Chapter 1

Matter in Our Surroundings

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As we look at our surroundings, we see a large variety of things with different shapes, sizes and textures. Everything in this universe is made up of material which scientists have named "matter". The air we breathe, the food we eat, stones, clouds, stars, plants and animals, even a small drop of water or a particle of sand — every thing is matter. We can also see as we look around that all the things mentioned above occupy space and have mass. In other words, they have both mass* and volume**.

Since early times, human beings have been trying to understand their surroundings. Early Indian philosophers classified matter in the form of five basic elements — the *"Panch Tatva"* — air, earth, fire, sky and water. According to them everything, living or non-living, was made up of these five basic elements. Ancient Greek philosophers had arrived at a similar classification of matter.

Modern day scientists have evolved two types of classification of matter based on their physical properties and chemical nature.

In this chapter we shall learn about matter based on its physical properties. Chemical aspects of matter will be taken up in subsequent chapters.

1.1 Physical Nature of Matter

1.1.1 Matter is made up of particles

For a long time, two schools of thought prevailed regarding the nature of matter. One school believed matter to be continuous like a block of wood, whereas, the other thought that matter was made up of particles like sand. Let us perform an activity to decide about the nature of matter — is it continuous or particulate?

Activity 1.1

- Take a 100 mL beaker.
- Fill half the beaker with water and mark the level of water.
- Dissolve some salt/ sugar with the help of a glass rod.
- Observe any change in water level.
- What do you think has happened to the salt?
- Where does it disappear?
- Does the level of water change?

In order to answer these questions we need to use the idea that matter is made up of particles. What was there in the spoon, salt or sugar, has now spread throughout water. This is illustrated in Fig. 1.1.

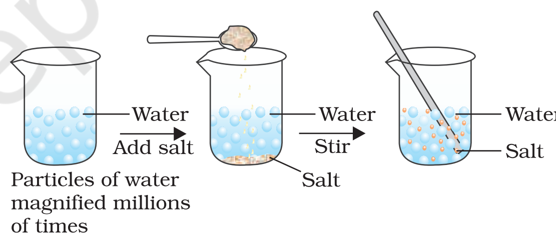

Fig. 1.1: *When we dissolve salt in water, the particles of salt get into the spaces between particles of water.*

1.1.2 How small are these particles of matter?

Activity 1.2

- Take 2–3 crystals of potassium permanganate and dissolve them in 100 mL of water.

* The SI unit of mass is kilogram (kg).

** The SI unit of volume is cubic metre (m^3). The common unit of measuring volume is litre (L) such that 1L = 1 dm^3, 1L = 1000 mL, 1 mL = 1 cm^3.

- Take out approximately 10 mL of this solution and put it into 90 mL of clear water.
- Take out 10 mL of this solution and put it into another 90 mL of clear water.
- Keep diluting the solution like this 5 to 8 times.
- Is the water still coloured ?

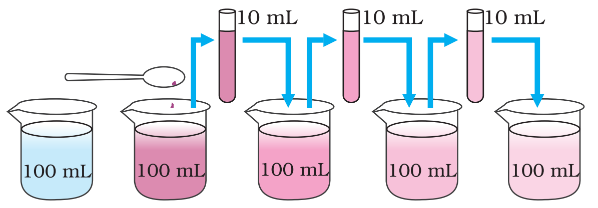

Fig. 1.2: *Estimating how small are the particles of matter. With every dilution, though the colour becomes light, it is still visible.*

This experiment shows that just a few crystals of potassium permanganate can colour a large volume of water (about 1000 L). So we conclude that there must be millions of tiny particles in just one crystal of potassium permanganate, which keep on dividing themselves into smaller and smaller particles.

The same activity can be done using 2 mL of Dettol instead of potassium permanganate. The smell can be detected even on repeated dilution.

> The particles of matter are very small – they are small beyond our imagination!!!!

1.2 Characteristics of Particles of Matter

1.2.1 Particles of matter have space between them

In activities 1.1 and 1.2 we saw that particles of sugar, salt, Dettol, or potassium permanganate got evenly distributed in water. Similarly, when we make tea, coffee or lemonade (*nimbu paani*), particles of one type of matter get into the spaces between particles of the other. This shows that there is enough space between particles of matter.

1.2.2 Particles of matter are continuously moving

Activity 1.3

- Put an unlit incense stick in a corner of your class. How close do you have to go near it so as to get its smell?
- Now light the incense stick. What happens? Do you get the smell sitting at a distance?
- Record your observations.

Activity 1.4

- Take two glasses/beakers filled with water.
- Put a drop of blue or red ink slowly and carefully along the sides of the first beaker and honey in the same way in the second beaker.
- Leave them undisturbed in your house or in a corner of the class.
- Record your observations.
- What do you observe immediately after adding the ink drop?
- What do you observe immediately after adding a drop of honey?
- How many hours or days does it take for the colour of ink to spread evenly throughout the water?

Activity 1.5

- Drop a crystal of copper sulphate or potassium permanganate into a glass of hot water and another containing cold water. Do not stir the solution. Allow the crystals to settle at the bottom.
- What do you observe just above the solid crystal in the glass?
- What happens as time passes?
- What does this suggest about the particles of solid and liquid?
- Does the rate of mixing change with temperature? Why and how?

From the above three activities (1.3, 1.4 and 1.5), we can conclude the following:

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Particles of matter are continuously moving, that is, they possess what we call the kinetic energy. As the temperature rises, particles move faster. So, we can say that with increase in temperature the kinetic energy of the particles also increases.

In the above three activities we observe that particles of matter intermix on their own with each other. They do so by getting into the spaces between the particles. This intermixing of particles of two different types of matter on their own is called diffusion. We also observe that on heating, diffusion becomes faster. Why does this happen?

1.2.3 Particles of matter attract each other

Activity 1.6

- Play this game in the field— make four groups and form human chains as suggested:
- The first group should hold each other from the back and lock arms like Idu-Mishmi dancers (Fig. 1.3).

Fig. 1.3

- The second group should hold hands to form a human chain.
- The third group should form a chain by touching each other with only their finger tips.
- Now, the fourth group of students should run around and try to break the three human chains one by one into as many small groups as possible.
- Which group was the easiest to break? Why?
- If we consider each student as a particle of matter, then in which group the particles held each other with the maximum force?

Activity 1.7

- Take an iron nail, a piece of chalk and a rubber band.
- Try breaking them by hammering, cutting or stretching.
- In which of the above three substances do you think the particles are held together with greater force?

Activity 1.8

- Take some water in a container, try cutting the surface of water with your fingers.
- Were you able to cut the surface of water?
- What could be the reason behind the surface of water remaining together?

The above three activities (1.6, 1.7 and 1.8) suggest that particles of matter have force acting between them. This force keeps the particles together. The strength of this force of attraction varies from one kind of matter to another.

Questions

1. *Which of the following are matter?*
   Chair, air, love, smell, hate, almonds, thought, cold, lemon water, smell of perfume.
2. *Give reasons for the following observation:*
   The smell of hot sizzling food reaches you several metres away, but to get the smell from cold food you have to go close.
3. *A diver is able to cut through water in a swimming pool. Which property of matter does this observation show?*
4. *What are the characteristics of the particles of matter?*

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1.3 States of Matter

Observe different types of matter around you. What are its different states? We can see that matter around us exists in three different states– solid, liquid and gas. These states of matter arise due to the variation in the characteristics of the particles of matter.

Now, let us study about the properties of these three states of matter in detail.

1.3.1 The solid state

Activity 1.9

- Collect the following articles — a pen, a book, a needle and a piece of wooden stick.
- Sketch the shape of the above articles in your notebook by moving a pencil around them.
- Do all these have a definite shape, distinct boundaries and a fixed volume?
- What happens if they are hammered, pulled or dropped?
- Are these capable of diffusing into each other?
- Try compressing them by applying force. Are you able to compress them?

All the above are examples of solids. We can observe that all these have a definite shape, distinct boundaries and fixed volumes, that is, have negligible compressibility. Solids have a tendency to maintain their shape when subjected to outside force. Solids may break under force but it is difficult to change their shape, so they are rigid.

Consider the following:

(a) What about a rubber band, can it change its shape on stretching? Is it a solid?

(b) What about sugar and salt? When kept in different jars these take the shape of the jar. Are they solid?

(c) What about a sponge? It is a solid yet we are able to compress it. Why?

All the above are solids as:

- A rubber band changes shape under force and regains the same shape when the force is removed. If excessive force is applied, it breaks.
- The shape of each individual sugar or salt crystal remains fixed, whether we take it in our hand, put it in a plate or in a jar.
- A sponge has minute holes, in which air is trapped, when we press it, the air is expelled out and we are able to compress it.

1.3.2 The liquid state

Activity 1.10

- Collect the following:
  (a) water, cooking oil, milk, juice, a cold drink.
  (b) containers of different shapes. Put a 50 mL mark on these containers using a measuring cylinder from the laboratory.
- What will happen if these liquids are spilt on the floor?
- Measure 50 mL of any one liquid and transfer it into different containers one by one. Does the volume remain the same?
- Does the shape of the liquid remain the same ?
- When you pour the liquid from one container into another, does it flow easily?

We observe that liquids have no fixed shape but have a fixed volume. They take up the shape of the container in which they are kept. Liquids flow and change shape, so they are not rigid but can be called fluid.

Refer to activities 1.4 and 1.5 where we saw that solids and liquids can diffuse into liquids. The gases from the atmosphere diffuse and dissolve in water. These gases, especially oxygen and carbon dioxide, are essential for the survival of aquatic animals and plants.

All living creatures need to breathe for survival. The aquatic animals can breathe under water due to the presence of dissolved oxygen in water. Thus, we may conclude that solids, liquids and gases can diffuse into liquids. The rate of diffusion of liquids is higher than that of solids. This is due to the fact that in the liquid state, particles move freely and have greater space between each other as compared to particles in the solid state.

1.3.3 THE GASEOUS STATE

Have you ever observed a balloon seller filling a large number of balloons from a single cylinder of gas? Enquire from him how many balloons is he able to fill from one cylinder. Ask him which gas does he have in the cylinder.

Activity _______________ *1.11*

- Take three 100 mL syringes and close their nozzles by rubber corks, as shown in Fig.1.4.
- Remove the pistons from all the syringes.
- Leaving one syringe untouched, fill water in the second and pieces of chalk in the third.
- Insert the pistons back into the syringes. You may apply some vaseline on the pistons before inserting them into the syringes for their smooth movement.
- Now, try to compress the content by pushing the piston in each syringe.

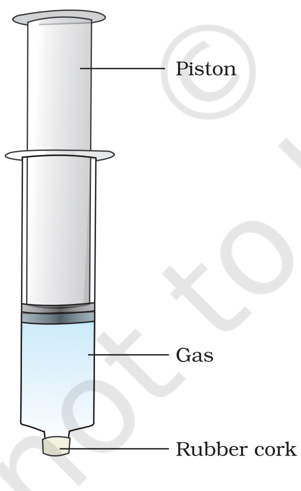

Fig. 1.4

- What do you observe? In which case was the piston easily pushed in?
- What do you infer from your observations?

We have observed that gases are highly compressible as compared to solids and liquids. The liquefied petroleum gas (LPG) cylinder that we get in our home for cooking or the oxygen supplied to hospitals in cylinders is compressed gas. Compressed natural gas (CNG) is used as fuel these days in vehicles. Due to its high compressibility, large volumes of a gas can be compressed into a small cylinder and transported easily.

We come to know of what is being cooked in the kitchen without even entering there, by the smell that reaches our nostrils. How does this smell reach us? The particles of the aroma of food mix with the particles of air spread from the kitchen, reach us and even farther away. The smell of hot cooked food reaches us in seconds; compare this with the rate of diffusion of solids and liquids. Due to high speed of particles and large space between them, gases show the property of diffusing very fast into other gases.

In the gaseous state, the particles move about randomly at high speed. Due to this random movement, the particles hit each other and also the walls of the container. The pressure exerted by the gas is because of this force exerted by gas particles per unit area on the walls of the container.

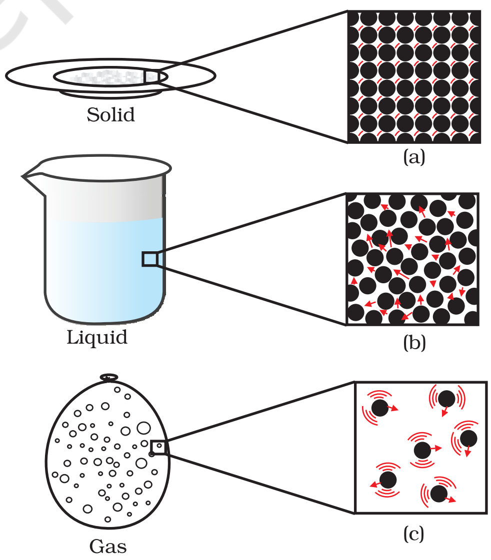

Fig.1.5: *a, b and c show the magnified schematic pictures of the three states of matter. The motion of the particles can be seen and compared in the three states of matter.*

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Questions

1. *The mass per unit volume of a substance is called density. (density = mass/volume). Arrange the following in order of increasing density – air, exhaust from chimneys, honey, water, chalk, cotton and iron.*
2. *(a) Tabulate the differences in the characterisitcs of states of matter.*
   (b) Comment upon the following: rigidity, compressibility, fluidity, filling a gas container, shape, kinetic energy and density.
3. *Give reasons*
   (a) A gas fills completely the vessel in which it is kept.
   (b) A gas exerts pressure on the walls of the container.
   (c) A wooden table should be called a solid.
   (d) We can easily move our hand in air but to do the same through a solid block of wood we need a karate expert.
4. *Liquids generally have lower density as compared to solids. But you must have observed that ice floats on water. Find out why.*

1.4 Can Matter Change its State?

We all know from our observation that water can exist in three states of matter–

- solid, as ice,
- liquid, as the familiar water, and
- gas, as water vapour.

What happens inside the matter during this change of state? What happens to the particles of matter during the change of states? How does this change of state take place? We need answers to these questions, isn't it?

1.4.1 Effect of Change of Temperature

Activity 1.12

- Take about 150 g of ice in a beaker and suspend a laboratory thermometer so that its bulb is in contact with the ice, as in Fig. 1.6.

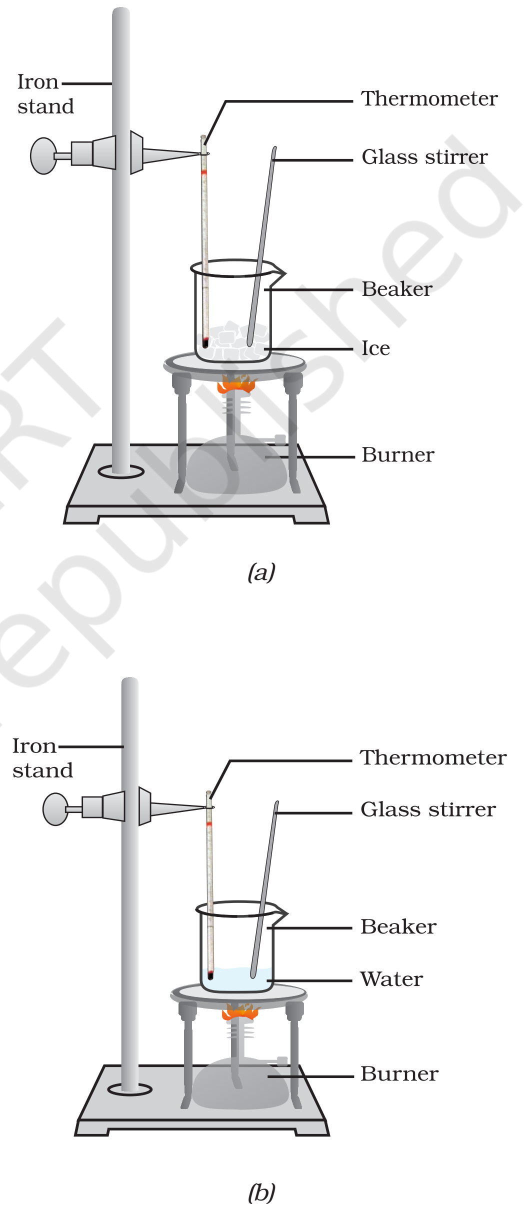

Fig. 1.6: (a) Conversion of ice to water, (b) conversion of water to water vapour

- Start heating the beaker on a low flame.
- Note the temperature when the ice starts melting.
- Note the temperature when all the ice has converted into water.
- Record your observations for this conversion of solid to liquid state.
- Now, put a glass rod in the beaker and heat while stirring till the water starts boiling.
- Keep a careful eye on the thermometer reading till most of the water has vaporised.
- Record your observations for the conversion of water in the liquid state to the gaseous state.

On increasing the temperature of solids, the kinetic energy of the particles increases. Due to the increase in kinetic energy, the particles start vibrating with greater speed. The energy supplied by heat overcomes the forces of attraction between the particles. The particles leave their fixed positions and start moving more freely. A stage is reached when the solid melts and is converted to a liquid. The minimum temperature at which a solid melts to become a liquid at the atmospheric pressure is called its melting point.

> The melting point of a solid is an indication of the strength of the force of attraction between its particles.

The melting point of ice is 273.15 K*. The process of melting, that is, change of solid state into liquid state is also known as fusion. **When a solid melts, its temperature remains the same, so where does the heat energy go?**

You must have observed, during the experiment of melting, that the temperature of the system does not change after the melting point is reached, till all the ice melts. This happens even though we continue to heat the beaker, that is, we continue to supply heat. This heat gets used up in changing the state by overcoming the forces of attraction between the particles. As this heat energy is absorbed by ice without showing any rise in temperature, it is considered that it gets hidden into the contents of the beaker and is known as the latent heat. The word latent means hidden. The amount of heat energy that is required to change 1 kg of a solid into liquid at atmospheric pressure at its melting point is known as the latent heat of fusion. So, particles in water at $0^{o}C$ (273 K) have more energy as compared to particles in ice at the same temperature.

When we supply heat energy to water, particles start moving even faster. At a certain temperature, a point is reached when the particles have enough energy to break free from the forces of attraction of each other. At this temperature the liquid starts changing into gas. The temperature at which a liquid starts boiling at the atmospheric pressure is known as its boiling point. Boiling is a bulk phenomenon. Particles from the bulk of the liquid gain enough energy to change into the vapour state.

For water this temperature is 373 K ($100^{o}C = 273 + 100 = 373$ K).

Can you define the latent heat of vaporisation? Do it in the same way as we have defined the latent heat of fusion. Particles in steam, that is, water vapour at 373 K (100^{0} C) have more energy than water at the same temperature. This is because particles in steam have absorbed extra energy in the form of latent heat of vaporisation.

$$\boxed{\text{Solid State}} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \boxed{\text{Liquid State}} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \boxed{\text{Gaseous State}}$$

So, we infer that the state of matter can be changed into another state by changing the temperature.

We have learnt that substances around us change state from solid to liquid and from liquid to gas on application of heat. But there

***Note**: *Kelvin* is the SI unit of temperature, 0^{o} C =273.15 K. For convenience, we take 0^{o} C = 273 K after rounding off the decimal. To change a temperature on the Kelvin scale to the Celsius scale you have to subtract 273 from the given temperature, and to convert a temperature on the Celsius scale to the Kelvin scale you have to add 273 to the given temperature.

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are some that change directly from solid state to gaseous state and vice versa without changing into the liquid state.

Activity 1.13

- Take some camphor. Crush it and put it in a china dish.
- Put an inverted funnel over the china dish.
- Put a cotton plug on the stem of the funnel, as shown in Fig. 1.7.

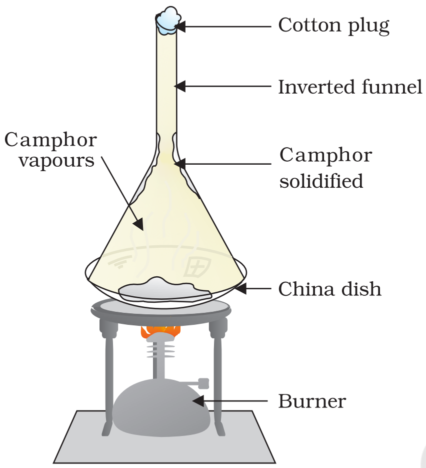

Fig. 1.7: Sublimation of camphor

- Now, heat slowly and observe.
- What do you infer from the above activity?

A change of state directly from solid to gas without changing into liquid state is called sublimation and the direct change of gas to solid without changing into liquid is called deposition.

1.4.2 Effect of change of pressure

We have already learnt that the difference in various states of matter is due to the difference in the distances between the constituent particles. What will happen when we start putting pressure and compress a gas enclosed in a cylinder? Will the particles come closer? Do you think that increasing or decreasing the pressure can change the state of matter?

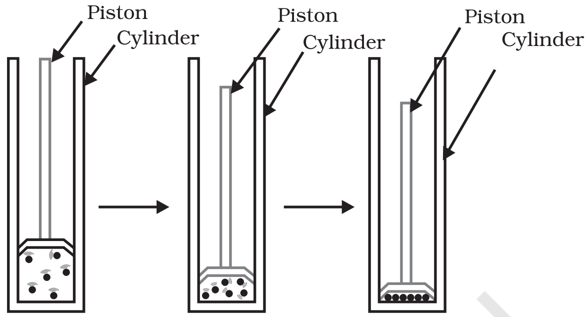

Fig. 1.8: By applying pressure, particles of matter can be brought close together

Applying pressure and reducing temperature can liquefy gases.

Have you heard of solid carbon dioxide (CO_2)? It is stored under high pressure. Solid CO_2 gets converted directly into gaseous state on decrease of pressure to 1 atmosphere* without coming into liquid state. This is the reason that solid carbon dioxide is also known as dry ice.

Thus, we can say that pressure and temperature determine the state of a substance, whether it will be solid, liquid or gas.

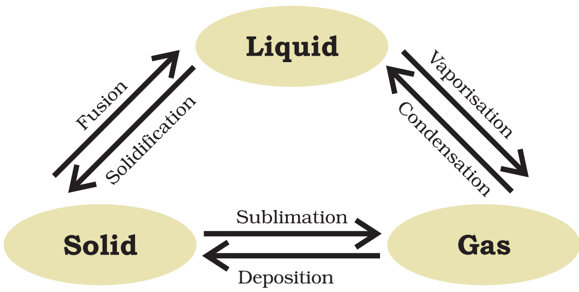

Fig. 1.9: Interconversion of the three states of matter

* *atmosphere (atm)* is a unit of measuring pressure exerted by a gas. The unit of pressure is Pascal (Pa): 1 atmosphere = 1.01×10^5 Pa. The pressure of air in atmosphere is called atmospheric pressure. The atmospheric pressure at sea level is 1 atmosphere, and is taken as the normal atmospheric pressure.

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Questions

1. *Convert the following temperature to celsius scale:*
   a. 300 K b. 573 K
2. *What is the physical state of water at:*
   a. 250°C b. 100°C ?
3. *For any substance, why does the temperature remain constant during the change of state?*
4. *Suggest a method to liquefy atmospheric gases.*

1.5 Evaporation

Do we always need to heat or change pressure for changing the state of matter? Can you quote some examples from everyday life where change of state from liquid to vapour takes place without the liquid reaching the boiling point? Water, when left uncovered, slowly changes into vapour. Wet clothes dry up. What happens to water in the above two examples?

We know that particles of matter are always moving and are never at rest. At a given temperature in any gas, liquid or solid, there are particles with different amounts of kinetic energy. In the case of liquids, a small fraction of particles at the surface, having higher kinetic energy, is able to break away from the forces of attraction of other particles and gets converted into vapour. This phenomenon of change of liquid into vapours at any temperature below its boiling point is called evaporation.

1.5.1 Factors affecting evaporation

Let us understand this with an activity.

Activity 1.14

- Take 5 mL of water in a test tube and keep it near a window or under a fan.
- Take 5 mL of water in an open china dish and keep it near a window or under a fan.
- Take 5 mL of water in an open china dish and keep it inside a cupboard or on a shelf in your class.
- Record the room temperature.
- Record the time or days taken for the evaporation process in the above cases.
- Repeat the above three steps of activity on a rainy day and record your observations.
- What do you infer about the effect of temperature, surface area and wind velocity (speed) on evaporation?

You must have observed that the rate of evaporation increases with–

- an increase of surface area:
  We know that evaporation is a surface phenomenon. If the surface area is increased, the rate of evaporation increases. For example, while putting clothes for drying up we spread them out.
- an increase of temperature:
  With the increase of temperature, more number of particles get enough kinetic energy to go into the vapour state.
- a decrease in humidity:
  Humidity is the amount of water vapour present in air. The air around us cannot hold more than a definite amount of water vapour at a given temperature. If the amount of water in air is already high, the rate of evaporation decreases.
- an increase in wind speed:
  It is a common observation that clothes dry faster on a windy day. With the increase in wind speed, the particles of water vapour move away with the wind, decreasing the amount of water vapour in the surrounding.

1.5.2 How does evaporation cause cooling?

In an open vessel, the liquid keeps on evaporating. The particles of liquid absorb energy from the surrounding to regain the energy lost during evaporation. This absorption of energy from the surroundings make the surroundings cold.

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What happens when you pour some acetone (nail polish remover) on your palm? The particles gain energy from your palm or surroundings and evaporate causing the palm to feel cool.

After a hot sunny day, people sprinkle water on the roof or open ground because the large latent heat of vaporisation of water helps to cool the hot surface.

Can you cite some more examples from daily life where we can feel the effect of cooling due to evaporation?

Why should we wear cotton clothes in summer?

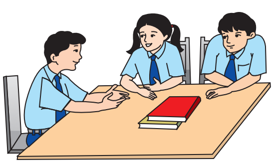
During summer, we perspire more because of the mechanism of our body which keeps us cool. We know that during evaporation, the particles at the surface of the liquid gain energy from the surroundings or body surface and change into vapour. The heat energy equal to the latent heat of vaporisation is absorbed from the body leaving the body cool. Cotton, being a good absorber of water helps in absorbing the sweat and exposing it to the atmosphere for easy evaporation.

Why do we see water droplets on the outer surface of a glass containing ice-cold water?

Let us take some ice-cold water in a tumbler. Soon we will see water droplets on the outer surface of the tumbler. The water vapour present in air, on coming in contact with the cold glass of water, loses energy and gets converted to liquid state, which we see as water droplets.

Questions

1. *Why does a desert cooler cool better on a hot dry day?*
2. *How does the water kept in an earthen pot (matka) become cool during summer?*
3. *Why does our palm feel cold when we put some acetone or petrol or perfume on it?*
4. *Why are we able to sip hot tea or milk faster from a saucer rather than a cup?*
5. *What type of clothes should we wear in summer?*



What you have learnt

- Matter is made up of small particles.
- The matter around us exists in three states—solid, liquid and gas.
- The forces of attraction between the particles are maximum in solids, intermediate in liquids and minimum in gases.
- The spaces in between the constituent particles and kinetic energy of the particles are minimum in the case of solids, intermediate in liquids and maximum in gases.

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- The arrangement of particles is most ordered in the case of solids, in the case of liquids layers of particles can slip and slide over each other while for gases, there is no order, particles just move about randomly.
- The states of matter are inter-convertible. The state of matter can be changed by changing temperature or pressure.
- Sublimation is the change of solid state directly to gaseous state without going through liquid state.
- Deposition is the change of gaseous state directly to solid state without going through liquid state.
- Boiling is a bulk phenomenon. Particles from the bulk (whole) of the liquid change into vapour state.
- Evaporation is a surface phenomenon. Particles from the surface gain enough energy to overcome the forces of attraction present in the liquid and change into the vapour state.
- The rate of evaporation depends upon the surface area exposed to the atmosphere, the temperature, the humidity and the wind speed.
- Evaporation causes cooling.
- Latent heat of vaporisation is the heat energy required to change 1 kg of a liquid to gas at atmospheric pressure at its boiling point.
- Latent heat of fusion is the amount of heat energy required to change 1 kg of solid into liquid at its melting point.
- Some measurable quantities and their units to remember:

Quantity	Unit	Symbol
Temperature	kelvin	K
Length	metre	m
Mass	kilogram	kg
Weight	newton	N
Volume	cubic metre	m^3
Density	kilogram per cubic metre	$kg\ m^{-3}$
Pressure	pascal	Pa

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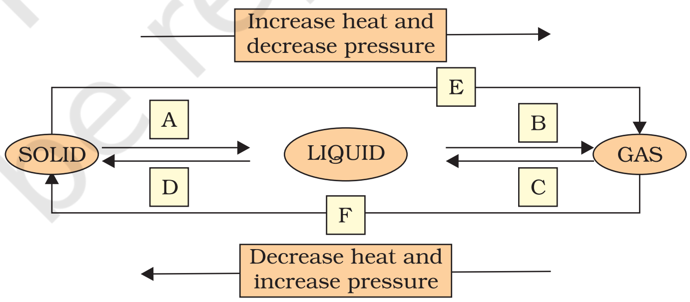
Exercises

1. Convert the following temperatures to the celsius scale.
   (a) 293 K (b) 470 K
2. Convert the following temperatures to the kelvin scale.
   (a) 25° C (b) 373° C
3. Give reason for the following observations.
   (a) Naphthalene balls disappear with time without leaving any solid.
   (b) We can get the smell of perfume sitting several metres away.
4. Arrange the following substances in increasing order of forces of attraction between the particles— water, sugar, oxygen.
5. What is the physical state of water at—
   (a) 25° C (b) 0° C (c) 100° C ?
6. Give two reasons to justify—
   (a) water at room temperature is a liquid.
   (b) an iron almirah is a solid at room temperature.
7. Why is ice at 273 K more effective in cooling than water at the same temperature?
8. What produces more severe burns, boiling water or steam?
9. Name A,B,C,D,E and F in the following diagram showing change in its state



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Group Activity

Prepare a model to demonstrate movement of particles in solids, liquids and gases.

For making this model you will need

- A transparent jar
- A big rubber balloon or piece of stretchable rubber sheet
- A string
- Few chickpeas or black gram or dry green peas.

How to make?

- Put the seeds in the jar.
- Sew the string to the centre of the rubber sheet and put some tape to keep it tied securely.
- Stretch and tie the rubber sheet on the mouth of the jar.
- Your model is ready. Now run your fingers up and down the string by first tugging at it slowly and then rapidly.

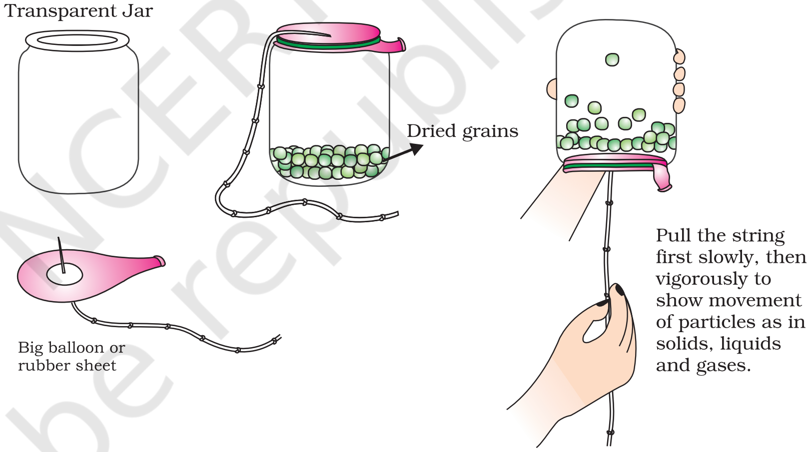

***Fig. 1.10:** A model for converting of solid to liquid and liquid to gas.*

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Chapter 2

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Is Matter Around Us Pure?

How do we judge whether milk, ghee, butter, salt, spices, mineral water or juice that we buy from the market are pure?

Fig. 2.1: Some consumable items

Have you ever noticed the word 'pure' written on the packs of these consumables? For a common person pure means having no adulteration. But, for a scientist all these things are actually mixtures of different substances and hence not pure. For example, milk is actually a mixture of water, fat, proteins, etc. When a scientist says that something is pure, it means that all the constituent particles of that substance are the same in their chemical nature. A pure substance consists of a single type of particle. In other words, a substance is a pure single form of matter.

