch :

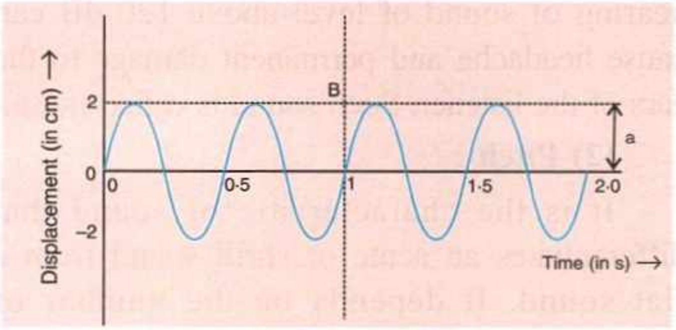
It is the characteristic of sound that differentiates an acute or shrill sound from a flat sound. It depends on the number of vibrations per second. Pitch refers only to the musical sounds and each musical note has a definite pitch. If the pitch is high, the sound is shrill and if the pitch is low, the sound is flat. In a tape recorder (or TV), bass and treble refer to low and high pitch respectively. At a bass (or woofer on), low pitch (*i.e.*, grave) sound produced by tabla or dholak becomes predominant, while at treble, high pitch (*i.e.*, shrill sound produced by flute or ghoonghroo (ankle bells) becomes predominant.

Pitch of a note depends on its frequency. Two notes sounded on the same instrument with same amplitude, will differ in pitch when their vibrations are of different frequencies.

Fig. 7.9 shows two waves A and B each of amplitude 2 cm. The wave A is of time period T = 1 s *i.e.* frequency $f = \frac{1}{1\,\text{s}} = 1\ \text{s}^{-1}$ while the wave B is of time period T = 0·5 s *i.e.* frequency $f = \frac{1}{0{\cdot}5\,\text{s}} = 2\ \text{s}^{-1}$. Thus, the wave A is of low pitch while the wave B is of high pitch.



(a) Low pitch note (Frequency = 1 s^{-1})



(b) High pitch note (Frequency = 2 s^{-1})

Fig. 7.9 Two waves of different pitch

Do You Know ?

(i) In the displacement-time graph, if number of waves in same time interval increases, it means that the time period of wave has decreased *i.e.*, its frequency (or pitch) has increased.

(ii) In the displacement-distance graph, if number of waves in the same distance increases, it means that the wavelength of wave has decreased so its frequency (or pitch) has increased.

Examples : (1) The frequency of a soun of a crying baby is more than that of a cryin adult, so the sound of a crying baby is shrille than that of a crying adult.

Similarly, the voice of a female is shriller than that of a male.

(2) If a post card is rubbed slowl against the teeth of a comb, a grave sound i heard but if it is rubbed fast, the soun becomes shrill.

In musical instruments like flute an clarinet, the pitch of sound changes b changing the length of vibrating air colum when different holes in it are closed at a time In stringed instruments such as guitar, sitar piano, violin, the pitch of sound changes b changing the place of plucking (or striking on the string. The stringed instruments a provided with a number of strings of differen thickness and under different tensions so tha each string produces sounds of different pitch

Ways of changing the pitch in different musical instruments

(i) In stringed instruments : Instrument such as piano, violin and guitar hav several strings of different thicknes under different tensions (Fig. 7.10). Th reason is that the frequency of vibration of a string depends on the tension and thickness of the string. A note of higher pitch can be obtained by vibrating the string under high tension or by vibrating a thinner string.

The pitch of sound proudced by a string instrument also depends on the place where it is plucked. If a string stretched between its ends, is plucked more closer to the one fixed end, higher is the pitch of the sound produced.

Fig. 7.10 Stringed musical instruments

(ii) In wind instruments : In case of a flute, clarinet, shehnai etc., (Fig. 7.11) a lower note is obtained by closing some more holes so that the length of the vibrating air column increases. Thus, the pitch of sound produced by the flute decreases *i.e.* the sound becomes grave. On the other hand, to increase the pitch (or make the sound shrill), the holes are opened so as to reduce the length of the vibrating air column.

Fig. 7.11 Musical instruments in form of pipe

This can be understood by the following activities.

ACTIVITY 4

Take a pitcher. Keep it below a water tap. You will notice that as the water level in the pitcher rises, the length of air column decreases, so the frequency of sound produced increases *i.e.*, the sound becomes shriller and shriller. Thus, by hearing the sound from a distance, one can get an idea of water level in the pitcher.

ACTIVITY 5

Take a steel wire of length nearly 0·5 m. Stretch the wire between two fixed supports under some tension. Pluck the wire at its middle, it will vibrate in one loop as shown in Fig. 7.12(a).

Now if you pluck the wire at a distance $\frac{1}{4}$ of its length from one end, it will vibrate in two loops as shown in Fig.7.12(b). The sound now will be shriller than before.

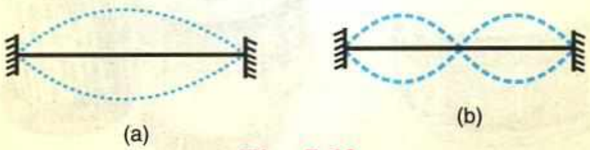


Fig. 7.12

ACTIVITY 6

Take a test tube with a little water in it as shown in Fig. 7.13(a). Blow air in the tube by placing your

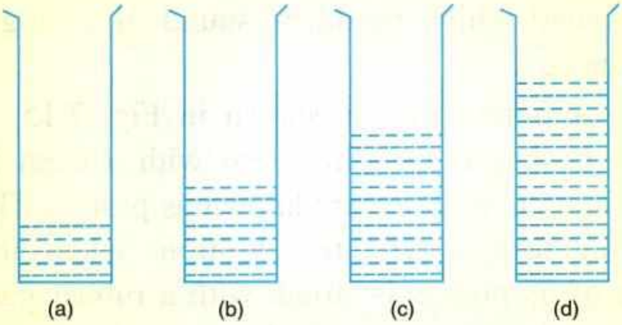


Fig. 7.13 Pitch increases with decreasing length of air column.

lip on the mouth of the test tube, You will hear a flat sound (*i.e.*, a sound of low pitch). Now add more and more water in the test tube as shown in Fig. 7.13(b), (c), and (d) so that the length of air column above the water level decreases. Each time, blow air and hear the sound. You will notice that the sound produced becomes more and more shrill.

(iii) In membrane Instruments : In instruments such as dholak, tabla, drum etc. shown in Fig. 7.14, there is a membrane which is stretched by means of strings. To produce sound, the membrane is made to vibrate by striking or tapping it. The pitch of sound depends on the size and tension of the membrane. More tight and small is the membrane, higher is the pitch of sound produced. Thus, to increase shrillness of sound, the instrument of small membrane is taken and its strings are stretched and tightened.

Fig. 7.14 Membrane instruments

MONOTONE

A sound of single frequency is called a monotone. A tuning fork is the only source of sound which produces sound of a single frequency.

A tuning fork is shown in Fig. 7.15. It is a U-shaped metallic piece with a stem in the middle. Its arms are known as prongs. The tuning fork is set into vibrations when any one of its prongs is struck with a rubber pad. Generally, tuning forks are made of frequencies which correspond to musical notes. Different tuning forks may have different frequencies. When struck with rubber pad, a tuning fork vibrates with it own frequency. The frequency produced b the tuning fork is marked on it. Generally th tuning forks are available of frequencie 256 s^{-1}, 288 s^{-1}, 320 s^{-1}, 384 s^{-1}, 480 s^{-1} and 512 s^{-1}.

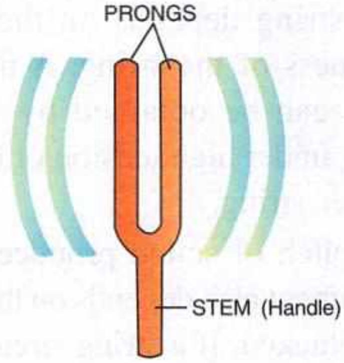


Fig. 7.15 Tuning fork

The wave form of sound of a tuning for is shown in Fig. 7.16.

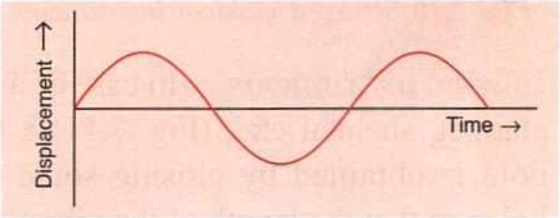


Fig. 7.16 Wave form of a monotone

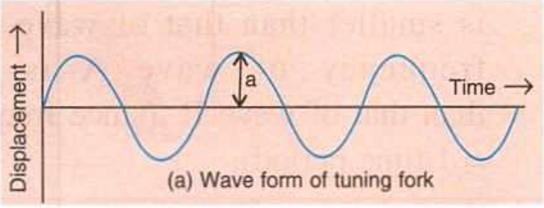
(3) Quality (or timbre or wave form)

Quality is the characteristic whic distinguishes two sounds of the same pitc and same loudness.

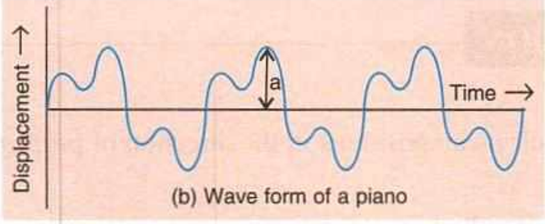
The sound produced by any musica instrument or human being contains in smal amplitudes two or more waves of differen frequencies which are integer multiples of th frequency of source. These waves ar different in different sources. Due to th presence of such vibrations, the wave for (or quality) of sound changes. The wave fo is different for different sources of sound eve if their loudness and pitch are same.

Each vibrating body has its characteristic wave form. This makes it possible for one to recognize the vibrating body even without seeing it. You generally recognize a person by hearing his voice on telephone, without seeing him. It is because the vibrations produced by the vocal chord of each person have a characteristic wave form which is different for different persons. Similarly, one can distinguish and recognize the sounds of two different musical instruments even if they are of same pitch and same loudness.

Fig. 7.17 shows the wave form of sound produced by a tuning fork and a piano, both of same pitch (*i.e.* same frequency) and same amplitude, but they have the different wave forms, by which they are distinguished from each other.



(a) Wave form of tuning fork



(b) Wave form of a piano

Fig. 7.17

A note played on a piano has a large number of notes, while the same note when played on a flute contains only a few notes. Thus, we can easily distinguish between the sounds of a piano and a flute by their different wave forms, though they may have exactly the same loudness and same pitch.

To summarize, the table below gives the factors affecting the different characteristics of sound.

Characteristics →	Loudness	Pitch	Timbre or quality
Factor →	Amplitude	Frequency	Wave form

MAKING A MUSICAL TOY

To make a guitar, take a shoe box (without lid), a card board cylinder of diameter nearly 6 to 7 cm, five-six rubber bands, cellotape, a pair of scissors and pencil.

1. Place one end of the card board tube on one side of the shoe box. Trace its outline. Cut this part of the box using scissors to make a hole in the box (Fig. 7.18).

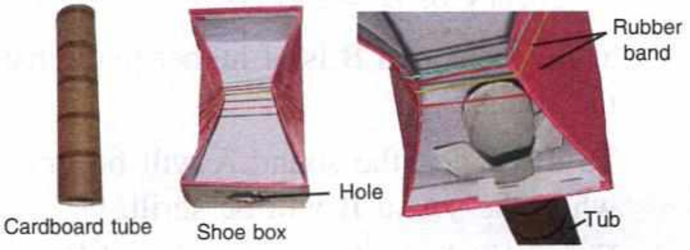


Fig. 7.18 Home made guitar

2. Insert the end of card board tube into the box. Fold the edges of tube inside the box so as to fix it in the box with a cellotape.
3. Stretch the rubber band across the shoe box. This will compress the central part of the box as shown in Fig. 7.18.
4. Play on rubber strings by your fingers. You will hear a twanging sound like guitar. Use the guitar for the following activity.

ACTIVITY 7

Use your internet to obtain a programme on tuning a guitar. Try to practice it yourself.

SOLVED EXAMPLES

1. Two waves A and B are of amplitudes 3 cm and 4 cm respectively. Compare their loudness. Which sound is louder ?

Solution : *Given*, amplitude of A = 3 cm, amplitude of B = 4 cm

$$\frac{\text{Loudness of A}}{\text{Loudness of B}} = \frac{(\text{amplitude of A})^2}{(\text{amplitude of B})^2}$$

$$= \frac{(3\text{ cm})^2}{(4\text{ cm})^2} = \frac{9}{16}$$

∴ Sound B is louder than sound A.

2. Two sources of sound A and B are of frequencies 120 Hz and 256 Hz respectively. Which sound is of higher pitch ? To a listener, how do the two sounds differ ?

Solution : *Given*, frequency of A = 128 Hz

Frequency of B = 256 Hz

Thus, the sound B is of higher pitch than the sound A.

To a listener, the sound A will be grave while the sound B will be shrill.

3. Fig. 7.19 shows two waves A and B.
   (i) Which sound is louder ? Give reason.
   (ii) Which sound is shriller ? Give reason.

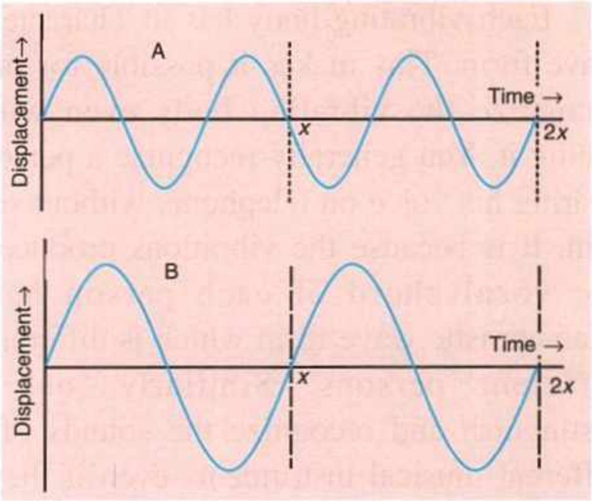


Fig. 7.19

Solution :

(i) Sound B is louder than sound A. Th reason is that the amplitude of sound is more than that of sound A.

(ii) Sound A is shriller than sound B. Th reason is that time period of wave is smaller than that of wave B *i.e.* frequency of wave A is mor than that of wave B. (since frequency = 1/time period).

RECAPITULATION

- Sound travels in air in form of longitudinal waves.
- In a longitudinal wave, the particles of air vibrate about their mean positions in the direction of propagation of sound.
- One complete to and fro motion of the particle of medium is called one vibration.
- The maximum displacement of a vibrating particle from its rest (or mean) position is called its amplitude. It is expressed in metre.
- The time taken by a vibrating particle to complete one vibration is called its time period. It is expressed in second.
- The number of complete vibrations that a vibrating particle makes in one second is called its frequency. It is expressed in hertz (symbol Hz).
- The frequency and time period are related as frequency = 1/time period.
- We distinguish different sounds by their loudness, pitch and quality.
- The loudness of sound depends on the amplitude of vibration of the vibrating body producing sound. Greater the amplitude, louder is the sound produced.

- Loudness is the characteristic of sound that distinguishes a loud sound from a feeble or soft sound.
- The loudness of sound increases if the vibrating area of the body is increased.
- The pitch of a sound depends on the frequency of the vibrating body. A sound of high frequency is said to have a high pitch, while a sound of low frequency is said to have a low pitch.
- Higher the pitch, the shriller is the sound. Lower the pitch, the flat (or grave) is the sound.
- Pitch is the characteristic of sound which distinguishes a shrill sound from a flat (or grave) sound.
- Quality is the characteristic of sound which distinguishes two sounds of the same pitch and same loudness since they differ in wave form due to the presence of sounds of other frequencies in small amplitudes.
- The sound of single frequency is called monotone. Only a tuning fork produces a monotone.

TEST YOURSELF

. Objective Questions :

1. Write **true** or **false** for each statement :

   (a) When sound propagates in air, it does not carry energy with it.

   (b) In a longitudinal wave, compression and rarefaction are formed.

   (c) The distance from one compression to nearest rarefaction is called wavelength.

   (d) The frequency is measured in second.

   (e) The quality of a sound depends on the amplitude of wave.

   (f) The pitch of sound depends on frequency.

   (g) Decibel is the unit of pitch of a sound.

   Ans. True—(b), (f) **False**—(a), (c), (d), (e), (g)

2. Fill in the blanks :

   (a) The time period of a wave is 2 s. Its frequency is ....

   (b) The pitch of a stringed instrument is increased by .... tension in string.

   (c) The pitch of a flute is decreased by .... length of air column.

   (d) Smaller the membrane, ... is the pitch.

   (e) If a drum is beaten hard, its loudness ....

   (f) A tuning fork produces sound of .... frequency.

   Ans. (a) 0·5 s^{-1} (b) increasing (c) increasing (d) higher (e) increases (f) single

3. Match the following :

Column A	Column B
(a) Amplitude	(i) frequency
(b) Frequency	(ii) amplitude
(c) Loudness	(iii) maximum displacement on either side
(d) Pitch	(iv) presence of other frequencies
(e) Wave form	(v) 1/Time period

   Ans. (a)–(iii), (b)–(v), (c)–(ii), (d)–(i), (e)–(iv)

4. Select the correct alternative :

   (a) Sound cannot travel in :

   (i) solid (ii) liquid
   (iii) gas (iv) vacuum

   (b) When sound travels in form of a wave

   (i) the particles of medium move from the source to the listener
   (ii) the particles of medium remain stationary
   (iii) the particles of medium start vibrating up and down
   (iv) the particles of medium transfer energy without leaving their mean positions.

   (c) The safe limit of loudness of audible sound is :

   (i) 0 to 80 dB (ii) above 80 dB
   (iii) 120 dB (iv) above 120 dB.

(d) The unit of loudness is :

(i) cm (ii) second

(iii) hertz (iv) decibel.

(e) In a piano, pitch is decreased by :

(i) using thicker string

(ii) increasing tension

(iii) reducing length of string

(iv) striking it hard.

Ans. (a)–(iv), (b)–(iv), (c)–(i), (d)–(iv), (e)–(i)

B. Short/Long Answer Questions :

1. How does sound travel in air ?
2. What is a longitudinal wave ?
3. Explain the mechanism of formation of a longitudinal wave when source vibrates in air.
4. Define the following terms :
   (a) Amplitude
   (b) Frequency
   (c) Time period.
5. Obtain relationship between the time period and frequency.
6. Name the three characteristics of a musical sound.
7. Which of the following determines the loudness of a sound wave ?
   (a) Wavelength (b) Frequency, or (c) Amplitude.
8. How is loudness related to the amplitude of a wave ?
9. If the amplitude of a wave is doubled, what will be the effect on its loudness ?
10. How does the wave pattern of a loud note differ from a soft note ? Draw a diagram.
11. Name the unit in which the loudness of sound is expressed.
12. Why is the loudness of sound heard by a plucked wire increased when mounted on a sound board ?
    [**Hint :** The surface area of vibrating air increases]
13. State three factors on which loudness of sound heard by a listener depends.
14. What determines the pitch of a sound ?
15. Name the characteristic of sound related to it frequency. **Ans.** pitch
16. Name and define the characteristic which enable one to distinguish two sounds of same loudness but of different frequencies, given by the sam instrument.
17. Draw a diagram to show the wave pattern of high pitch note and a low pitch note, but of th same loudness.
18. Standing at a distance, how is it possible to detec the filling of a bucket under a water tap b hearing the sound ?
19. The frequencies of notes given by flute, guita and trumpet are respectively 400 Hz, 200 Hz an 500 Hz. Which one of these has the highe pitch ? **Ans.** Trumpe
20. Fig. 7.20 shows two jars A and B containin water up to different heights. Which will produc sound of higher pitch when air is blown in them

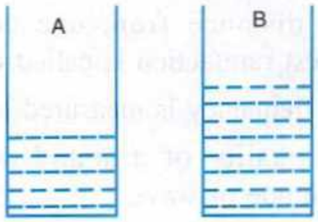


Fig. 7.21 **Ans.**

21. Two identical guitars are played by two perso to give notes of the same pitch. Will they diff in quality ? Give reason for your answer.
22. Two musical notes of the same pitch and san loudness are played on two different instrument Their wave patterns are as shown in Fig. 7.21.

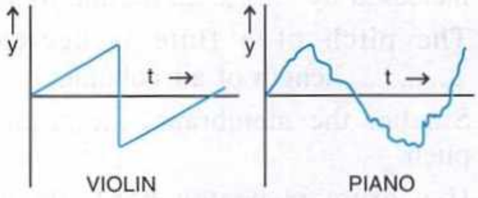


Fig. 7.21

How do they differ in

(a) loudness, (b) pitch and

(c) quality ?

Ans. (a) Same (b) Same (c) Differe

3. Which characteristic of sound makes it possible to recognize a person by his voice without seeing him ?

4. State the factors that determine
   (a) the pitch of a note.
   (b) the loudness of the sound heard.
   (c) the quality of the note.

Ans. (a) frequency (b) amplitude (c) wave form.

5. Name the characteristic of the sound affected due to a change in its (a) amplitude (b) wave form (c) frequency.

Ans. (a) loudness (b) quality (c) pitch.

5. Fig. 7.22 shows four waves A, B, C, and D.

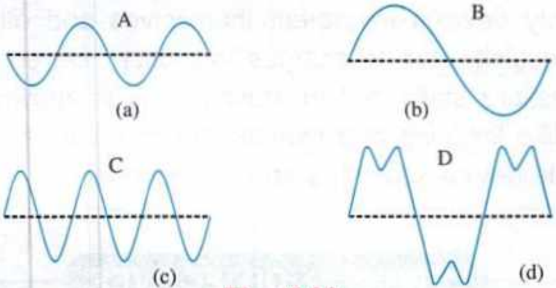


Fig. 7.22

Name the wave which shows
   (a) a note from a musical instrument,
   (b) a soft note,
   (c) a shrill note.

Ans. (a)–(D) (b)–(A) (c)–(C)

27. How is the pitch of sound in a guitar changed if (a) a thin wire is used, (b) a wire under less tension is used ?

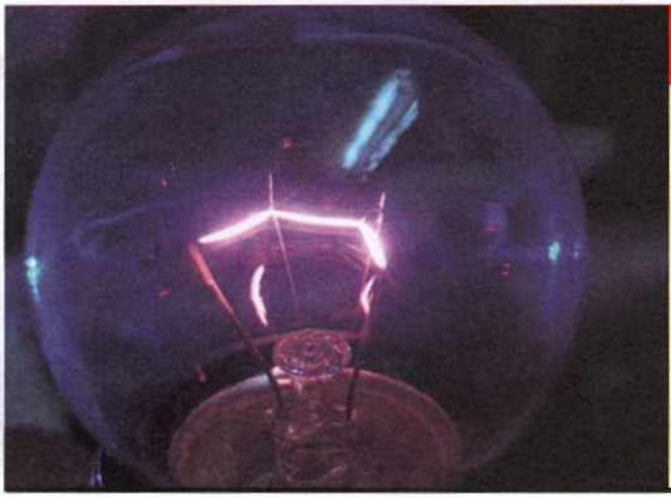
C. Numericals

1. Two waves of the same pitch have amplitudes in the ratio 1 : 3. What will be the ratio of their (i) loudness, (ii) pitch ? **Ans.** (i) 1 : 9 (ii) 1 : 1

2. Two waves have frequencies 256 Hz and 512 Hz, but same amplitude. Compare their (i) loudness, and (ii) pitch.
   Ans. (i) 1 : 1 (ii) 1 : 2

3. Two waves have the same pitch but their amplitudes are in the ratio of 1 : 2. Draw a figure to show the two waves.

4. Two waves of the same amplitude have frequencies 256 Hz and 512 Hz respectively. Represent the two waves in the graphical form. (**Hint :** 1 wave represents 256 Hz of frequency)



8

Electricity

Theme : In this theme the aim is that children will develope the ability to estimate consumption of electricity by knowing the power rating of appliances used. They will also appreciate and understand the need and importance of taking certain precautions and using of safety devices to protect themselves and others against electrical hazards. Previous learning stressed on electricity due to charges in motion, *i.e.* current electricity. However, objects can be charged, where charges are static, not in motion. This is known as static electricity. This leads to many phenomena in nature, like lightning and thunder during rainy season. How an object that is charged may be detected using a simple device known as an electroscope.

In this chapter you will learn to

- describe household consumption of electricity.
- identify live wire, neutral wire and earth wire in terms of their energy and path they travel.
- describe safety components (fuses, circuits breakers).
- describe phenomenon of static electricity.
- explain conservation of charges.
- describe conduction and working of an electroscope.
- describe a lightning conductor.
- identify dangers of electricity.
- conduct scientific experiments keeping in mind all the parameters.
- study the impact of energy consumption and draw conclusions from the same and suggest alternate approaches.
- learn the use of safety precautions while dealing with electrical appliances.

LEARNING OBJECTIVES

- Revising or revisiting previous concepts learnt by children.
- Building on children's previous learning.
- Calculating energy consumption using household electricity bills by children.
- Helping children identify live, neutral and earth wires.
- Demonstrating safety components and their uses.
- Demonstrating static electricity.
- Demonstrating induction and conduction.
- Engaging children in activities related to static electricity.
- Demonstrating the construction and working of an electroscope.

KNOWING CONCEPTS

- Household consumption of electric energy (kilowatt hour).
- Identify live wire, neutral wire and earth wire in terms of their energy and path they travel.
- Safety components (fuses/circuit breakers (qualitative approach only)/grounding).
- Static electricity.
  - Conservation of charges.
  - Induction.
  - Conduction.
  - Electroscope (Gold leaf electroscope).
- Lightning conductor.
- Dangers of electricity.

(A) HOUSEHOLD ELECTRICITY

NTRODUCTION

In our daily life, we all use electricity for lifferent purposes such as to light our home, chool, office etc., to run fan, television, heater, adio and many other electrical appliances. The lifferent sources of electricity are : cells (or attery), mains (electricity supplied by local lectricity board), electric generator (or lynamo) and solar cells. In earlier classes, we ave read the use of cells (or battery) in orches, watches, calculators, remote controls, tc. In this chapter, we shall study the use of nains as a source of electricity for household urposes.

The cell or battery provides us current vhich remains constant with time. This current s called direct current (or D.C.). The mains nd electric generator provide us the lternating current (A.C.) which changes its nagnitude and polarity with time. Generally, ve use A.C. of frequency 50 Hz in which the olarity is 50 times positive and 50 times egative in each one second.

LECTRICAL ENERGY AND POWER ONSUMED IN A CIRCUIT

In class VII, we have read that current from a cell flows in a circuit due to the motion of electrons in the metallic wires used in that circuit. A cell has a potential difference (or voltage) between its electrodes, namely, the anode and cathode. ***Potential difference*** *is defined as the work done in moving a unit charge from one electrode to another electrode.* It is expressed in the unit volt (symbol V) after the name of the scientist Alessandro Volta.

We have defined current as the rate of flow of charges in a unit time. It is measured in ampere (symbol A) after the name of the scientist Andre Marie Ampere.

In Fig. 8.1, suppose a current I flows through a conductor of resistance R for time t, when a source of potential difference V is connected across its ends. We are to find the amount of electrical energy supplied by the source.

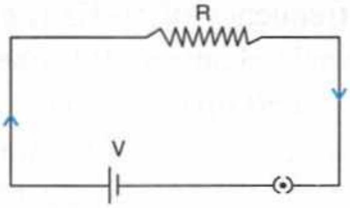


Fig. 8.1 Current flowing in a resistance

By definition, potential difference is the work done in moving a unit charge, so work needed to move a charge Q through a potential difference V is

$$\boxed{W = QV}$$

But current $I = \frac{\text{charge } Q}{\text{time } t}$

$$\therefore \quad \boxed{Q = It}$$

Hence,

$$W = VIt$$

This gives the electrical energy W supplied by the source (battery or mains) in providing the current I for time t in the conductor under a potential difference V.