As we look around, we can see that most of the matter around us exists as mixtures of two or more pure components, for example, sea water, minerals, soil, etc., are all mixtures.

2.1 What is a Mixture?

Mixtures are constituted by more than one kind of pure form of matter. We know that dissolved sodium chloride can be separated from water by the physical process of evaporation. However, sodium chloride is itself a pure substance and cannot be separated by physical process into its chemical constituents. Similarly, sugar is a substance which contains only one kind of pure matter and its composition is the same throughout.

Soft drink and soil are not single pure substances. Whatever the source of a pure substance may be, it will always have the same characteristic properties.

Therefore, we can say that a mixture contains more than one pure substance.

2.1.1 Types of mixtures

Depending upon the nature of the components that form a mixture, we can have different types of mixtures.

Activity 2.1

- Let us divide the class into groups A, B, C and D.
- Group A takes a beaker containing 50 mL of water and one spatula full of copper sulphate powder. Group B takes 50 mL of water and two spatula full of copper sulphate powder in a beaker.
- Groups C and D can take different amounts of copper sulphate and potassium permanganate or common salt (sodium chloride) and mix the given components to form a mixture.
- Report the observations on the uniformity in colour and texture.
- Groups A and B have obtained a mixture which has a uniform composition throughout. Such mixtures are called homogeneous mixtures or solutions. Some other examples of such mixtures are: (i) salt dissolved in water and (ii) sugar dissolved in water. Compare the

colour of the solutions of the two groups. Though both the groups have obtained copper sulphate solution but the intensity of colour of the solutions is different. This shows that a homogeneous mixture can have a variable composition.

- Groups C and D have obtained mixtures, which contain physically distinct parts and have non-uniform compositions. Such mixtures are called heterogeneous mixtures. Mixtures of sodium chloride and iron filings, salt and sulphur, and oil and water are examples of heterogeneous mixtures.

Activity 2.2

- Let us again divide the class into four groups— A, B, C and D.
- Distribute the following samples to each group:
  - Few crystals of copper sulphate to group A.
  - One spatula full of copper sulphate to group B.
  - Chalk powder or wheat flour to group C.
  - Few drops of milk or ink to group D.
- Each group should add the given sample in water and stir properly using a glass rod. Are the particles in the mixture visible?
- Direct a beam of light from a torch through the beaker containing the mixture and observe from the front. Was the path of the beam of light visible?
- Leave the mixtures undisturbed for a few minutes (and set up the filtration apparatus in the meantime). Is the mixture stable or do the particles begin to settle after some time?
- Filter the mixture. Is there any residue on the filter paper?
- Discuss the results and form an opinion.

  Groups A and B have got a solution.
  Group C has got a suspension.
  Group D has got a colloidal solution.

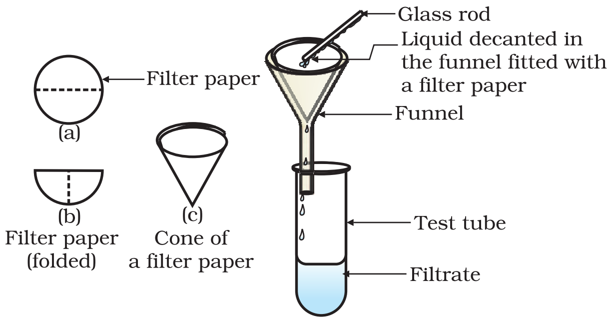

Fig. 2.2: *Filtration*

Now, we shall learn about solutions, suspensions and colloidal solutions in the following sections.

Questions

1. *What is meant by a substance?*
2. *List the points of differences between homogeneous and heterogeneous mixtures.*

2.2 What is a Solution?

A solution is a homogeneous mixture of two or more substances. You come across various types of solutions in your daily life. Lemonade, soda water, etc., are all examples of solutions. Usually we think of a solution as a liquid that contains either a solid, liquid or a gas dissolved in it. But, we can also have solid solutions (alloys) and gaseous solutions (air). In a solution there is homogeneity at the particle level. For example, lemonade tastes the same throughout. This shows that particles of sugar or salt are evenly distributed in the solution.

More to know

Alloys: Alloys are mixtures of two or more metals or a metal and a non-metal and cannot be separated into their components by physical methods. But still, an alloy is considered as a mixture because it shows the properties of its constituents and can have variable composition. For example, brass is a mixture of approximately 30% zinc and 70% copper.

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A solution has a solvent and a solute as its components. The component of the solution that dissolves the other component in it (usually the component present in larger amount) is called the solvent. The component of the solution that is dissolved in the solvent (usually present in lesser quantity) is called the solute.

Examples:

(i) A solution of sugar in water is a solid in liquid solution. In this solution, sugar is the solute and water is the solvent.

(ii) A solution of iodine in alcohol known as 'tincture of iodine', has iodine (solid) as the solute and alcohol (liquid) as the solvent.

(iii) Aerated drinks like soda water, etc., are gas in liquid solutions. These contain carbon dioxide (gas) as solute and water (liquid) as solvent.

(iv) Air is a mixture of gas in gas. Air is a homogeneous mixture of a number of gases. Its two main constituents are: oxygen (21%) and nitrogen (78%). The other gases are present in very small quantities.

Properties of a Solution

- A solution is a homogeneous mixture.
- The particles of a solution are smaller than 1 nm (10^{-9} metre) in diameter. So, they cannot be seen by naked eyes.
- Because of very small particle size, they do not scatter a beam of light passing through the solution. So, the path of light is not visible in a solution.
- The solute particles cannot be separated from the mixture by the process of filtration. The solute particles do not settle down when left undisturbed, that is, a solution is stable.

2.2.1 Concentration of a solution

In activity 2.2, we observed that groups A and B obtained different shades of solutions. So, we understand that in a solution the relative proportion of the solute and solvent can be varied. Depending upon the amount of solute present in a solution, it can be called dilute, concentrated or saturated solution. Dilute and concentrated are comparative terms. In activity 2.2, the solution obtained by group A is dilute as compared to that obtained by group B.

Activity 2.3

- Take approximately 50 mL of water each in two separate beakers.
- Add salt in one beaker and sugar or barium chloride in the second beaker with continuous stirring.
- When no more solute can be dissolved, heat the contents of the beaker to raise the temperature by about 5°C.
- Start adding the solute again.

Is the amount of salt and sugar or barium chloride, that can be dissolved in water at a given temperature, the same?

At any particular temperature, a solution that has dissolved as much solute as it is capable of dissolving, is said to be a saturated solution. In other words, when no more solute can be dissolved in a solution at a given temperature, it is called a saturated solution. The amount of the solute present in the saturated solution at this temperature is called its solubility.

If the amount of solute contained in a solution is less than the saturation level, it is called an unsaturated solution.

What would happen if you were to take a saturated solution at a certain temperature and cool it slowly.

We can infer from the above activity that different substances in a given solvent have different solubilities at the same temperature.

The concentration of a solution is the amount (mass or volume) of solute present in a given amount (mass or volume) of solution.

There are various ways of expressing the concentration of a solution, but here we will learn only three methods.

(i) Mass by mass percentage of a solution

$$= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

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(ii) Mass by volume percentage of a solution

$$= \frac{\text{Mass of solute}}{\text{Volume of solution}} \times 100$$

(iii) Volume by volume percentage of a solution

$$= \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100$$

Example 2.1 A solution contains 40 g of common salt in 320 g of water. Calculate the concentration in terms of mass by mass percentage of the solution.

Solution:

Mass of solute (salt) = 40 g
Mass of solvent (water) = 320 g

We know,

Mass of solution = Mass of solute + Mass of solvent
= 40 g + 320 g
= 360 g

Mass percentage of solution

$$= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

$$= \frac{40}{360} \times 100 = 11.1\%$$

2.2.2 What is a suspension?

Non-homogeneous systems, like those obtained by group C in activity 2.2, in which solids are dispersed in liquids, are called suspensions. A suspension is a heterogeneous mixture in which the solute particles do not dissolve but remain suspended throughout the bulk of the medium. Particles of a suspension are visible to the naked eye.

Properties of a Suspension

- Suspension is a heterogeneous mixture.
- The particles of a suspension can be seen by the naked eye.
- The particles of a suspension scatter a beam of light passing through it and make its path visible.
- The solute particles settle down when a suspension is left undisturbed, that is, a suspension is unstable. They can be separated from the mixture by the process of filtration. When the particles settle down, the suspension breaks and it does not scatter light any more.

2.2.3 What is a colloidal solution?

The mixture obtained by group D in activity 2.2 is called a colloid or a colloidal solution. The particles of a colloid are uniformly spread throughout the solution. Due to the relatively smaller size of particles, as compared to that of a suspension, the mixture appears to be homogeneous. But actually, a colloidal solution is a heterogeneous mixture, for example, milk.

Because of the small size of colloidal particles, we cannot see them with naked eyes. But, these particles can easily scatter a beam of visible light as observed in activity 2.2. This scattering of a beam of light is called the Tyndall effect after the name of the scientist who discovered this effect.

Tyndall effect can also be observed when a fine beam of light enters a room through a small hole. This happens due to the scattering of light by the particles of dust and smoke in the air.

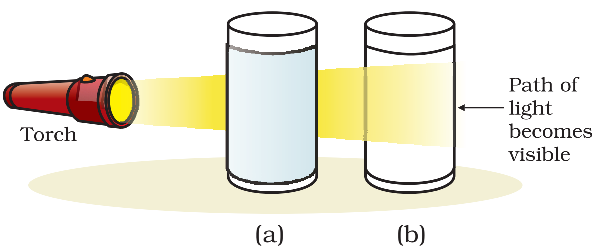

Fig. 2.3: (a) Solution of copper sulphate does not show Tyndall effect, (b) mixture of water and milk shows Tyndall effect.

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Tyndall effect can be observed when sunlight passes through the canopy of a dense forest. In the forest, mist contains tiny droplets of water, which act as particles of colloid dispersed in air.

Fig. 2.4: *The Tyndall effect*

Properties of a Colloid

- A colloid is a heterogeneous mixture.
- The size of particles of a colloid is too small to be individually seen with naked eyes.
- Colloids are big enough to scatter a beam of light passing through it and make its path visible.
- They do not settle down when left undisturbed, that is, a colloid is quite stable.
- They cannot be separated from the mixture by the process of filtration. But, a special technique of separation known as centrifugation can be used to separate the colloidal particles.

The components of a colloidal solution are the dispersed phase and the dispersion medium. The solute-like component or the dispersed particles in a colloid form the dispersed phase, and the component in which the dispersed phase is suspended is known as the dispersing medium. Colloids are classified according to the state (solid, liquid or gas) of the dispersing medium and the dispersed phase. A few common examples are given in Table 2.1. From this table you can see that they are very common everyday life.

Questions

1. *Differentiate between homogeneous and heterogeneous mixtures with examples.*
2. *How are sol, solution and suspension different from each other?*
3. *To make a saturated solution, 36 g of sodium chloride is dissolved in 100 g of water at 293 K. Find its concentration at this temperature.*

Table 2.1: Common examples of colloids

Dispersed phase	Dispersing Medium	Type	Example
Liquid	Gas	Aerosol	Fog, clouds, mist
Solid	Gas	Aerosol	Smoke, automobile exhaust
Gas	Liquid	Foam	Shaving cream
Liquid	Liquid	Emulsion	Milk, face cream
Solid	Liquid	Sol	Milk of magnesia, mud
Gas	Solid	Foam	Foam, rubber, sponge, pumice
Liquid	Solid	Gel	Jelly, cheese, butter
Solid	Solid	Solid Sol	Coloured gemstone, milky glass

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2.3 Physical and Chemical Changes

In the previous chapter, we have learnt about a few physical properties of matter. The properties that can be observed and specified like colour, hardness, rigidity, fluidity, density, melting point, boiling point etc. are the physical properites.

The interconversion of states is a physical change because these changes occur without a change in composition and no change in the chemical nature of the substance. Although ice, water and water vapour all look different and display different physical properties, they are chemically the same.

Both water and cooking oil are liquid but their chemical characteristics are different. They differ in odour and inflammability. We know that oil burns in air whereas water extinguishes fire. It is this chemical property of oil that makes it different from water. Burning is a chemical change. During this process one substance reacts with another to undergo a change in chemical composition. Chemical change brings change in the chemical properties of matter and we get new substances. A chemical change is also called a chemical reaction.

During burning of a candle, both physical and chemical changes take place. Can you distinguish these?

Questions

1. *Classify the following as chemical or physical changes:*
   - *cutting of trees,*
   - *melting of butter in a pan,*
   - *rusting of almirah,*
   - *boiling of water to form steam,*
   - *passing of electric current, through water and the water breaking down into hydrogen and oxygen gases,*
   - *dissolving common salt in water,*
   - *making a fruit salad with raw fruits, and*
   - *burning of paper and wood.*
2. *Try segregating the things around you as pure substances or mixtures.*

2.4 What are the Types of Pure Substances?

On the basis of their chemical composition, substances can be classified either as elements or compounds.

2.4.1 Elements

Robert Boyle was the first scientist to use the term element in 1661. Antoine Laurent Lavoisier (1743–94), a French chemist, was the first to establish an experimentally useful definition of an element. He defined an element as a basic form of matter that cannot be broken down into simpler substances by chemical reactions.

Elements can be normally divided into metals, non-metals and metalloids.

Metals usually show some or all of the following properties:

- They have a lustre (shine).
- They have silvery-grey or golden-yellow colour.
- They conduct heat and electricity.
- They are ductile (can be drawn into wires).
- They are malleable (can be hammered into thin sheets).
- They are sonorous (make a ringing sound when hit).

Examples of metals are gold, silver, copper, iron, sodium, potassium etc. Mercury is the only metal that is liquid at room temperature.

Non-metals usually show some or all of the following properties:

- They display a variety of colours.
- They are poor conductors of heat and electricity.
- They are not lustrous, sonorous or malleable.

Examples of non-metals are hydrogen, oxygen, iodine, carbon (coal, coke), bromine,

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chlorine etc. Some elements have intermediate properties between those of metals and non-metals, they are called metalloids; examples are boron, silicon, germanium, etc.

More to know

- The number of elements known at present are more than 100. Ninety-two elements are naturally occurring and the rest are man-made.
- Majority of the elements are solid.
- Eleven elements are in gaseous state at room temperature.
- Two elements are liquid at room temperature—mercury and bromine.
- Elements, gallium and cesium become liquid at a temperature slightly above room temperature (303 K).

2.4.2 Compounds

A compound is a substance composed of two or more elements, chemically combined with one another in a fixed proportion.

What do we get when two or more elements are combined?

Activity 2.4

- Divide the class into two groups. Give 5 g of iron filings and 3 g of sulphur powder in a china dish to both the groups.

Group I

- Mix and crush iron filings and sulphur powder.

Group II

- Mix and crush iron filings and sulphur powder. Heat this mixture strongly till red hot. Remove from flame and let the mixture cool.

Groups I and II

- Check for magnetism in the material obtained. Bring a magnet near the material and check if the material is attracted towards the magnet.
- Compare the texture and colour of the material obtained by the groups.
- Add carbon disulphide to one part of the material obtained. Stir well and filter.
- Add dilute sulphuric acid or dilute hydrochloric acid to the other part of the material obtained. *(Note: teacher supervision is necessary for this activity).*
- Perform all the above steps with both the elements (iron and sulphur) separately.

Now answer

- *Did the material obtained by the two groups look the same?*
- *Which group has obtained a material with magnetic properties?*
- *Can we separate the components of the material obtained?*
- *On adding dilute sulphuric acid or dilute hydrochloric acid, did both the groups obtain a gas? Did the gas in both the cases smell the same or different?*

The gas obtained by Group I is hydrogen, it is colourless, odourless and combustible– it is not advised to do the combustion test for hydrogen in the class. The gas obtained by Group II is hydrogen sulphide. It is a colourless gas with the smell of rotten eggs.

You must have observed that the products obtained by both the groups show different properties, though the starting materials were the same. Group I has carried out the activity involving a physical change whereas in case of Group II, a chemical change (a chemical reaction) has taken place.

- The material obtained by group I is a mixture of the two substances. The substances given are the elements—iron and sulphur.
- The properties of the mixture are the same as that of its constituents.

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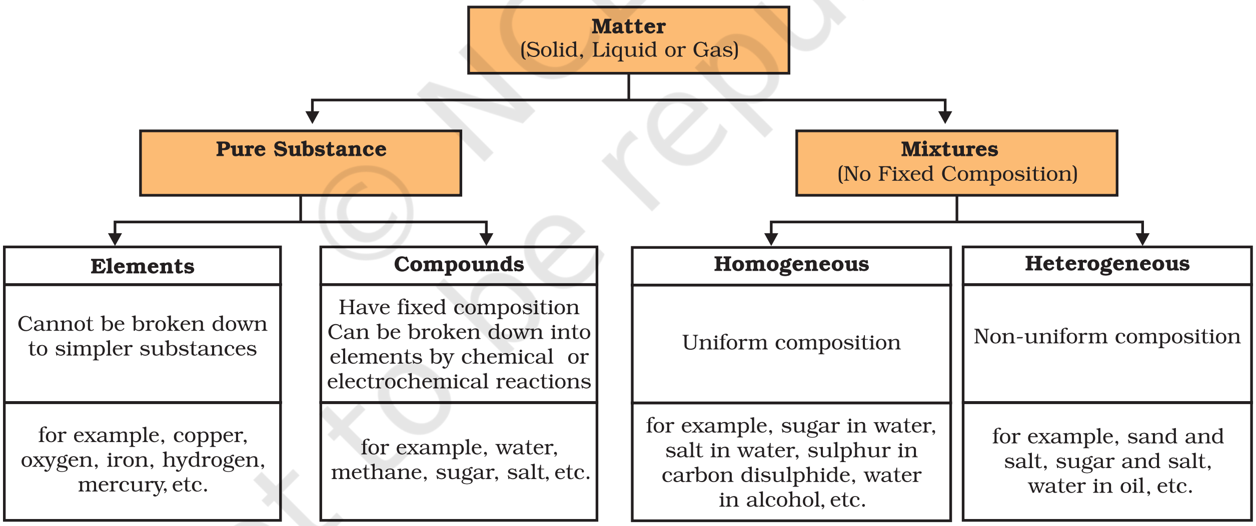
Table 2.2: Mixtures and Compounds

Mixtures	Compounds
1. Elements or compounds just mix together to form a mixture and no new compound is formed.	1. Elements react to form new compounds.
2. A mixture has a variable composition.	2. The composition of each new substance is always fixed.
3, A mixture shows the properties of the constituent substances.	3. The new substance has totally different properties.
4. The constituents can be seperated fairly easily by physical methods.	4. The constituents can be separated only by chemical or electrochemical reactions.

- The material obtained by group II is a compound.
- On heating the two elements strongly we get a compound, which has totally different properties compared to the combining elements.
- The composition of a compound is the same throughout. We can also observe that the texture and the colour of the compound are the same throughout.

Thus, we can summarise the physical and chemical nature of matter in the following graphical organiser:



What you have learnt

- A mixture contains more than one substance (element and/ or compound) mixed in any proportion.

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- Mixtures can be separated into pure substances using appropriate separation techniques.
- A solution is a homogeneous mixture of two or more substances. The major component of a solution is called the solvent, and the minor, the solute.
- The concentration of a solution is the amount of solute present per unit volume or per unit mass of the solution.
- Materials that are insoluble in a solvent and have particles that are visible to naked eyes, form a suspension. A suspension is a heterogeneous mixture.
- Colloids are heterogeneous mixtures in which the particle size is too small to be seen with the naked eye, but is big enough to scatter light. Colloids are useful in industry and daily life. The particles are called the dispersed phase and the medium in which they are distributed is called the dispersion medium.
- Pure substances can be elements or compounds. An element is a form of matter that cannot be broken down by chemical reactions into simpler substances. A compound is a substance composed of two or more different types of elements, chemically combined in a fixed proportion.
- Properties of a compound are different from its constituent elements, whereas a mixture shows the properties of its constituting elements or compounds.

Exercises

1. Which separation techniques will you apply for the separation of the following?
   (a) Sodium chloride from its solution in water
   (b) Ammonium chloride from a mixture containing sodium chloride and ammonium chloride
   (c) Small pieces of metal in the engine oil of a car
   (d) Different pigments from an extract of flower petals
   (e) Butter from curd
   (f) Oil from water
   (g) Tea leaves from tea
   (h) Iron pins from sand
   (i) Wheat grains from husk
   (j) Fine mud particles suspended in water

2. Write the steps you would use for making tea. Use the words solution, solvent, solute, dissolve, soluble, insoluble, filtrate and residue.
3. Pragya tested the solubility of three different substances at different temperatures and collected the data as given below (results are given in the following table, as grams of substance dissolved in 100 grams of water to form a saturated solution).

Substance Dissolved	Temperature in K				
	283	293	313	333	353
	Solubility				
Potassium nitrate	21	32	62	106	167
Sodium chloride	36	36	36	37	37
Potassium chloride	35	35	40	46	54
Ammonium chloride	24	37	41	55	66

(a) What mass of potassium nitrate would be needed to produce a saturated solution of potassium nitrate in 50 grams of water at 313 K?
(b) Pragya makes a saturated solution of potassium chloride in water at 353 K and leaves the solution to cool at room temperature. What would she observe as the solution cools? Explain.
(c) Find the solubility of each salt at 293 K. Which salt has the highest solubility at this temperature?
(d) What is the effect of change of temperature on the solubility of a salt?
4. Explain the following giving examples.
(a) Saturated solution
(b) Pure substance
(c) Colloid
(d) Suspension
5. Classify each of the following as a homogeneous or heterogeneous mixture.
soda water, wood, air, soil, vinegar, filtered tea.
6. How would you confirm that a colourless liquid given to you is pure water?

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7. Which of the following materials fall in the category of a "pure substance"?
   (a) Ice
   (b) Milk
   (c) Iron
   (d) Hydrochloric acid
   (e) Calcium oxide
   (f) Mercury
   (g) Brick
   (h) Wood
   (i) Air
8. Identify the solutions among the following mixtures.
   (a) Soil
   (b) Sea water
   (c) Air
   (d) Coal
   (e) Soda water
9. Which of the following will show "Tyndall effect"?
   (a) Salt solution
   (b) Milk
   (c) Copper sulphate solution
   (d) Starch solution
10. Classify the following into elements, compounds and mixtures.
   (a) Sodium
   (b) Soil
   (c) Sugar solution
   (d) Silver
   (e) Calcium carbonate
   (f) Tin
   (g) Silicon
   (h) Coal
   (i) Air
   (j) Soap
   (k) Methane
   (l) Carbon dioxide
   (m) Blood
11. Which of the following are chemical changes?
   (a) Growth of a plant
   (b) Rusting of iron

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(c) Mixing of iron filings and sand
(d) Cooking of food
(e) Digestion of food
(f) Freezing of water
(g) Burning of a candle

Group Activity

Take an earthen pot (*matka*), some pebbles and sand. Design a small-scale filtration plant that you could use to clean muddy water.

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Chapter 3

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Atoms and Molecules

Ancient Indian and Greek philosophers have always wondered about the unknown and unseen form of matter. The idea of divisibility of matter was considered long back in India, around 500 BC. An Indian philosopher Maharishi Kanad, postulated that if we go on dividing matter (*padarth*), we shall get smaller and smaller particles. Ultimately, a stage will come when we shall come across the smallest particles beyond which further division will not be possible. He named these particles *Parmanu*. Another Indian philosopher, Pakudha Katyayama, elaborated this doctrine and said that these particles normally exist in a combined form which gives us various forms of matter.

Around the same era, ancient Greek philosophers – Democritus and Leucippus suggested that if we go on dividing matter, a stage will come when particles obtained cannot be divided further. Democritus called these indivisible particles atoms (meaning indivisible). All this was based on philosophical considerations and not much experimental work to validate these ideas could be done till the eighteenth century.

By the end of the eighteenth century, scientists recognised the difference between elements and compounds and naturally became interested in finding out how and why elements combine and what happens when they combine.

Antoine L. Lavoisier laid the foundation of chemical sciences by establishing two important laws of chemical combination.

3.1 Laws of Chemical Combination

The following two laws of chemical combination were established after much experimentations by Lavoisier and Joseph L. Proust.

3.1.1 Law of conservation of mass

Is there a change in mass when a chemical change (chemical reaction) takes place?

Activity 3.1

- Take one of the following sets, X and Y of chemicals—

	X	Y
(i)	copper sulphate	sodium carbonate
(ii)	barium chloride	sodium sulphate
(iii)	lead nitrate	sodium chloride

- Prepare separately a 5% solution of any one pair of substances listed under X and Y each in 10 mL in water.
- Take a little amount of solution of Y in a conical flask and some solution of X in an ignition tube.
- Hang the ignition tube in the flask carefully; see that the solutions do not get mixed. Put a cork on the flask (see Fig. 3.1).

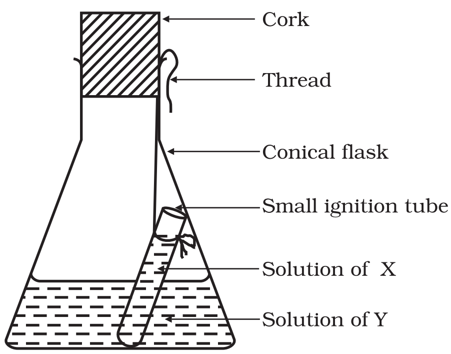

Fig. 3.1: Ignition tube containing solution of X, dipped in a conical flask containing solution of Y

- Weigh the flask with its contents carefully.
- Now tilt and swirl the flask, so that the solutions X and Y get mixed.
- Weigh again.
- What happens in the reaction flask?
- Do you think that a chemical reaction has taken place?
- Why should we put a cork on the mouth of the flask?
- Does the mass of the flask and its contents change?

Law of conservation of mass states that mass can neither be created nor destroyed in a chemical reaction.

3.1.2 Law of constant proportions

Lavoisier, along with other scientists, noted that many compounds were composed of two or more elements and each such compound had the same elements in the same proportions, irrespective of where the compound came from or who prepared it.

In a compound such as water, the ratio of the mass of hydrogen to the mass of oxygen is always 1:8, whatever the source of water. Thus, if 9 g of water is decomposed, 1 g of hydrogen and 8 g of oxygen are always obtained. Similarly in ammonia, nitrogen and hydrogen are always present in the ratio 14:3 by mass, whatever the method or the source from which it is obtained.

This led to the law of constant proportions which is also known as the law of definite proportions. This law was stated by Proust as "*In a chemical substance the elements are always present in definite proportions by mass*".

The next problem faced by scientists was to give appropriate explanations of these laws. British chemist John Dalton provided the basic theory about the nature of matter. Dalton picked up the idea of divisibility of matter, which was till then just a philosophy. He took the name 'atoms' as given by the Greeks and said that the smallest particles of matter are atoms. His theory was based on the laws of chemical combination. Dalton's atomic theory provided an explanation for the law of conservation of mass and the law of definite proportions.

John Dalton

John Dalton was born in a poor weaver's family in 1766 in England. He began his career as a teacher at the age of twelve. Seven years later he became a school principal. In 1793, Dalton left for Manchester to teach mathematics, physics and chemistry in a college. He spent most of his life there teaching and researching. In 1808, he presented his atomic theory which was a turning point in the study of matter.

According to Dalton's atomic theory, all matter, whether an element, a compound or a mixture is composed of small particles called atoms. The postulates of this theory may be stated as follows:

(i) All matter is made of very tiny particles called atoms, which participate in chemical reactions.
(ii) Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.
(iii) Atoms of a given element are identical in mass and chemical properties.
(iv) Atoms of different elements have different masses and chemical properties.
(v) Atoms combine in the ratio of small whole numbers to form compounds.
(vi) The relative number and kinds of atoms are constant in a given compound.

You will study in the next chapter that all atoms are made up of still smaller particles.

Questions

1. *In a reaction, 5.3 g of sodium carbonate reacted with 6 g of acetic acid. The products were 2.2 g of carbon dioxide, 0.9 g water and 8.2 g of sodium acetate. Show that these*

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observations are in agreement with the law of conservation of mass.
sodium carbonate + acetic acid → sodium acetate + carbon dioxide + water

2. *Hydrogen and oxygen combine in the ratio of 1:8 by mass to form water. What mass of oxygen gas would be required to react completely with 3 g of hydrogen gas?*
3. *Which postulate of Dalton's atomic theory is the result of the law of conservation of mass?*
4. *Which postulate of Dalton's atomic theory can explain the law of definite proportions?*

3.2 What is an Atom?

Have you ever observed a mason building walls, from these walls a room and then a collection of rooms to form a building? What is the building block of the huge building? What about the building block of an ant-hill? It is a small grain of sand. Similarly, the building blocks of all matter are atoms.

How big are atoms?

Atoms are very small, they are smaller than anything that we can imagine or compare with. More than millions of atoms when stacked would make a layer barely as thick as this sheet of paper.

Atomic radius is measured in nanometres.

$$1/10^9\ \text{m} = 1\ \text{nm}$$
$$1\ \text{m} = 10^9\ \text{nm}$$

Relative Sizes	
Radii (in m)	**Example**
10^{-10}	Atom of hydrogen
10^{-9}	Molecule of water
10^{-8}	Molecule of haemoglobin
10^{-4}	Grain of sand
10^{-3}	Ant
10^{-1}	Apple

We might think that if atoms are so insignificant in size, why should we care about them? This is because our entire world is made up of atoms. We may not be able to see them, but they are there, and constantly affecting whatever we do. Through modern techniques, we can now produce magnified images of surfaces of elements showing atoms.

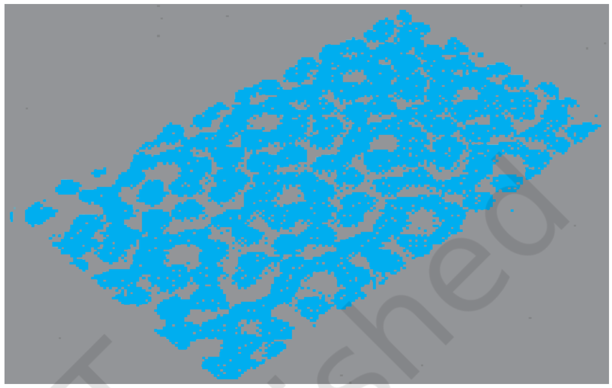

Fig. 3.2: *An image of the surface of silicon*

3.2.1 What are the modern day symbols of atoms of different elements?

Dalton was the first scientist to use the symbols for elements in a very specific sense. When he used a symbol for an element he also meant a definite quantity of that element, that is, one atom of that element. Berzilius suggested that the symbols of elements be made from one or two letters of the name of the element.

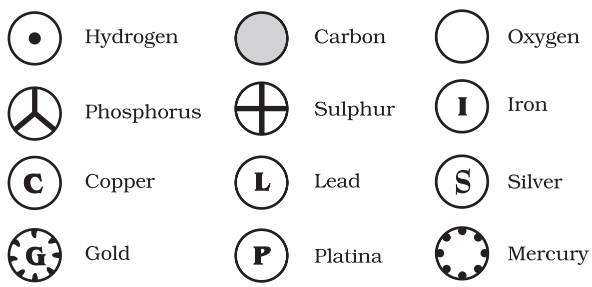

Fig. 3.3: *Symbols for some elements as proposed by Dalton*

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In the beginning, the names of elements were derived from the name of the place where they were found for the first time. For example, the name copper was taken from Cyprus. Some names were taken from specific colours. For example, gold was taken from the English word meaning yellow. Now-a-days, IUPAC (International Union of Pure and Applied Chemistry) is an international scientific organisation which approves names of elements, symbols and units. Many of the symbols are the first one or two letters of the element's name in English. The first letter of a symbol is always written as a capital letter (uppercase) and the second letter as a small letter (lowercase).

For example

(i) hydrogen, H
(ii) aluminium, Al and not AL
(iii) cobalt, Co and not CO.

Symbols of some elements are formed from the first letter of the name and a letter, appearing later in the name. Examples are: (i) chlorine, Cl, (ii) zinc, Zn etc.