Now power is the rate of doing work. So power supplied by the source

$$P = \frac{W}{t} = \frac{VIt}{t} = VI$$

Thus, power (in watt)

= (potential difference in volt) × (current in ampere)

Thus 1 W = 1 V × 1 A

or 1 watt = 1 volt × 1 ampere.

TRANSMISSION OF POWER FROM THE POWER GENERATING STATION TO THE CONSUMER

Electric power is generated at the power generating stations which are usually located very far from the areas where it is consumed. At the generating station, the electric power is generated at 11 kV. The voltage generated has alternating frequency of 50 Hz (*i.e.* its polarity at the terminals changes 100 times a second, 50 times + and 50 times –). The voltage of the power generated at the generating station is first raised from 11 kV to 132 kV to reduce loss of energy in transmission due to heating of line wires and then is transmitted to the grid sub station. At the grid sub station, its voltage is reduced from 132 kV to 33 kV before it sent to main substation where its voltage i further reduced to 11 kV. Once reduced, t power is supplied to the city substation whe its voltage is further reduced to 220 V befo it is supplied to the consumer.

SUPPLY OF POWER TO A HOUSE

To supply electric power to a hou from the city substation, either the overhea wires or cable on poles or an undergroun cable is used. The cable has three wires (i) live (or phase) wire (L), (ii) neutral wi (N), and (iii) earth wire (E). The neutral an the earth wires are connected together at th local substation so that the neutral and eart wires are at the same potential (*i.e.* at 0 V The live wire, also called the phase wire, is 220 V and it carries current from the source t the distribution board, while the neutral wi is for the return path of current. The earth wi passes the current to the earth and protects from electric shocks.

Do You Know ?

(1) A.C. voltage is raised up by using a step up transformer while it is lowered down with a step down transformer.

(2) D.C. voltage can neither be increased nor decreased by any device. This is why D.C. power is not used in household circuits.

(3) In household circuits, we use A.C. power at 220 volts.

COLOUR CODING OF LIVE, NEUTRA AND EARTH WIRES

In the cable, the live, neutral and eart wires have insulations of different colours s that they can be easily distinguished.

Live wire is red or brown.

Neutral wire is black or light blue.

Earth wire is green or yellow.

To summarize, the voltage, colours and he purpose of the three wires are given below.

Wire	Colour	Voltage	Purpose
Live	Red or brown	220 V	To carry current from source to the appliance
Neutral	Black or light blue	0 V	To provide the return path from appliance to source
Earth	Green or yellow	0 V	To provide connection to earth

CONNECTION FROM POLE TO THE DISTRIBUTION BOARD

To connect the cable from pole to the meter in a house, first a fuse of high rating (= 50 A) is connected in the live wire at the pole or just before the meter. This fuse is called the company fuse or pole fuse. Only the electric supply company staff are authorized to handle it. The rating of the fuse depends on the load for which connection is taken from the company. After the company fuse, the cable is connected to an electric meter. The electric meter is usually mounted on the front or outside wall of the house. From the meter, connections are made to the distribution board through a main fuse and a main switch. The main fuse is connected to the live wire, while the main switch is connected to the live and neutral wires.

COMMERCIAL UNIT OF ELECTRICAL ENERGY

Electrical energy is generally measured in a unit called B.O.T (Board of Trade) unit or kWh, (*i.e.*, kilowatt hour) or simply as unit.

1 kilowatt hour is defined as the amount of energy consumed when an electrical appliance of power 1 kilowatt is used for 1 hour.

The energy consumed in our houses, shops, factories etc. is measured in kWh.

Since, $$\text{Power} = \frac{\text{Energy}}{\text{Time}}$$

$$\text{Energy} = \text{Power} \times \text{Time}$$

i.e. Energy (in kWh)

$$= \text{Power (in kW)} \times \text{time (in h)}$$

$$\begin{aligned} \text{Hence, } 1\text{ kWh} &= 1\text{ kW} \times 1\text{ h} \\ &= (1000\text{ W}) \times (60 \times 60\text{ s}) \\ &= 36{,}00{,}000\text{ J} \\ &= 3{\cdot}6 \times 10^6\text{ J} \end{aligned}$$

Electric meter : The electric meter is also called the kWh meter because it measures the amount of electric energy consumed by the consumer in the unit kWh (called kilo watt hour) for which the electricity bill is paid by him to the electricity board.

Fig. 8.2 shows a kWh meter. The main part of the meter is the armature A which is connected to the main line (Fig. 8.3). When any electrical appliance is put on, the electric current flows which rotates the armature. The counter fixed on the armature reads the number of rotations.

Fig. 8.2 kWh meter

Then five dials on the counter read electricity consumption directly in kWh units as shown in Fig. 8.3. These five dials from right to left measure the energy in (i) units, (ii) tens, (iii) hundreds, (iv) thousands and (v) ten thousands respectively. In Fig. 8.3, the reading on the meter is 49180 kWh.

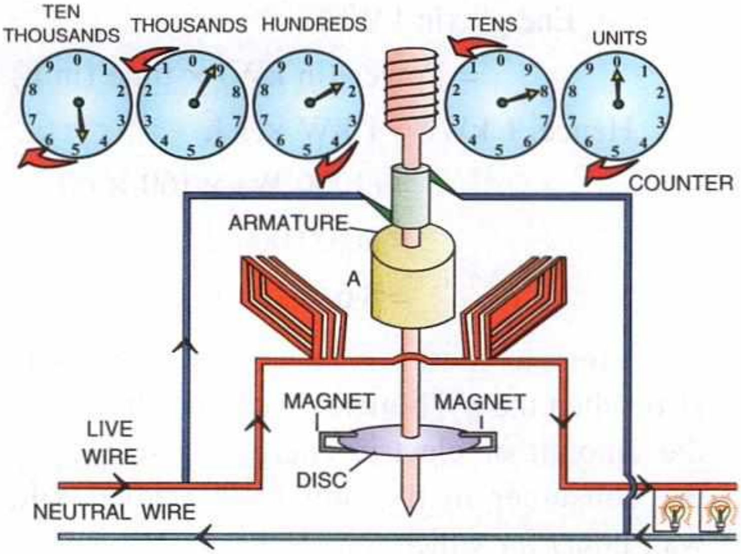


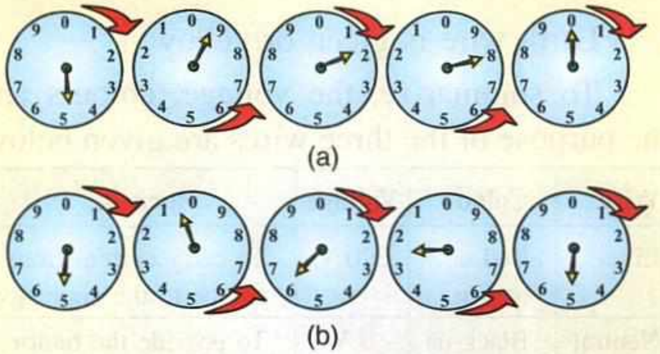
Fig. 8.3 Working of a household electric meter

Nowadays, the old meters are being replaced by electronic digital meters which are totally different from the meters shown above. The following activity will make clear how the electrical energy consumed in a given time is measured by the electric meter.

ACTIVITY 1

To find the consumption of electricity in a month and pay the electricity bill.

Fig. 8.4 (a) shows the reading on dials of the meter on the first day of a month and Fig. 8.4(b) shows the reading on the last day of the month. You are to find the initial reading, final reading, the electrical energy consumed in the month and the electricity bill at a rate of ₹ 6·25 per kWh.


(a)

(b)

Fig. 8.4 (a) Initial reading in kWh meter
(b) Final reading in kWh meter

The initial reading is 49180 kWh and the final reading is 50625 kWh. The total consumption of electricity in the month is 50625 kWh – 49180 kWh = 1445 kWh *i.e.* the electricity consumed is 1445 units. If the rate of electricity per unit is ₹ 6.25, the bill will be 1445 × ₹ 6.25 = ₹ 9031.25 only.

ELECTRIC FUSE (A SAFETY DEVICE)

The electric fuse is a device which i used to limit the current in an electric circuit It safeguards the circuit and the appliance connected in the circuit from being damage if the current in the circuit exceeds th specified value due to voltage fluctuations o short circuiting. Fig. 8.5 shows an electri fuse arrangement commonly used in ou household circuits. It consists of a fuse wir F which is stretched between the two metal terminals T_1 and T_2 in a porcelain holder The holder fits into a porcelain socket.

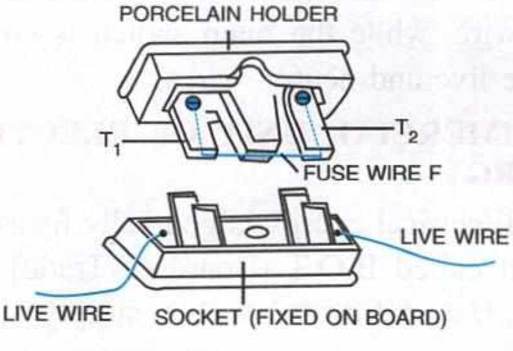


Fig. 8.5 Electric fuse

The fuse wire is a short and thin piece f wire of a material of low melting point.

Generally, the fuse wire is made of an alloy f lead and tin, having 50% of each metal.

Purpose of fuse : If the insulation on the ire of cable used in wiring (or used with an ppliance) breaks, the live wire comes in ontact with the neutral wire which results in short circuit. Maximum current then passes hrough the wires which can cause burning of he wires due to excessive heat. Similarly, lue to voltage fluctuations, sometimes high urrent flows through the wires that can cause urning of wires. To prevent this damage, a use is connected to the live wire of the ircuit. When there is a short circuit, the fuse ire gets heated up to the extent that it melts. s a result, a gap is produced in the live wire nd the circuit becomes incomplete or breaks. o current then flows and the appliance or he circuit is saved. After removing the fault n the circuit or the appliance, a new fuse wire s fixed between the terminals T_1 and T_2 in e holder to complete the circuit again.

Note : Nowadays the domestic gadgets uch as oven, geyser, press, refrigerator, irconditioner etc. are provided with a artridge type fuse in its live wire.

CHARACTERISTICS OF A FUSE

1. It is a short wire with a low melting point. The fuse wire is made of an alloy of lead and tin. It melts at about 200°C.
2. Fuse wire is connected in series with the live wire. Its temperature rises much faster than the connecting copper wires when an excessive current flows as its resistance is higher than that of the connecting copper wires.
3. The thickness of fuse wire depends on the current rating of it. Higher the rating, thicker is the wire. It means that 15 A fuse is thicker than the 5 A fuse. The heating of fuse wire does not depend on its length.

Note : An ordinary copper wire must not be used as the fuse wire because its melting point is much high.

These days miniature circuit breakers (MCB) are used. They switch off the circuit in a very short time (nearly 25 milli seconds) in case of short circuiting.

MINIATURE CIRCUIT BREAKER (MCB)

A miniature circuit breaker (Fig. 8.6) is an automatic switch that is nowadays used to protect the household wiring from the excessive flow of electric current in a circuit. When the current flow is in excess, the MCB automatically falls down to break the electric circuit. It is reset (*i.e.* raised up) after the fault is rectified.

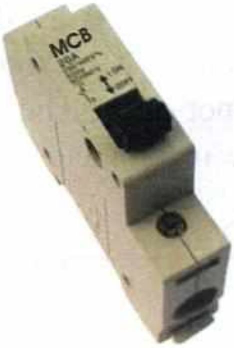


Fig. 8.6 MCB

HOUSEHOLD ELECTRICAL CIRCUITS

In your house, you notice that each electrical appliance can be used separately. You can light a bulb without running the fan, or you can light the bulb in one room without lighting the bulbs in the other rooms. Further, you can notice that if one bulb fuses or one appliance fails, it does not affect the working of the other appliances in the house. All the appliances work at the same voltage equal to the voltage of mains (= 220 V). Now the question arises how are the various appliances connected in the circuit ? To answer this question, perform the following two experiments.

Experiment 1 : Take two torch bulbs. Mark them as A and B. Connect the two bulbs to a cell through a switch as shown in Fig 8.7. The bulbs are said to be connected in series. Close the switch. You will see that both the bulbs glow.

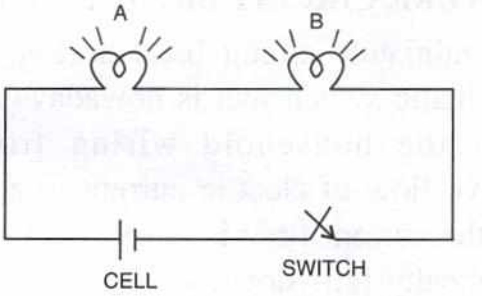


Fig. 8.7 Both the bulbs glow when switch is closed

Now swtich off and take out the connections of the bulb B as shown in Fig. 8.8. Again close the switch. You will see that the bulb A does not glow. The reason is that the circuit is now incomplete.

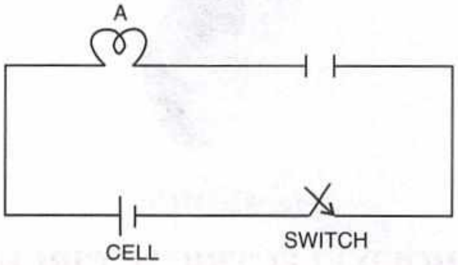


Fig. 8.8 The bulb A does not glow because the circuit is incomplete

Now replace the bulb B by a fused bulb as shown in Fig. 8.9. Close the switch. You will again find that the bulb A does not glow since the circuit is incomplete.