Other symbols have been taken from the names of elements in Latin, German or Greek. For example, the symbol of iron is Fe from its Latin name ferrum, sodium is Na from natrium, potassium is K from kalium. Therefore, each element has a name and a unique chemical symbol.

Table 3.1: Symbols for some elements

Element	Symbol	Element	Symbol	Element	Symbol
Aluminium	Al	Copper	Cu	Nitrogen	N
Argon	Ar	Fluorine	F	Oxygen	O
Barium	Ba	Gold	Au	Potassium	K
Boron	B	Hydrogen	H	Silicon	Si
Bromine	Br	Iodine	I	Silver	Ag
Calcium	Ca	Iron	Fe	Sodium	Na
Carbon	C	Lead	Pb	Sulphur	S
Chlorine	Cl	Magnesium	Mg	Uranium	U
Cobalt	Co	Neon	Ne	Zinc	Zn

(The above table is given for you to refer to whenever you study about elements. Do not bother to memorise all in one go. With the passage of time and repeated usage you will automatically be able to reproduce the symbols).

3.2.2 Atomic mass

The most remarkable concept that Dalton's atomic theory proposed was that of the atomic mass. According to him, each element had a characteristic atomic mass. The theory could explain the law of constant proportions so well that scientists were prompted to measure the atomic mass of an atom. Since determining the mass of an individual atom was a relatively difficult task, relative atomic masses were determined using the laws of chemical combinations and the compounds formed.

Let us take the example of a compound, carbon monoxide (CO) formed by carbon and oxygen. It was observed experimentally that 3 g of carbon combines with 4 g of oxygen to form CO. In other words, carbon combines with 4/3 times its mass of oxygen. Suppose we define the atomic mass unit (earlier abbreviated as 'amu', but according to the latest IUPAC recommendations, it is now written as 'u' – unified mass) as equal to the mass of one carbon atom, then we would assign carbon an atomic mass of 1.0 u and oxygen an atomic mass of 1.33 u. However, it is more convenient to have these numbers as

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whole numbers or as near to a whole numbers as possible. While searching for various atomic mass units, scientists initially took 1/16 of the mass of an atom of naturally occurring oxygen as the unit. This was considered relevant due to two reasons:

- oxygen reacted with a large number of elements and formed compounds.
- this atomic mass unit gave masses of most of the elements as whole numbers.

However, in 1961 for a universally accepted atomic mass unit, carbon-12 isotope was chosen as the standard reference for measuring atomic masses. One atomic mass unit is a mass unit equal to exactly one-twelfth ($1/12^{th}$) the mass of one atom of carbon-12. The relative atomic masses of all elements have been found with respect to an atom of carbon-12.

Imagine a fruit seller selling fruits without any standard weight with him. He takes a watermelon and says, “this has a mass equal to 12 units” (12 watermelon units or 12 fruit mass units). He makes twelve equal pieces of the watermelon and finds the mass of each fruit he is selling, relative to the mass of one piece of the watermelon. Now he sells his fruits by relative fruit mass unit (fmu), as in Fig. 3.4.

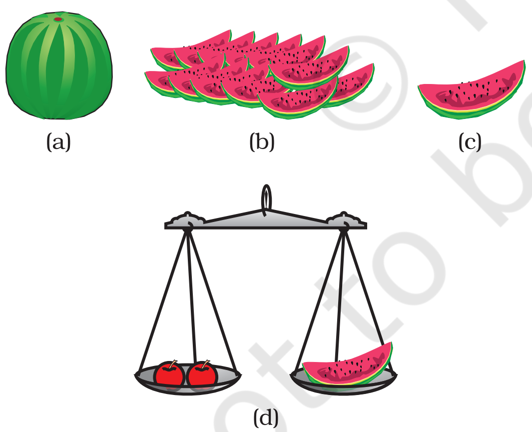

Fig. 3.4 : *(a) Watermelon, (b) 12 pieces, (c) 1/12 of watermelon, (d) how the fruit seller can weigh the fruits using pieces of watermelon*

Similarly, the relative atomic mass of the atom of an element is defined as the average mass of the atom, as compared to $1/12^{th}$ the mass of one carbon-12 atom.

Table 3.2: Atomic masses of a few elements

Element	Atomic Mass (u)
Hydrogen	1
Carbon	12
Nitrogen	14
Oxygen	16
Sodium	23
Magnesium	24
Sulphur	32
Chlorine	35.5
Calcium	40

3.2.3 How do atoms exist?

Atoms of most elements are not able to exist independently. Atoms form molecules and ions. These molecules or ions aggregate in large numbers to form the matter that we can see, feel or touch.

Questions

1. *Define the atomic mass unit.*
2. *Why is it not possible to see an atom with naked eyes?*

3.3 What is a Molecule?

A molecule is in general a group of two or more atoms that are chemically bonded together, that is, tightly held together by attractive forces. A molecule can be defined as the smallest particle of an element or a compound that is capable of an independent existence and shows all the properties of that substance. Atoms of the same element or of different elements can join together to form molecules.

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3.3.1 Molecules of elements

The molecules of an element are constituted by the same type of atoms. Molecules of many elements, such as argon (Ar), helium (He) etc. are made up of only one atom of that element. But this is not the case with most of the non-metals. For example, a molecule of oxygen consists of two atoms of oxygen and hence it is known as a diatomic molecule, O_2. If 3 atoms of oxygen unite into a molecule, instead of the usual 2, we get ozone, O_3. The number of atoms constituting a molecule is known as its atomicity.

Metals and some other elements, such as carbon, do not have a simple structure but consist of a very large and indefinite number of atoms bonded together.

Let us look at the atomicity of some non-metals.

Table 3.3 : Atomicity of some elements

Type of Element	Name	Atomicity
Non-Metal	Argon	Monoatomic
	Helium	Monoatomic
	Oxygen	Diatomic
	Hydrogen	Diatomic
	Nitrogen	Diatomic
	Chlorine	Diatomic
	Phosphorus	Tetra-atomic
	Sulphur	Poly-atomic

3.3.2 Molecules of compounds

Atoms of different elements join together in definite proportions to form molecules of compounds. Few examples are given in Table 3.4.

Table 3.4 : Molecules of some compounds

Compound	Combining Elements	Ratio by Mass
Water (H_2O)	Hydrogen, Oxygen	1:8
Ammonia (NH_3)	Nitrogen, Hydrogen	14:3
Carbon dioxide (CO_2)	Carbon, Oxygen	3:8

Activity 3.2

- Refer to Table 3.4 for ratio by mass of atoms present in molecules and Table 3.2 for atomic masses of elements. Find the ratio by number of the atoms of elements in the molecules of compounds given in Table 3.4.
- The ratio by number of atoms for a water molecule can be found as follows:

Element	Ratio by mass	Atomic mass (u)	Mass ratio/ atomic mass	Simplest ratio
H	*1*	*1*	$\frac{1}{1} = 1$	*2*
O	*8*	*16*	$\frac{8}{16} = \frac{1}{2}$	*1*

- Thus, the ratio by number of atoms for water is H:O = 2:1.

3.3.3 What is an ion?

Compounds composed of metals and non-metals contain charged species. The charged species are known as *ions*. Ions may consist of a single charged atom or a group of atoms that have a net charge on them. An ion can be negatively or positively charged. A negatively charged ion is called an 'anion' and the positively charged ion, a 'cation'. Take, for example, sodium chloride (NaCl). Its constituent particles are positively charged sodium ions (Na^+) and negatively charged chloride ions (Cl^-). A group of atoms carrying a charge is known as a polyatomic ion (Table 3.6). We shall learn more about the formation of ions in Chapter 4.

Table 3.5: Some ionic compounds

Ionic Compound	Constituting Elements	Ratio by Mass
Calcium oxide	Calcium and oxygen	5:2
Magnesium sulphide	Magnesium and sulphur	3:4
Sodium chloride	Sodium and chlorine	23:35.5

3.4 Writing Chemical Formulae

The chemical formula of a compound is a symbolic representation of its composition. The chemical formulae of different compounds can be written easily. For this exercise, we need to learn the symbols and combining capacity of the elements.

The combining power (or capacity) of an element is known as its valency. Valency can be used to find out how the atoms of an element will combine with the atom(s) of another element to form a chemical compound. The valency of the atom of an element can be thought of as hands or arms of that atom.

Human beings have two arms and an octopus has eight. If one octopus has to catch hold of a few people in such a manner that all the eight arms of the octopus and both arms of all the humans are locked, how many humans do you think the octopus can hold? Represent the octopus with O and humans with H. Can you write a formula for this combination? Do you get OH_4 as the formula? The subscript 4 indicates the number of humans held by the octopus.

The valencies of some common ions are given in Table 3.6. We will learn more about valency in the next chapter.

Table 3.6: Names and symbols of some ions

Valency	Name of ion	Symbol	Non-metallic element	Symbol	Polyatomic ions	Symbol
1.	Sodium Potassium Silver Copper (I)*	Na^+ K^+ Ag^+ Cu^+	Hydrogen Hydride Chloride Bromide Iodide	H^+ H^- Cl^- Br^- I^-	Ammonium Hydroxide Nitrate Hydrogen carbonate	NH_4^+ OH^- NO_3^- HCO_3^-
2.	Magnesium Calcium Zinc Iron (II)* Copper (II)*	Mg^{2+} Ca^{2+} Zn^{2+} Fe^{2+} Cu^{2+}	Oxide Sulphide	O^{2-} S^{2-}	Carbonate Sulphite Sulphate	CO_3^{2-} SO_3^{2-} SO_4^{2-}
3.	Aluminium Iron (III)*	Al^{3+} Fe^{3+}	Nitride	N^{3-}	Phosphate	PO_4^{3-}

* *Some elements show more than one valency. A Roman numeral shows their valency in a bracket.*

The rules that you have to follow while writing a chemical formula are as follows:

- the valencies or charges on the ion must balance.
- when a compound consists of a metal and a non-metal, the name or symbol of the metal is written first. For example: calcium oxide (CaO), sodium chloride (NaCl), iron sulphide (FeS), copper oxide (CuO), etc., where oxygen, chlorine, sulphur are non-metals and are written on the right, whereas calcium, sodium, iron and copper are metals, and are written on the left.
- in compounds formed with polyatomic ions, the number of ions present in the compound is indicated by enclosing the formula of ion in a bracket and writing the number of ions outside the bracket. For example, $Mg(OH)_2$. In case the number of polyatomic ion is one, the bracket is not required. For example, NaOH.

3.4.1 Formulae of simple compounds

The simplest compounds, which are made up of two different elements are called binary compounds. Valencies of some ions are given in Table 3.6. You can use these to write formulae for compounds.

While writing the chemical formulae for compounds, we write the constituent elements and their valencies as shown below. Then we must crossover the valencies of the combining atoms.

Examples

1. Formula of hydrogen chloride

Symbol H Cl

Valency 1 1

Formula of the compound would be HCl.

2. Formula of hydrogen sulphide

Symbol H S

Valency 1 2

Formula : H_2S

3. Formula of carbon tetrachloride

Symbol C Cl

Valency 4 1

Formula : CCl_4

For magnesium chloride, we write the symbol of cation (Mg^{2+}) first followed by the symbol of anion (Cl^-). Then their charges are criss-crossed to get the formula.

4. Formula of magnesium chloride

Symbol Mg Cl

Charge 2+ 1-

Formula : $MgCl_2$

Thus, in magnesium chloride, there are two chloride ions (Cl^-) for each magnesium ion (Mg^{2+}). The positive and negative charges must balance each other and the overall structure must be neutral. Note that in the formula, the charges on the ions are not indicated.

Some more examples

(a) Formula for aluminium oxide:

Symbol Al O

Charge 3+ 2-

Formula : Al_2O_3

(b) Formula for calcium oxide:

Symbol Ca O

Charge 2+ 2-

Here, the valencies of the two elements are the same. You may arrive at the formula Ca_2O_2. But we simplify the formula as CaO.

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(c) Formula of sodium nitrate:

Symbol/ Formula	Na	NO_3
Charge	1+	1-

Formula : $NaNO_3$

(d) Formula of calcium hydroxide:

Symbol/ Formula	Ca	OH
Charge	2+	1-

Formula : $Ca(OH)_2$

Note that the formula of calcium hydroxide is $Ca(OH)_2$ and not $CaOH_2$. We use brackets when we have two or more of the same ions in the formula. Here, the bracket around OH with a subscript 2 indicates that there are two hydroxyl (OH) groups joined to one calcium atom. In other words, there are two atoms each of oxygen and hydrogen in calcium hydroxide.

(e) Formula of sodium carbonate:

Symbol/ Formula	Na	CO_3
Charge	1+	2-

Formula : Na_2CO_3

In the above example, brackets are not needed if there is only one ion present.

(f) Formula of ammonium sulphate:

Formula	NH_4	SO_4
Charge	1+	2-

Formula : $(NH_4)_2SO_4$

Questions

1. *Write down the formulae of*
   - *(i) sodium oxide*
   - *(ii) aluminium chloride*
   - *(iii) sodium sulphide*
   - *(iv) magnesium hydroxide*
2. *Write down the names of compounds represented by the following formulae:*
   - *(i)* $Al_2(SO_4)_3$
   - *(ii)* $CaCl_2$
   - *(iii)* K_2SO_4
   - *(iv)* KNO_3
   - *(v)* $CaCO_3$.
3. *What is meant by the term chemical formula?*
4. *How many atoms are present in a*
   - *(i)* H_2S *molecule and*
   - *(ii)* PO_4^{3-} *ion?*

3.5 Molecular Mass

In section 3.2.2 we discussed the concept of atomic mass. This concept can be extended to calculate molecular masses. The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance. It is therefore the relative mass of a molecule expressed in *atomic mass units (u).*

Example 3.1 (a) Calculate the relative molecular mass of water (H_2O). (b) Calculate the molecular mass of HNO_3.

Solution:

(a) Atomic mass of hydrogen = 1u,
oxygen = 16 u

So the molecular mass of water, which contains two atoms of hydrogen and one atom of oxygen is $= 2 \times 1 + 1 \times 16$
$= 18$ u

(b) The molecular mass of HNO_3 = the atomic mass of H + the atomic mass of N+ 3 × the atomic mass of O
= 1 + 14 + 48 = 63 u

3.5.1 Formula Unit Mass

The formula unit mass of a substance is a sum of the atomic masses of all atoms in a formula unit of a compound. Formula unit mass is calculated in the same manner as we calculate the molecular mass. The only difference is that

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we use the word formula unit for those substances whose constituent particles are ions. For example, sodium chloride as discussed above, has a formula unit NaCl. Its formula unit mass can be calculated as–

$$1 \times 23 + 1 \times 35.5 = 58.5 \text{ u}$$

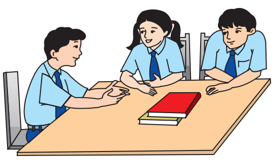
Example 3.2 Calculate the formula unit mass of $CaCl_2$.

Solution:

Atomic mass of Ca
+ (2 × atomic mass of Cl)
= 40 + 2 × 35.5 = 40 + 71 = 111 u

Questions

1. *Calculate the molecular masses of H_2, O_2, Cl_2, CO_2, CH_4, C_2H_6, C_2H_4, NH_3, CH_3OH.*
2. *Calculate the formula unit masses of ZnO, Na_2O, K_2CO_3, given atomic masses of Zn = 65 u, Na = 23 u, K = 39 u, C = 12 u, and O = 16 u.*



What you have learnt

- During a chemical reaction, the sum of the masses of the reactants and products remains unchanged. This is known as the Law of Conservation of Mass.
- In a pure chemical compound, elements are always present in a definite proportion by mass. This is known as the Law of Definite Proportions.
- An atom is the smallest particle of the element that cannot usually exist independently and retain all its chemical properties.
- A molecule is the smallest particle of an element or a compound capable of independent existence under ordinary conditions. It shows all the properties of the substance.
- A chemical formula of a compound shows its constituent elements and the number of atoms of each combining element.
- Clusters of atoms that act as an ion are called polyatomic ions. They carry a fixed charge on them.
- The chemical formula of a molecular compound is determined by the valency of each element.
- In ionic compounds, the charge on each ion is used to determine the chemical formula of the compound.

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Exercises

1. A 0.24 g sample of compound of oxygen and boron was found by analysis to contain 0.096 g of boron and 0.144 g of oxygen. Calculate the percentage composition of the compound by weight.
2. When 3.0 g of carbon is burnt in 8.00 g oxygen, 11.00 g of carbon dioxide is produced. What mass of carbon dioxide will be formed when 3.00 g of carbon is burnt in 50.00 g of oxygen? Which law of chemical combination will govern your answer?
3. What are polyatomic ions? Give examples.
4. Write the chemical formulae of the following.
   (a) Magnesium chloride
   (b) Calcium oxide
   (c) Copper nitrate
   (d) Aluminium chloride
   (e) Calcium carbonate.
5. Give the names of the elements present in the following compounds.
   (a) Quick lime
   (b) Hydrogen bromide
   (c) Baking powder
   (d) Potassium sulphate.
6. Calculate the molar mass of the following substances.
   (a) Ethyne, C_2H_2
   (b) Sulphur molecule, S_8
   (c) Phosphorus molecule, P_4 (Atomic mass of phosphorus = 31)
   (d) Hydrochloric acid, HCl
   (e) Nitric acid, HNO_3

Group Activity

Play a game for writing formulae.

Example1 : Make placards with symbols and valencies of the elements separately. Each student should hold two placards, one with the symbol in the right hand and the other with the valency in the left hand. Keeping the symbols in place, students should criss-cross their valencies to form the formula of a compound.

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Example 2 : A low cost model for writing formulae: Take empty blister packs of medicines. Cut them in groups, according to the valency of the element, as shown in the figure. Now, you can make formulae by fixing one type of ion into other.

For example:

Na^+ SO_4^{2-} PO_4^{3-}

Formula for sodium sulphate:

2 sodium ions can be fixed on one sulphate ion.

Hence, the formula will be: Na_2SO_4

Do it yourself :

Now, write the formula of sodium phosphate.

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Chapter 4

STRUCTURE OF THE ATOM

In Chapter 3, we have learnt that atoms and molecules are the fundamental building blocks of matter. The existence of different kinds of matter is due to different atoms constituting them. Now the questions arise: (i) What makes the atom of one element different from the atom of another element? and (ii) Are atoms really indivisible, as proposed by Dalton, or are there smaller constituents inside the atom? We shall find out the answers to these questions in this chapter. We will learn about sub-atomic particles and the various models that have been proposed to explain how these particles are arranged within the atom.

A major challenge before the scientists at the end of the 19th century was to reveal the structure of the atom as well as to explain its important properties. The elucidation of the structure of atoms is based on a series of experiments.

One of the first indications that atoms are not indivisible, comes from studying static electricity and the condition under which electricity is conducted by different substances.

4.1 Charged Particles in Matter

For understanding the nature of charged particles in matter, let us carry out the following activities:

Activity 4.1

A. Comb dry hair. Does the comb then attract small pieces of paper?
B. Rub a glass rod with a silk cloth and bring the rod near an inflated balloon. Observe what happens.

From these activities, can we conclude that on rubbing two objects together, they become electrically charged? Where does this charge come from? This question can be answered by knowing that an atom is divisible and consists of charged particles.

Many scientists contributed in revealing the presence of charged particles in an atom.

It was known by 1900 that the atom was indivisible particle but contained at least one sub-atomic particle – the electron identified by J.J. Thomson. Even before the electron was identified, E. Goldstein in 1886 discovered the presence of new radiations in a gas discharge and called them canal rays. These rays were positively charged radiations which ultimately led to the discovery of another sub-atomic particle. This sub-atomic particle had a charge, equal in magnitude but opposite in sign to that of the electron. Its mass was approximately 2000 times as that of the electron. It was given the name of proton. In general, an electron is represented as 'e^-' and a proton as 'p^+'. The mass of a proton is taken as one unit and its charge as plus one. The mass of an electron is considered to be negligible and its charge is minus one.

It seemed that an atom was composed of protons and electrons, mutually balancing their charges. It also appeared that the protons were in the interior of the atom, for whereas electrons could easily be removed off but not protons. Now the big question was: what sort of structure did these particles of the atom form? We will find the answer to this question below.

Questions

1. *What are canal rays?*
2. *If an atom contains one electron and one proton, will it carry any charge or not?*

4.2 The Structure of an Atom

We have learnt Dalton's atomic theory in Chapter 3, which suggested that the atom was indivisible and indestructible. But the discovery of two fundamental particles (electrons and protons) inside the atom, led to the failure of this aspect of Dalton's atomic theory. It was then considered necessary to know how electrons and protons are arranged within an atom. For explaining this, many scientists proposed various atomic models. J.J. Thomson was the first one to propose a model for the structure of an atom.

4.2.1 Thomson's model of an atom

Thomson proposed the model of an atom to be similar to that of a Christmas pudding. The electrons, in a sphere of positive charge, were like currants (dry fruits) in a spherical Christmas pudding. We can also think of a watermelon, the positive charge in the atom is spread all over like the red edible part of the watermelon, while the electrons are studded in the positively charged sphere, like the seeds in the watermelon (Fig. 4.1).

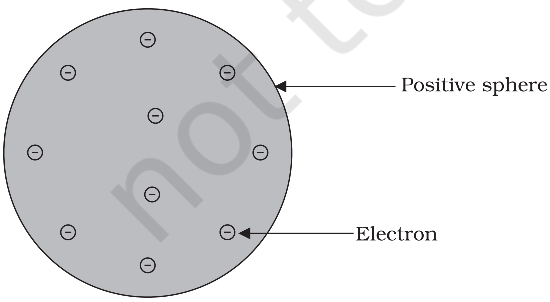

Fig. 4.1: Thomson's model of an atom

J.J. Thomson (1856–1940), a British physicist, was born in Cheetham Hill, a suburb of Manchester, on 18 December 1856. He was awarded the Nobel prize in Physics in 1906 for his work on the discovery of electrons. He directed the Cavendish Laboratory at Cambridge for 35 years and seven of his research assistants subsequently won Nobel prizes.

Thomson proposed that:

(i) An atom consists of a positively charged sphere and the electrons are embedded in it.

(ii) The negative and positive charges are equal in magnitude. So, the atom as a whole is electrically neutral.

Although Thomson's model explained that atoms are electrically neutral, the results of experiments carried out by other scientists could not be explained by this model, as we will see below.

4.2.2 Rutherford's model of an atom

Ernest Rutherford was interested in knowing how the electrons are arranged within an atom. Rutherford designed an experiment for this. In this experiment, fast moving alpha (α)-particles were made to fall on a thin gold foil.

- He selected a gold foil because he wanted as thin a layer as possible. This gold foil was about 1000 atoms thick.
- α-particles are doubly-charged helium ions. Since they have a mass of 4 u, the fast-moving α-particles have a considerable amount of energy.
- It was expected that α-particles would be deflected by the sub-atomic particles in the gold atoms. Since the α-particles were much heavier than the protons, he did not expect to see large deflections.

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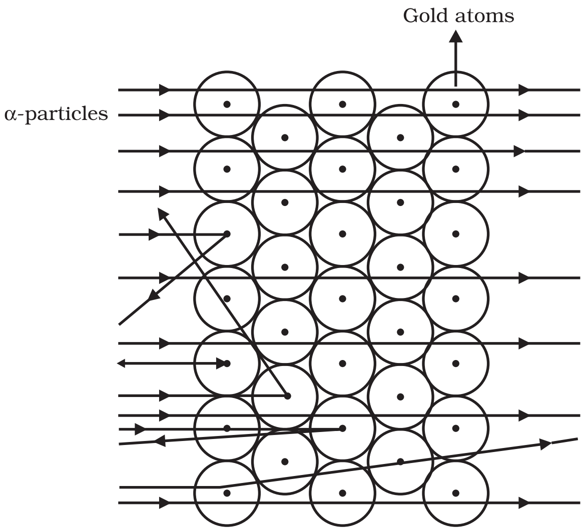

Fig. 4.2: Scattering of α-particles by a gold foil

But, the α-particle scattering experiment gave totally unexpected results (Fig. 4.2). The following observations were made:

(i) Most of the fast moving α-particles passed straight through the gold foil.
(ii) Some of the α-particles were deflected by the foil by small angles.
(iii) Surprisingly one out of every 12000 particles appeared to rebound.

In the words of Rutherford, "*This result was almost as incredible as if you fire a 15-inch shell at a piece of tissue paper and it comes back and hits you*".

E. Rutherford (1871–1937) was born at Spring Grove on 30 August 1871. He was known as the 'Father' of nuclear physics. He is famous for his work on radioactivity and the discovery of the nucleus of an atom with the gold foil experiment. He got the Nobel prize in chemistry in 1908.

Let us think of an activity in an open field to understand the implications of this experiment. Let a child stand in front of a wall with his eyes closed. Let him throw stones at the wall from a distance. He will hear a sound when each stone strikes the wall. If he repeats this ten times, he will hear the sound ten times. But if a blind-folded child were to throw stones at a barbed-wire fence, most of the stones would not hit the fencing and no sound would be heard. This is because there are lots of gaps in the fence which allow the stone to pass through them.

Following a similar reasoning, Rutherford concluded from the α-particle scattering experiment that—

(i) Most of the space inside the atom is empty because most of the α-particles passed through the gold foil without getting deflected.
(ii) Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space.
(iii) A very small fraction of α-particles were deflected by 180^0, indicating that all the positive charge and mass of the gold atom were concentrated in a very small volume within the atom.

From the data he also calculated that the radius of the nucleus is about 10^5 times less than the radius of the atom.

On the basis of his experiment, Rutherford put forward the nuclear model of an atom, which had the following features:

(i) There is a positively charged centre in an atom called the nucleus. Nearly all the mass of an atom resides in the nucleus.
(ii) The electrons revolve around the nucleus in circular paths.
(iii) The size of the nucleus is very small as compared to the size of the atom.

Drawbacks of Rutherford's model of the atom

The revolution of the electron in a circular orbit is not expected to be stable. Any particle in a circular orbit would undergo acceleration. During acceleration, charged particles would radiate energy. Thus, the revolving electron would lose energy and finally fall into the nucleus. If this were so, the atom should be highly unstable and hence matter would not exist in the form that we know. We know that atoms are quite stable.

4.2.3 Bohr's model of atom

In order to overcome the objections raised against Rutherford's model of the atom, Neils Bohr put forward the following postulates about the model of an atom:

(i) Only certain special orbits known as discrete orbits of electrons, are allowed inside the atom.

(ii) While revolving in discrete orbits the electrons do not radiate energy.

Neils Bohr (1885–1962) was born in Copenhagen on 7 October 1885. He was appointed professor of physics at Copenhagen University in 1916. He got the Nobel prize for his work on the structure of atom in 1922. Among Professor Bohr's numerous writings, three appearing as books are: (i) The Theory of Spectra and Atomic Constitution, (ii) Atomic Theory and, (iii) The Description of Nature.

These orbits or shells are called energy levels. Energy levels in an atom are shown in Fig. 4.3.

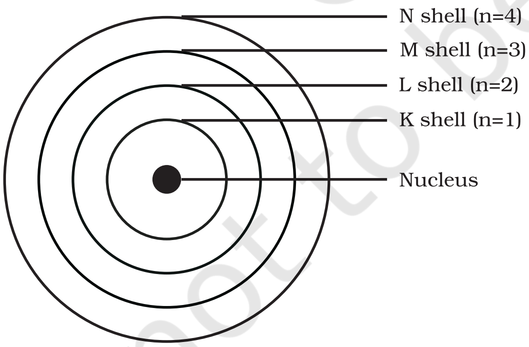

Fig. 4.3: *A few energy levels in an atom*

These orbits or shells are represented by the letters K,L,M,N,… or the numbers, n=1,2,3,4,….

Questions

1. *On the basis of Thomson's model of an atom, explain how the atom is neutral as a whole.*
2. *On the basis of Rutherford's model of an atom, which sub-atomic particle is present in the nucleus of an atom?*
3. *Draw a sketch of Bohr's model of an atom with three shells.*
4. *What do you think would be the observation if the α-particle scattering experiment is carried out using a foil of a metal other than gold?*

4.2.4 Neutrons

In 1932, J. Chadwick discovered another sub-atomic particle which had no charge and a mass nearly equal to that of a proton. It was eventually named as neutron. Neutrons are present in the nucleus of all atoms, except hydrogen. In general, a neutron is represented as 'n'. The mass of an atom is therefore given by the sum of the masses of protons and neutrons present in the nucleus.

Questions

1. *Name the three sub-atomic particles of an atom.*
2. *Helium atom has an atomic mass of 4 u and two protons in its nucleus. How many neutrons does it have?*

4.3 How are Electrons Distributed in Different Orbits (Shells)?

The distribution of electrons into different orbits of an atom was suggested by Bohr and Bury.

The following rules are followed for writing the number of electrons in different energy levels or shells:

(i) The maximum number of electrons present in a shell is given by the

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formula $2n^2$, where 'n' is the orbit number or energy level index, 1,2,3,.... Hence the maximum number of electrons in different shells are as follows:

first orbit or K-shell will be = $2 \times 1^2 = 2$,
second orbit or L-shell will be = $2 \times 2^2 = 8$,
third orbit or M-shell will be = $2 \times 3^2 = 18$,
fourth orbit or N-shell will be = $2 \times 4^2 = 32$, and so on.

(ii) The maximum number of electrons that can be accommodated in the outermost orbit is 8.

(iii) Electrons are not accommodated in a given shell, unless the inner shells are filled. That is, the shells are filled in a step-wise manner.

Atomic structure of the first eighteen elements is shown schematically in Fig. 4.4.

- The composition of atoms of the first eighteen elements is given in Table 4.1.

Questions

1. *Write the distribution of electrons in carbon and sodium atoms.*
2. *If K and L shells of an atom are full, then what would be the total number of electrons in the atom?*

4.4 Valency

We have learnt how the electrons in an atom are arranged in different shells/orbits. The electrons present in the outermost shell of an atom are known as the valence electrons.

From the Bohr-Bury scheme, we also know that the outermost shell of an atom can

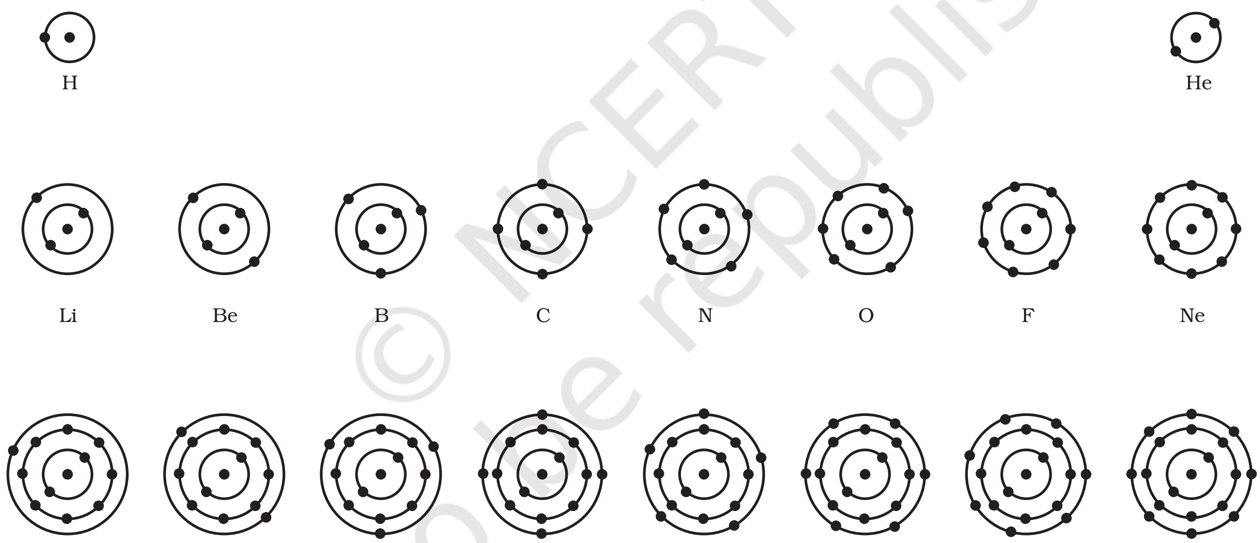

Fig. 4.4: Schematic atomic structure of the first eighteen elements

accommodate a maximum of 8 electrons. It was observed that the atoms of elements, completely filled with 8 electrons in the outermost shell show little chemical activity. In other words, their combining capacity or valency is zero. Of these inert elements, the

Activity 4.2

- Make a static atomic model displaying electronic configuration of the first eighteen elements.