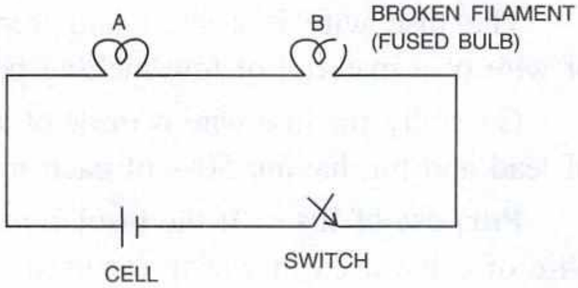


Fig. 8.9 The bulb A does not glow since the circuit is incomplete

Experiment 2 : Connect the two bulb marked A and B through the switches S$_1$ and S$_2$ to a cell as shown in Fig. 8.10. The bulbs are said to be connected in parallel. Close both the switches S$_1$ and S$_2$. You will find that both the bulbs glow.

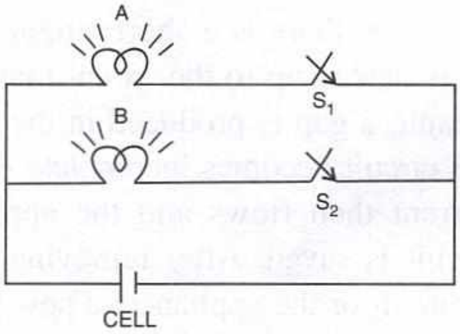


Fig. 8.10 Both the bulbs glow when switches S$_1$ and S$_2$ both are closed

Now close only the switch S$_1$ and leave the switch S$_2$ open (Fig. 8.11). You will find that the bulb A glows, but the bulb B does not glow.

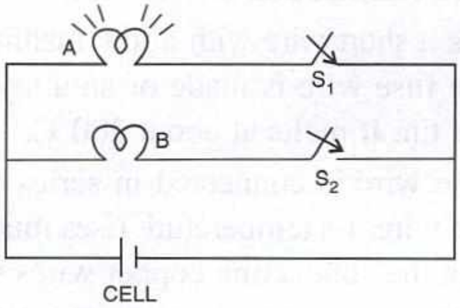


Fig. 8.11 Only the bulb A glows when the switch S$_1$ is closed

Then close only the switch S_2 and leave e switch S_1 open (Fig. 8.12). You will find at the bulb B glows, but the bulb A does ot glow.

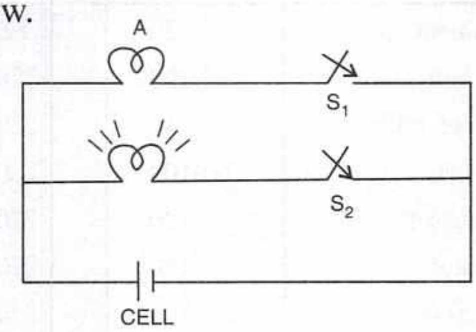


Fig. 8.12 Only the bulb B glows when the switch S_2 is closed

Now replace the bulb B by a fused bulb ig. 8.13). Close both the switches S_1 and $_2$. You will find that the bulb A still glows, t the bulb B being fused, does not glow.

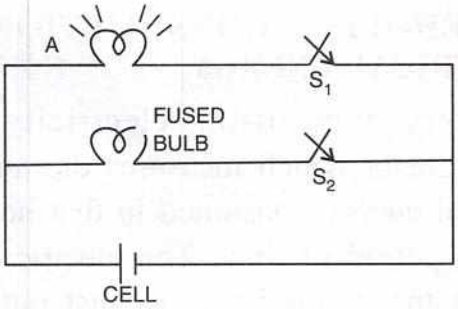


Fig. 8.13 The bulb A still glows when both switches are closed

From the above experiments, you nclude that in series connection, if one of e bulbs is removed or it is fused, the other lb does not glow on closing the switch, t in parallel connection, a bulb glows respective of whether the other bulb glows not (or it is fused).

Thus, it is clear that all the electrical ppliances in our homes, offices, schools, ctories etc., are connected in parallel. Each pliance has an independent path for current d works at the same voltage.

ELECTRIC CIRCUIT IN A ROOM

Electricity is supplied to us at a voltage of 220 volt through a cable which has three wires, namely the live wire, the neutral wire and the earth wire. From the distribution board, electricity is distributed to various parts of the house such as rooms, kitchen, toilet, staircase, etc. All electrical appliances are connected in parallel. Fig. 8.14 shows an electric circuit of a room having two bulbs and a fan. Each appliance has a separate switch connected with its live wire. In Fig. 8.14, earth wire has not been shown.

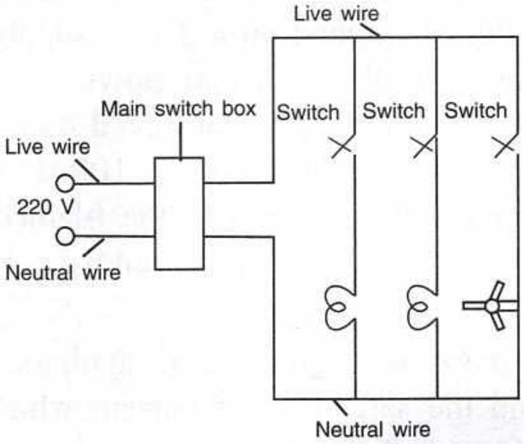


Fig. 8.14 Electrical circuit in a room

EARTHING OF THE APPLIANCES

The metallic outer body (case) of each appliance such as refrigerator, oven, geyser etc., is connected to the earth wire. The reason is that sometimes due to breaking of insulation of wires, live wires come in contact with the body of the appliance, and we get a fatal shock when the appliance is touched. If the appliance is earthed, the current will pass to the earth and we remain protected from the electric shock.

Do You Know ?

1. Short circuit occurs when a naked live wire and a neutral wire come in contact or the live wire and the earth wire come in contact. Its major cause is the poor insulation on wires.

2. Overloading of an electric circuit, is a condition when it draws more current than it is designed for.

3. Earthing is done in a house near the kWh meter.

POWER RATING OF APPLIANCES

Generally, an electric appliance such as electric bulb, geyser, heater etc. is rated with power and voltage. *For example*, an electric bulb is rated as 100 W – 220 V. It means that if the bulb is lighted on a 220 V supply, it consumes 100 W electrical power (*i.e.* 100 J of electrical energy is consumed by the bulb in 1 s or in other words, 100 J of electrical energy is converted in the filament of bulb into light and heat energy in 1 second).

From the power rating of an appliance, we can find the safe limit of current which can flow through that appliance.

From relation P = VI.

Safe limit of current for an appliance

$$I = \frac{\text{Power of appliance}}{\text{Voltage at which it works}}$$

For example, for a bulb rated 100 W, 220 V, the safe limit of current when it is lighted at 220 V is

$$I = \frac{P}{V} = \frac{100\,\text{W}}{220\,\text{V}} = 0{\cdot}45\ \text{A}$$

The table alongside gives the power rating of some common appliances.

Power rating of some common appliances

Appliance	Power (in watt)	Voltage (in volt)
Car (filament) bulb	20	12
Electric bulb	15-200	220
Fluorescent tube	40	220
Electric fan	60-100	220
Television set	120	220
Refrigerator	150	220
Electric iron	700	220
Electric mixer	750	220
Room heater	1000	220
Geyser	1500	220
Electric kettle	2000	220
Electric oven	3000	220

In our country a.c. is supplied at voltage equal to 220 V.

HOUSEHOLD CONSUMPTION OF ELECTRICAL ENERGY

Every home using electricity has ar electric meter which measures the amount o electrical energy consumed in that home ove a given period of time. The electric meter i fixed at the mains board or just outside ou house. The electrical energy is sold in unit of kilowatt hour (kWh). It is the unit in whic the consumer pays the cost of electricity.

The electrical energy consumed by a appliance in a certain time can be calculate in kWh by using the following relation :

$$\begin{aligned}\text{Energy (in kWh)} &= \text{Power (in kW)} \times \text{time (in h)}\\ &= \frac{\text{Power (in watt)} \times \text{time (in hour)}}{1000}\\ &= \frac{\text{V(volt)} \times \text{I (ampere)} \times \text{t (hour)}}{1000}\end{aligned}$$

Thus the total energy consumed by an electrical appliance in kWh can be calculated by multiplying its power rating in kW with the time duration in hour (h) for which it was in use. The cost of electricity will then be the product of energy consumed in kWh with the rate in rupees per kWh.

Example : If an electric oven of power 3 kW works for two hour per day, the electrical energy consumed by the oven per day will be 3 kW × 2 h = 6 kWh, while the total electrical energy consumed in a month of 30 days will be 3 kW × (2 × 30 h) = 180 kWh. The cost of electricity at the rate of ₹ 6·25 per kWh will then be 180 kWh × ₹ 6·25 = ₹ 1125.

ACTIVITY 2

To find consumption of electrical energy.

List the electrical appliances such as bulbs, fans, airconditioners, heaters, ovens, refrigerators, washing machines etc. which are used in your house in a day. Write the power rated on these appliances and the time duration of their use.

Name of appliances	Number	Power (in watt)	Time (in hour)	Electrical energy (kWh)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Then use the following relation to find the energy consumed by each appliance.

Electrical energy in kWh

$$= \frac{\text{Number} \times \text{power} \times \text{time}}{1000}$$

Record it in the above table.

Find the total sum which will give the total electrical energy consumed in your house each day.

HAZARDS (DANGERS) OF ELECTRICITY

Apart from a number of its uses, there are some hazards too with electricity which are given below :

1. When you use a number of electrical gadgets connected in a circuit at the same time, a heavy current flows through the connecting wires. In other words, the house circuit gets overloaded. There will be overheating of the electric wires which may cause short circuiting and even electric fire.
2. Sometimes, due to poor insulation of wires, the live wire touches the neutral wire. This causes short circuiting and the flow of current becomes excess. This excess flow of current damages the electrical appliances such as T.V., refrigerator, tubelights, bulbs etc. Even the wires catch fire and there can be a mishap in form of electric fire.
3. If a person comes in contact with a live wire, he gets an electric shock. If it is a huge shock, it can cause death.

PRECAUTIONS TO BE TAKEN WHILE USING ELECTRICITY

1. We should not touch switches with wet hands.
2. The connecting wires to the plugs, sockets and switches should be tightly joined.
3. We should ensure that all the appliances are properly earthed.
4. We should not try to repair an appliance while it is in use.
5. We should ensure that the MCB or fuse and switch are connected to the live wire.
6. The wiring used must have proper insulation.
7. The ordinary copper wire should not be used as a fuse wire because the melting point of copper is 1080°C, so it will not melt even if the current exceeds its safe limit.
8. To switch off the gadgets like T.V., geyser, press, air conditioner etc. take out the plug from the socket instead of using the remote.

SOLVED EXAMPLES

1. From a battery of potential difference 12·0 volt, current 2·0 ampere flows through a wire for 30 minute. Find :
   (i) the electrical energy supplied by the battery, and
   (ii) the power spent.

Solution : *Given :* Potential difference $V = 12{\cdot}0$ volt

Current $I = 2{\cdot}0$ ampere,

time $t = 30$ min. $= 30 \times 60 = 1800$ s

(i) Energy supplied $W = VIt$

$= 12{\cdot}0 \times 2{\cdot}0 \times 1800 = 43200$ J

(ii) Power $P = VI$

$= 12{\cdot}0 \times 2{\cdot}0 = 24{\cdot}0$ W

2. An electric heater is rated 1·5 kW, 220 V.
   (a) Find the safe current which can flow through it.
   (b) Can fuse of current rating 5 A be used with it ?
   (c) What must be the current rating of the fuse ?

Solution :

(a) *Given :* $P = 1{\cdot}5$ kW $=1500$ W, $V = 220$ volt

From relation $P = VI$

$$\text{Safe current } I = \frac{P}{V} = \frac{1500\text{ W}}{220\text{ V}} = 6{\cdot}8\text{ A}$$

(b) No, the fuse of current rating 5 A can not be used.

(c) The current rating of the fuse must be 7 A.

3. An electric geyser of power 2500 watt is used for 1 h 30 min. Find the electrical energy consumed in kWh.

Solution : *Given*, $P = 2500$ W,

$t = 1$ h 30 min $= 1{\cdot}5$ h

$$\text{Since} \quad P = \frac{W}{t}$$

Electrical energy consumed $W = P \times t$

$= 2500\text{ W} \times 1{\cdot}5\text{ h} = 3750$ Wh

$$= \frac{3750}{1000}\text{ kWh} = 3{\cdot}75\text{ kWh}$$

4. An electric bulb of 100 watt, an electric iron of 750 watt and a television of 100 watt are used for 3 hour a day. Calculate the energy consumed per day.

Solution : *Given*, Total power P

$= (100 + 750 +100)$

$= 950$ watt

Time $t = 3$ h

From relation $P = \frac{W}{t}$

nergy consumed $W = 950 \text{ watt} \times 3 \text{ h}$

$= 2850$ Wh

$= \frac{2850}{1000}$ kWh

$= 2{\cdot}85$ kWh

5. An electrical appliance of power 1·5 kW is used for 4 hour each day. Find :
   (a) The electrical energy consumed in kWh, each day.
   (b) The electrical energy consumed in 60 days.
   (c) The cost of electrical energy consumed in 60 days at the rate of ₹ 6·25 per kWh.

Solution : Given : Power = 1·5 kW and time = 4 h

(a) Electrical energy consumed each day

= Power × time

$= 1{\cdot}5 \text{ kW} \times 4 \text{ h} = 6$ kWh

(b) Electrical energy consumed in 60 days

$= 60 \times 6$ kWh

$= 360$ kWh

(c) Cost of electrical energy consumed in 60 days

$= 360 \times$ ₹ 6·25

= **₹ 2,250**

RECAPITULATION

- In our houses, we use electricity from mains which is an alternating current (a.c) of frequency 50 Hz at a potential difference of 220 volt.
- The electrical energy supplied by a source of potential difference V in flowing a current of I ampere in a circuit for time t second is given as

$$W = VIt \text{ joule}$$

and electrical power $P = \text{Energy } W/\text{time } t = VI$ watt

Thus 1 watt = 1 volt × 1 ampere or $1 \text{ W} = 1 \text{ V} \times 1 \text{ A}$

- Commercial unit of electrical energy is kilowatt hour (symbol kWh) where

$$1 \text{ kWh} = 3{\cdot}6 \times 10^6 \text{ joule}$$

- At the power generating station, electricity is generated at 11 kV. It is supplied from there at 132 kV to the different substations where its voltage is decreased in steps 132 kV to 33 kV, 33 kV to 11 kV and then from 11 kV to 220 V.
- The electric supply comes to a house first to a meter fixed on a board. The meter measures the consumption of electricity in kWh unit for which we pay to the electricity board.
- The electric fuse is a device which is used to limit the current in an electric circuit. It is a short and thin wire made of an alloy of lead and tin to have a low melting point. It safeguards the circuit and the appliances connected in the circuit from being damaged due to voltage fluctuations or electrical short circuit.
- The fuse wire is always connected with the live wire.

- In household circuits, all the electrical appliances are connected in parallel. Each appliance has an independent path for current and works at the same voltage. Each appliance has a separate switch connected with its live wire.
- The cable used for wiring has three wires with insulation of different colours. The red or brown wire is live wire, the black or blue wire is neutral wire and the green or yellow wire is the earth wire.
- The live wire carries current from mains to the appliance. It is at 220 V. The neutral wire is for the return of current from appliance to the mains. It is at 0 V. The earth wire is to connect the metallic case of the appliances to the earth. It is at 0 V.
- The metallic outer body of each appliance is connected to the earth wire.
- Each appliance must have its switch and fuse connected to the live wire.
- Each appliance is rated with its power and voltage. This rating indicates that the appliance when used at that voltage, the energy consumed by it in 1 second will be the power rated on it. From this rating, we can find the safe limit of current that can pass through the appliance ($I = P/V$).
- A fuse of high current rating is thicker than a fuse of low current rating.
- A switch should never be touched with wet hands.
- Electrical energy consumed in kWh by an appliance = (Power in watt/1000) × time in hour.

  kWh is also called unit (*i.e.*, 1 kWh = 1 unit)
- Cost of electricity = energy in kWh × rate of electricity per kWh.

TEST YOURSELF

A. Objective Questions :

1. Write **true** or **false** for each statement :

   (a) A fuse wire has a high melting point.

   (b) Flow of protons constitutes electric current.

   (c) A fuse wire is made of silver.

   (d) S.I. unit and commercial unit of electrical energy are same.

   (e) Overloading of electric current in circuits can lead to an electrical short circuit.

   (f) Our body can pass electricity through it.

   (g) The metallic cases of all appliances are insulators of electricity.

   (h) The earth wire protects us from an electric shock.

   (i) A switch should not be touched with wet hands.

   (j) All electrical appliances in a household circuit work at the same voltage.

   (k) In a cable, the green wire is the live wire.

   (l) A fuse is connected to the live wire.

   (m) A switch is connected to the neutral wire.

   Ans: True— (e), (f), (h), (i), (j), (l
   False—(a), (b), (c), (d), (g), (k), (m

2. Fill in the blanks :

   (a) The unit in which we pay the cost o electricity is ....

   (b) The electrical energy consumed in a hou is measured by ....

   (c) In a household electrical circuit, th appliances are connected in .... wi the mains.

   (d) A switch is connected to the .... wire.

   (e) The insulated wire in red colour in a cab is the .... wire.

(f) One kilowatt hour is equal to.................... joule.

(g) A fuse wire should have low ....

Ans: (a) kWh, (b) kWh meter (c) parallel (d) live (e) live (f) 3·6 × 10^6 (g) melting point

3. Match the following :

Column A	**Column B**
(a) Electric power	(i) volt
(b) kWh	(ii) joule
(c) Electric current	(iii) volt × ampere
(d) Electrical energy	(iv) watt
(e) watt	(v) ampere
(f) Potential difference	(vi) electrical energy

Ans: (a)–(iv), (b)–(vi), (c)–(v), (d)–(ii), (e)–(iii), (f)–(i)

4. Select the correct alternative :

(a) All wires used in electric circuits should be covered with :
   (i) colouring material
   (ii) conducting material
   (iii) an insulating material
   (iv) none of the above.

(b) Electrical work done per unit time is :
   (i) electrical energy
   (ii) electric current
   (iii) electric voltage
   (iv) electrical power.

(c) One kilowatt is equal to :
   (i) 100 watt (ii) 1000 watt
   (iii) 10 watt (iv) none of these.

(d) Fuse wire is an alloy of :
   (i) tin-lead (ii) copper-lead
   (iii) tin-copper (iv) lead-silver.

(e) A fuse wire should have :
   (i) a low melting point
   (ii) high melting point
   (iii) very high melting point
   (iv) none of the above.

(f) When switch of an electric appliance is put off, it disconnects :
   (i) the live wire
   (ii) the neutral wire
   (iii) the earth wire
   (iv) the live and the neutral wires.

(g) The purpose of an electric meter in a house is :
   (i) to give the cost of electricity directly
   (ii) to give the consumption of elecrical energy
   (iii) to safeguard the circuit from electrical short circuit
   (iv) to put on or off the mains.

(h) If out of the two lighted bulbs in a room, one bulb suddenly fuses, then :
   (i) the other bulb will glow more
   (ii) the other bulb will glow less
   (iii) the other bulb will also fuse
   (iv) the other bulb will remain lighted and unaffected.

Ans: (a)–(iii), (b)–(iv), (c)–(ii), (d)–(i), (e)–(i), (f)–(i), (g)–(ii), (h)–(iv)

B. Short/Long Answer Questions :

1. From where does electricity come to our homes ?
2. What is an electric meter ? Where is it fixed in our house ?
3. State the purpose of kWh meter.
4. For which unit do we pay our electricity bill ?
5. How can you check just by seeing the meter whether electricity is in use or not ?
6. Fig. 8.15 shows the reading on the dials of a meter. State what is its reading.

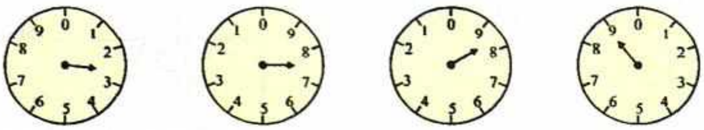


Fig. 8.15

7. One day the meter reading was 7643 units while on the following day, it was 7657 units. What is the consumption of electricity in a day ?

8. A source of potential difference V volt sends current I ampere in a circuit for time t second. Write expressions for (a) electrical energy supplied by the source, and (b) electrical power spent by the source.

9. Name the unit in which you pay the cost of your electricity bill. How is it related to joule ?

10. If an appliance of power P watt is used for time t hour, how much electrical energy is consumed in kWh ?

11. What is an electric fuse ? State its purpose in the household electrical circuit.

12. State one property of the material of a fuse wire.

13. Name the material of a fuse wire.

14. Can we use copper wire as a fuse wire ? Give reason.

15. How does a fuse protect the electric wiring (or an appliance) from being damaged ?

16. Which fuse wire is thick : 5 A or 15 A ?

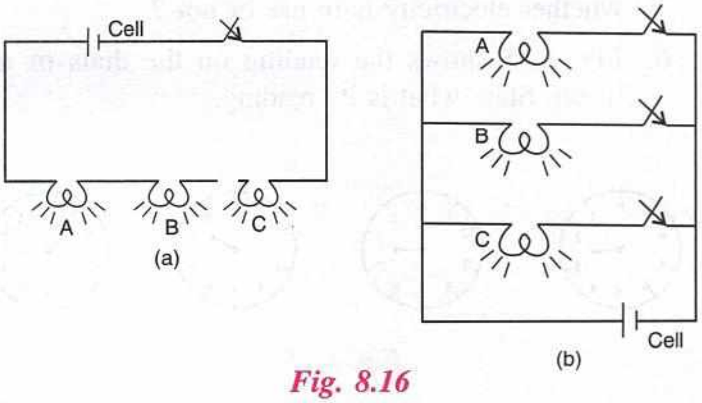
17. Write the full form of M.C.B.

18. How is M.C.B. superior to the fuse wire ?

19. With which wire : live or neutral is the fuse wire connected ?

20. What do you mean by short circuiting of a circuit ?

21. Fig. 8.16 shows two ways of connecting the three bulbs A, B and C to a battery. Name the two arrangements. Which of them do you prefer to use in a household circuit ? Give a reason to support your answer.



(a) (b)

Fig. 8.16

22. How are the electrical appliances connected a house circuit : in series or in parallel ? Gi reason.

23. In the household electric circuit, if one bulb i fused in a room, the other bulbs keep glowin Explain the reason.

24. State the voltage at which electricity is supplic to our houses.

25. Draw a labelled diagram with the necessar switches to connect a bulb, a fan and a pl socket in a room with the mains. In wh arrangement will you connect them to t mains ?

25. State the colour coding of the three wires in cable used for wiring in a household electric circuit.

26. Why is the metal covering of an electric appliance earthed?

C. Numericals

1. An electrical appliance is rated as 60 W – 150
   (a) What do you understand by this statemen
   (b) How much current will flow through th appliance when in use ? **Ans:** 0·4

2. An electric iron of power 1·5 kW is used f 30 minutes to press clothes Calculate t electrical energy consumed in (a) kilowatt ho (b) joule. **Ans:** (a) 0·75 kWh, (b) $2{\cdot}7 \times 10^6$

3. Assuming the electric consumption per day be 12 kWh and the rate of electricity to ₹ 6·25 per unit, find how much money is to paid in a month of 30 days ? **Ans:** ₹ 225

4. In a premise 5 bulbs each of 100 W, 2 fans ea of 60 W, 2 A.Cs each of 1·5 kW are used for 5 per day. Find :
   (a) total power consumed per day,
   (b) total power consumed in 30 days,
   (c) total electrical energy consumed in 30 day
   (d) the cost of electricity at the rate of ₹ 6· per unit.
   Ans: (a) 3620 W, (b) 108·6 k
   (c) 543 kWh (d) ₹ 3393·

(B) STATIC ELECTRICITY

STATIC ELECTRICITY

The electricity which we use in our daily life for various purposes such as to glow a bulb, run a fan etc. is due to the motion of charges (or electrons). It is called current electricity. Now we shall consider the electricity at rest or the static electricity.

The word electricity came from a Greek word *elektron* which means amber (a kind of resin). About 2500 years ago, a Greek philosopher Thales found that when amber was rubbed with wool, it acquired the property of attracting small pieces of paper or cork. Later on, Dr Gilbert found that besides amber, there are many other substances such as glass, plastic, nylon, hard rubber, sealing wax, ebonite etc., which also show the same attractive property. The substance which acquires the attractive property is said to be electrified or charged.

When an object made of a substance like glass, plastic, ebonite, amber, nylon, hard rubber etc., is rubbed with wool, fur or silk, it acquires an electric charge due to friction. The object is said to be charged and it acquires the property to attract small pieces of paper, leaves or cork. This can be demonstrated by the following activities.

ACTIVITY 3

Take a plastic (or rubber) comb. Bring it near the small bits of paper lying on a table. You will observe that the comb does not attract the paper bits.

Now rub the comb on your dry hair. Again bring it close to the paper bits. You will observe that the comb now attracts the paper bits (Fig. 8.17). Thus, the plastic (or rubber) comb acquires the attractive property on rubbing it with dry hair due to friction.

Fig. 8.17 Plastic comb rubbed with dry hair attracts small bits of paper

ACTIVITY 4

Place some small bits of paper on a table. Take a plastic pen (or a plastic ruler) and bring it close to the paper bits. You will notice that the pen (or ruler) does not attract them.

Now rub the same pen (or ruler) with wool and again bring it close to the paper bits. You will observe that the pen (or ruler) now attracts the bits of paper (Fig. 8.18).

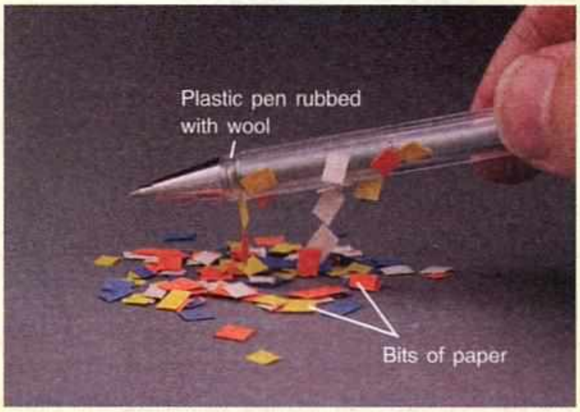


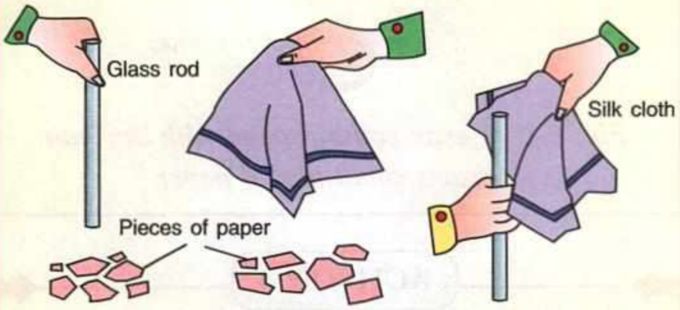
Fig. 8.18 A charged plastic pen attracts paper bits

Thus, the pen (or ruler) acquires the attractive property on rubbing it with wool due to friction.

ACTIVITY 5

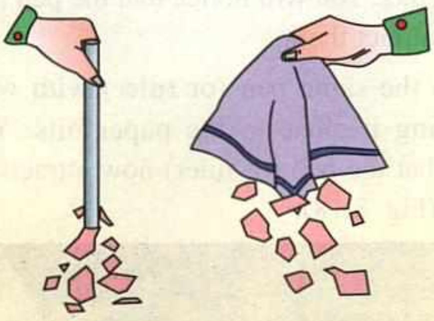
Take a glass rod and a piece of silk cloth. Hold them close to small pieces of paper. None of them will attract the pieces of paper [Fig. 8.19(a)].