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Table 4.1: Composition of Atoms of the First Eighteen Elements with Electron Distribution in Various Shells

Name of Element	Symbol	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Distribution of Electrons				Vale-ncy
						K	L	M	N	
Hydrogen	H	1	1	-	1	1	-	-	-	1
Helium	He	2	2	2	2	2	-	-	-	0
Lithium	Li	3	3	4	3	2	1	-	-	1
Beryllium	Be	4	4	5	4	2	2	-	-	2
Boron	B	5	5	6	5	2	3	-	-	3
Carbon	C	6	6	6	6	2	4	-	-	4
Nitrogen	N	7	7	7	7	2	5	-	-	3
Oxygen	O	8	8	8	8	2	6	-	-	2
Fluorine	F	9	9	10	9	2	7	-	-	1
Neon	Ne	10	10	10	10	2	8	-	-	0
Sodium	Na	11	11	12	11	2	8	1	-	1
Magnesium	Mg	12	12	12	12	2	8	2	-	2
Aluminium	Al	13	13	14	13	2	8	3	-	3
Silicon	Si	14	14	14	14	2	8	4	-	4
Phosphorus	P	15	15	16	15	2	8	5	-	3,5
Sulphur	S	16	16	16	16	2	8	6	-	2
Chlorine	Cl	17	17	18	17	2	8	7	-	1
Argon	Ar	18	18	22	18	2	8	8		0

helium atom has two electrons in its outermost shell and all other elements have atoms with eight electrons in the outermost shell.

The combining capacity of the atoms of elements, that is, their tendency to react and form molecules with atoms of the same or different elements, was thus explained as an attempt to attain a fully-filled outermost shell. An outermost-shell, which had eight electrons was said to possess an octet. Atoms would thus react, so as to achieve an octet in the outermost shell. This was done by sharing, gaining or losing electrons. The number of electrons gained, lost or shared so as to make the octet of electrons in the outermost shell, gives us directly the combining capacity of the element, that is, the valency discussed in the previous chapter. For example, hydrogen/lithium/sodium atoms contain one electron each in their outermost shell, therefore each one of them can lose one electron. So, they are said to have valency of one. Can you tell, what is valency of magnesium and aluminium? It is two and three, respectively, because magnesium has two electrons in its outermost shell and aluminium has three electrons in its outermost shell.

If the number of electrons in the outermost shell of an atom is close to its full capacity, then valency is determined in a different way. For example, the fluorine atom has 7 electrons in the outermost shell, and its valency could be 7. But it is easier for

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fluorine to gain one electron instead of losing seven electrons. Hence, its valency is determined by subtracting seven electrons from the octet and this gives you a valency of one for fluorine. Valency can be calculated in a similar manner for oxygen. What is the valency of oxygen that you get from this calculation?

Therefore, an atom of each element has a definite combining capacity, called its valency. Valency of the first eighteen elements is given in the last column of Table 4.1.

Question

1. *How will you find the valency of chlorine, sulphur and magnesium?*

4.5 Atomic Number and Mass Number

4.5.1 Atomic number

We know that protons are present in the nucleus of an atom. It is the number of protons of an atom, which determines its atomic number. It is denoted by 'Z'. All atoms of an element have the same atomic number, Z. In fact, elements are defined by the number of protons they possess. For hydrogen, Z = 1, because in hydrogen atom, only one proton is present in the nucleus. Similarly, for carbon, Z = 6. Therefore, the atomic number is defined as the total number of protons present in the nucleus of an atom.

4.5.2 Mass number

After studying the properties of the sub-atomic particles of an atom, we can conclude that mass of an atom is practically due to protons and neutrons alone. These are present in the nucleus of an atom. Hence protons and neutrons are also called nucleons. Therefore, the mass of an atom resides in its nucleus. For example, mass of carbon is 12 u because it has 6 protons and 6 neutrons, 6 u + 6 u = 12 u. Similarly, the mass of aluminium is 27 u (13 protons+14 neutrons). The mass number is defined as the sum of the total number of protons and neutrons present in the nucleus of an atom. It is denoted by 'A'. In the notation for an atom, the atomic number, mass number and symbol of the element are to be written as:

Mass Number
Symbol of element
Atomic Number

$$^{A}_{Z}\boxed{X}$$

For example, nitrogen is written as $^{14}_{7}N$.

Questions

1. *If number of electrons in an atom is 8 and number of protons is also 8, then (i) what is the atomic number of the atom? and (ii) what is the charge on the atom?*
2. *With the help of Table 4.1, find out the mass number of oxygen and sulphur atom.*

4.6 Isotopes

In nature, a number of atoms of some elements have been identified, which have the same atomic number but different mass numbers. For example, take the case of hydrogen atom, it has three atomic species, namely protium ($^{1}_{1}H$), deuterium ($^{2}_{1}H$ or D) and tritium ($^{3}_{1}H$ or T). The atomic number of each one is 1, but the mass number is 1, 2 and 3, respectively. Other such examples are (i) carbon, $^{12}_{6}C$ and $^{14}_{6}C$, (ii) chlorine, $^{35}_{17}Cl$ and $^{37}_{17}Cl$, etc.

On the basis of these examples, isotopes are defined as the atoms of the same element, having the same atomic number but different mass numbers. Therefore, we can say that there are three isotopes of hydrogen atom, namely protium, deuterium and tritium.

Many elements consist of a mixture of isotopes. Each isotope of an element is a pure substance. The chemical properties of isotopes are similar but their physical properties are different.

Chlorine occurs in nature in two isotopic forms, with masses 35 u and 37 u in the ratio of 3:1. Obviously, the question arises: what should we take as the mass of chlorine atom? Let us find out.

The average atomic mass of chlorine atom, on the basis of above data, will be

$$\left[\left(35 \times \frac{75}{100} + 37 \times \frac{25}{100}\right)\right.$$

$$\left.= \left(\frac{105}{4} + \frac{37}{4}\right) = \frac{142}{4} = 35.5\,\mathrm{u}\right]$$

The mass of an atom of any natural element is taken as the average mass of all the naturally occuring atoms of that element. If an element has no isotopes, then the mass of its atom would be the same as the sum of protons and neutrons in it. But if an element occurs in isotopic forms, then we have to know the percentage of each isotopic form and then the average mass is calculated.

This does not mean that any one atom of chlorine has a fractional mass of 35.5 u. It means that if you take a certain amount of chlorine, it will contain both isotopes of chlorine and the average mass is 35.5 u.

Applications

Since the chemical properties of all the isotopes of an element are the same, normally we are not concerned about taking a mixture. But some isotopes have special properties which find them useful in various fields. Some of them are :

(i) An isotope of uranium is used as a fuel in nuclear reactors.

(ii) An isotope of cobalt is used in the treatment of cancer.

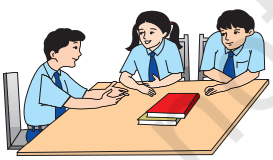
(iii) An isotope of iodine is used in the treatment of goitre.

4.6.1 Isobars

Let us consider two elements — calcium, atomic number 20, and argon, atomic number 18. The number of protons in these atoms is different, but the mass number of both these elements is 40. That is, the total number of nucleons is the same in the atoms of this pair of elements. Atoms of different elements with different atomic numbers, which have the same mass number, are known as isobars.

Questions

1. *For the symbol H,D and T tabulate three sub-atomic particles found in each of them.*
2. *Write the electronic configuration of any one pair of isotopes and isobars.*



What you have learnt

- Credit for the discovery of electron and proton goes to J.J. Thomson and E.Goldstein, respectively.
- J.J. Thomson proposed that electrons are embedded in a positive sphere.

- Rutherford's alpha-particle scattering experiment led to the discovery of the atomic nucleus.
- Rutherford's model of the atom proposed that a very tiny nucleus is present inside the atom and electrons revolve around this nucleus. The stability of the atom could not be explained by this model.
- Neils Bohr's model of the atom was more successful. He proposed that electrons are distributed in different shells with discrete energy around the nucleus. If the atomic shells are complete, then the atom will be stable and less reactive.
- J. Chadwick discovered presence of neutrons in the nucleus of an atom. So, the three sub-atomic particles of an atom are: (i) electrons, (ii) protons and (iii) neutrons. Electrons are negatively charged, protons are positively charged and neutrons have no charges. The mass of an electron is about $\frac{1}{2000}$ times the mass of an hydrogen atom. The mass of a proton and a neutron is taken as one unit each.
- Shells of an atom are designated as K,L,M,N,….
- Valency is the combining capacity of an atom.
- The atomic number of an element is the same as the number of protons in the nucleus of its atom.
- The mass number of an atom is equal to the number of nucleons in its nucleus.
- Isotopes are atoms of the same element, which have different mass numbers.
- Isobars are atoms having the same mass number but different atomic numbers.
- Elements are defined by the number of protons they possess.

Exercises

1. Compare the properties of electrons, protons and neutrons.
2. What are the limitations of J.J. Thomson's model of the atom?
3. What are the limitations of Rutherford's model of the atom?
4. Describe Bohr's model of the atom.
5. Compare all the proposed models of an atom given in this chapter.
6. Summarise the rules for writing of distribution of electrons in various shells for the first eighteen elements.
7. Define valency by taking examples of silicon and oxygen.

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8. Explain with examples (i) Atomic number, (ii) Mass number, (iii) Isotopes and iv) Isobars. Give any two uses of isotopes.
9. Na^+ has completely filled K and L shells. Explain.
10. If bromine atom is available in the form of, say, two isotopes $^{79}_{35}Br$ (49.7%) and $^{81}_{35}Br$ (50.3%), calculate the average atomic mass of bromine atom.
11. The average atomic mass of a sample of an element X is 16.2 u. What are the percentages of isotopes $^{16}_{8}X$ and $^{18}_{8}X$ in the sample?
12. If Z = 3, what would be the valency of the element? Also, name the element.
13. Composition of the nuclei of two atomic species X and Y are given as under

		X	Y
Protons	=	6	6
Neutrons	=	6	8

Give the mass numbers of X and Y. What is the relation between the two species?
14. For the following statements, write T for True and F for False.
    (a) J.J. Thomson proposed that the nucleus of an atom contains only nucleons.
    (b) A neutron is formed by an electron and a proton combining together. Therefore, it is neutral.
    (c) The mass of an electron is about $\frac{1}{2000}$ times that of proton.
    (d) An isotope of iodine is used for making tincture iodine, which is used as a medicine.

    Put tick (✓) against correct choice and cross (×) against wrong choice in questions 15, 16 and 17
15. Rutherford's alpha-particle scattering experiment was responsible for the discovery of
    (a) Atomic Nucleus (b) Electron
    (c) Proton (d) Neutron
16. Isotopes of an element have
    (a) the same physical properties
    (b) different chemical properties
    (c) different number of neutrons
    (d) different atomic numbers.
17. Number of valence electrons in Cl^- ion are:
    (a) 16 (b) 8 (c) 17 (d) 18

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18. Which one of the following is a correct electronic configuration of sodium?

(a) 2,8 (b) 8,2,1 (c) 2,1,8 (d) 2,8,1.

19. Complete the following table.

Atomic Number	Mass Number	Number of Neutrons	Number of Protons	Number of Electrons	Name of the Atomic Species
9	-	10	-	-	-
16	32	-	-	-	Sulphur
-	24	-	12	-	-
-	2	-	1	-	-
-	1	0	1	0	-

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Chapter 5

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The Fundamental Unit of Life

While examining a thin slice of cork, Robert Hooke saw that the cork resembled the structure of a honeycomb consisting of many little compartments. Cork is a substance which comes from the bark of a tree. This was in the year 1665 when Hooke made this chance observation through a self-designed microscope. Robert Hooke called these boxes cells. Cell is a Latin word for 'a little room'.

This may seem to be a very small and insignificant incident but it is very important in the history of science. This was the very first time that someone had observed that living things appear to consist of separate units. The use of the word 'cell' to describe these units is being used till this day in biology.

Let us find out about cells.

5.1 What are Living Organisms Made Up of?

Activity 5.1

- Let us take a small piece from an onion bulb. With the help of a pair of forceps, we can peel off the skin (called epidermis) from the concave side (inner layer) of the onion. This layer can be put immediately in a watch-glass containing water. This will prevent the peel from getting folded or getting dry. What do we do with this peel?
- Let us take a glass slide, put a drop of water on it and transfer a small piece of the peel from the watch glass to the slide. Make sure that the peel is perfectly flat on the slide. A thin camel hair paintbrush might be necessary to help transfer the peel. Now we put a drop of safranin solution on this piece followed by a cover slip. Take care to avoid air bubbles while putting the cover slip with the help of a mounting needle. Ask your teacher for help. We have prepared a temporary mount of onion peel. We can observe this slide under low power followed by high powers of a compound microscope.

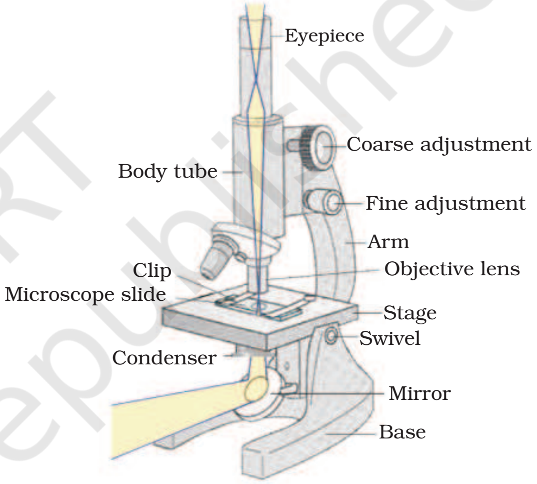

Fig. 5.1: Compound microscope

What do we observe as we look through the lens? Can we draw the structures that we are able to see through the microscope, on an observation sheet? Does it look like Fig. 5.2?

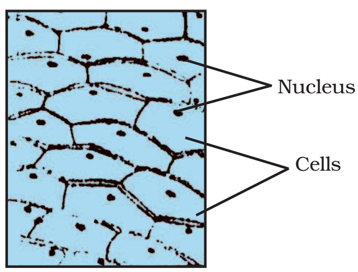

Fig. 5.2: Cells of an onion peel

We can try preparing temporary mounts of peels of onions of different sizes. What do we observe? Do we see similar structures or different structures?

What are these structures?

These structures look similar to each other. Together they form a big structure like an onion bulb! We find from this activity that onion bulbs of different sizes have similar small structures visible under a microscope. The cells of the onion peel will all look the same, regardless of the size of the onion they came from.

These small structures that we see are the basic building units of the onion bulb. These structures are called cells. Not only onions, but all organisms that we observe around are made up of cells. However, there are also single cells that live on their own.

More to know

Cells were first discovered by Robert Hooke in 1665. He observed the cells in a cork slice with the help of a primitive microscope. Leeuwenhoek (1674), with the improved microscope, discovered the free living cells in pond water for the first time. It was Robert Brown in 1831 who discovered the nucleus in the cell. Purkinje in 1839 coined the term 'protoplasm' for the fluid substance of the cell. The cell theory, that all the plants and animals are composed of cells and that the cell is the basic unit of life, was presented by two biologists, Schleiden (1838) and Schwann (1839). The cell theory was further expanded by Virchow (1855) by suggesting that all cells arise from pre-existing cells. With the discovery of the electron microscope in 1940, it was possible to observe and understand the complex structure of the cell and its various organelles.

The invention of magnifying lenses led to the discovery of the microscopic world. It is now known that a single cell may constitute a whole organism as in *Amoeba*, *Chlamydomonas*, *Paramoecium* and bacteria. These organisms are called unicellular organisms (uni = single). On the other hand, many cells group together in a single body and assume different functions in it to form various body parts in multicellular organisms (multi = many) such as some fungi, plants and animals. Can we find out names of some more unicellular organisms?

Every multi-cellular organism has come from a single cell. How? Cells divide to produce cells of their own kind. All cells thus come from pre-existing cells.

Activity 5.2

- We can try preparing temporary mounts of leaf peels, tip of roots of onion or even peels of onions of different sizes.
- After performing the above activity, let us see what the answers to the following questions would be:
  (a) Do all cells look alike in terms of shape and size?
  (b) Do all cells look alike in structure?
  (c) Could we find differences among cells from different parts of a plant body?
  (d) What similarities could we find?

Some organisms can also have cells of different kinds. Look at the following picture. It depicts some cells from the human body.

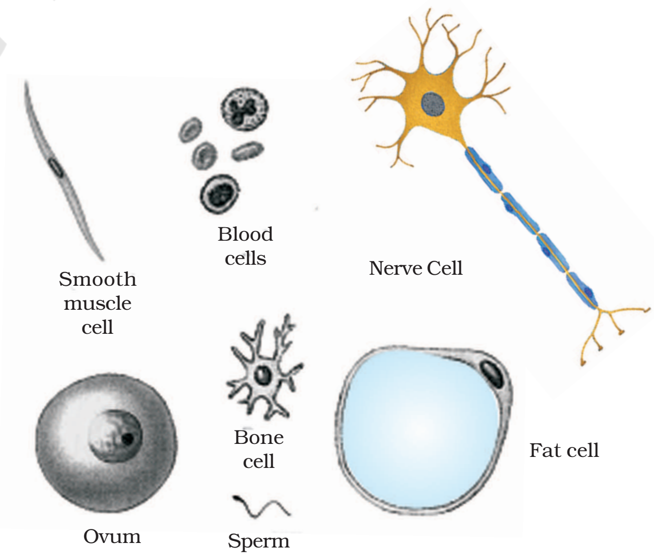

***Fig. 5.3:** Various cells from the human body*

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The shape and size of cells are related to the specific function they perform. Some cells like *Amoeba* have changing shapes. In some cases the cell shape could be more or less fixed and peculiar for a particular type of cell; for example, nerve cells have a typical shape.

Each living cell has the capacity to perform certain basic functions that are characteristic of all living forms. How does a living cell perform these basic functions? We know that there is a division of labour in multicellular organisms such as human beings. This means that different parts of the human body perform different functions. The human body has a heart to pump blood, a stomach to digest food and so on. Similarly, division of labour is also seen within a single cell. In fact, each such cell has got certain specific components within it known as cell organelles. Each kind of cell organelle performs a special function, such as making new material in the cell, clearing up the waste material from the cell and so on. A cell is able to live and perform all its functions because of these organelles. These organelles together constitute the basic unit called the cell. It is interesting that all cells are found to have the same organelles, no matter what their function is or what organism they are found in.

Questions

1. *Who discovered cells, and how?*
2. *Why is the cell called the structural and functional unit of life?*

5.2 What is a Cell Made Up of? What is the Structural Organisation of a Cell?

We saw above that the cell has special components called organelles. How is a cell organised?

If we study a cell under a microscope, we would come across three features in almost every cell; plasma membrane, nucleus and cytoplasm. All activities inside the cell and interactions of the cell with its environment are possible due to these features. Let us see how.

5.2.1 Plasma membrane or cell membrane

This is the outermost covering of the cell that separates the contents of the cell from its external environment. The plasma membrane allows or permits the entry and exit of some materials in and out of the cell. It also prevents movement of some other materials. The cell membrane, therefore, is called a selectively permeable membrane.

How does the movement of substances take place into the cell? How do substances move out of the cell?

Some substances like carbon dioxide or oxygen can move across the cell membrane by a process called diffusion. We have studied the process of diffusion in earlier chapters. We saw that there is spontaneous movement of a substance from a region of high concentration to a region where its concentration is low.

Something similar to this happens in cells when, for example, some substance like CO_2 (which is cellular waste and requires to be excreted out by the cell) accumulates in high concentrations inside the cell. In the cell's external environment, the concentration of CO_2 is low as compared to that inside the cell. As soon as there is a difference of concentration of CO_2 inside and outside a cell, CO_2 moves out of the cell, from a region of high concentration, to a region of low concentration outside the cell by the process of diffusion. Similarly, O_2 enters the cell by the process of diffusion when the level or concentration of O_2 inside the cell decreases. Thus, diffusion plays an important role in gaseous exchange between the cells as well as the cell and its external environment.

Water also obeys the law of diffusion. The movement of water molecules through such a selectively permeable membrane is called osmosis.

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The movement of water across the plasma membrane is also affected by the amount of substance dissolved in water. Thus, osmosis is the net diffusion of water across a selectively permeable membrane toward a higher solute concentration.

What will happen if we put an animal cell or a plant cell into a solution of sugar or salt in water?

One of the following three things could happen:

1. If the medium surrounding the cell has a higher water concentration than the cell, meaning that the outside solution is very dilute, the cell will gain water by osmosis. Such a solution is known as a hypotonic solution.

   Water molecules are free to pass across the cell membrane in both directions, but more water will come into the cell than will leave. The net (overall) result is that water enters the cell. The cell is likely to swell up.
2. If the medium has exactly the same water concentration as the cell, there will be no net movement of water across the cell membrane. Such a solution is known as an isotonic solution.

   Water crosses the cell membrane in both directions, but the amount going in is the same as the amount going out, so there is no overall movement of water. The cell will stay the same size.
3. If the medium has a lower concentration of water than the cell, meaning that it is a very concentrated solution, the cell will lose water by osmosis. Such a solution is known as a hypertonic solution.

   Again, water crosses the cell membrane in both directions, but this time more water leaves the cell than enters it. Therefore the cell will shrink.

Thus, osmosis is a special case of diffusion through a selectively permeable membrane. Now let us try out the following activity:

Activity 5.3

(a) Remove the shell of an egg by dissolving it in dilute hydrochloric acid. The shell is mostly calcium carbonate. A thin outer skin now encloses the egg. Put the egg in pure water and observe after 5 minutes. What do we observe?
The egg swells because water passes into it by osmosis.

(b) Place a similar de-shelled egg in a concentrated salt solution and observe for 5 minutes. The egg shrinks. Why? Water passes out of the egg solution into the salt solution because the salt solution is more concentrated.

We can also try a similar activity with dried raisins or apricots.

Activity 5.4

- Put dried raisins or apricots in plain water and leave them for some time. Then place them into a concentrated solution of sugar or salt. You will observe the following:
  (a) Each gains water and swells when placed in water.
  (b) However, when placed in the concentrated solution it loses water, and consequently shrinks.

Unicellular freshwater organisms and most plant cells tend to gain water through osmosis. Absorption of water by plant roots is also an example of osmosis.

Thus, diffusion is important in exhange of gases and water in the life of a cell. In additions to this, the cell also obtains nutrition from its environment. Different molecules move in and out of the cell through a type of transport requiring use of energy.

The plasma membrane is flexible and is made up of organic molecules called lipids and proteins. However, we can observe the structure of the plasma membrane only through an electron microscope.

The flexibility of the cell membrane also enables the cell to engulf in food and other material from its external environment. Such processes are known as endocytosis. *Amoeba* acquires its food through such processes.

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Activity 5.5

- Find out about electron microscopes from resources in the school library or through the internet. Discuss it with your teacher.

Questions

1. *How do substances like CO_2 and water move in and out of the cell? Discuss.*
2. *Why is the plasma membrane called a selectively permeable membrane?*

5.2.2 Cell wall

Plant cells, in addition to the plasma membrane, have another rigid outer covering called the cell wall. The cell wall lies outside the plasma membrane. The plant cell wall is mainly composed of cellulose. Cellulose is a complex substance and provides structural strength to plants.

When a living plant cell loses water through osmosis there is shrinkage or contraction of the contents of the cell away from the cell wall. This phenomenon is known as plasmolysis. We can observe this phenomenon by performing the following activity:

Activity 5.6

- Mount the peel of a Rhoeo leaf in water on a slide and examine cells under the high power of a microscope. Note the small green granules, called chloroplasts. They contain a green substance called chlorophyll. Put a strong solution of sugar or salt on the mounted leaf on the slide. Wait for a minute and observe under a microscope. What do we see?
- Now place some Rhoeo leaves in boiling water for a few minutes. This kills the cells. Then mount one leaf on a slide and observe it under a microscope. Put a strong solution of sugar or salt on the mounted leaf on the slide. Wait for a minute and observe it again. What do we find? Did plasmolysis occur now?

What do we infer from this activity? It appears that only living cells, and not dead cells, are able to absorb water by osmosis.

Cell walls permit the cells of plants, fungi and bacteria to withstand very dilute (hypotonic) external media without bursting. In such media the cells tend to take up water by osmosis. The cell swells, building up pressure against the cell wall. The wall exerts an equal pressure against the swollen cell. Because of their walls, such cells can withstand much greater changes in the surrounding medium than animal cells.

5.2.3 Nucleus

Remember the temporary mount of onion peel we prepared? We had put iodine solution on the peel. Why? What would we see if we tried observing the peel without putting the iodine solution? Try it and see what the difference is. Further, when we put iodine solution on the peel, did each cell get evenly coloured?

According to their chemical composition different regions of cells get coloured differentially. Some regions appear darker than other regions. Apart from iodine solution we could also use safranin solution or methylene blue solution to stain the cells.

We have observed cells from an onion; let us now observe cells from our own body.

Activity 5.7

- Let us take a glass slide with a drop of water on it. Using an ice-cream spoon gently scrape the inside surface of the cheek. Does any material get stuck on the spoon? With the help of a needle we can transfer this material and spread it evenly on the glass slide kept ready for this. To colour the material we can put a drop of methylene blue solution on it. Now the material is ready for observation under microscope. Do not forget to put a cover-slip on it!
- What do we observe? What is the shape of the cells we see? Draw it on the observation sheet.

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- Was there a darkly coloured, spherical or oval, dot-like structure near the centre of each cell? This structure is called nucleus. Were there similar structures in onion peel cells?

The nucleus has a double layered covering called nuclear membrane. The nuclear membrane has pores which allow the transfer of material from inside the nucleus to its outside, that is, to the cytoplasm (which we will talk about in section 5.2.4).

The nucleus contains chromosomes, which are visible as rod-shaped structures only when the cell is about to divide. Chromosomes contain information for inheritance of characters from parents to next generation in the form of DNA (Deoxyribo Nucleic Acid) molecules. Chromosomes are composed of DNA and protein. DNA molecules contain the information necessary for constructing and organising cells. Functional segments of DNA are called genes. In a cell which is not dividing, this DNA is present as part of chromatin material. Chromatin material is visible as entangled mass of thread like structures. Whenever the cell is about to divide, the chromatin material gets organised into chromosomes.

The nucleus plays a central role in cellular reproduction, the process by which a single cell divides and forms two new cells. It also plays a crucial part, along with the environment, in determining the way the cell will develop and what form it will exhibit at maturity, by directing the chemical activities of the cell.

In some organisms like bacteria, the nuclear region of the cell may be poorly defined due to the absence of a nuclear membrane. Such an undefined nuclear region containing only nucleic acids is called a nucleoid. Such organisms, whose cells lack a nuclear membrane, are called prokaryotes (Pro = primitive or primary; karyote ≈ karyon = nucleus). Organisms with cells having a nuclear membrane are called eukaryotes.

Prokaryotic cells (see Fig. 5.4) also lack most of the other cytoplasmic organelles present in eukaryotic cells. Many of the functions of such organelles are also performed by poorly organised parts of the cytoplasm (see section 5.2.4). The chlorophyll in photosynthetic prokaryotic bacteria is associated with membranous vesicles (bag like structures) but not with plastids as in eukaryotic cells (see section 5.2.5).

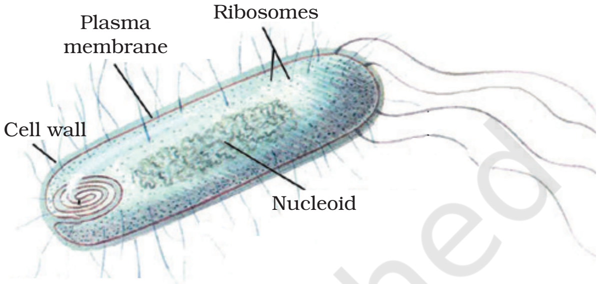

Fig. 5.4: *Prokaryotic cell*

5.2.4 Cytoplasm

When we look at the temporary mounts of onion peel as well as human cheek cells, we can see a large region of each cell enclosed by the cell membrane. This region takes up very little stain. It is called the cytoplasm. The cytoplasm is the fluid content inside the plasma membrane. It also contains many specialised cell organelles. Each of these organelles performs a specific function for the cell.

Cell organelles are enclosed by membranes. In prokaryotes, beside the absence of a defined nuclear region, the membrane-bound cell organelles are also absent. On the other hand, the eukaryotic cells have nuclear membrane as well as membrane-enclosed organelles.

The significance of membranes can be illustrated with the example of viruses. Viruses lack any membranes and hence do not show characteristics of life until they enter a living body and use its cell machinery to multiply.

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Question

1. Fill in the gaps in the following table illustrating differences between prokaryotic and eukaryotic cells.

Prokaryotic Cell	Eukaryotic Cell
1. Size : generally small (1-10 μm) 1 μm = 10^{-6} m	1. Size: generally large (5-100 μm)
2. Nuclear region: ______________ ______________ and known as__	2. Nuclear region: well defined and surrounded by a nuclear membrane
3. Chromosome: single	3. More than one chromosome
4. Membrane-bound cell organelles absent	4. ______________ ______________ ______________

5.2.5 Cell organelles

Every cell has a membrane around it to keep its own contents separate from the external environment. Large and complex cells, including cells from multicellular organisms, need a lot of chemical activities to support their complicated structure and function. To keep these activities of different kinds separate from each other, these cells use membrane-bound little structures (or 'organelles') within themselves. This is one of the features of the eukaryotic cells that distinguish them from prokaryotic cells. Some of these organelles are visible only with an electron microscope.

We have talked about the nucleus in a previous section. Some important examples of cell organelles which we will discuss now are: endoplasmic reticulum, Golgi apparatus, lysosomes, mitochondria and plastids. They are important because they carry out some very crucial functions in cells.

5.2.5 (i) *Endoplasmic reticulum (ER)*

The endoplasmic reticulum (ER) is a large network of membrane-bound tubes and sheets. It looks like long tubules or round or oblong bags (vesicles). The ER membrane is similar in structure to the plasma membrane. There are two types of ER– rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). RER looks rough under a microscope because it has particles called ribosomes attached to its surface. The ribosomes, which are present in all active cells, are the sites of protein manufacture. The manufactured proteins are then sent to various places in the cell depending on need, using the ER. The SER helps in the manufacture of fat molecules, or lipids, important for cell function. Some of these proteins and lipids help in building the cell membrane. This process is known as membrane biogenesis. Some other proteins and lipids function as enzymes and hormones. Although the ER varies greatly in appearance in different cells, it always forms a network system.

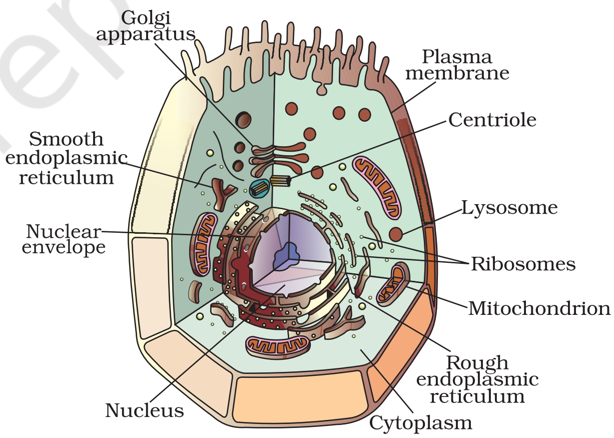


Fig. 5.5: Animal cell

Thus, one function of the ER is to serve as channels for the transport of materials (especially proteins) between various regions of the cytoplasm or between the cytoplasm and the nucleus. The ER also functions as a cytoplasmic framework providing a surface for some of the biochemical activities of the cell. In the liver cells of the group of animals called vertebrates (see Chapter 7), SER plays a crucial role in detoxifying many poisons and drugs.