Now rub the glass rod with the silk cloth [Fig. 8.19(b)]. Bring one by one, the glass rod and the cloth slightly above the bits of paper. You will observe that both glass rod and silk cloth attract the pieces of paper [Fi.g 8.19 (c)]



(a) No attraction taken place

(b) Rubbing the glass rod with silk cloth

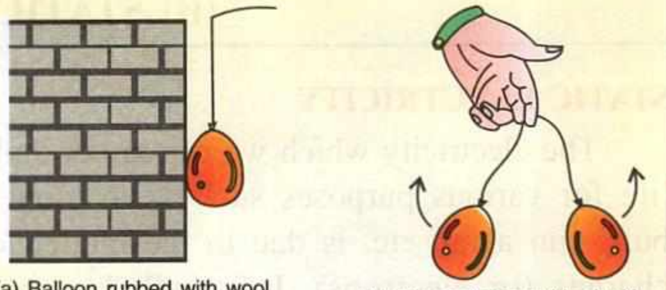


(c) Glass rod and silk cloth attract pieces of paper

Fig. 8.19 Glass rod and silk cloth get charged on rubbing

ACTIVITY 6

Take a rubber balloon. Inflate it. Bring the balloon in contact with the wall and withdraw your hand gradually. You will find that the balloon falls down (*i.e.*, it does not stick to the wall).



(a) Balloon rubbed with wool sticks to the wall

(b) Two balloons rubbed with the same wool repel each other

Fig. 8.20 Balloon gets charged on rubbing with wool

(1) Now rub the balloon with wool and again bring it in contact with the wall and withdraw your hand gradually. You will find that the balloon now sticks to the wall [Fig. 8.20(a)]. This shows that the balloon on rubbing with wool gets charged due to friction and therefore it sticks to the wall.

(2) Now take two such balloons and rub both of them with wool. Bring the balloons close to each other. Both will move away from each other *i.e.* both will repel each other [Fig. 8.20)b)].

The above activities show that an object can be charged by rubbing. If a glass rod is rubbed with silk, it will attract small bits of paper. Similarly, if an ebonite rod is rubbed with fur, it will also attract small bits of paper.

However, a charged object not only attracts small bits of paper, but it can also attract or repel other charged objects. It is found that two charged objects having like charges repel each other, while two charged objects having unlike charges always attract each other.

Do You Know ?

(1) The body which possesses electric charge is called a charged body.

(2) The body which does not possess any electric charge is called an uncharged or neutral body.

(3) A charged body attracts an uncharged body.

(4) Only insulators and isolated conductors can be charged by rubbing.

(5) Charging of two bodies on rubbing them together is also called static electricity produced by friction.

KINDS OF ELECTRIC CHARGES (LIKE CHARGES REPEL AND UNLIKE CHARGES ATTRACT)

There are two kinds of electric charges. Ve call them positive and negative charges. e existence of these electric charges can be emonstrated by the following experiment.

Experiment : (i) Take a glass rod A. Rub t with silk to make it charged. Suspend the harged rod A with a thread. Then take nother glass rod B. Rub it also with silk and ring it near one end of the suspended rod A s shown in Fig. 8.21. You will observe that he suspended glass rod A gets repelled (*i.e.*, t moves away).

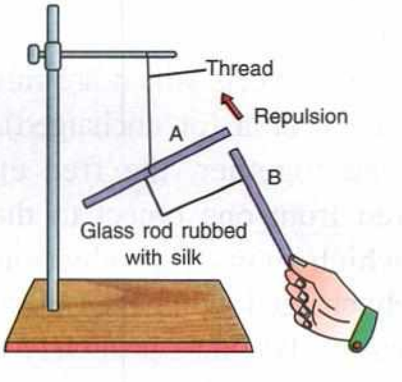


Fig. 8.21 Two charged glass rods repel each other

(ii) Take an ebonite rod A and rub it with fur to make it charged. Suspend the charged rod A with a thread. Now take another ebonite rod B. Rub it also with fur and bring it near one end of the suspended rod A as shown in Fig. 8.22. You will observe that the suspended ebonite rod A gets repelled.

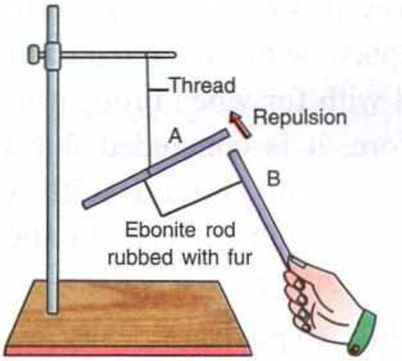


Fig. 8.22 Two charged ebonite rods repel each other

(iii) Now suspend the glass rod A rubbed with silk by means of a thread and bring the ebonite rod B rubbed with fur near one end of the rod A as shown in Fig. 8.23. You will observe that the suspended charged glass rod A gets attracted towards the charged ebonite rod B.

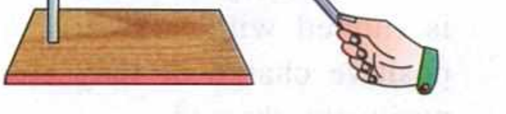


Fig. 8.23 A charged glass rod and a charged ebonite rod attract each other

In all the above steps, if the rods have not been rubbed with silk or fur, we would have found that there is no repulsion or attraction between the rods. Thus, the attraction or repulsion between the rods arises only when they are charged. In step (i) both the glass rods have been rubbed with silk, *i.e.*, they must have similar kind of charges. It is seen that these rods when brought near each other, repel each other. Hence, it is concluded that like charges repel each other. Similar is the case in step (ii). Now in step (iii), it is seen that the glass rod rubbed with silk attracts the ebonite rod rubbed with fur when brought near each other. Therefore, it is concluded that the charge on the glass rod rubbed with silk must be opposite to the charge on the ebonite rod rubbed with fur.

This experiment suggests that like charges repel (Fig. 8.21 and Fig. 8.22) while unlike charges attract (Fig. 8.23) each other.

Thus, from this experiment we can conclude that

(i) There are two kinds of charges.
(ii) Like charges repel and unlike charges attract each other.

When other substances are charged by rubbing and are tested in a similar manner, it is found that they fall into the following two categories :

1. Substances which have the similar charge as that developed on a glass rod when it is rubbed with silk, are said to have positive charge or they are said to be positively charged.
2. Substances which have the similar charge as that developed on an ebonite rod when it is rubbed with fur, are said to have negative charge or they are said to be negatively charged.

Thus, there are two kinds of charges : a positive charge and a negative charge.

CONSERVATION OF CHARGE

Before rubbing the two objects, each object is uncharged, so the net charge is zero.

Now when two objects are rubbed together, both are charged equally, but th charges on them are of the opposite kinds Thus, the total charge of the objects before and after rubbing remains same. This is called conservation of charges.

Example : When a glass rod is rubbed with silk, the glass rod is charged positively and the silk is charged negatively by the same amount.

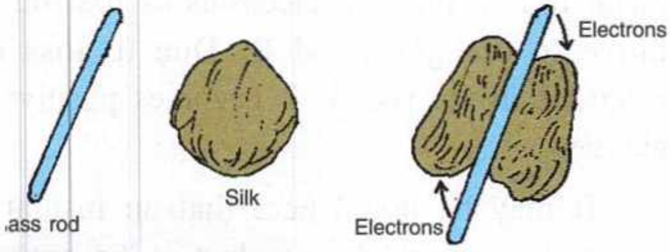
Similarly, when an ebonite rod is rubbe with fur, the ebonite rod is charged negatively and the fur is charged positively by the sam amount.

Explanation of charging on rubbing

Each body has atoms. An atom is electrically neutral. It has protons (positively charged) and neutrons (uncharged) inside its nucleus at the centre, around which the electrons (negatively charged) revolve in different orbits. The number of electrons in an atom is equal to the number of protons. However, some of these electrons can easily leave their atoms. These are called free electrons.

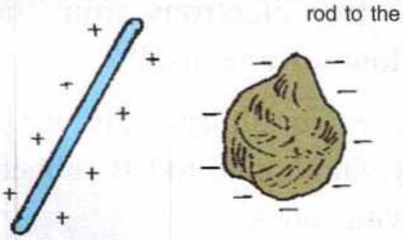
The two objects which are rubbed togethe are initially neutral (or uncharged). When they are rubbed together, the free electrons are transferred from one object to the other. The object which gains free electrons, become negatively charged, while the object which loses free electrons, becomes positively charged.

Examples : (1) When a glass rod i rubbed with silk, the free electrons from th ass rod are transferred to the silk. The glass d loses some electrons, so it becomes sitively charged, and the silk gains the same mber of electrons, so it becomes negatively arged by an equal amount. The charging glass rod and silk on rubbing is shown in g. 8.24.



(a) Before rubbing, both the glass rod and silk are electrically neutral

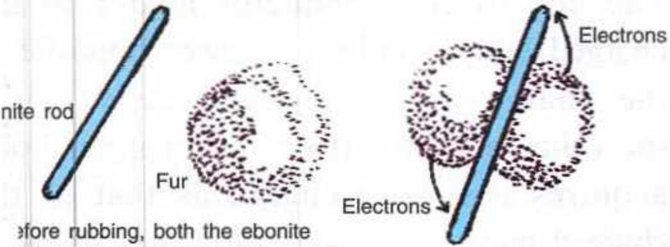
(b) While rubbing the glass rod with silk, electrons are transferred from the glass rod to the silk



(c) After rubbing, the glass rod becomes positively charged and the silk becomes negatively charged

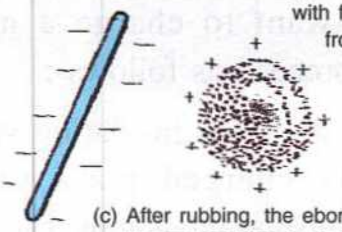
g. 8.24 Charging of glass rod and silk on rubbing

(2) When an ebonite rod is rubbed with r, the free electrons from the fur are transferred to the ebonite rod. The fur loses some electrons and it becomes positively charged and the ebonite rod gains the same number of electrons and it becomes negatively charged by the same amount. The charges of ebonite rod and fur on rubbing is shown in Fig. 8.25.



fore rubbing, both the ebonite rod and the fur are neutral

(b) While rubbing the ebonite rod with fur, electrons are transferred from fur to the ebonite rod



(c) After rubbing, the ebonite rod becomes negatively charged and the fur becomes positively charged

Fig. 8.25 Charging of an ebonite rod and fur on rubbing

CONDUCTORS AND INSULATORS

In Class VII, you have learnt that substances such as silver, copper, aluminium, iron, brass, steel, mercury, carbon, human body etc., are conductors of electricity. They allow electricity to flow through them. But substances such as cotton, rubber, plastic, wood, paper, glass, ebonite, mica, wax, wool, pure water etc., are insulators of electricity. They do not allow electricity to flow through them.

The reason for some substances to be conductors and others to be insulators of electricity is that, different substances have different number of free electrons in them. Substances which have a large number of free electrons are called **conductors**, while those with very less number of free electrons or no free electrons are called **insulators**. The conductors allow the charges to flow through the motion of free electrons, but the insulators do not allow the charges to flow because free electrons are not available for motion.

Only insulators can be charged by rubbing (or by friction). The conductors cannot be charged by rubbing because charge developed on them will flow away and will not remain with them.

METHODS OF CHARGING A CONDUCTOR

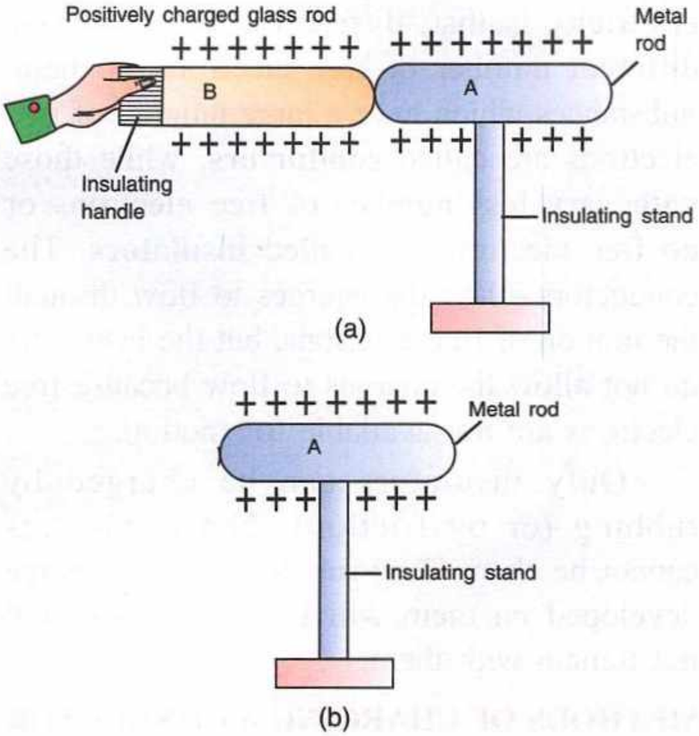
You have learnt that the two insulators can be charged by rubbing them together. But a conductor cannot be charged by rubbing it with another conductor. A conductor can be charged by the following two methods :

(i) By conduction, and (ii) By induction.

(i) Charging a conductor by conduction :

In this method, the conductor to be charged is touched (or brought in contact) with a charged body. The conductor gets charged by the similar kind of charge as on the charging body. The charge of the charging body is shared by the conductor to be charged.

Suppose we want to charge a metal rod A with a positive charge. Place it on an insulating stand. Take a positively charged glass rod B provided with an insulating handle (or cap) and touch it with the metal rod A as shown in Fig. 8.26(a). Some positive charge of the glass rod B is shared by tl metal rod A. Remove the glass rod B. The r A gets positively charged Fig. 8.26(b).



(a)

(b)

Fig. 8.26 Charging by conduction

Explanation : The glass rod B positively charged, so it has a deficiency electrons. When it is touched with tl metal rod A, the free electrons of the rod move to the glass rod B. Due to loss electrons in the rod A, it becomes positive charged.

It may be noted here that an insulato cannot be charged by conduction because does not contain free electrons and so it do not allow free electrons from the charg body to flow towards itself.

Note : To charge the metal rod negatively, an ebonite rod B rubbed on fur touched with rod A.

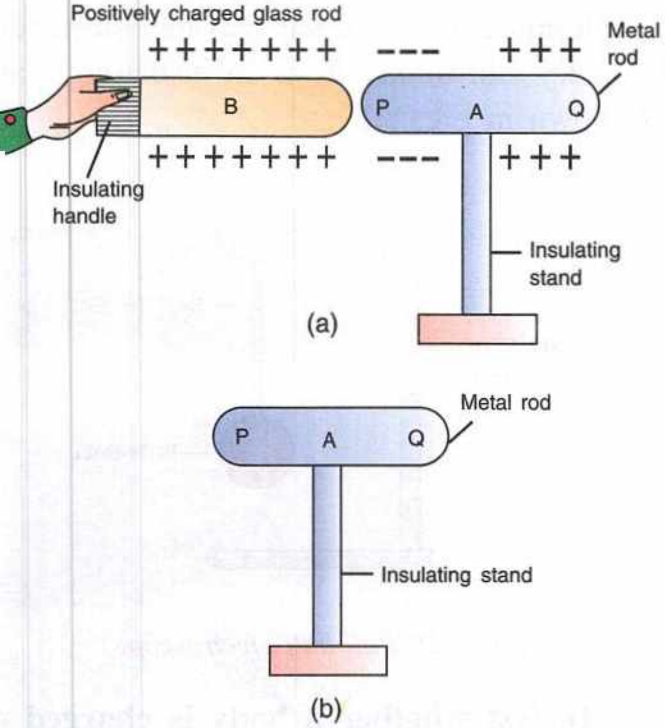
(ii) Charging a conductor by induction :

In this method, the conductor to charged is not touched with the charg body, but it is kept near the charged bo The end of the conductor nearer to tl charged body acquires a charge opposite the charge of the charged body, whi the other end, far from the charged boc acquires a similar charge as that of t charged body.

Suppose we want to charge a me rod A negatively, proceed as follows :

(1) Place rod A on an insulating sta Take a positively charged glass rod provided with an insulating handle (or c and bring it near the rod A as shown

g. 8.27 (a). The near end P of the metal d A acquires negative charge, while the far d Q acquires positive charge. On removing e glass rod B, the metal rod A becomes charged as shown in Fig. 8.27(b).



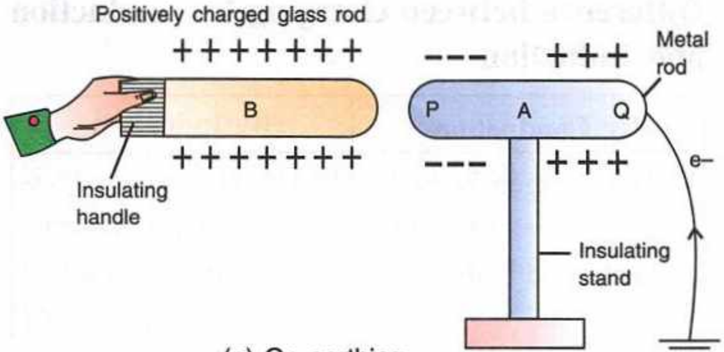
(a)

(b)

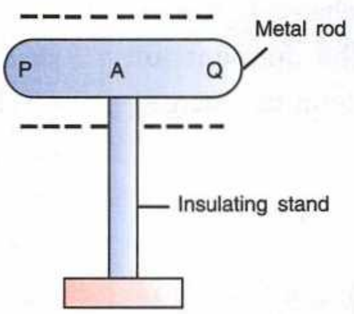
Fig. 8.27 Charging by induction

Explanation : The positively charged ass rod B attracts the free electrons of e metal rod A. Therefore, the free electrons the rod A move from the end Q wards the end P. Thus, the end P becomes gatively charged as it gains the electrons d the end Q becomes positively charged as loses the electrons. On removing the glass d B, the electrons of metal rod A move from d P to end Q to neutralize the positive arge.

(2) Now touch the end Q of rod A by nd. And then remove your hand as well as glass rod B simultaneously as shown in Fig. 8.28 (a) and (b). The rod A becomes negatively charged.



(a) On earthing



(b)

Fig. 8.28 Charging by induction

Explanation : On touching (or earthing) the end Q of rod A, the free electrons move from earth to neutralize the positive charge at the end Q.

On removal of glass rod B and hand simultaneously, the negative charge (*i.e.*, excess of electrons) at the end P gets distributed throughout the rod A making it negatively charged.

Note : To charge the rod A positively, an ebonite rod B rubbed on fur is to be used.

Difference between charging by conduction and induction

By Conduction	By Induction
1. The charged body is touched with the uncharged body.	1. The charged body is not actually touched with the uncharged body, but it is only kept close to it.
2. The charge is shared, so the amount of charge in the charged body reduces.	2. The charge is not shared, so the amount of charge of charged body does not decrease.
3. The charge on uncharged body is of same type as that of the charged body	3. The charge on uncharged body is of opposite type to that of the charged body.
4. On removing the charged body, the uncharged body still retains the charge.	4. The charge on uncharged body remains only as long as the charged body is close. As soon as the charged body is removed, no charge is left on the uncharged body. To retain charge, the far end of the body has to be earthed.

ELECTROSCOPE

An electroscope is a device which is used to detect the presence and nature of charge on a body. In other words, it is used to find whether a body is charged or uncharged and if the body is charged, then whether it carries a positive charge or a negative charge.

Types of electroscope :

There are two types of electroscopes:

(i) Pith ball electroscope, and

(ii) Gold leaf electroscope.

(i) Pith ball electroscope

It consists of a small pith ball suspende by a dry silk thread from an insulating star as shown in Fig. 8.29.

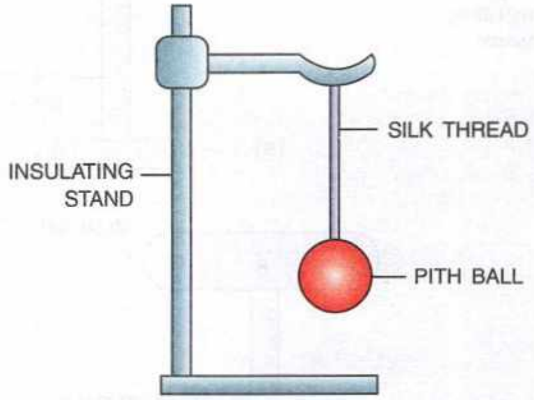


Fig. 8.29 Pith ball electroscope

To test whether a body is charged c uncharged : Bring the body near the pith ba (without touching it). If the pith ball mov towards the body, the body is charged. But the pith ball remains stationary, the body uncharged.

To test whether the charged body ha a positive charge or a negative charge Take a charged pith ball electroscope (*i.e.*, t pith ball is provided with some charg Suppose the pith ball is positively charge Bring the charged body near the pith b (without touching it). If the pith ball mov away, the body has a positive charge and the pith ball moves towards the body, t body has a negative charge.

(ii) Gold leaf electroscope

Construction : Fig. 8.30 shows a gold leaf electroscope. It consists of two gold (or aluminium) leaves hanging from a brass rod having a brass disc at its upper end. The rod passes through an ebonite cork fitted in the mouth of a glass bottle. The glass bottle has tin foils on its sides near its bottom which are earthed. The glass bottle protects the gold leaves from the effect of air, wind etc.

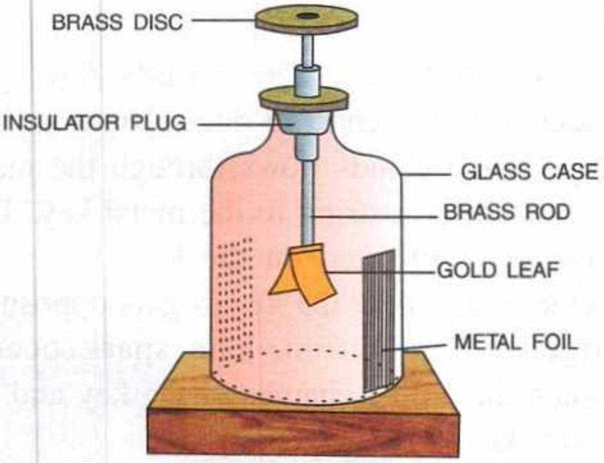


Fig. 8.30 Gold leaf electroscope

To test whether a body is charged or ncharged : Bring the body and touch it with he brass disc of the gold leaf electroscope. f the leaves diverge, the body is charged. ig. 8.31. But if the leaves do not diverge, he body is uncharged (Fig. 8.32).

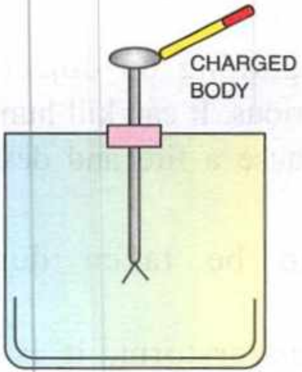


Fig. 8.31 Gold leaves diverge

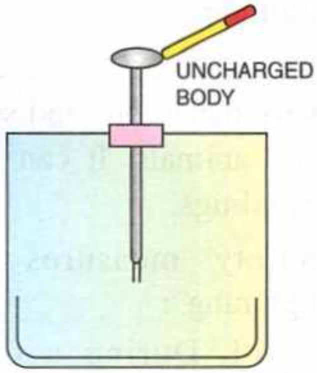
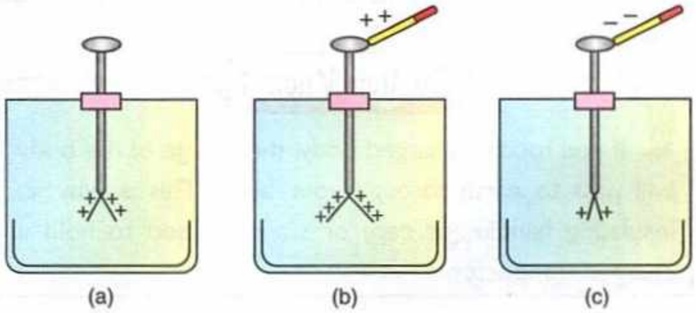


Fig. 3.32 No effect on leaves

To test whether the charged body has a positive charge or a negative charge : Take a charged gold leaf electroscope. Suppose the electroscope is positively charged [Fig. 8.33(a)].

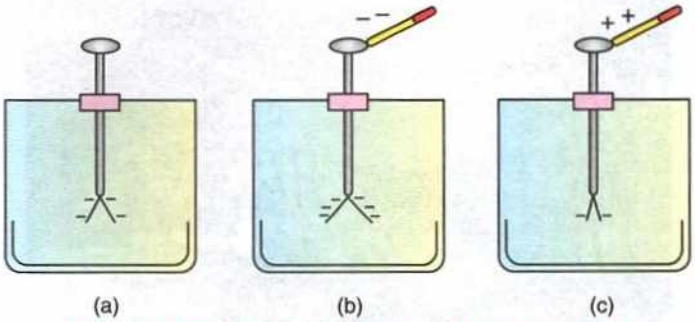
Bring the charged body to be tested in contact with the brass disc of the electroscope. If the divergence of the leaves increases, the body has positive charge [Fig. 8.33(b)]. But if the divergence of the leaves decreases, the body has a negative charge [Fig. 8.33(c)].



(a) (b) (c)

Fig. 8.33 To detect the kind of charge by a positively charged gold leaf electroscope

This testing can also be done by taking a negatively charged electroscope [Fig. 8.34(a)]. On touching the body to be tested, if the body is negatively charged, then the divergence of the leaves increases [Fig. 8.34 (b)]. If the divergence decreases, then the body is positively charged [Fig. 8.34(c)].



(a) (b) (c)

Fig. 8.34 To detect the kind of charge by a negatively charged gold leaf electroscope.

The above observations can be summarized as below.

Charge on gold leaf electroscope	*Divergence of leaves*	*Nature of charge on body*
1. No charge	Leaves diverge Leaves do not diverge	Body is charged Body is not charged
2. Positive	Increases Decreases	Positive Negative
3. Negative	Increases Decreases	Negative Positive

Do You Know ?

If you touch a charged body, the charge of the body will pass to earth through your body. This is why an insulating handle (or cap) or stand is used to hold a charged conductor.

ATMOSPHERIC ELECTRICITY

In 1749, an American scientist, Benjamin Franklin, by his experiment concluded that in a thunderstorm, the clouds acquire an electric charge. His experiment is given below.

Franklin's experiment : Benjamin Franklin took a kite made of silk. At the top corner of the kite, he fixed a metal wire about 30 cm long. The other end of the wire was joined to a string. At the lower end of the string, he tied a metal key and then a silk strip. The silk strip serves the purpose of an insulating handle. He flew the kite in a thunderstorm as shown in Fig. 8.35.

Fig. 8.35 Franklin's experiment

Observation : When the string got wet, he obtained a number of sparks between hi knuckle and the key.

He explained the above observation a follows.

Explanation : The clouds during thunderstorm get charged due to friction. Th charge of the clouds flows through the meta wire and the wet string to the metal key. This charge gets collected on the key. When th knuckle comes near the key, it gets oppositely charged by induction. The spark occur between the unlike charges of the key and th the knuckle.

LIGHTNING

During a thunderstorm, when a charged cloud passes over the earth (or over the othe cloud), it acquires an opposite charge by induction. A spark may occur between th two oppositely charged clouds (or a charg cloud and the earth). This spark is calle lightning.

The effect of lightning on objects i very dangerous and serious. It can kill human and animals. It can cause a fire and destro buildings.

Safety measures to be taken durin lightning :

1. During a thunderstorm, it is n advisable to stand under a tree or ne a tall building.

2. On hearing a thunder, rush to a safe place such as a low house/building.
3. If you are travelling by car/bus, you are safe inside. Keep the windows/doors of the vehicle closed.
4. Do not carry an umbrella over your head particularly if walking in an open ground.
5. If there are trees around, take shelter under a shorter tree.
6. Do not lie on the ground, but squat low on the ground with your hands on your knees and head in between.
7. Take out the plugs of TV sets, computers, etc. Do not use the wired phone.
8. Do not take bath during thunderstorms and avoid contact with running water or metallic tap.
9. Do not stand near the windows or in balcony having metallic railings.