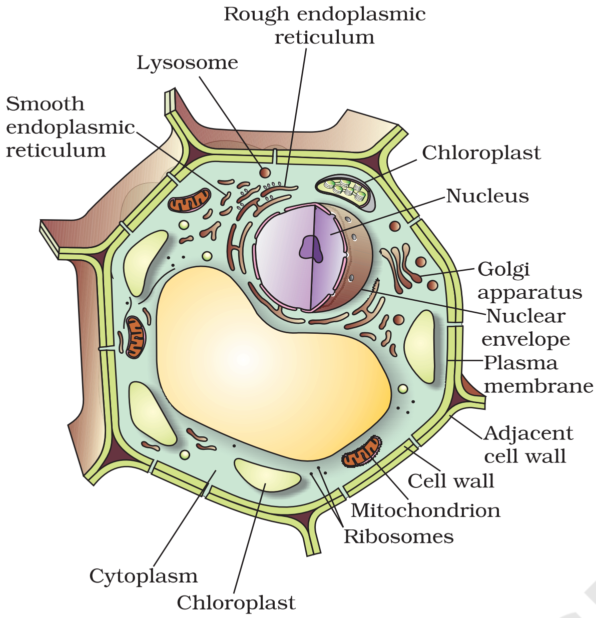
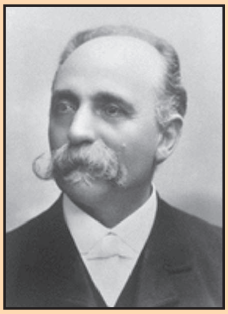


Fig. 5.6: *Plant cell*

5.2.5 (ii) *GOLGI APPARATUS*

The Golgi apparatus, first described by Camillo Golgi, consists of a system of membrane-bound vesicles (flattened sacs) arranged approximately parallel to each other in stacks called cisterns. These membranes often have connections with the membranes of ER and therefore constitute another portion of a complex cellular membrane system.

The material synthesised near the ER is packaged and dispatched to various targets inside and outside the cell through the Golgi apparatus. Its functions include the storage, modification and packaging of products in vesicles. In some cases, complex sugars may be made from simple sugars in the Golgi apparatus. The Golgi apparatus is also involved in the formation of lysosomes [see 5.2.5 (iii)].



Camillo Golgi was born at Corteno near Brescia in 1843. He studied medicine at the University of Pavia. After graduating in 1865, he continued to work in Pavia at the Hospital of St. Matteo. At that time most of his investigations were concerned with the nervous system, In 1872 he accepted the post of Chief Medical Officer at the Hospital for the Chronically Sick at Abbiategrasso. He first started his investigations into the nervous system in a little kitchen of this hospital, which he had converted into a laboratory. However, the work of greatest importance, which Golgi carried out was a revolutionary method of staining individual nerve and cell structures. This method is referred to as the 'black reaction'. This method uses a weak solution of silver nitrate and is particularly valuable in tracing the processes and most delicate ramifications of cells. All through his life, he continued to work on these lines, modifying and improving this technique. Golgi received the highest honours and awards in recognition of his work. He shared the Nobel prize in 1906 with Santiago Ramony Cajal for their work on the structure of the nervous system.

5.2.5 (iii) *LYSOSOMES*

Structurally, lysosomes are membrane-bound sacs filled with digestive enzymes. These enzymes are made by RER. Lysosomes are a kind of waste disposal system of the cell. These help to keep the cell clean by digesting any foreign material as well as worn-out cell organelles. Foreign materials entering the cell, such as bacteria or food, as well as old organelles end up in the lysosomes, which break complex substances into simpler substances. Lysosomes are able to do this because they contain powerful digestive enzymes capable of breaking down all organic material. During the disturbance in cellular metabolism, for example, when the cell gets

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damaged, lysosomes may burst and the enzymes digest their own cell. Therefore, lysosomes are also known as the 'suicide bags' of a cell.

5.2.5 (iv) *Mitochondria*

Mitochondria are known as the powerhouses of the cell. Mitochondria have two membrane coverings. The outer membrane is porous while the inner membrane is deeply folded. These folds increase surface area for ATP-generating chemical reactions. The energy required for various chemical activities needed for life is released by mitochondria in the form of ATP (Adenosine triphosphate) molecules. ATP is known as the energy currency of the cell. The body uses energy stored in ATP for making new chemical compounds and for mechanical work.

Mitochondria are strange organelles in the sense that they have their own DNA and ribosomes. Therefore, mitochondria are able to make some of their own proteins.

5.2.5 (v) *Plastids*

Plastids are present only in plant cells. There are two types of plastids – chromoplasts (coloured plastids) and leucoplasts (white or colourless plastids). Chromoplasts containing the pigment chlorophyll are known as chloroplasts. Chloroplasts are important for photosynthesis in plants. Chloroplasts also contain various yellow or orange pigments in addition to chlorophyll. Leucoplasts are primarily organelles in which materials such as starch, oils and protein granules are stored.

The internal organisation of the Chloroplast consists of numerous membrane layers embedded in a material called the stroma. These are similar to mitochondria in external structure. Like the mitochondria, plastids also have their own DNA and ribosomes.

5.2.5 (vi) *Vacuoles*

Vacuoles are storage sacs for solid or liquid contents. Vacuoles are small sized in animal cells while plant cells have very large vacuoles. The central vacuole of some plant cells may occupy 50-90% of the cell volume.

In plant cells vacuoles are full of cell sap and provide turgidity and rigidity to the cell. Many substances of importance in the life of the plant cell are stored in vacuoles. These include amino acids, sugars, various organic acids and some proteins. In single-celled organisms like *Amoeba*, the food vacuole contains the food items that the *Amoeba* has consumed. In some unicellular organisms, specialised vacuoles also play important roles in expelling excess water and some wastes from the cell.

Questions

1. *Can you name the two organelles we have studied that contain their own genetic material?*
2. *If the organisation of a cell is destroyed due to some physical or chemical influence, what will happen?*
3. *Why are lysosomes known as suicide bags?*
4. *Where are proteins synthesised inside the cell?*

Each cell thus acquires its structure and ability to function because of the organisation of its membrane and organelles in specific ways. The cell thus has a basic structural organisation. This helps the cells to perform functions like respiration, obtaining nutrition, and clearing of waste material, or forming new proteins.

Thus, the cell is the fundamental structural unit of living organisms. It is also the basic functional unit of life.

Cell Division

New cells are formed in organisms in order to grow, to replace old, dead and injured cells, and to form gametes required for reproduction. The process by which new cells are made is called cell division. There are two main types of cell division: mitosis and meiosis.

The process of cell division by which most of the cells divide for growth is called mitosis. In this process, each cell called mother cell

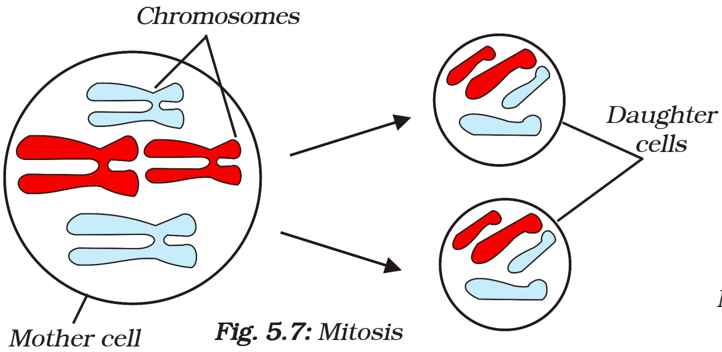

Fig. 5.7: Mitosis

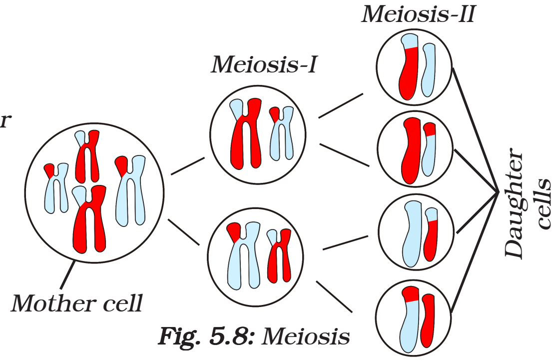

Fig. 5.8: Meiosis

divides to form two identical daughter cells (Fig. 5.7). The daughter cells have the same number of chromosomes as mother cell. It helps in growth and repair of tissues in organisms.

Specific cells of reproductive organs or tissues in animals and plants divide to form gametes, which after fertilisation give rise to offspring. They divide by a different process called meiosis which involves two consecutive divisions. When a cell divides by meiosis it produces four new cells instead of just two (Fig. 5.8). The new cells only have half the number of chromosomes than that of the mother cells. Can you think as to why the chromosome number has reduced to half in daughter cells?

What you have learnt

- The fundamental organisational unit of life is the cell.
- Cells are enclosed by a plasma membrane composed of lipids and proteins.
- The cell membrane is an active part of the cell. It regulates the movement of materials between the ordered interior of the cell and the outer environment.
- In plant cells, a cell wall composed mainly of cellulose is located outside the cell membrane.
- The presence of the cell wall enables the cells of plants, fungi and bacteria to exist in hypotonic media without bursting.
- The nucleus in eukaryotes is separated from the cytoplasm by double-layered membrane and it directs the life processes of the cell.
- The ER functions both as a passageway for intracellular transport and as a manufacturing surface.
- The Golgi apparatus consists of stacks of membrane-bound vesicles that function in the storage, modification and packaging of substances manufactured in the cell.
- Most plant cells have large membranous organelles called plastids, which are of two types—chromoplasts and leucoplasts.

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- Chromoplasts that contain chlorophyll are called chloroplasts and they perform photosynthesis.
- The primary function of leucoplasts is storage.
- Most mature plant cells have a large central vacuole that helps to maintain the turgidity of the cell and stores important substances including wastes.
- Prokaryotic cells have no membrane-bound organelles, their chromosomes are composed of only nucleic acid, and they have only very small ribosomes as organelles.
- Cells in organisms divide for growth of body, for repalcing dead cells, and for forming gametes for reproduction.

Exercises

1. Make a comparison and write down ways in which plant cells are different from animal cells.
2. How is a prokaryotic cell different from a eukaryotic cell?
3. What would happen if the plasma membrane ruptures or breaks down?
4. What would happen to the life of a cell if there was no Golgi apparatus?
5. Which organelle is known as the powerhouse of the cell? Why?
6. Where do the lipids and proteins constituting the cell membrane get synthesised?
7. How does an *Amoeba* obtain its food?
8. What is osmosis?
9. Carry out the following osmosis experiment:
   - Take four peeled potato halves and scoos each one out to make potato cups. One of these potato cups should be made from a boiled potato. Put each potato cup in a trough containing water. Now,
     (a) Keep cup A empty
     (b) Put one teaspoon sugar in cup B
     (c) Put one teaspoon salt in cup C
     (d) Put one teaspoon sugar in the boiled potato cup D.

     Keep these for two hours. Then observe the four potato cups and answer the following:
     (i) Explain why water gathers in the hollowed portion of B and C.
     (ii) Why is potato A necessary for this experiment?
     (iii) Explain why water does not gather in the hollowed out portions of A and D.
10. Which type of cell division is required for growth and repair of body and which type is involved in formation of gametes?

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Chapter 6

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TISSUES

From the last chapter, we recall that all living organisms are made of cells. In unicellular organisms, a single cell performs all basic functions. For example, in *Amoeba*, a single cell carries out movement, intake of food, gaseous exchange and excretion. But in multi-cellular organisms there are millions of cells. Most of these cells are specialised to carry out specific functions. Each specialised function is taken up by a different group of cells. Since these cells carry out only a particular function, they do it very efficiently. In human beings, muscle cells contract and relax to cause movement, nerve cells carry messages, blood flows to transport oxygen, food, hormones and waste material and so on. In plants, vascular tissues conduct food and water from one part of the plant to other parts. So, multi-cellular organisms show division of labour. Cells specialising in one function are often grouped together in the body. This means that a particular function is carried out by a cluster of cells at a definite place in the body. This cluster of cells, called a tissue, is arranged and designed so as to give the highest possible efficiency of function. Blood, phloem and muscle are all examples of tissues.

A group of cells that are similar in structure and/or work together to achieve a particular function forms a tissue.

6.1 Are Plants and Animals Made of Same Types of Tissues?

Let us compare their structure and functions. Do plants and animals have the same structure? Do they both perform similar functions?

There are noticeable differences between the two. Plants are stationary or fixed – they don't move. Since they have to be upright, they have a large quantity of supportive tissue. The supportive tissue generally has dead cells.

Animals on the other hand move around in search of food, mates and shelter. They consume more energy as compared to plants. Most of the tissues they contain are living.

Another difference between animals and plants is in the pattern of growth. The growth in plants is limited to certain regions, while this is not so in animals. There are some tissues in plants that divide throughout their life. These tissues are localised in certain regions. Based on the dividing capacity of the tissues, various plant tissues can be classified as growing or meristematic tissue and permanent tissue. Cell growth in animals is more uniform. So, there is no such demarcation of dividing and non-dividing regions in animals.

The structural organisation of organs and organ systems is far more specialised and localised in complex animals than even in very complex plants. This fundamental difference reflects the different modes of life pursued by these two major groups of organisms, particularly in their different feeding methods. Also, they are differently adapted for a sedentary existence on one hand (plants) and active locomotion on the other (animals), contributing to this difference in organ system design.

It is with reference to these complex animal and plant bodies that we will now talk about the concept of tissues in some detail.

Questions

1. *What is a tissue?*
2. *What is the utility of tissues in multi-cellular organisms?*

6.2 Plant Tissues

6.2.1 Meristematic tissue

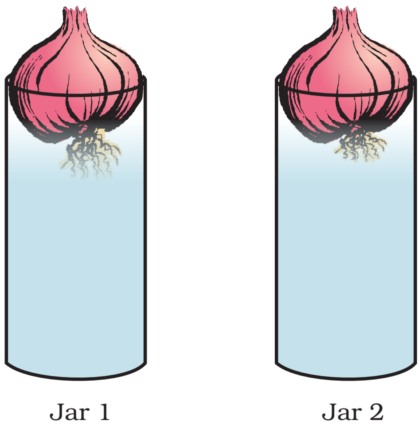

Fig. 6.1: Growth of roots in onion bulbs

Activity 6.1

- Take two glass jars and fill them with water.
- Now, take two onion bulbs and place one on each jar, as shown in Fig. 6.1.
- Observe the growth of roots in both the bulbs for a few days.
- Measure the length of roots on day 1, 2 and 3.
- On day 4, cut the root tips of the onion bulb in jar 2 by about 1 cm. After this, observe the growth of roots in both the jars and measure their lengths each day for five more days and record the observations in tables, like the table below:

Length	Day 1	Day 2	Day 3	Day 4	Day 5
Jar 1					
Jar 2					

- From the above observations, answer the following questions:
  1. Which of the two onions has longer roots? Why?
  2. Do the roots continue growing even after we have removed their tips?
  3. Why would the tips stop growing in jar 2 after we cut them?

The growth of plants occurs only in certain specific regions. This is because the dividing tissue, also known as meristematic tissue, is located only at these points. Depending on the region where they are present, meristematic tissues are classified as apical, lateral and intercalary (Fig. 6.2). New cells produced by meristem are initially like those of meristem itself, but as they grow and mature, their characteristics slowly change and they become differentiated as components of other tissues.

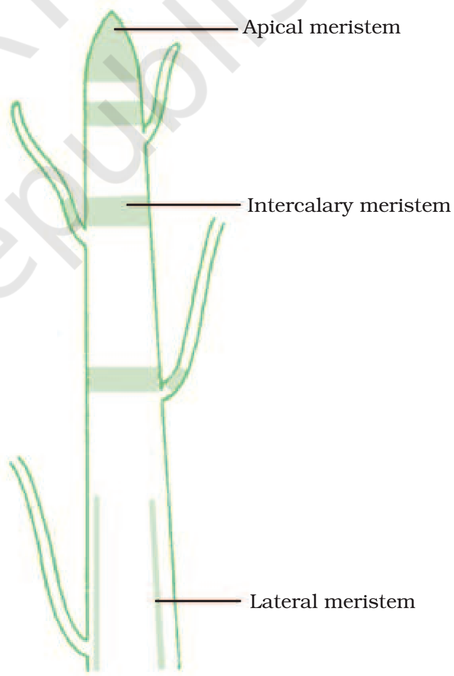

Fig. 6.2: Location of meristematic tissue in plant body

Apical meristem is present at the growing tips of stems and roots and increases the length of the stem and the root. The girth of the stem or root increases due to lateral meristem (cambium). Intercalary meristem seen in some plants is located near the node.

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Cells of meristematic tissue are very active, they have dense cytoplasm, thin cellulose walls and prominent nuclei. They lack vacuoles. Can we think why they would lack vacuoles? (You might want to refer to the functions of vacuoles in the chapter on cells.)

6.2.2 Permanent tissue

What happens to the cells formed by meristematic tissue? They take up a specific role and lose the ability to divide. As a result, they form a permanent tissue. This process of taking up a permanent shape, size, and a function is called differentiation. Differentiation leads to the development of various types of permanent tissues.

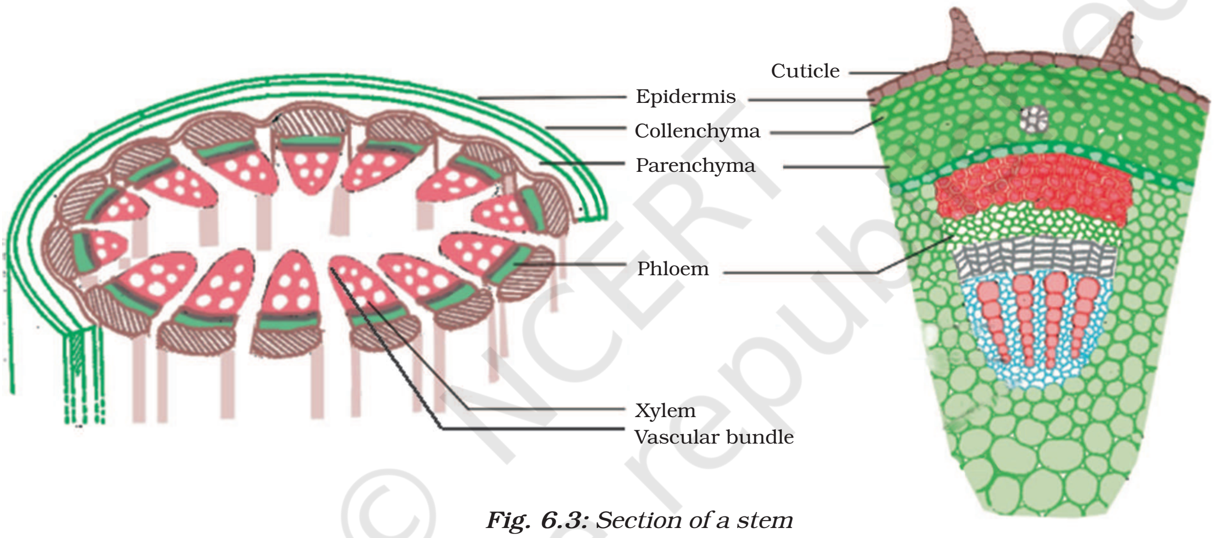

Fig. 6.3: Section of a stem

Activity 6.2

- Take a plant stem and with the help of your teacher cut into very thin slices or sections.
- Now, stain the slices with safranin. Place one neatly cut section on a slide, and put a drop of glycerine.
- Cover with a cover-slip and observe under a microscope. Observe the various types of cells and their arrangement. Compare it with Fig. 6.3.
- Now, answer the following on the basis of your observation:
  1. Are all cells similar in structure?
  2. How many types of cells can be seen?
  3. Can we think of reasons why there would be so many types of cells?
- We can also try to cut sections of plant roots. We can even try cutting sections of root and stem of different plants.

6.2.2 (i) *Simple permanent tissue*

A few layers of cells beneath the epidermis are generally simple permanent tissue. Parenchyma is the most common simple permanent tissue. It consists of relatively unspecialised cells with thin cell walls. They are living cells. They are usually loosely arranged, thus large spaces between cells (intercellular spaces) are found in this tissue (Fig. 6.4a). This tissue generally stores food. In some situations, it contains chlorophyll and performs photosynthesis, and then it is called chlorenchyma. In aquatic plants, large air cavities are present in parenchyma to help them float. Such a parenchyma type is called aerenchyma.

The flexibility in plants is due to another permanent tissue, collenchyma. It allows bending of various parts of a plant like tendrils and stems of climbers without breaking. It also provides mechanical support. We can find this tissue in leaf stalks below the epidermis. The cells of this tissue are living, elongated and irregularly thickened at the corners. There is very little intercellular space (Fig. 6.4 b).

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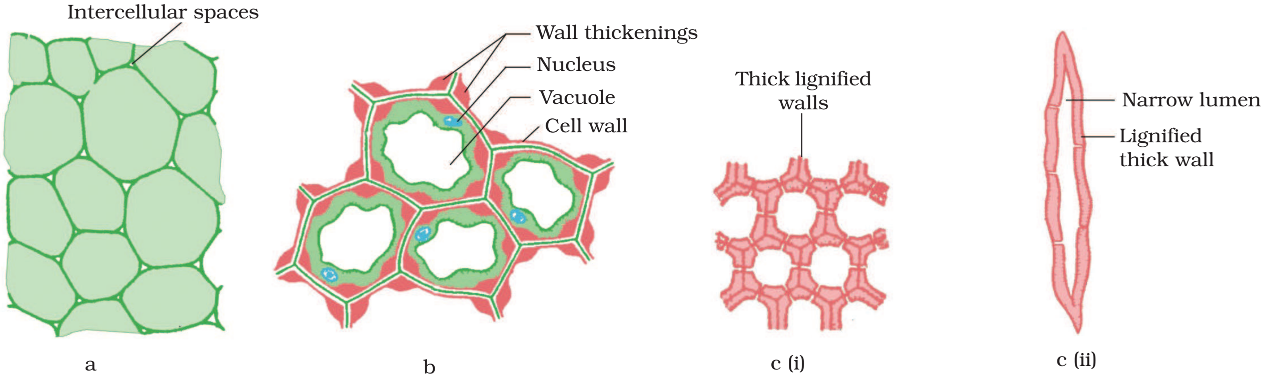

Fig. 6.4: Various types of simple tissues: (a) Parenchyma (b) Collenchyma (c) Sclerenchyma (i) transverse section, (ii) longitudinal section.

Yet another type of permanent tissue is sclerenchyma. It is the tissue which makes the plant hard and stiff. We have seen the husk of a coconut. It is made of sclerenchymatous tissue. The cells of this tissue are dead. They are long and narrow as the walls are thickened due to lignin. Often these walls are so thick that there is no internal space inside the cell (Fig. 6.4 c). This tissue is present in stems, around vascular bundles, in the veins of leaves and in the hard covering of seeds and nuts. It provides strength to the plant parts.

Activity 6.3

- Take a freshly plucked leaf of Rhoeo.
- Stretch and break it by applying pressure.
- While breaking it, keep it stretched gently so that some peel or skin projects out from the cut.
- Remove this peel and put it in a petri dish filled with water.
- Add a few drops of safranin.
- Wait for a couple of minutes and then transfer it onto a slide. Gently place a cover slip over it.
- Observe under microscope.

What you observe is the outermost layer of cells, called epidermis. The epidermis is usually made of a single layer of cells. In some plants living in very dry habitats, the epidermis may be thicker since protection against water loss is critical. The entire surface of a plant has an outer covering epidermis. It protects all the parts of the plant. Epidermal cells on the aerial parts of the plant often secrete a waxy, water-resistant layer on their outer surface. This aids in protection against loss of water, mechanical injury and invasion by parasitic fungi. Since it has a protective role to play, cells of epidermal tissue form a continuous layer without intercellular spaces. Most epidermal cells are relatively flat. Often their outer and side walls are thicker than the inner wall.

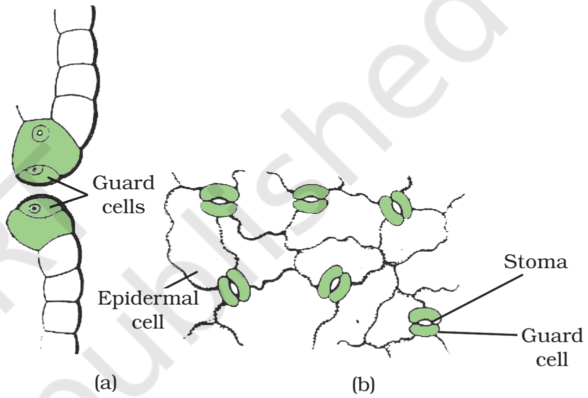

Fig. 6.5: Guard cells and epidermal cells: (a) lateral view, (b) surface view

We can observe small pores here and there in the epidermis of the leaf. These pores are called stomata (Fig. 6.5). Stomata are enclosed by two kidney-shaped cells called guard cells. They are necessary for exchanging gases with the atmosphere. Transpiration (loss of water in the form of water vapour) also takes place through stomata.

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Recall which gas is required for photosynthesis.
Find out the role of transpiration in plants.

Epidermal cells of the roots, whose function is water absorption, commonly bear long hair-like parts that greatly increase the total absorptive surface area.

In some plants like desert plants, epidermis has a thick waxy coating of cutin (chemical substance with waterproof quality) on its outer surface. Can we think of a reason for this?

Is the outer layer of a branch of a tree different from the outer layer of a young stem?

As plants grow older, the outer protective tissue undergoes certain changes. A strip of secondary meristem located in the cortex forms layers of cells which constitute the cork. Cells of cork are dead and compactly arranged without intercellular spaces (Fig. 6.6). They also have a substance called suberin in their walls that makes them impervious to gases and water.

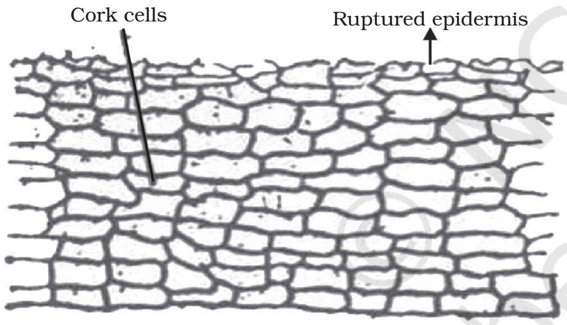

Fig. 6.6: *Protective tissue*

6.2.2 (ii) Complex permanent tissue

The different types of tissues we have discussed until now are all made of one type of cells, which look like each other. Such tissues are called simple permanent tissue. Yet another type of permanent tissue is complex tissue. Complex tissues are made of more than one type of cells. All these cells coordinate to perform a common function. Xylem and phloem are examples of such complex tissues. They are both conducting tissues and constitute a vascular bundle. Vascular tissue is a distinctive feature of the complex plants, one that has made possible their survival in the terrestrial environment. In Fig. 6.3 showing a section of stem, can you see different types of cells in the vascular bundle?

Xylem consists of tracheids, vessels, xylem parenchyma (Fig. 6.7 a,b,c) and xylem fibres. Tracheids and vessels have thick walls, and many are dead cells when mature. Tracheids and vessels are tubular structures. This allows them to transport water and minerals vertically. The parenchyma stores food. Xylem fibres are mainly supportive in function.

Phloem is made up of five types of cells: sieve cells, sieve tubes, companion cells, phloem fibres and the phloem parenchyma [Fig. 6.7 (d)]. Sieve tubes are tubular cells with perforated walls. Phloem transports food from leaves to other parts of the plant. Except phloem fibres, other phloem cells are living cells.

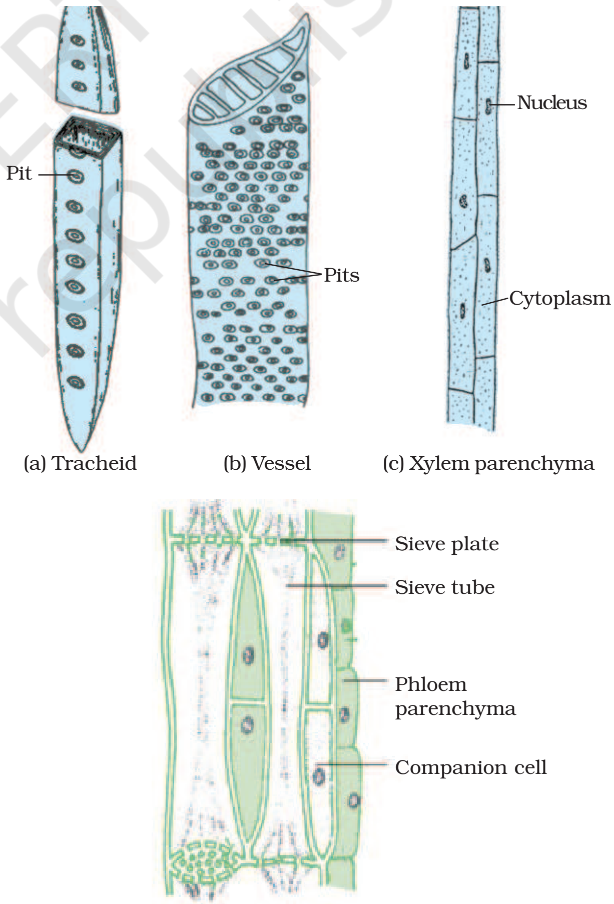

Fig. 6.7: *Types of complex tissue*

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Questions

1. *Name types of simple tissues.*
2. *Where is apical meristem found?*
3. *Which tissue makes up the husk of coconut?*
4. *What are the constituents of phloem?*

6.3 Animal Tissues

When we breathe we can actually feel the movement of our chest. How do these body parts move? For this we have specialised cells called muscle cells (Fig. 6.8). The contraction and relaxation of these cells result in movement.

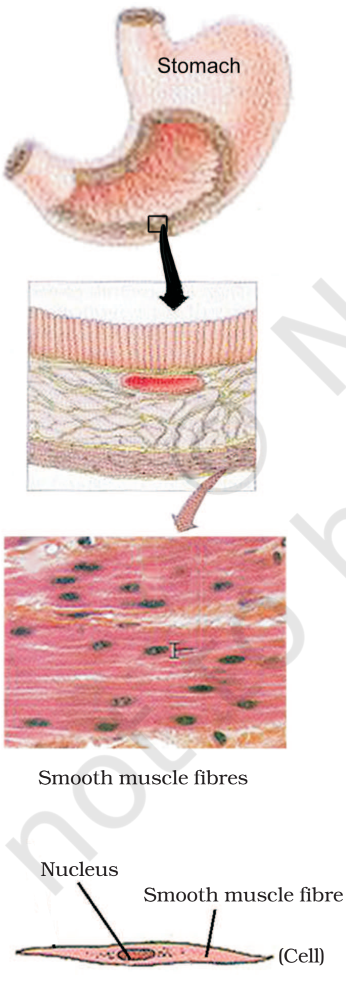

Fig. 6.8: Location of muscle fibres

During breathing we inhale oxygen. Where does this oxygen go? It is absorbed in the lungs and then is transported to all the body cells through blood. Why would cells need oxygen? The functions of mitochondria we studied earlier provide a clue to this question. Blood flows and carries various substances from one part of the body to the other. For example, it carries oxygen and food to all cells. It also collects wastes from all parts of the body and carries them to the liver and kidney for disposal.

Blood and muscles are both examples of tissues found in our body. On the basis of the functions they perform we can think of different types of animal tissues, such as epithelial tissue, connective tissue, muscular tissue and nervous tissue. Blood is a type of connective tissue, and muscle forms muscular tissue.

6.3.1 Epithelial tissue

The covering or protective tissues in the animal body are epithelial tissues. Epithelium covers most organs and cavities within the body. It also forms a barrier to keep different body systems separate. The skin, the lining of the mouth, the lining of blood vessels, lung alveoli and kidney tubules are all made of epithelial tissue. Epithelial tissue cells are tightly packed and form a continuous sheet. They have only a small amount of cementing material between them and almost no intercellular spaces. Obviously, anything entering or leaving the body must cross at least one layer of epithelium. As a result, the permeability of the cells of various epithelia play an important role in regulating the exchange of materials between the body and the external environment and also between different parts of the body. Regardless of the type, all epithelium is usually separated from the underlying tissue by an extracellular fibrous basement membrane.

Different epithelia (Fig. 6.9) show differing structures that correlate with their unique functions. For example, in cells lining blood vessels or lung alveoli, where transportation of substances occurs through a selectively permeable surface, there is a simple flat kind

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of epithelium. This is called the simple squamous epithelium (squama means scale of skin). Simple squamous epithelial cells are extremely thin and flat and form a delicate lining. The oesophagus and the lining of the mouth are also covered with squamous epithelium. The skin, which protects the body, is also made of squamous epithelium. Skin epithelial cells are arranged in many layers to prevent wear and tear. Since they are arranged in a pattern of layers, the epithelium is called stratified squamous epithelium.

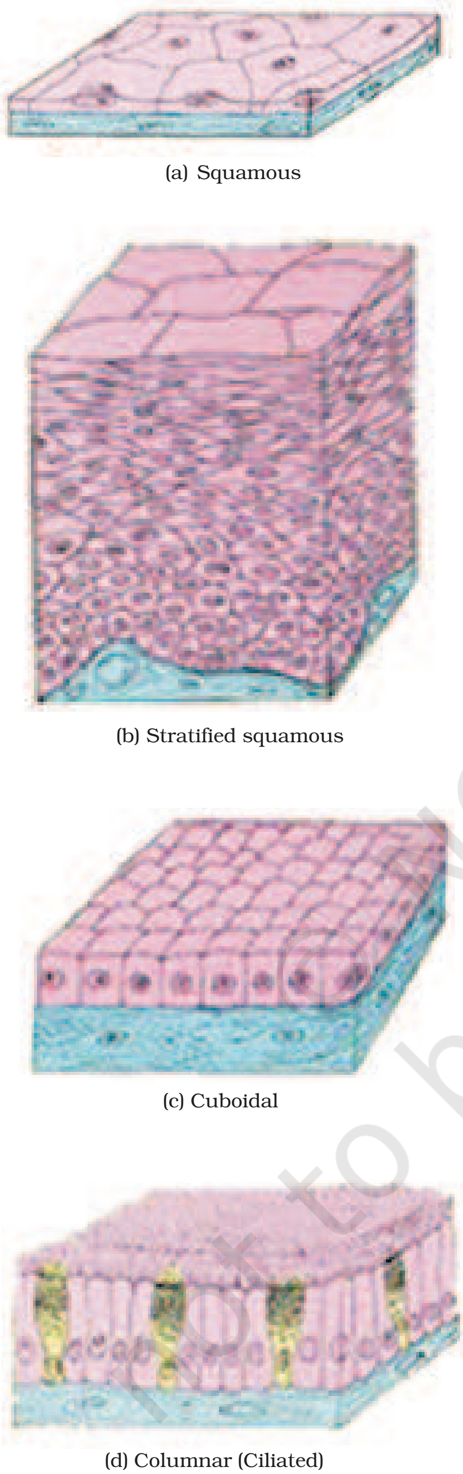

Fig. 6.9: Different types of epithelial tissues

Where absorption and secretion occur, as in the inner lining of the intestine, tall epithelial cells are present. This columnar (meaning 'pillar-like') epithelium facilitates movement across the epithelial barrier. In the respiratory tract, the columnar epithelial tissue also has cilia, which are hair-like projections on the outer surfaces of epithelial cells. These cilia can move, and their movement pushes the mucus forward to clear it. This type of epithelium is thus ciliated columnar epithelium.

Cuboidal epithelium (with cube-shaped cells) forms the lining of kidney tubules and ducts of salivary glands, where it provides mechanical support. Epithelial cells often acquire additional specialisation as gland cells, which can secrete substances at the epithelial surface. Sometimes a portion of the epithelial tissue folds inward, and a multicellular gland is formed. This is glandular epithelium.

6.3.2 Connective tissue

Blood is a type of connective tissue. Why would it be called 'connective' tissue? A clue is provided in the introduction of this chapter! Now, let us look at this type of tissue in some more detail. The cells of connective tissue are loosely spaced and embedded in an intercellular matrix (Fig. 6.10). The matrix may be jelly like, fluid, dense or rigid. The nature of matrix differs in concordance with the function of the particular connective tissue.

Activity 6.4

- Take a drop of blood on a slide and observe different cells present in it under a microscope.

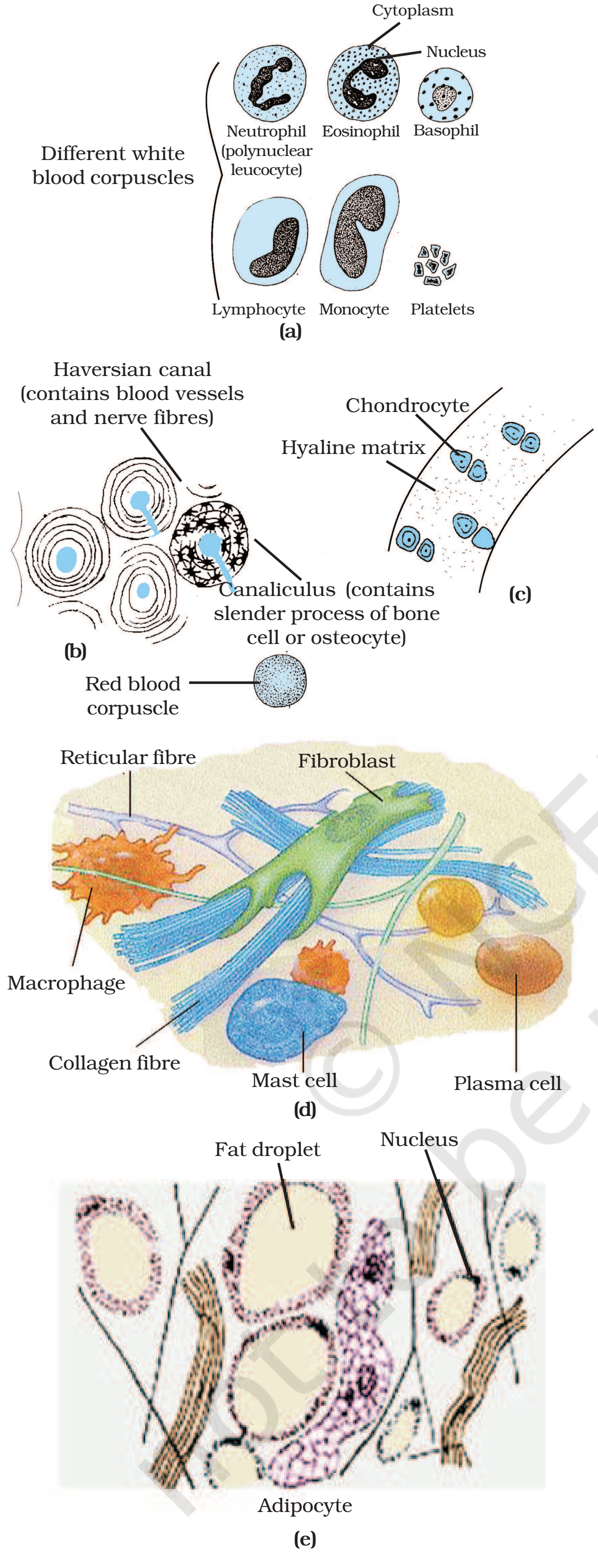

Fig. 6.10: Types of connective tissues: (a) types of blood cells, (b) compact bone, (c) hyaline cartilage, (d) areolar tissue, (e) adipose tissue

Blood has a fluid (liquid) matrix called plasma, in which red blood corpuscles (RBCs), white blood corpuscles (WBCs) and platelets are suspended. The plasma contains proteins, salts and hormones. Blood flows and transports gases, digested food, hormones and waste materials to different parts of the body.

Bone is another example of a connective tissue. It forms the framework that supports the body. It also anchors the muscles and supports the main organs of the body. It is a strong and nonflexible tissue (what would be the advantage of these properties for bone functions?). Bone cells are embedded in a hard matrix that is composed of calcium and phosphorus compounds.

Two bones can be connected to each other by another type of connective tissue called the ligament. This tissue is very elastic. It has considerable strength. Ligaments contain very little matrix and connect bones with bones. Tendons connect muscles to bones and are another type of connective tissue. Tendons are fibrous tissue with great strength but limited flexibility.

Another type of connective tissue, cartilage, has widely spaced cells. The solid matrix is composed of proteins and sugars. Cartilage smoothens bone surfaces at joints and is also present in the nose, ear, trachea and larynx. We can fold the cartilage of the ears, but we cannot bend the bones in our arms. Think of how the two tissues are different!

Areolar connective tissue is found between the skin and muscles, around blood vessels and nerves and in the bone marrow. It fills the space inside the organs, supports internal organs and helps in repair of tissues.

Where are fats stored in our body? Fat-storing adipose tissue is found below the skin and between internal organs. The cells of this tissue are filled with fat globules. Storage of fats also lets it act as an insulator.

6.3.3 Muscular tissue

Muscular tissue consists of elongated cells, also called muscle fibres. This tissue is responsible for movement in our body.

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Muscles contain special proteins called contractile proteins, which contract and relax to cause movement.

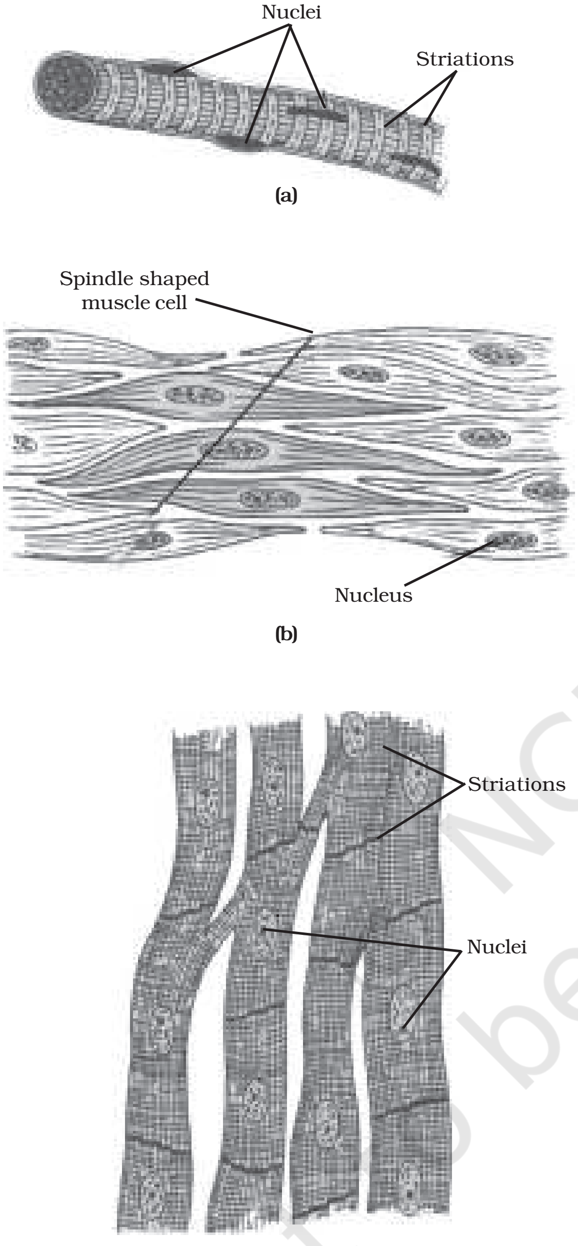

Fig. 6.11: Types of muscles fibres: (a) striated muscle, (b) smooth muscle, (c) cardiac muscle

We can move some muscles by conscious will. Muscles present in our limbs move when we want them to, and stop when we so decide. Such muscles are called voluntary muscles [Fig. 6.11(a)]. These muscles are also called skeletal muscles as they are mostly attached to bones and help in body movement. Under the microscope, these muscles show alternate light and dark bands or striations when stained appropriately. As a result, they are also called striated muscles. The cells of this tissue are long, cylindrical, unbranched and multinucleate (having many nuclei).

The movement of food in the alimentary canal or the contraction and relaxation of blood vessels are involuntary movements. We cannot really start them or stop them simply by wanting to do so! Smooth muscles [Fig. 6.11(b)] or involuntary muscles control such movements. They are also found in the iris of the eye, in ureters and in the bronchi of the lungs. The cells are long with pointed ends (spindle-shaped) and uninucleate (having a single nucleus). They are also called unstriated muscles – why would they be called that?

The muscles of the heart show rhythmic contraction and relaxation throughout life. These involuntary muscles are called cardiac muscles [Fig. 6.11(c)]. Heart muscle cells are cylindrical, branched and uninucleate.

Activity 6.5

Compare the structures of different types of muscular tissues. Note down their shape, number of nuclei and position of nuclei within the cell in the Table 6.1.

Table 6.1:

Features	Striated	Smooth	Cardiac
Shape			
Number of nuclei			
Position of nuclei			

6.3.4 Nervous tissue

All cells possess the ability to respond to stimuli. However, cells of the nervous tissue are highly specialised for being stimulated and

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then transmitting the stimulus very rapidly from one place to another within the body. The brain, spinal cord and nerves are all composed of the nervous tissue. The cells of this tissue are called nerve cells or neurons. A neuron consists of a cell body with a nucleus and cytoplasm, from which long thin hair-like parts arise (Fig. 6.12). Usually each neuron has a single long part (process) in the form of a fibre, called the axon, and many short, branched parts (processes) called dendrites. An individual nerve cell may be up to a metre long. Many nerve fibres bound together by connective tissue make up a nerve.

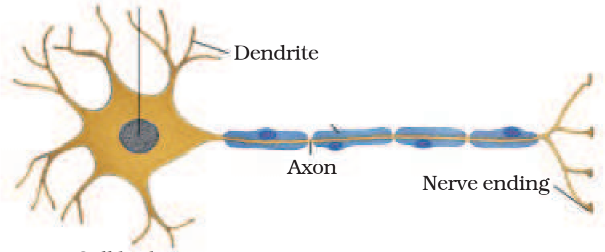
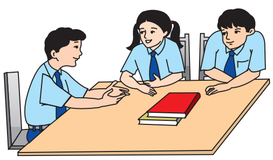


Fig. 6.12: *Neuron—a unit of nervous tissue*

The signal that passes along the nerve fibre is called a nerve impulse. The nerve impulse from the nerve endings in transmitted to the dendrites of the next nerve cell. Nerve impulses allow us to move our muscles when we want to. The functional combination of nerve and muscle tissue is fundamental to most animals. This combination enables animals to move rapidly in response to stimuli.

Questions

1. *Name the tissue responsible for movement in our body.*
2. *What does a neuron look like?*
3. *Give three features of cardiac muscles.*
4. *What are the functions of areolar tissue?*



What you have learnt

- Tissue is a group of cells similar in structure and function.
- Plant tissues are of two main types – meristematic and permanent.
- Meristematic tissue is the dividing tissue present in the growing regions of the plant.
- Permanent tissues are derived from meristematic tissue once they lose the ability to divide. They are classified as simple and complex tissues.
- Parenchyma, collenchyma and sclerenchyma are three types of simple tissues. Xylem and phloem are types of complex tissues.
- Animal tissues can be epithelial, connective, muscular and nervous tissue.
- Depending on shape and function, epithelial tissue is classified as squamous, cuboidal, columnar, ciliated and glandular.

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- The different types of connective tissues in our body include areolar tissue, adipose tissue, bone, tendon, ligament, cartilage and blood.
- Striated, unstriated and cardiac are three types of muscle tissues.
- Nervous tissue is made of neurons that receive and conduct impulses.

Exercises

1. Define the term “tissue”.
2. How many types of elements together make up the xylem tissue? Name them.
3. How are simple tissues different from complex tissues in plants?
4. Differentiate between parenchyma, collenchyma and sclerenchyma on the basis of their cell wall.
5. What are the functions of the stomata?
6. Diagrammatically show the difference between the three types of muscle fibres.
7. What is the specific function of the cardiac muscle?
8. Differentiate between striated, unstriated and cardiac muscles on the basis of their structure and site/location in the body.
9. Draw a labelled diagram of a neuron.
10. Name the following.
    (a) Tissue that forms the inner lining of our mouth.
    (b) Tissue that connects muscle to bone in humans.
    (c) Tissue that transports food in plants.
    (d) Tissue that stores fat in our body.
    (e) Connective tissue with a fluid matrix.
    (f) Tissue present in the brain.
11. Identify the type of tissue in the following: skin, bark of tree, bone, lining of kidney tubule, vascular bundle.

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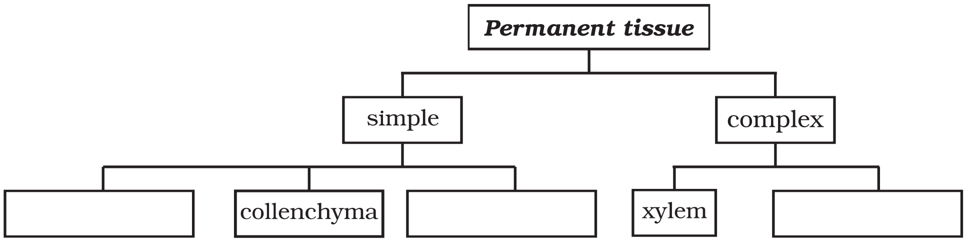
12. Name the regions in which parenchyma tissue is present.
13. What is the role of epidermis in plants?
14. How does the cork act as a protective tissue?
15. Complete the following chart:



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Chapter 7

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MOTION

In everyday life, we see some objects at rest and others in motion. Birds fly, fish swim, blood flows through veins and arteries, and cars move. Atoms, molecules, planets, stars and galaxies are all in motion. We often perceive an object to be in motion when its position changes with time. However, there are situations where the motion is inferred through indirect evidences. For example, we infer the motion of air by observing the movement of dust and the movement of leaves and branches of trees. What causes the phenomena of sunrise, sunset and changing of seasons? Is it due to the motion of the earth? If it is true, why don't we directly perceive the motion of the earth?

An object may appear to be moving for one person and stationary for some other. For the passengers in a moving bus, the roadside trees appear to be moving backwards. A person standing on the road–side perceives the bus alongwith the passengers as moving. However, a passenger inside the bus sees his fellow passengers to be at rest. What do these observations indicate?

Most motions are complex. Some objects may move in a straight line, others may take a circular path. Some may rotate and a few others may vibrate. There may be situations involving a combination of these. In this chapter, we shall first learn to describe the motion of objects along a straight line. We shall also learn to express such motions through simple equations and graphs. Later, we shall discuss ways of describing circular motion.

Activity 7.1

- Discuss whether the walls of your classroom are at rest or in motion.

Activity 7.2

- Have you ever experienced that the train in which you are sitting appears to move while it is at rest?
- Discuss and share your experience.

Think and Act

We sometimes are endangered by the motion of objects around us, especially if that motion is erratic and uncontrolled as observed in a flooded river, a hurricane or a tsunami. On the other hand, controlled motion can be a service to human beings such as in the generation of hydro-electric power. Do you feel the necessity to study the erratic motion of some objects and learn to control them?

7.1 Describing Motion

We describe the location of an object by specifying a reference point. Let us understand this by an example. Let us assume that a school in a village is 2 km north of the railway station. We have specified the position of the school with respect to the railway station. In this example, the railway station is the reference point. We could have also chosen other reference points according to our convenience. Therefore, to describe the position of an object we need to specify a reference point called the origin.

7.1.1 Motion along a straight line

The simplest type of motion is the motion along a straight line. We shall first learn to describe this by an example. Consider the motion of an object moving along a straight path. The object starts its journey from O which is treated as its reference point (Fig. 7.1). Let A, B and C represent the position of the object at different instants. At first, the object moves through C and B and reaches A. Then it moves back along the same path and reaches C through B.

The total path length covered by the object is OA + AC, that is 60 km + 35 km = 95 km. This is the distance covered by the object. To describe distance we need to specify only the numerical value and not the direction of motion. There are certain quantities which are described by specifying only their numerical values. The numerical value of a physical quantity is its magnitude. From this example, can you find out the distance of the final position C of the object from the initial position O? This difference will give you the numerical value of the displacement of the object from O to C through A. The shortest distance measured from the initial to the final position of an object is known as the displacement.

Can the magnitude of the displacement be equal to the distance travelled by an object? Consider the example given in (Fig. 7.1). For motion of the object from O to A, the distance covered is 60 km and the magnitude of displacement is also 60 km. During its motion from O to A and back to B, the distance covered = 60 km + 25 km = 85 km while the magnitude of displacement = 35 km. Thus, the magnitude of displacement (35 km) is not equal to the path length (85 km). Further, we will notice that the magnitude of the displacement for a course of motion may be zero but the corresponding distance covered is not zero. If we consider the object to travel back to O, the final position concides with the initial position, and therefore, the displacement is zero. However, the distance covered in this journey is OA + AO = 60 km + 60 km = 120 km. Thus, two different physical quantities—the distance and the displacement, are used to describe the overall motion of an object and to locate its final position with reference to its initial position at a given time.

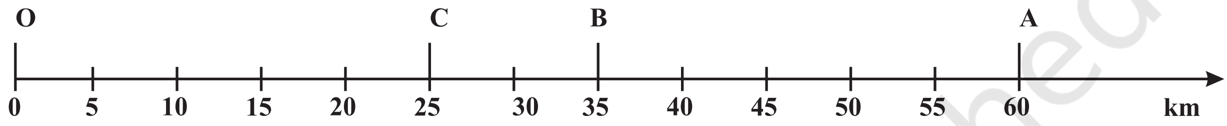

Fig. 7.1: *Positions of an object on a straight line path*

Activity _______________ 7.3

- Take a metre scale and a long rope.
- Walk from one corner of a basket-ball court to its oppposite corner along its sides.
- Measure the distance covered by you and magnitude of the displacement.
- What difference would you notice between the two in this case?

Activity _______________ 7.4

- Automobiles are fitted with a device that shows the distance travelled. Such a device is known as an odometer. A car is driven from Bhubaneshwar to New Delhi. The difference between the final reading and the initial reading of the odometer is 1850 km.
- Find the magnitude of the displacement between Bhubaneshwar and New Delhi by using the Road Map of India.

Questions

1. *An object has moved through a distance. Can it have zero displacement? If yes, support your answer with an example.*
2. *A farmer moves along the boundary of a square field of side 10 m in 40 s. What will be the magnitude of displacement of the farmer at the end of 2 minutes 20 seconds from his initial position?*
3. *Which of the following is true for displacement?*
   (a) It cannot be zero.
   (b) Its magnitude is greater than the distance travelled by the object.

7.1.2 Uniform motion and non-uniform motion

Consider an object moving along a straight line. Let it travel 5 m in the first second, 5 m more in the next second, 5 m in the third second and 5 m in the fourth second. In this case, the object covers 5 m in each second. As the object covers equal distances in equal intervals of time, it is said to be in uniform motion. The time interval in this motion should be small. In our day-to-day life, we come across motions where objects cover unequal distances in equal intervals of time, for example, when a car is moving on a crowded street or a person is jogging in a park. These are some instances of non-uniform motion.

Activity 7.5

- The data regarding the motion of two different objects A and B are given in Table 7.1.
- Examine them carefully and state whether the motion of the objects is uniform or non-uniform.

Table 7.1

Time	Distance travelled by object A in m	Distance travelled by object B in m
9:30 am	10	12
9:45 am	20	19
10:00 am	30	23
10:15 am	40	35
10:30 am	50	37
10:45 am	60	41
11:00 am	70	44

7.2 Measuring the Rate of Motion

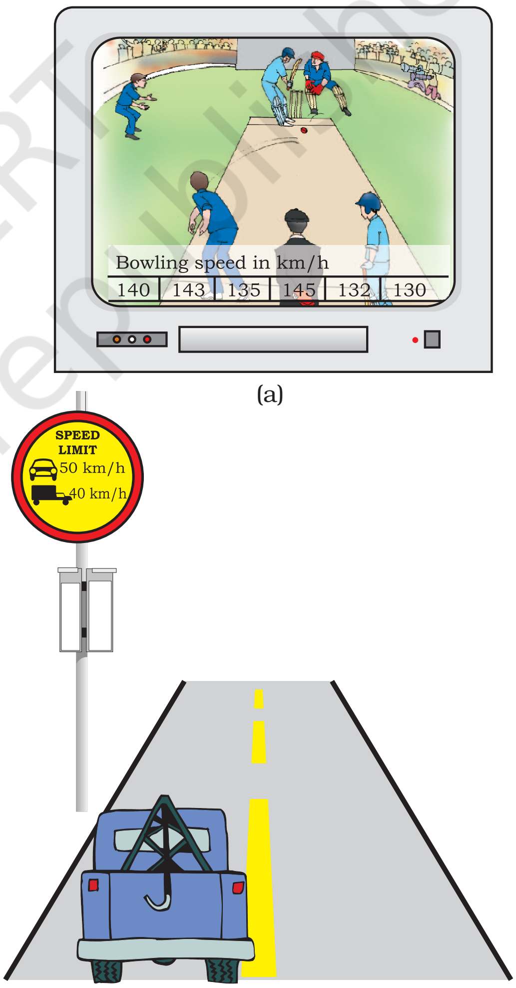

Fig. 7.2

Look at the situations given in Fig. 7.2. If the bowling speed is 143 km h^{-1} in Fig. 7.2(a) what does it mean? What do you understand from the signboard in Fig. 7.2(b)?

Different objects may take different amounts of time to cover a given distance. Some of them move fast and some move slowly. The rate at which objects move can be different. Also, different objects can move at the same rate. One of the ways of measuring the rate of motion of an object is to find out the distance travelled by the object in unit time. This quantity is referred to as speed. The SI unit of speed is metre per second. This is represented by the symbol m s^{-1} or m/s. The other units of speed include centimetre per second (cm s^{-1}) and kilometre per hour (km h^{-1}). To specify the speed of an object, we require only its magnitude. The speed of an object need not be constant. In most cases, objects will be in non-uniform motion. Therefore, we describe the rate of motion of such objects in terms of their average speed. The average speed of an object is obtained by dividing the total distance travelled by the total time taken. That is,

$$\text{average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

If an object travels a distance s in time t then its speed v is,

$$v = \frac{s}{t} \tag{7.1}$$

Let us understand this by an example. A car travels a distance of 100 km in 2 h. Its average speed is 50 km h^{-1}. The car might not have travelled at 50 km h^{-1} all the time. Sometimes it might have travelled faster and sometimes slower than this.

Example 7.1 An object travels 16 m in 4 s and then another 16 m in 2 s. What is the average speed of the object?

Solution:

Total distance travelled by the object = 16 m + 16 m = 32 m

Total time taken = 4 s + 2 s = 6 s

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

$$= \frac{32 \text{ m}}{6 \text{ s}} = 5.33 \text{ m s}^{-1}$$

Therefore, the average speed of the object is 5.33 m s^{-1}.

7.2.1 Speed with direction

The rate of motion of an object can be more comprehensive if we specify its direction of motion along with its speed. The quantity that specifies both these aspects is called velocity. Velocity is the speed of an object moving in a definite direction. The velocity of an object can be uniform or variable. It can be changed by changing the object's speed, direction of motion or both. When an object is moving along a straight line at a variable speed, we can express the magnitude of its rate of motion in terms of average velocity. It is calculated in the same way as we calculate average speed.

In case the velocity of the object is changing at a uniform rate, then average velocity is given by the arithmetic mean of initial velocity and final velocity for a given period of time. That is,

$$\text{average velocity} = \frac{\text{initial velocity} + \text{final velocity}}{2}$$

Mathematically, $$v_{av} = \frac{u + v}{2} \tag{7.2}$$

where v_{av} is the average velocity, u is the initial velocity and v is the final velocity of the object.

Speed and velocity have the same units, that is, m s^{-1} or m/s.

Activity 7.6

- Measure the time it takes you to walk from your house to your bus stop or the school. If you consider that your average walking speed is 4 km h^{-1}, estimate the distance of the bus stop or school from your house.

Activity 7.7

- At a time when it is cloudy, there may be frequent thunder and lightning. The sound of thunder takes some time to reach you after you see the lightning.
- Can you answer why this happens?
- Measure this time interval using a digital wrist watch or a stop watch.
- Calculate the distance of the nearest point of lightning. (Speed of sound in air = 346 m s^{-1}.)

Questions

1. *Distinguish between speed and velocity.*
2. *Under what condition(s) is the magnitude of average velocity of an object equal to its average speed?*
3. *What does the odometer of an automobile measure?*
4. *What does the path of an object look like when it is in uniform motion?*
5. *During an experiment, a signal from a spaceship reached the ground station in five minutes. What was the distance of the spaceship from the ground station? The signal travels at the speed of light, that is, 3×10^8 m s^{-1}.*

Example 7.2 The odometer of a car reads 2000 km at the start of a trip and 2400 km at the end of the trip. If the trip took 8 h, calculate the average speed of the car in km h^{-1} and m s^{-1}.

Solution:

Distance covered by the car,
s = 2400 km – 2000 km = 400 km
Time elapsed, t = 8 h
Average speed of the car is,

$$v_{av} = \frac{s}{t} = \frac{400 \text{ km}}{8 \text{ h}}$$

$$= 50 \text{ km h}^{-1}$$

$$= 50 \frac{\text{km}}{\text{h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}}$$

$$= 13.9 \text{ m s}^{-1}$$

The average speed of the car is 50 km h^{-1} or 13.9 m s^{-1}.

Example 7.3 Usha swims in a 90 m long pool. She covers 180 m in one minute by swimming from one end to the other and back along the same straight path. Find the average speed and average velocity of Usha.

Solution:

Total distance covered by Usha in 1 min is 180 m.
Displacement of Usha in 1 min = 0 m

$$\text{Average speed} = \frac{\text{Total distance covered}}{\text{Total time taken}}$$

$$= \frac{180 \text{ m}}{1 \text{ min}} = \frac{180 \text{ m}}{1 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}}$$

$$= 3 \text{ m s}^{-1}$$

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Total time taken}}$$

$$= \frac{0 \text{ m}}{60 \text{ s}}$$

$$= 0 \text{ m s}^{-1}$$

The average speed of Usha is 3 m s^{-1} and her average velocity is 0 m s^{-1}.

7.3 Rate of Change of Velocity

During uniform motion of an object along a straight line, the velocity remains constant with time. In this case, the change in velocity of the object for any time interval is zero. However, in non-uniform motion, velocity varies with time. It has different values at different instants and at different points of the path. Thus, the change in velocity of the object during any time interval is not zero. Can we now express the change in velocity of an object?

To answer such a question, we have to introduce another physical quantity called acceleration, which is a measure of the change in the velocity of an object per unit time. That is,

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

If the velocity of an object changes from an initial value u to the final value v in time t, the acceleration a is,

$$a = \frac{v - u}{t} \qquad (7.3)$$

This kind of motion is known as accelerated motion. The acceleration is taken to be positive if it is in the direction of velocity and negative when it is opposite to the direction of velocity. The SI unit of acceleration is m s^{-2}.

If an object travels in a straight line and its velocity increases or decreases by equal amounts in equal intervals of time, then the acceleration of the object is said to be uniform. The motion of a freely falling body is an example of uniformly accelerated motion. On the other hand, an object can travel with non-uniform acceleration if its velocity changes at a non-uniform rate. For example, if a car travelling along a straight road increases its speed by unequal amounts in equal intervals of time, then the car is said to be moving with non-uniform acceleration.

Activity 7.8

- In your everyday life you come across a range of motions in which
  - (a) acceleration is in the direction of motion,
  - (b) acceleration is against the direction of motion,
  - (c) acceleration is uniform,
  - (d) acceleration is non-uniform.
- Can you identify one example each for the above type of motion?

Example 7.4 Starting from a stationary position, Rahul paddles his bicycle to attain a velocity of 6 m s^{-1} in 30 s. Then he applies brakes such that the velocity of the bicycle comes down to 4 m s^{-1} in the next 5 s. Calculate the acceleration of the bicycle in both the cases.