LIGHTNING CONDUCTOR

A lightning conductor is a device which is used to protect buildings from being damaged due to lightning.

Construction : A lightning conductor is a long copper rod with sharp points or spikes projecting above the top of the building. The lower end of the rod is connected to a copper plate buried deep into the ground as shown in Fig. 8.36.

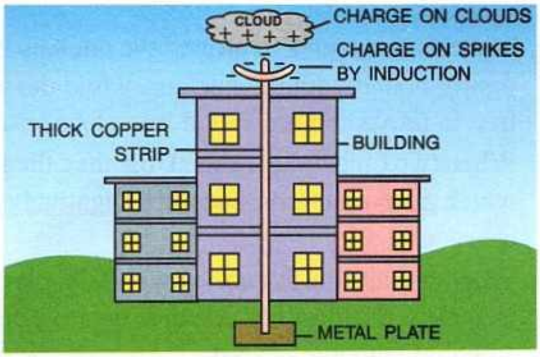


Fig. 8.36 Lightning conductor

Working : When a charged cloud passes over the building, an opposite charge is induced on the spikes. This charge passes to the earth through the copper rod. Thus, the lightning spark is prevented and the building is saved from damage.

RECAPITULATION

- The word electricity comes from a Greek word 'elektron' which means amber.
- The way of producing electricity by friction was discovered about 2500 years ago by a Greek philosopher Thales.
- Substances such as glass, plastic, nylon, hard rubber, sealing wax, ebonite, etc., can be charged by friction (*i.e.*, by rubbing with silk, wool or fur).
- There are two kinds of electric charges : (i) positive, and (ii) negative.
- We call the charge developed on the glass rod when it is rubbed with silk as positive and the charge developed on the ebonite rod when it is rubbed with fur as negative.
- Like charges repel each other and unlike charges attract each other.
- When two objects are rubbed together, both are charged equally, but with charges of opposite kinds. The sum total of charges on two objects before and after rubbing, remains the same. This is called conservation of charges.
- When a glass rod is rubbed with silk, the glass rod acquires a positive charge and the silk acquires an equal negative charge.

- When an ebonite rod is rubbed with fur, the ebonite rod acquires a negative charge and the fur acquires an equal positive charge.
- An atom consists of electrons, protons and neutrons. The electrons are negatively charged, the protons are positively charged and the neutrons have no charge.
- The mass of a proton is almost equal to that of a neutron. The mass of an electron is nearly 1/1836 of that of a proton.
- An electron has a unit negative charge, a proton has a unit positive charge and a neutron has zero charge.
- In an atom, the number of electrons is equal to the number of protons. Thus, an atom is electrically neutral.
- The central part of the atom, called the nucleus, contains protons and neutrons. The nucleus is thus positively charged.
- The electrons revolve around the nucleus in definite orbits. The electrons in the orbits close to the nucleus are tightly bound with the nucleus, while the electrons in the orbits far away from the nucleus are comparatively free to move and are called free electrons.
- When two objects are rubbed together, the free electrons are transferred from one object to the other. The object which gains electrons, becomes negatively charged, while the object which loses electrons, becomes positively charged.
- When a glass rod is rubbed with silk, electrons are transferred from the glass rod to the silk. Due to loss of electrons, the glass rod acquires positive charge and due to gain of equal number of electrons, the silk acquires an equal negative charge.
- When an ebonite rod is rubbed with fur, electrons are transferred from fur to the ebonite rod. Due to gain of electrons, the ebonite rod acquires negative charge and due to loss of equal number of electrons, the fur acquires an equal positive charge.
- There are two kinds of electric charges : positive and negative.
- Like charges repel and unlike charges attract each other.
- A body is said to be positively charged if it has a deficit of electrons, and it is said to be negatively charged if it has an excess of electrons.
- Substances (such as metals) which have a large number of free electrons, are called conductors. They allow the charge to pass through them.
- Substances (such as ebonite, glass, wood, etc.) which have a negligible number of free electrons, are called insulators. They do not allow the charge to pass through them.
- Conductors cannot be charged by rubbing them together (or by friction).
- A conductor can be charged in two ways : (i) by conduction and (ii) by induction.
- In conduction, the conductor to be charged is touched with a charged body. The conductor gets charged by the similar kind of charge as on the charging body. The charge is thus shared.
- An insulator cannot be charged by the method of conduction.
- In induction, a conductor gets charged in the presence of the charged body (without touching), and it gets uncharged on removal of the charged body. The end of the conductor nearer to the charged body, is oppositely charged, while the other end far from the charged body, is charged by the same kind of charge.
- An electroscope is a device which is used to detect the presence and nature of the charge on a body.
- There are two types of electroscopes : (i) pith ball electroscope, and (ii) gold leaf electroscope.
- During a thunderstorm, the clouds acquire electric charges due to friction. When a charged cloud passes over another cloud (or the earth), an opposite charge is induced on it. A spark may occur between the two oppositely charged clouds. This spark is called lightning.
- A lightning conductor is a device which is used to protect buildings from damage due to lightning.

TEST YOURSELF

A. Objective Questions :

1. Write **true** or **false** for each statement :

(a) The number of electrons and protons in an atom are same.

(b) If the charge is not in motion, we call it static electricity.

(c) Human body is a conductor of electricity.

(d) When an ebonite rod is rubbed with fur, the electrons move from ebonite to fur.

(e) When a glass rod is rubbed with dry silk cloth, the electrons move from glass to silk.

(f) The cap of gold leaf electroscope is made of copper.

(g) If a glass rod rubbed with silk is brought near the cap of a negatively charged electroscope, the divergence of leaves will decrease.

(h) In induction, a positively charged body can make an uncharged body positively charged.

(i) A lightning conductor saves the building from lightning.

(j) When a comb is rubbed with dry hair both comb and paper get similarly charged.

(k) A glass rod rubbed with silk repels an ebonite rod rubbed with fur.

(l) When an ebonite rod is rubbed with fur, the protons move from the ebonite rod to the fur.

(m) A conductor has a large number of free electrons.

(n) An ebonite rod can be charged by touching it with a charged copper rod.

(o) To find whether a body is charged or not, an uncharged electroscope is used.

(p) To find whether the charge on a body is positive or negative, an uncharged electroscope is used.

(q) If a negatively charged rod is brought near a negatively charged pith ball electroscope, the pith ball will be stuck with the rod.

Ans. True—(a), (b), (c), (e), (f), (g), (i), (m), (o)
False—(d), (g), (h), (j), (k), (l), (n), (p), (q)

2. Fill in the blanks :

(a) Like charges .... while unlike charges ....

(b) Mercury is a .... of electricity while pure water is .... of electricity.

(c) An ebonite rod when rubbed with fur acquires the .... charge.

(d) When an uncharged conductor is brought in contact with the disc of a gold leaf electroscope, its leaves ....

(e) Charge is shared in charging a conductor by the method of ....

Ans: (a) repel, attract (b) conductor, insulator (c) negative (d) will remain unchanged (e) conduction

3. Match the following :

Column A	**Column B**
(a) Two like charges	(i) negative charge
(b) Two unlike charges	(ii) repel
(c) Silver is a	(iii) insulator
(d) Silk is an	(iv) attract
(e) Ebonite rod rubbed with fur acquires	(v) conductor

Ans. : (a)–(ii), (b)–(iv), (c)–(v), (d)–(iii), (e)–(i)

4. Select the correct alternative :

(a) When a glass rod is rubbed with dry silk cloth, the charge acquired by the silk cloth is :

(i) positive
(ii) negative
(iii) both positive and negative
(iv) none of the above.

(b) When an ebonite rod is rubbed with fur, the rod acquires :

(i) positive charge

(ii) negative charge

(iii) no charge

(iv) none of the above.

(c) When a negatively charged body is brought closer to another negatively charged body, then they will show :

(i) attraction

(ii) no effect

(iii) repulsion

(iv) none of the above.

(d) Charging a conductor by bringing another charged conductor close to it without touching is called :

(i) induction (ii) conduction

(iii) convection (iv) radiation.

(e) The factor responsible for charging a conductor is :

(i) transfer of protons

(ii) transfer of neutrons

(iii) transfer of electrons

(iv) transfer of both protons and electrons.

(f) Two objects when rubbed together get charged. The charges on them are :

(i) equal and opposite

(ii) equal and similar

(iii) unequal and similar

(iv) unequal and opposite

(g) When a glass rod is rubbed with silk, the glass rod and the silk get charged because :

(i) electrons are transferred from the silk to the glass rod

(ii) electrons are transferred from the glass rod to the silk

(iii) protons are transferred from the silk to the glass rod

(iv) protons are transferred from the glass rod to the silk.

(h) The conductor of electricity is :

(i) wood (ii) glass

(iii) ebonite (iv) human body.

(i) A gold leaf electroscope is to be charged positively by conduction. For this :

(i) a positively charged rod is held close to the disc of electroscope

(ii) a positively charged rod is placed in contact with the disc of electroscope

(iii) a negatively charged rod is held close to the disc of electroscope

(iv) a negatively charged rod is touched with the disc of electroscope

(j) A glass rod rubbed with silk is touched with the disc of a negatively charged gold leaf electroscope. The divergence of leaves will :

(i) decrease

(ii) increase

(iii) remain unchanged

(iv) first decreases and then increases.

(k) The rod in a gold leaf electroscope is made up of :

(i) wood (ii) brass

(iii) glass (iv) ebonite.

(l) Lightning conductor is made up of :

(i) copper (ii) glass

(iii) ebonite (iv) wood.

Ans.(a)-(ii), (b)-(ii), (c)-(iii), (d)-(i), (e)-(iii), (f)-(i), (g)-(ii), (h)-(iv), (i)-(ii), (j)-(i), (k)-(ii), (l)-(i)

B. Short/Long Answer Questions :

1. What do you understand by electricity at rest ?
2. Why does a plastic comb rubbed with dry hair attract bits of paper ?
3. Who discovered the way of producing electricity by friction ?
4. Name two substances which can be charged by friction.
5. What are the two kinds of charges ?
6. A glass rod is rubbed with silk. State the kind of charge acquired by each.

7. An ebonite rod is rubbed with fur. State the kind of charge acquired by each.

8. Describe an experiment to demonstrate that there are two kinds of charges.

9. How will you show that like charges repel and unlike charges attract each other ?

10. A glass rod rubbed with silk is suspended near an ebonite rod rubbed with fur. What will be your observation ? Give a reason to your answer.

11. An ebonite rod rubbed with fur is suspended near another ebonite rod rubbed with fur. State your observation and give a reason to support your answer.

12. What do you mean by conservation of charges ?

13. An ebonite rod is rubbed with fur. Compare the charges acquired by them.

14. Name three constituents of an atom and state the kind of charge on each of them.

15. What is the net charge on an atom ?

16. Briefly describe the structure of an atom.

17. What are free electrons ?

18. What causes the charging of two objects when they are rubbed together ?

19. In each of the following cases, state which body loses electrons :
    (a) A glass rod when rubbed with silk.
    (b) An ebonite rod when rubbed with fur.

20. A glass rod is rubbed with silk. Explain the charging of the glass rod and the silk on the basis of electron movement.

21. An ebonite rod is rubbed with fur. Explain the charging of the ebonite rod and the fur on the basis of electron movement.

22. Distinguish between conductors and insulators of electricity.

23. Give one example each of a conductor and an insulator of electricity.

24. State two ways of charging a conductor.

25. Name the way of charging a conductor in which the charge is shared.

26. Describe the method of charging a conductor by conduction.

27. A metal rod A is to be charged positively by using another charged rod B. What should be the kind of charge on the rod B if charging is to be done by conduction ?

28. Explain the charging by conduction in terms of movement of electrons.

29. Describe the method of charging a conductor by induction.

30. Explain the charging by induction in terms of movement of electrons.

31. Fig.8.37 below shows a metal rod AB placed on an insulating stand. In Fig.(a), a negatively charged ebonite rod C is touched with the metal rod AB, while in Fig.(b), the negatively charged ebonite rod C is held near the rod AB. State the kind of charges at the ends A and B of the rod, in each case.

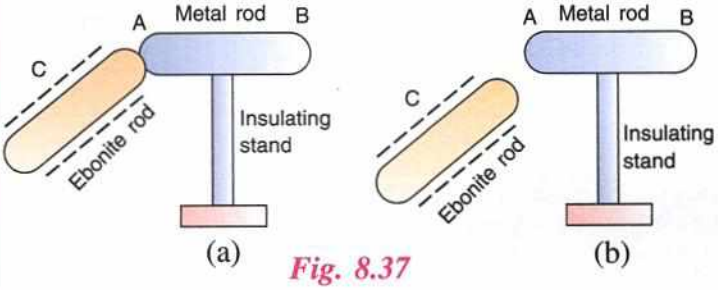


Fig. 8.37

32. Can you charge an insulator by the method of conduction ?

33. What is an electroscope ? Name the two types of electroscopes.

34. Describe a pith ball electroscope. How can you use it to test whether a body is charged or uncharged ?

35. How will you use a pith ball electroscope to find out whether the charge on a charged body is positive or negative ?

36. Draw a labelled diagram of a gold leaf electroscope and describe its construction.

37. A positively charged glass rod is touched with the disc of an uncharged gold leaf electroscope. What will be your observation ?

38. How will you use a gold leaf electroscope to find out whether a body is charged or uncharged ?

39. How will you use a gold leaf electroscope to find out whether the charge on a charged body is positive or negative ?

40. A negatively charged ebonite rod is touched with the disc of a negatively charged gold leaf electroscope. What will be your observation ?

41. When a charged rod is touched with the disc of a positively charged gold leaf electroscope, it is observed that the divergence of leaves decreases. What is the kind of charge on the rod ?

42. Describe Franklin's experiment. What did he conclude from his experiment?

43. What causes lightning ?

44. What are the effects of lightning ?

45. What is a lightning conductor ? How does it work ?

46. How is a tall building protected from damage due to lightning ?

47. State three safety measures,that you will observe in a thunder storm.