Solution:

In the first case:
initial velocity, $u = 0$;
final velocity, $v = 6$ m s^{-1} ;
time, $t = 30$ s .
From Eq. (8.3), we have

$$a = \frac{v - u}{t}$$

Substituting the given values of u, v and t in the above equation, we get

$$a = \frac{(6\,\text{m s}^{-1} - 0\,\text{m s}^{-1})}{30\,\text{s}}$$

$$= 0.2\ \text{m s}^{-2}$$

In the second case:
initial velocity, $u = 6$ m s^{-1};
final velocity, $v = 4$ m s^{-1};
time, $t = 5$ s.

$$\text{Then, } a = \frac{(4\,\text{m s}^{-1} - 6\,\text{m s}^{-1})}{5\,\text{s}}$$

$$= -0.4\ \text{m s}^{-2}.$$

The acceleration of the bicycle in the first case is 0.2 m s^{-2} and in the second case, it is –0.4 m s^{-2}.

Questions

1. *When will you say a body is in (i) uniform acceleration? (ii) non-uniform acceleration?*
2. *A bus decreases its speed from 80 km h^{-1} to 60 km h^{-1} in 5 s. Find the acceleration of the bus.*
3. *A train starting from a railway station and moving with uniform acceleration attains a speed 40 km h^{-1} in 10 minutes. Find its acceleration.*

7.4 Graphical Representation of Motion

Graphs provide a convenient method to present basic information about a variety of events. For example, in the telecast of a one-day cricket match, vertical bar graphs show the run rate of a team in each over. As you have studied in mathematics, a straight line graph helps in solving a linear equation having two variables.

To describe the motion of an object, we can use line graphs. In this case, line graphs show dependence of one physical quantity, such as distance or velocity, on another quantity, such as time.

7.4.1 Distance–time graphs

The change in the position of an object with time can be represented on the distance-time graph adopting a convenient scale of choice. In this graph, time is taken along the *x*–axis and distance is taken along the *y*-axis. Distance-time graphs can be employed under various conditions where objects move with uniform speed, non-uniform speed, remain at rest etc.

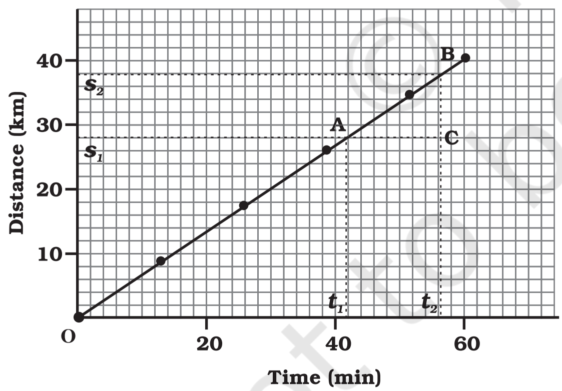

Fig. 7.3: *Distance-time graph of an object moving with uniform speed*

We know that when an object travels equal distances in equal intervals of time, it moves with uniform speed. This shows that the distance travelled by the object is directly proportional to time taken. Thus, for uniform speed, a graph of distance travelled against time is a straight line, as shown in Fig. 7.3. The portion OB of the graph shows that the distance is increasing at a uniform rate. Note that, you can also use the term uniform velocity in place of uniform speed if you take the magnitude of displacement equal to the distance travelled by the object along the *y*-axis.

We can use the distance-time graph to determine the speed of an object. To do so, consider a small part AB of the distance-time graph shown in Fig 7.3. Draw a line parallel to the *x*-axis from point A and another line parallel to the *y*-axis from point B. These two lines meet each other at point C to form a triangle ABC. Now, on the graph, AC denotes the time interval $(t_2 - t_1)$ while BC corresponds to the distance $(s_2 - s_1)$. We can see from the graph that as the object moves from the point A to B, it covers a distance $(s_2 - s_1)$ in time $(t_2 - t_1)$. The speed, v of the object, therefore can be represented as

$$v = \frac{s_2 - s_1}{t_2 - t_1} \tag{7.4}$$

We can also plot the distance-time graph for accelerated motion. Table 7.2 shows the distance travelled by a car in a time interval of two seconds.

Table 7.2: Distance travelled by a car at regular time intervals

Time in seconds	Distance in metres
0	0
2	1
4	4
6	9
8	16
10	25
12	36

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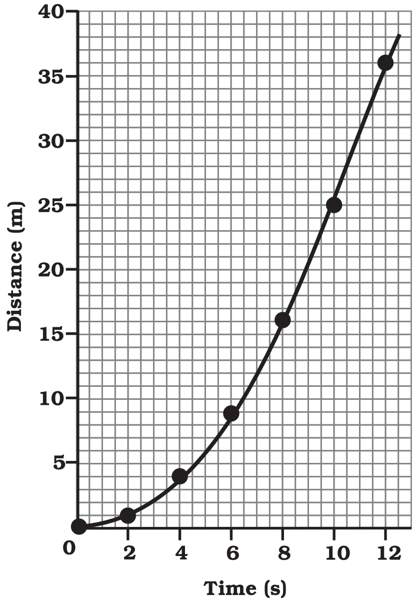

Fig. 7.4: Distance-time graph for a car moving with non-uniform speed

The distance-time graph for the motion of the car is shown in Fig. 7.4. Note that the shape of this graph is different from the earlier distance-time graph (Fig. 7.3) for uniform motion. The nature of this graph shows non-linear variation of the distance travelled by the car with time. Thus, the graph shown in Fig 7.4 represents motion with non-uniform speed.

7.4.2 Velocity-time graphs

The variation in velocity with time for an object moving in a straight line can be represented by a velocity-time graph. In this graph, time is represented along the x-axis and the velocity

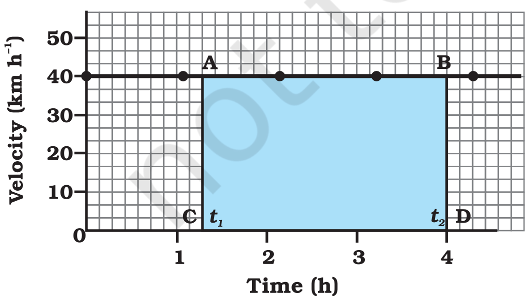

Fig. 7.5: Velocity-time graph for uniform motion of a car

is represented along the y-axis. If the object moves at uniform velocity, the height of its velocity-time graph will not change with time (Fig. 7.5). It will be a straight line parallel to the x-axis. Fig. 7.5 shows the velocity-time graph for a car moving with uniform velocity of 40 km h^{-1}.

We know that the product of velocity and time give displacement of an object moving with uniform velocity. The area enclosed by velocity-time graph and the time axis will be equal to the magnitude of the displacement.

To know the distance moved by the car between time t_1 and t_2 using Fig. 7.5, draw perpendiculars from the points corresponding to the time t_1 and t_2 on the graph. The velocity of 40 km h^{-1} is represented by the height AC or BD and the time $(t_2 - t_1)$ is represented by the length AB.

So, the distance s moved by the car in time $(t_2 - t_1)$ can be expressed as

s = AC   CD
= [(40 km h^{-1}) $(t_2 - t_1)$ h]
= 40 $(t_2 - t_1)$ km
= area of the rectangle ABDC (shaded in Fig. 7.5).

We can also study about uniformly accelerated motion by plotting its velocity–time graph. Consider a car being driven along a straight road for testing its engine. Suppose a person sitting next to the driver records its velocity after every 5 seconds by noting the reading of the speedometer of the car. The velocity of the car, in km h^{-1} as well as in m s^{-1}, at different instants of time is shown in table 7.3.

Table 7.3: Velocity of a car at regular instants of time

Time (s)	Velocity of the car (m s^{-1})	(km h^{-1})
0	0	0
5	2.5	9
10	5.0	18
15	7.5	27
20	10.0	36
25	12.5	45
30	15.0	54

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In this case, the velocity-time graph for the motion of the car is shown in Fig. 7.6. The nature of the graph shows that velocity changes by equal amounts in equal intervals of time. Thus, for all uniformly accelerated motion, the velocity-time graph is a straight line.

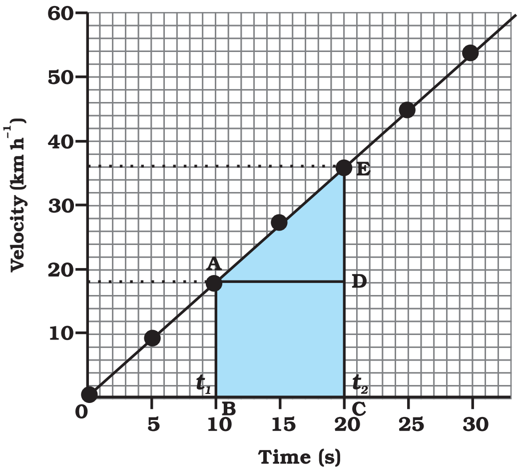

Fig. 7.6: *Velocity-time graph for a car moving with uniform accelerations.*

You can also determine the distance moved by the car from its velocity-time graph. The area under the velocity-time graph gives the distance (magnitude of displacement) moved by the car in a given interval of time. If the car would have been moving with uniform velocity, the distance travelled by it would be represented by the area ABCD under the graph (Fig. 7.6). Since the magnitude of the velocity of the car is changing due to acceleration, the distance s travelled by the car will be given by the area ABCDE under the velocity-time graph (Fig. 7.6).

That is,

s = area ABCDE

= area of the rectangle ABCD + area of the triangle ADE

$$= AB \times BC + \frac{1}{2}(AD \times DE)$$

In the case of non-uniformly accelerated motion, velocity-time graphs can have any shape.

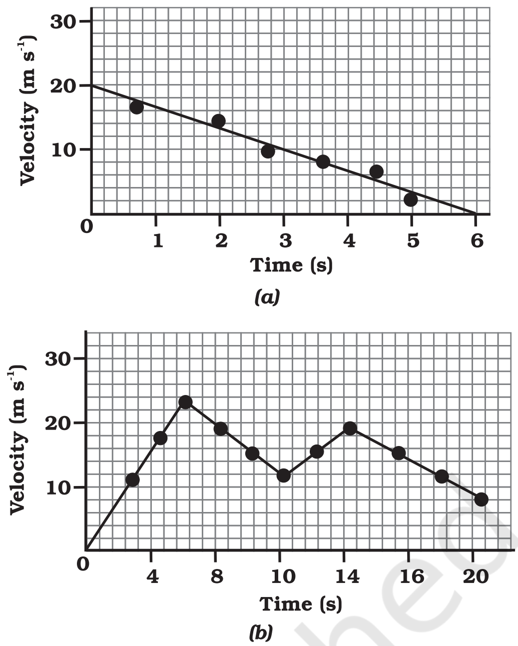

Fig. 7.7: *Velocity-time graphs of an object in non-uniformly accelerated motion.*

Fig. 7.7(a) shows a velocity-time graph that represents the motion of an object whose velocity is decreasing with time while Fig. 7.7 (b) shows the velocity-time graph representing the non-uniform variation of velocity of the object with time. Try to interpret these graphs.

Activity 7.9

- The times of arrival and departure of a train at three stations A, B and C and the distance of stations B and C from station A are given in Table 7.4.

Table 7.4: Distances of stations B and C from A and times of arrival and departure of the train

Station	Distance from A (km)	Time of arrival (hours)	Time of departure (hours)
A	0	08:00	08:15
B	120	11:15	11:30
C	180	13:00	13:15

- Plot and interpret the distance-time graph for the train assuming that its motion between any two stations is uniform.

Activity 7.10

- Feroz and his sister Sania go to school on their bicycles. Both of them start at the same time from their home but take different times to reach the school although they follow the same route. Table 7.5 shows the distance travelled by them in different times

Table 7.5: Distance covered by Feroz and Sania at different times on their bicycles

Time	Distance travelled by Feroz (km)	Distance travelled by Sania (km)
8:00 am	0	0
8:05 am	1.0	0.8
8:10 am	1.9	1.6
8:15 am	2.8	2.3
8:20 am	3.6	3.0
8:25 am	–	3.6

- Plot the distance-time graph for their motions on the same scale and interpret.

Questions

1. *What is the nature of the distance-time graphs for uniform and non-uniform motion of an object?*
2. *What can you say about the motion of an object whose distance-time graph is a straight line parallel to the time axis?*
3. *What can you say about the motion of an object if its speed-time graph is a straight line parallel to the time axis?*
4. *What is the quantity which is measured by the area occupied below the velocity-time graph?*

7.5 Equations of Motion

When an object moves along a straight line with uniform acceleration, it is possible to relate its velocity, acceleration during motion and the distance covered by it in a certain time interval by a set of equations known as the equations of motion. For convenience, a set of three such equations are given below:

$$v = u + at \qquad (7.5)$$

$$s = ut + ½\, at^2 \qquad (7.6)$$

$$2\,as = v^2 - u^2 \qquad (7.7)$$

where u is the initial velocity of the object which moves with uniform acceleration a for time t, v is the final velocity, and s is the distance travelled by the object in time t. Eq. (7.5) describes the velocity-time relation and Eq. (7.6) represents the position-time relation. Eq. (7.7), which represents the relation between the position and the velocity, can be obtained from Eqs. (7.5) and (7.6) by eliminating t. These three equations can be derived by graphical method.

Example 7.5 A train starting from rest attains a velocity of 72 km h^{-1} in 5 minutes. Assuming that the acceleration is uniform, find (i) the acceleration and (ii) the distance travelled by the train for attaining this velocity.

Solution:

We have been given
$u = 0$; $v = 72$ km h^{-1} = 20 m s^{-1} and
t = 5 minutes = 300 s.

(i) From Eq. (7.5) we know that

$$a = \frac{(v-u)}{t}$$

$$= \frac{20\ \text{m s}^{-1} - 0\ \text{m s}^{-1}}{300\ \text{s}}$$

$$= \frac{1}{15}\ \text{m s}^{-2}$$

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(ii) From Eq. (7.7) we have
$2\,as = v^2 - u^2 = v^2 - 0$
Thus,

$$s = \frac{v^2}{2a}$$

$$= \frac{(20 \text{ m s}^{-1})^2}{2 \times (1/15) \text{ m s}^{-2}}$$

$= 3000$ m
$= 3$ km

The acceleration of the train is $\frac{1}{15}$ m s^{-2} and the distance travelled is 3 km.

Example 7.6 A car accelerates uniformly from 18 km h^{-1} to 36 km h^{-1} in 5 s. Calculate (i) the acceleration and (ii) the distance covered by the car in that time.

Solution:

We are given that
u = 18 km h^{-1} = 5 m s^{-1}
v = 36 km h^{-1} = 10 m s^{-1} and
t = 5 s .

(i) From Eq. (7.5) we have

$$a = \frac{v - u}{t}$$

$$= \frac{10 \text{ m s}^{-1} - 5 \text{ m s}^{-1}}{5 \text{ s}}$$

$= 1$ m s^{-2}

(ii) From Eq. (7.6) we have

$$s = u\,t + \frac{1}{2}a\,t^2$$

$$= 5 \text{ m s}^{-1} \times 5 \text{ s} + \frac{1}{2} \times 1 \text{ m s}^{-2} \times (5 \text{ s})^2$$

$= 25$ m $+ 12.5$ m

$= 37.5$ m

The acceleration of the car is 1 m s^{-2} and the distance covered is 37.5 m.

Example 7.7 The brakes applied to a car produce an acceleration of 6 m s^{-2} in the opposite direction to the motion. If the car takes 2 s to stop after the application of brakes, calculate the distance it travels during this time.

Solution:

We have been given
$a = -6$ m s^{-2} ; $t = 2$ s and $v = 0$ m s^{-1}.
From Eq. (7.5) we know that
$v = u + at$
$0 = u + (-6 \text{ m s}^{-2}) \times 2 \text{ s}$
or $u = 12$ m s^{-1} .
From Eq. (7.6) we get

$$s = u\,t + \frac{1}{2}\,a\,t^2$$

$$= (12 \text{ m s}^{-1}) \times (2 \text{ s}) + \frac{1}{2}(-6 \text{ m s}^{-2})(2 \text{ s})^2$$

$= 24$ m $- 12$ m
$= 12$ m

Thus, the car will move 12 m before it stops after the application of brakes. Can you now appreciate why drivers are cautioned to maintain some distance between vehicles while travelling on the road?

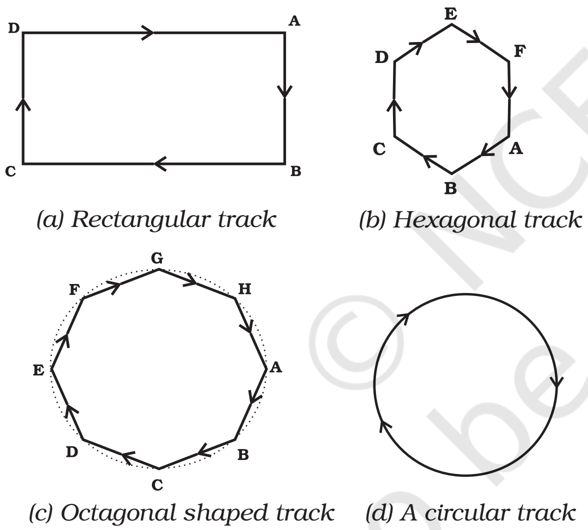
Questions

1. *A bus starting from rest moves with a uniform acceleration of 0.1 m s^{-2} for 2 minutes. Find (a) the speed acquired, (b) the distance travelled.*
2. *A train is travelling at a speed of 90 km h^{-1}. Brakes are applied so as to produce a uniform acceleration of – 0.5 m s^{-2}. Find how far the train will go before it is brought to rest.*
3. *A trolley, while going down an inclined plane, has an acceleration of 2 cm s^{-2}. What will be its velocity 3 s after the start?*

4. *A racing car has a uniform acceleration of 4 m s^{-2}. What distance will it cover in 10 s after start?*
5. *A stone is thrown in a vertically upward direction with a velocity of 5 m s^{-1}. If the acceleration of the stone during its motion is 10 m s^{-2} in the downward direction, what will be the height attained by the stone and how much time will it take to reach there?*

7.6 Uniform Circular Motion

When the velocity of an object changes, we say that the object is accelerating. The change in the velocity could be due to change in its magnitude or the direction of the motion or both. Can you think of an example when an object does not change its magnitude of velocity but only its direction of motion?



(a) Rectangular track *(b) Hexagonal track*

(c) Octagonal shaped track *(d) A circular track*

Fig. 7.8: *The motion of an athlete along closed tracks of different shapes.*

Let us consider an example of the motion of a body along a closed path. Fig 8.9 (a) shows the path of an athlete along a rectangular track ABCD. Let us assume that the athlete runs at a uniform speed on the straight parts AB, BC, CD and DA of the track. In order to keep himself on track, he quickly changes his speed at the corners. How many times will the athlete have to change his direction of motion, while he completes one round? It is clear that to move in a rectangular track once, he has to change his direction of motion four times.

Now, suppose instead of a rectangular track, the athlete is running along a hexagonal shaped path ABCDEF, as shown in Fig. 7.8(b). In this situation, the athlete will have to change his direction six times while he completes one round. What if the track was not a hexagon but a regular octagon, with eight equal sides as shown by ABCDEFGH in Fig. 7.8(c)? It is observed that as the number of sides of the track increases the athelete has to take turns more and more often. What would happen to the shape of the track as we go on increasing the number of sides indefinitely? If you do this you will notice that the shape of the track approaches the shape of a circle and the length of each of the sides will decrease to a point. If the athlete moves with a velocity of constant magnitude along the circular path, the only change in his velocity is due to the change in the direction of motion. The motion of the athlete moving along a circular path is, therefore, an example of an accelerated motion.

We know that the circumference of a circle of radius r is given by $2\pi r$. If the athlete takes t seconds to go once around the circular path of radius r, the speed v is given by

$$v = \frac{2\pi r}{t} \qquad (7.8)$$

When an object moves in a circular path with uniform speed, its motion is called uniform circular motion.

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Activity 7.11

- Take a piece of thread and tie a small piece of stone at one of its ends. Move the stone to describe a circular path with constant speed by holding the thread at the other end, as shown in Fig. 7.9.

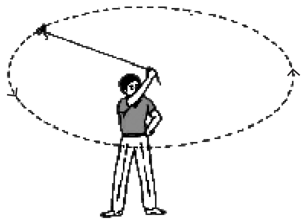
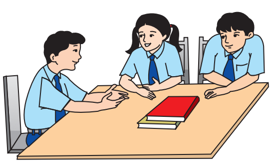


Fig. 7.9: *A stone describing a circular path with a velocity of constant magnitude.*

- Now, let the stone go by releasing the thread.
- Can you tell the direction in which the stone moves after it is released?
- By repeating the activity for a few times and releasing the stone at different positions of the circular path, check whether the direction in which the stone moves remains the same or not.

If you carefully note, on being released the stone moves along a straight line tangential to the circular path. This is because once the stone is released, it continues to move along the direction it has been moving at that instant. This shows that the direction of motion changed at every point when the stone was moving along the circular path.

When an athlete throws a hammer or a discus in a sports meet, he/she holds the hammer or the discus in his/her hand and gives it a circular motion by rotating his/her own body. Once released in the desired direction, the hammer or discus moves in the direction in which it was moving at the time it was released, just like the piece of stone in the activity described above. There are many more familiar examples of objects moving under uniform circular motion, such as the motion of the moon and the earth, a satellite in a circular orbit around the earth, a cyclist on a circular track at constant speed and so on.



What you have learnt

- Motion is a change of position; it can be described in terms of the distance moved or the displacement.
- The motion of an object could be uniform or non-uniform depending on whether its velocity is constant or changing.
- The speed of an object is the distance covered per unit time, and velocity is the displacement per unit time.
- The acceleration of an object is the change in velocity per unit time.
- Uniform and non-uniform motions of objects can be shown through graphs.
- The motion of an object moving at uniform acceleration can be described with the help of the following equations, namely

$$v = u + at$$
$$s = ut + \tfrac{1}{2} at^2$$
$$2as = v^2 - u^2$$

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where u is initial velocity of the object, which moves with uniform acceleration a for time t, v is its final velocity and s is the distance it travelled in time t.

- If an object moves in a circular path with uniform speed, its motion is called uniform circular motion.

Exercises

1. An athlete completes one round of a circular track of diameter 200 m in 40 *s*. What will be the distance covered and the displacement at the end of 2 minutes 20 s?
2. Joseph jogs from one end A to the other end B of a straight 300 m road in 2 minutes 30 seconds and then turns around and jogs 100 m back to point C in another 1 minute. What are Joseph's average speeds and velocities in jogging (a) from A to B and (b) from A to C?
3. Abdul, while driving to school, computes the average speed for his trip to be 20 km h^{-1}. On his return trip along the same route, there is less traffic and the average speed is 30 km h^{-1}. What is the average speed for Abdul's trip?
4. A motorboat starting from rest on a lake accelerates in a straight line at a constant rate of 3.0 m s^{-2} for 8.0 s. How far does the boat travel during this time?
5. A driver of a car travelling at 52 km h^{-1} applies the brakes Shade the area on the graph that represents the distance travelled by the car during the period.
   (b) Which part of the graph represents uniform motion of the car?
6. Fig 7.10 shows the distance-time graph of three objects A,B and C. Study the graph and answer the following questions:

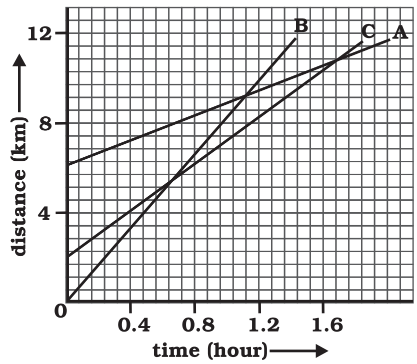

Fig. 7.10

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(a) Which of the three is travelling the fastest?
(b) Are all three ever at the same point on the road?
(c) How far has C travelled when B passes A?
(d) How far has B travelled by the time it passes C?

7. A ball is gently dropped from a height of 20 m. If its velocity increases uniformly at the rate of 10 m s^{-2}, with what velocity will it strike the ground? After what time will it strike the ground?
8. The speed-time graph for a car is shown is Fig. 7.11.

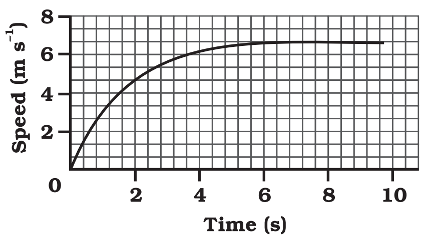


Fig. 7.11

(a) Find how far does the car travel in the first 4 seconds. Shade the area on the graph that represents the distance travelled by the car during the period.
(b) Which part of the graph represents uniform motion of the car?

9. State which of the following situations are possible and give an example for each of these:
(a) an object with a constant acceleration but with zero velocity
(b) an object moving with an acceleration but with uniform speed.
(c) an object moving in a certain direction with an acceleration in the perpendicular direction.

10. An artificial satellite is moving in a circular orbit of radius 42250 km. Calculate its speed if it takes 24 hours to revolve around the earth.

Chapter 8

FORCE AND LAWS OF MOTION

In the previous chapter, we described the motion of an object along a straight line in terms of its position, velocity and acceleration. We saw that such a motion can be uniform or non-uniform. We have not yet discovered what causes the motion. Why does the speed of an object change with time? Do all motions require a cause? If so, what is the nature of this cause? In this chapter we shall make an attempt to quench all such curiosities.

For many centuries, the problem of motion and its causes had puzzled scientists and philosophers. A ball on the ground, when given a small hit, does not move forever. Such observations suggest that rest is the "natural state" of an object. This remained the belief until Galileo Galilei and Isaac Newton developed an entirely different approach to understand motion.

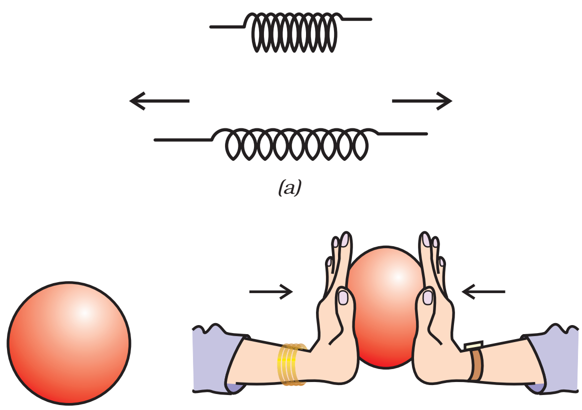
(a) The trolley moves along the direction we push it. (b) The drawer is pulled.

(c) The hockey stick hits the ball forward

Fig. 8.1: *Pushing, pulling, or hitting objects change their state of motion.*

In our everyday life we observe that some effort is required to put a stationary object into motion or to stop a moving object. We ordinarily experience this as a muscular effort and say that we must push or hit or pull on an object to change its state of motion. The concept of force is based on this push, hit or pull. Let us now ponder about a 'force'. What is it? In fact, no one has seen, tasted or felt a force. However, we always see or feel the effect of a force. It can only be explained by describing what happens when a force is applied to an object. Pushing, hitting and pulling of objects are all ways of bringing objects in motion (Fig. 8.1). They move because we make a force act on them.

From your studies in earlier classes, you are also familiar with the fact that a force can be used to change the magnitude of velocity of an object (that is, to make the object move faster or slower) or to change its direction of motion. We also know that a force can change the shape and size of objects (Fig. 8.2).



(a)

(b)

Fig. 8.2: (a) *A spring expands on application of force;* (b) *A spherical rubber ball becomes oblong as we apply force on it.*

8.1 Balanced and Unbalanced Forces

Fig. 8.3 shows a wooden block on a horizontal table. Two strings X and Y are tied to the two opposite faces of the block as shown. If we apply a force by pulling the string X, the block begins to move to the right. Similarly, if we pull the string Y, the block moves to the left. But, if the block is pulled from both the sides with equal forces, the block will not move. Such forces are called balanced forces and do not change the state of rest or of motion of an object. Now, let us consider a situation in which two opposite forces of different magnitudes pull the block. In this case, the block would begin to move in the direction of the greater force. Thus, the two forces are not balanced and the unbalanced force acts in the direction the block moves. This suggests that an unbalanced force acting on an object brings it in motion.

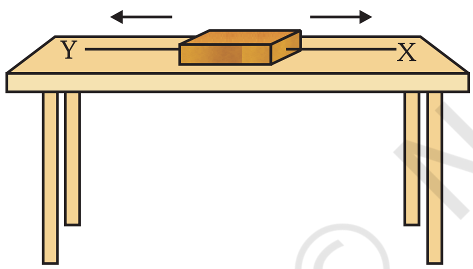


Fig. 8.3: *Two forces acting on a wooden block*

What happens when some children try to push a box on a rough floor? If they push the box with a small force, the box does not move because of friction acting in a direction opposite to the push [Fig. 8.4(a)]. This friction force arises between two surfaces in contact; in this case, between the bottom of the box and floor's rough surface. It balances the pushing force and therefore the box does not move. In Fig. 8.4(b), the children push the box harder but the box still does not move. This is because the friction force still balances the pushing force. If the children push the box harder still, the pushing force becomes bigger than the friction force [Fig. 8.4(c)]. There is an unbalanced force. So the box starts moving.

What happens when we ride a bicycle? When we stop pedalling, the bicycle begins to slow down. This is again because of the friction forces acting opposite to the direction of motion. In order to keep the bicycle moving, we have to start pedalling again. It thus appears that an object maintains its motion under the continuous application of an unbalanced force. However, it is quite incorrect. An object moves with a uniform velocity when the forces (pushing force and frictional force) acting on the object are balanced and there is no net external force on it. If an unbalanced force is applied on the object, there will be a change either in its speed or in the direction of its motion. Thus, to accelerate the motion of an object, an unbalanced force is required. And the change in its speed (or in the direction of motion) would continue as long as this unbalanced force is applied. However, if this force is

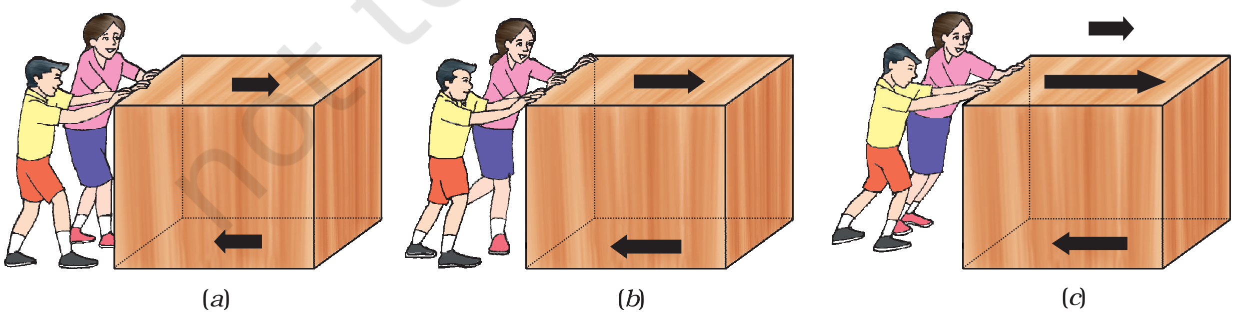


Fig. 8.4

removed completely, the object would continue to move with the velocity it has acquired till then.

8.2 First Law of Motion

By observing the motion of objects on an inclined plane Galileo deduced that objects move with a constant speed when no force acts on them. He observed that when a marble rolls down an inclined plane, its velocity increases [Fig. 8.5(a)]. In the next chapter, you will learn that the marble falls under the unbalanced force of gravity as it rolls down and attains a definite velocity by the time it reaches the bottom. Its velocity decreases when it climbs up as shown in Fig. 8.5(b). Fig. 8.5(c) shows a marble resting on an ideal frictionless plane inclined on both sides. Galileo argued that when the marble is released from left, it would roll down the slope and go up on the opposite side to the same height from which it was released. If the inclinations of the planes on both sides are equal then the marble will climb the same distance that it covered while rolling down. If the angle of inclination of the right-side plane were gradually decreased, then the marble would travel further distances till it reaches the original height. If the right-side plane were ultimately made horizontal (that is, the slope is reduced to zero), the marble would continue to travel forever trying to reach the same height that it was released from. The unbalanced forces on the marble in this case are zero. It thus suggests that an unbalanced (external) force is required to change the motion of the marble but no net force is needed to sustain the uniform motion of the marble. In practical situations it is difficult to achieve a zero unbalanced force. This is because of the presence of the frictional force acting opposite to the direction of motion. Thus, in practice the marble stops after travelling some distance. The effect of the frictional force may be minimised by using a smooth marble and a smooth plane and providing a lubricant on top of the planes.

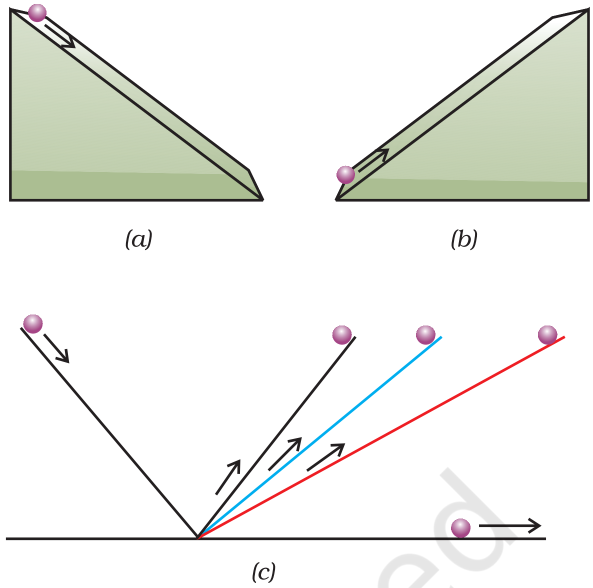


Fig. 8.5: *(a) the downward motion; (b) the upward motion of a marble on an inclined plane; and (c) on a double inclined plane.*

Newton further studied Galileo's ideas on force and motion and presented three fundamental laws that govern the motion of objects. These three laws are known as Newton's laws of motion. The first law of motion is stated as:

An object remains in a state of rest or of uniform motion in a straight line unless compelled to change that state by an applied force.

In other words, all objects resist a change in their *state of motion*. In a qualitative way, the tendency of undisturbed objects to stay at rest or to keep moving with the same velocity is called inertia. This is why, the first law of motion is also known as the law of inertia.

Certain experiences that we come across while travelling in a motorcar can be explained on the basis of the law of inertia. We tend to remain at rest with respect to the seat until the driver applies a braking force to stop the motorcar. With the application of brakes, the car slows down but our body tends to continue in the same state of motion because of its inertia. A sudden application of brakes may thus cause injury to us by impact

Galileo Galilei was born on 15 February 1564 in Pisa, Italy. Galileo, right from his childhood, had interest in mathematics and natural philosophy. But his father Vincenzo Galilei wanted him to become a medical doctor. Accordingly, Galileo enrolled himself for a medical degree at the University of Pisa in 1581 which he never completed because of his real interest in mathematics. In 1586, he wrote his first scientific book *'The Little Balance* [*La Balancitta*]', in which he described Archimedes' method of finding the relative densities (or specific gravities) of substances using a balance. In 1589, in his series of essays – *De Motu*, he presented his theories about falling objects using an inclined plane to slow down the rate of descent.

Galileo Galilei (1564 – 1642)

In 1592, he was appointed professor of mathematics at the University of Padua in the Republic of Venice. Here he continued his observations on the theory of motion and through his study of inclined planes and the pendulum, formulated the correct law for uniformly accelerated objects that the distance the object moves is proportional to the square of the time taken.

Galileo was also a remarkable craftsman. He developed a series of telescopes whose optical performance was much better than that of other telescopes available during those days. Around 1640, he designed the first pendulum clock. In his book *'Starry Messenger'* on his astronomical discoveries, Galileo claimed to have seen mountains on the moon, the milky way made up of tiny stars, and four small bodies orbiting Jupiter. In his books *'Discourse on Floating Bodies'* and *'Letters on the Sunspots'*, he disclosed his observations of sunspots.

Using his own telescopes and through his observations on Saturn and Venus, Galileo argued that all the planets must orbit the Sun and not the earth, contrary to what was believed at that time.

or collision with the panels in front. Safety belts are worn to prevent such accidents. Safety belts exert a force on our body to make the forward motion slower. An opposite experience is encountered when we are standing in a bus and the bus begins to move suddenly. Now we tend to fall backwards. This is because the sudden start of the bus brings motion to the bus as well as to our feet in contact with the floor of the bus. But the rest of our body opposes this motion because of its inertia.

When a motorcar makes a sharp turn at a high speed, we tend to get thrown to one side. This can again be explained on the basis of the law of inertia. We tend to continue in our straight-line motion. When an unbalanced force is applied by the engine to change the direction of motion of the motorcar, we slip to one side of the seat due to the inertia of our body.

The fact that a body will remain at rest unless acted upon by an unbalanced force can be illustrated through the following activities:

Activity 8.1

- Make a pile of similar carom coins on a table, as shown in Fig. 8.6.
- Attempt a sharp horizontal hit at the bottom of the pile using another carom coin or the striker. If the hit is strong enough, the bottom coin moves out quickly. Once the lowest coin is removed, the inertia of the other coins makes them 'fall' vertically on the table.

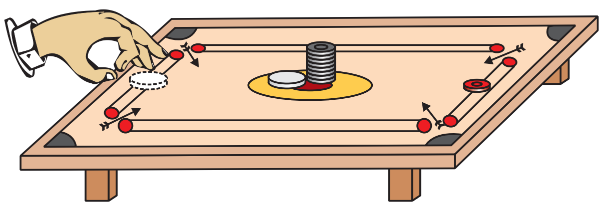


Fig. 8.6: *Only the carom coin at the bottom of a pile is removed when a fast moving carom coin (or striker) hits it.*

Activity 8.2

- Set a five-rupee coin on a stiff card covering an empty glass tumbler standing on a table as shown in Fig. 8.7.
- Give the card a sharp horizontal flick with a finger. If we do it fast then the card shoots away, allowing the coin to fall vertically into the glass tumbler due to its inertia.
- The inertia of the coin tries to maintain its state of rest even when the card flows off.

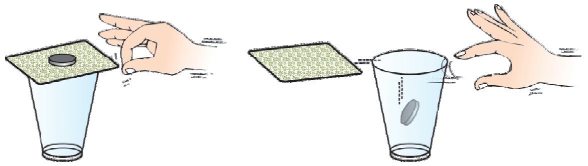


Fig. 8.7: When the card is flicked with the finger the coin placed over it falls in the tumbler.

Activity 8.3

- Place a water-filled tumbler on a tray.
- Hold the tray and turn around as fast as you can.
- We observe that the water spills. Why?

Observe that a groove is provided in a saucer for placing the tea cup. It prevents the cup from toppling over in case of sudden jerks.

8.3 Inertia and Mass

All the examples and activities given so far illustrate that there is a resistance offered by an object to change its state of motion. If it is at rest it tends to remain at rest; if it is moving it tends to keep moving. This property of an object is called its inertia. Do all bodies have the same inertia? We know that it is easier to push an empty box than a box full of books. Similarly, if we kick a football it flies away. But if we kick a stone of the same size with equal force, it hardly moves. We may, in fact, get an injury in our foot while doing so! Similarly, in activity 8.2, instead of a five-rupees coin if we use a one-rupee coin, we find that a lesser force is required to perform the activity. A force that is just enough to cause a small cart to pick up a large velocity will produce a negligible change in the motion of a train. This is because, in comparison to the cart the train has a much lesser tendency to change its state of motion. Accordingly, we say that the train has more inertia than the cart. Clearly, heavier or more massive objects offer larger inertia. Quantitatively, the inertia of an object is measured by its mass. We may thus relate inertia and mass as follows:
Inertia is the natural tendency of an object to resist a change in its state of motion or of rest. The mass of an object is a measure of its inertia.

Questions

1. *Which of the following has more inertia: (a) a rubber ball and a stone of the same size? (b) a bicycle and a train? (c) a five-rupees coin and a one-rupee coin?*
2. *In the following example, try to identify the number of times the velocity of the ball changes:*
   "A football player kicks a football to another player of his team who kicks the football towards the goal. The goalkeeper of the opposite team collects the football and kicks it towards a player of his own team".
   Also identify the agent supplying the force in each case.
3. *Explain why some of the leaves may get detached from a tree if we vigorously shake its branch.*
4. *Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest?*

8.4 Second Law of Motion

The first law of motion indicates that when an unbalanced external force acts on an object,

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its velocity changes, that is, the object gets an acceleration. We would now like to study how the acceleration of an object depends on the force applied to it and how we measure a force. Let us recount some observations from our everyday life. During the game of table tennis if the ball hits a player it does not hurt him. On the other hand, when a fast moving cricket ball hits a spectator, it may hurt him. A truck at rest does not require any attention when parked along a roadside. But a moving truck, even at speeds as low as 5 m s^{-1}, may kill a person standing in its path. A small mass, such as a bullet may kill a person when fired from a gun. These observations suggest that the impact produced by the objects depends on their mass and velocity. Similarly, if an object is to be accelerated, we know that a greater force is required to give a greater velocity. In other words, there appears to exist some quantity of importance that combines the object's mass and its velocity. One such property called momentum was introduced by Newton. The momentum, p of an object is defined as the product of its mass, m and velocity, v. That is,

$$p = mv \tag{8.1}$$

Momentum has both direction and magnitude. Its direction is the same as that of velocity, v. The SI unit of momentum is kilogram-metre per second (kg m s^{-1}). Since the application of an unbalanced force brings a change in the velocity of the object, it is therefore clear that a force also produces a change of momentum.

Let us consider a situation in which a car with a dead battery is to be pushed along a straight road to give it a speed of 1 m s^{-1}, which is sufficient to start its engine. If one or two persons give a sudden push (unbalanced force) to it, it hardly starts. But a continuous push over some time results in a gradual acceleration of the car to this speed. It means that the change of momentum of the car is not only determined by the magnitude of the force but also by the time during which the force is exerted. It may then also be concluded that the force necessary to change the momentum of an object depends on the time rate at which the momentum is changed.

The second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of force.

8.4.1 Mathematical formulation of second law of motion

Suppose an object of mass, m is moving along a straight line with an initial velocity, u. It is uniformly accelerated to velocity, v in time, t by the application of a constant force, F throughout the time, t. The initial and final momentum of the object will be, $p_1 = mu$ and $p_2 = mv$ respectively.

The change in momentum $\propto p_2 - p_1$

$\propto mv - mu$

$\propto m \times (v - u)$.

The rate of change of momentum $\propto \dfrac{m \times (v-u)}{t}$

Or, the applied force,

$$F \propto \frac{m \times (v-u)}{t}$$

$$F = \frac{km \times (v-u)}{t} \tag{8.2}$$

$$= k\,m\,a \tag{8.3}$$

Here $a \propto = [(v - u)/t]$ is the acceleration, which is the rate of change of velocity. The quantity, k is a constant of proportionality. The SI units of mass and acceleration are kg and m s^{-2} respectively. The unit of force is so chosen that the value of the constant, k becomes one. For this, one unit of force is defined as the amount that produces an acceleration of 1 m s^{-2} in an object of 1 kg mass. That is,

$$1 \text{ unit of force} = k \times (1 \text{ kg}) \times (1 \text{ m s}^{-2}).$$

Thus, the value of k becomes 1. From Eq. (8.3)

$$F = ma \tag{8.4}$$

The unit of force is kg m s^{-2} or newton, which has the symbol N. The second law of motion gives us a method to measure the force acting on an object as a product of its mass and acceleration.

The second law of motion is often seen in action in our everyday life. Have you noticed that while catching a fast moving cricket ball, a fielder in the ground gradually pulls his hands backwards with the moving ball? In doing so, the fielder increases the time during which the high velocity of the moving ball decreases to zero. Thus, the acceleration of the ball is decreased and therefore the impact of catching the fast moving ball (Fig. 8.8) is also reduced. If the ball is stopped suddenly then its high velocity decreases to zero in a very short interval of time. Thus, the rate of change of momentum of the ball will be large. Therefore, a large force would have to be applied for holding the catch that may hurt the palm of the fielder. In a high jump athletic event, the athletes are made to fall either on a cushioned bed or on a sand bed. This is to increase the time of the athlete's fall to stop after making the jump. This decreases the rate of change of momentum and hence the force. Try to ponder how a karate player breaks a slab of ice with a single blow.

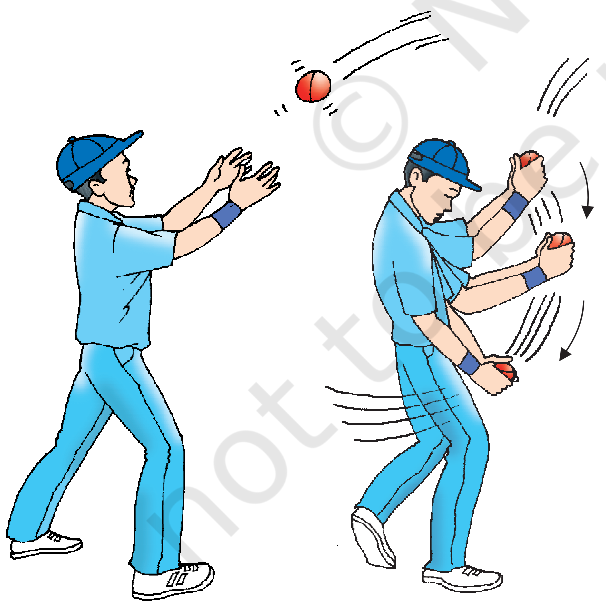

Fig. 8.8: A fielder pulls his hands gradually with the moving ball while holding a catch.

The first law of motion can be mathematically stated from the mathematical expression for the second law of motion. Eq. (8.4) is

$$F = ma$$

$$\text{or} \quad F = \frac{m(v-u)}{t} \tag{8.5}$$

$$\text{or} \quad Ft = mv - mu$$

That is, when $F = 0$, $v = u$ for whatever time, t is taken. This means that the object will continue moving with uniform velocity, u throughout the time, t. If u is zero then v will also be zero. That is, the object will remain at rest.

Example 8.1 A constant force acts on an object of mass 5 kg for a duration of 2 s. It increases the object's velocity from 3 m s^{-1} to 7 m s^{-1}. Find the magnitude of the applied force. Now, if the force was applied for a duration of 5 s, what would be the final velocity of the object?

Solution:

We have been given that u = 3 m s^{-1} and v = 7 m s^{-1}, t = 2 s and m = 5 kg. From Eq. (8.5) we have,

$$F = \frac{m(v-u)}{t}$$

Substitution of values in this relation gives

F = 5 kg (7 m s^{-1} – 3 m s^{-1})/2 s = 10 N.

Now, if this force is applied for a duration of 5 s (t = 5 s), then the final velocity can be calculated by rewriting Eq. (8.5) as

$$v = u + \frac{Ft}{m}$$

On substituting the values of u, F, m and t, we get the final velocity,

v = 13 m s^{-1}.

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Example 8.2 Which would require a greater force — accelerating a 2 kg mass at 5 m s^{-2} or a 4 kg mass at 2 m s^{-2}?

Solution:

From Eq. (8.4), we have $F = ma$.
Here we have m_1 = 2 kg; a_1 = 5 m s^{-2} and m_2 = 4 kg; a_2 = 2 m s^{-2}.
Thus, $F_1 = m_1a_1$ = 2 kg × 5 m s^{-2} = 10 N;
and $F_2 = m_2a_2$ = 4 kg × 2 m s^{-2} = 8 N.
$\Rightarrow F_1 > F_2$.
Thus, accelerating a 2 kg mass at 5 m s^{-2} would require a greater force.

Example 8.3 A motorcar is moving with a velocity of 108 km/h and it takes 4 s to stop after the brakes are applied. Calculate the force exerted by the brakes on the motorcar if its mass along with the passengers is 1000 kg.

Solution:

The initial velocity of the motorcar
u = 108 km/h
= 108 × 1000 m/(60 × 60 s)
= 30 m s^{-1}
and the final velocity of the motorcar
v = 0 m s^{-1}.
The total mass of the motorcar along with its passengers = 1000 kg and the time taken to stop the motorcar, t = 4 s.
From Eq. (8.5) we have the magnitude of the force (F) applied by the brakes as $m(v – u)/t$.
On substituting the values, we get
F = 1000 kg × (0 – 30) m s^{-1}/4 s
= – 7500 kg m s^{-2} or – 7500 N.
The negative sign tells us that the force exerted by the brakes is opposite to the direction of motion of the motorcar.

Example 8.4 A force of 5 N gives a mass m_1, an acceleration of 10 m s^{-2} and a mass m_2, an acceleration of 20 m s^{-2}. What acceleration would it give if both the masses were tied together?

Solution:

From Eq. (8.4) we have $m_1 = F/a_1$; and $m_2 = F/a_2$. Here, a_1 = 10 m s^{-2};
a_2 = 20 m s^{-2} and F = 5 N.
Thus, m_1 = 5 N/10 m s^{-2} = 0.50 kg; and m_2 = 5 N/20 m s^{-2} = 0.25 kg.
If the two masses were tied together, the total mass, m would be
m = 0.50 kg + 0.25 kg = 0.75 kg.
The acceleration, a produced in the combined mass by the 5 N force would be, $a = F/m$ = 5 N/0.75 kg = 6.67 m s^{-2}.

Example 8.5 The velocity-time graph of a ball of mass 20 g moving along a straight line on a long table is given in Fig. 8.9.

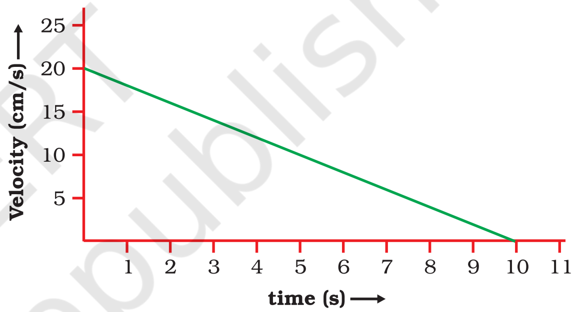

Fig. 8.9

How much force does the table exert on the ball to bring it to rest?

Solution:

The initial velocity of the ball is 20 cm s^{-1}. Due to the frictional force exerted by the table, the velocity of the ball decreases down to zero in 10 s. Thus, u = 20 cm s^{-1}; v = 0 cm s^{-1} and t = 10 s. Since the velocity-time graph is a straight line, it is clear that the ball moves with a constant acceleration. The acceleration a is

$$a = \frac{v - u}{t}$$

= (0 cm s^{-1} – 20 cm s^{-1})/10 s
= –2 cm s^{-2} = –0.02 m s^{-2}.

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The force exerted on the ball F is,

$F = ma = (20/1000)$ kg × (– 0.02 m s^{-2})
 = – 0.0004 N.

The negative sign implies that the frictional force exerted by the table is opposite to the direction of motion of the ball.

8.5 Third Law of Motion

The first two laws of motion tell us how an applied force changes the motion and provide us with a method of determining the force. The third law of motion states that when one object exerts a force on another object, the second object instantaneously exerts a force back on the first. These two forces are always equal in magnitude but opposite in direction. These forces act on different objects and never on the same object. In the game of football sometimes we, while looking at the football and trying to kick it with a greater force, collide with a player of the opposite team. Both feel hurt because each applies a force to the other. In other words, there is a pair of forces and not just one force. The two opposing forces are also known as action and reaction forces.

Let us consider two spring balances connected together as shown in Fig. 8.10. The fixed end of balance B is attached with a rigid support, like a wall. When a force is applied through the free end of spring balance A, it is observed that both the spring balances show the same readings on their scales. It means that the force exerted by spring balance A on balance B is equal but opposite in direction to the force exerted by the balance B on balance A. Any of these two forces can be called as *action* and the other as *reaction*. This gives us an alternative statement of the third law of motion i.e., to every action there is an equal and opposite reaction. However, it must be remembered that the action and reaction always act on two different objects, simultaneously.

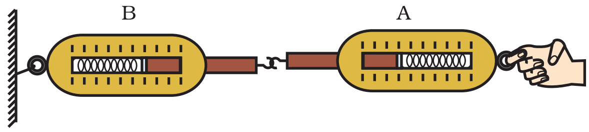

Fig. 8.10: Action and reaction forces are equal and opposite.

Suppose you are standing at rest and intend to start walking on a road. You must accelerate, and this requires a force in accordance with the second law of motion. Which is this force? Is it the muscular effort you exert on the road? Is it in the direction we intend to move? No, you push the road below backwards. The road exerts an equal and opposite force on your feet to make you move forward.

It is important to note that even though the action and reaction forces are always equal in magnitude, these forces may not produce accelerations of equal magnitudes. This is because each force acts on a different object that may have a different mass.

When a gun is fired, it exerts a forward force on the bullet. The bullet exerts an equal and opposite force on the gun. This results in the recoil of the gun (Fig. 8.11). Since the gun has a much greater mass than the bullet, the acceleration of the gun is much less than the acceleration of the bullet. The third law of motion can also be illustrated when a sailor jumps out of a rowing boat. As the sailor jumps forward, the force on the boat moves it backwards (Fig. 8.12).

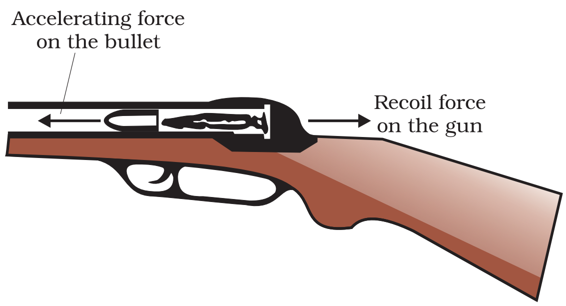

Fig. 8.11: A forward force on the bullet and recoil of the gun.

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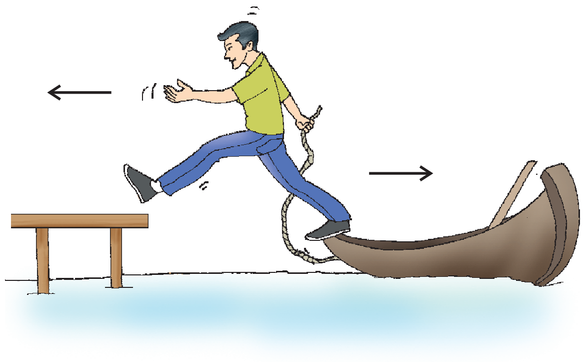

Fig. 8.12: As the sailor jumps in forward direction, the boat moves backwards.

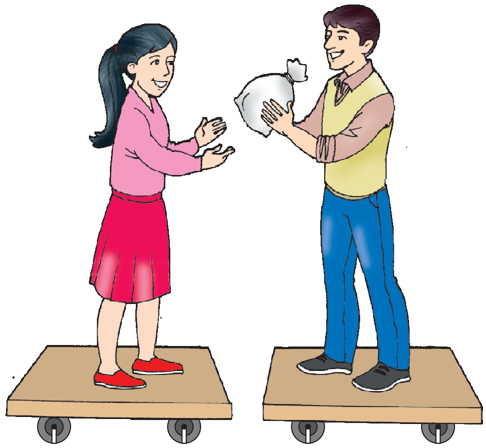

Fig. 8.13

Activity 8.4

- Request two children to stand on two separate carts as shown in Fig. 8.13.
- Give them a bag full of sand or some other heavy object. Ask them to play a game of catch with the bag.
- Does each of them experience an instantaneous force as a result of throwing the sand bag?
- You can paint a white line on cartwheels to observe the motion of the two carts when the children throw the bag towards each other.

Now, place two children on one cart and one on another cart. The second law of motion can be seen, as this arrangement would show different accelerations for the same force.

The cart shown in this activity can be constructed by using a 12 mm or 18 mm thick plywood board of about 50 cm × 100 cm with two pairs of hard ball-bearing wheels (skate wheels are good to use). Skateboards are not as effective because it is difficult to maintain straight-line motion.

What you have learnt

- First law of motion: An object continues to be in a state of rest or of uniform motion along a straight line unless acted upon by an unbalanced force.
- The natural tendency of objects to resist a change in their state of rest or of uniform motion is called inertia.
- The mass of an object is a measure of its inertia. Its SI unit is kilogram (kg).
- Force of friction always opposes motion of objects.
- Second law of motion: The rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of the force.

- The SI unit of force is kg m s^{-2}. This is also known as newton and represented by the symbol N. A force of one newton produces an acceleration of 1 m s^{-2} on an object of mass 1 kg.
- The momentum of an object is the product of its mass and velocity and has the same direction as that of the velocity. Its SI unit is kg m s^{-1}.
- Third law of motion: To every action, there is an equal and opposite reaction and they act on two different bodies.

Exercises

1. An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling with a non-zero velocity? If yes, state the conditions that must be placed on
2. When a carpet is beaten with a stick, dust comes out of it, Explain.
3. Why is it advised to tie any luggage kept on the roof of a bus with a rope?
4. A batsman hits a cricket ball which then rolls on a level ground. After covering a short distance, the ball comes to rest. The ball slows to a stop because
   (a) the batsman did not hit the ball hard enough.
   (b) velocity is proportional to the force exerted on the ball.
   (c) there is a force on the ball opposing the motion.
   (d) there is no unbalanced force on the ball, so the ball would want to come to rest.
5. A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 tonnes (*Hint*: 1 tonne = 1000 kg.)
6. A stone of 1 kg is thrown with a velocity of 20 m s^{-1} across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?
7. A 8000 kg engine pulls a train of 5 wagons, each of 2000 kg, along a horizontal track. If the engine exerts a force of 40000 N and the track offers a friction force of 5000 N, then calculate:
   (a) the net accelerating force and
   (b) the acceleration of the train.
8. An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be

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stopped with a negative acceleration of 1.7 m s^{-2}?

9. What is the momentum of an object of mass *m*, moving with a velocity *v*?

   (a) $(mv)^2$ (b) mv^2 (c) ½ mv^2 (d) mv

10. Using a horizontal force of 200 N, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet?

11. According to the third law of motion when we push on an object, the object pushes back on us with an equal and opposite force. If the object is a massive truck parked along the roadside, it will probably not move. A student justifies this by answering that the two opposite and equal forces cancel each other. Comment on this logic and explain why the truck does not move.

12. A hockey ball of mass 200 g travelling at 10 m s^{-1} is struck by a hockey stick so as to return it along its original path with a velocity at 5 m s^{-1}. Calculate the magnitude of change of momentum occurred in the motion of the hockey ball by the force applied by the hockey stick.

13. A bullet of mass 10 g travelling horizontally with a velocity of 150 m s^{-1} strikes a stationary wooden block and comes to rest in 0.03 s. Calculate the distance of penetration of the bullet into the block. Also calculate the magnitude of the force exerted by the wooden block on the bullet.

14. An object of mass 1 kg travelling in a straight line with a velocity of 10 m s^{-1} collides with, and sticks to, a stationary wooden block of mass 5 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.

15. An object of mass 100 kg is accelerated uniformly from a velocity of 5 m s^{-1} to 8 m s^{-1} in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

16. Akhtar, Kiran and Rahul were riding in a motorcar that was moving with a high velocity on an expressway when an insect hit the windshield and got stuck on the windscreen. Akhtar and Kiran started pondering over the situation. Kiran suggested that the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar (because the change in the velocity of the insect was much more than that of the motorcar). Akhtar said that since the motorcar was moving with a larger velocity, it exerted a larger force on the insect. And as a result the insect died. Rahul while putting an entirely new explanation

said that both the motorcar and the insect experienced the same force and a change in their momentum. Comment on these suggestions.

17. How much momentum will a dumb-bell of mass 10 kg transfer to the floor if it falls from a height of 80 cm? Take its downward acceleration to be 10 m s^{-2}.

Additional Exercises

A1. The following is the distance-time table of an object in motion:

Time in seconds	Distance in metres
0	0
1	1
2	8
3	27
4	64
5	125
6	216
7	343

(a) What conclusion can you draw about the acceleration? Is it constant, increasing, decreasing, or zero?

(b) What do you infer about the forces acting on the object?

A2. Two persons manage to push a motorcar of mass 1200 kg at a uniform velocity along a level road. The same motorcar can be pushed by three persons to produce an acceleration of 0.2 m s^{-2}. With what force does each person push the motorcar? (Assume that all persons push the motorcar with the same muscular effort.)

A3. A hammer of mass 500 g, moving at 50 m s^{-1}, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. What is the force of the nail on the hammer?

A4. A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4 s by an unbalanced external force. Calculate the acceleration and change in momentum. Also calculate the magnitude of the force required.

Chapter 9

GRAVITATION

We have learnt about the motion of objects and force as the cause of motion. We have learnt that a force is needed to change the speed or the direction of motion of an object. We always observe that an object dropped from a height falls towards the earth. We know that all the planets go around the Sun. The moon goes around the earth. In all these cases, there must be some force acting on the objects, the planets and on the moon. Isaac Newton could grasp that the same force is responsible for all these. This force is called the gravitational force.

In this chapter we shall learn about gravitation and the universal law of gravitation. We shall discuss the motion of objects under the influence of gravitational force on the earth. We shall study how the weight of a body varies from place to place. We shall also discuss the conditions for objects to float in liquids.

9.1 Gravitation

We know that the moon goes around the earth. An object when thrown upwards, reaches a certain height and then falls downwards. It is said that when Newton was sitting under a tree, an apple fell on him. The fall of the apple made Newton start thinking. He thought that: if the earth can attract an apple, can it not attract the moon? Is the force the same in both cases? He conjectured that the same type of force is responsible in both the cases. He argued that at each point of its orbit, the moon falls towards the earth, instead of going off in a straight line. So, it must be attracted by the earth. But we do not really see the moon falling towards the earth.

Let us try to understand the motion of the moon by recalling activity 7.11.

Activity 9.1

- Take a piece of thread.
- Tie a small stone at one end. Hold the other end of the thread and whirl it round, as shown in Fig. 9.1.
- Note the motion of the stone.
- Release the thread.
- Again, note the direction of motion of the stone.

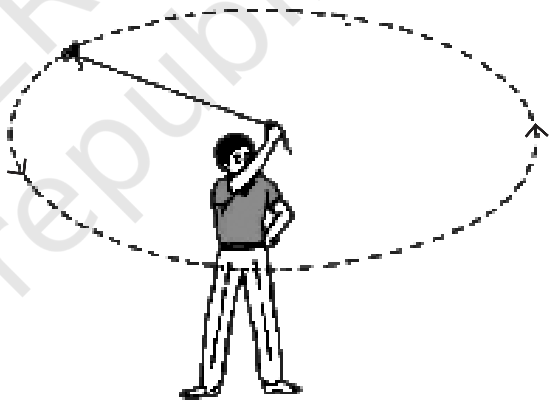


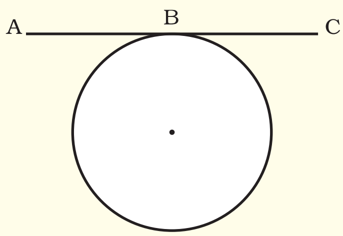
Fig. 9.1: A stone describing a circular path with a velocity of constant magnitude.

Before the thread is released, the stone moves in a circular path with a certain speed and changes direction at every point. The change in direction involves change in velocity or acceleration. The force that causes this acceleration and keeps the body moving along the circular path is acting towards the centre. This force is called the centripetal (meaning 'centre-seeking') force.

In the absence of this force, the stone flies off along a straight line. This straight line will be a tangent to the circular path.

More to know

Tangent to a circle



A straight line that meets the circle at one and only one point is called a tangent to the circle. Straight line ABC is a tangent to the circle at point B.

The motion of the moon around the earth is due to the centripetal force. The centripetal force is provided by the force of attraction of the earth. If there were no such force, the moon would pursue a uniform straight line motion.

It is seen that a falling apple is attracted towards the earth. Does the apple attract the earth? If so, we do not see the earth moving towards an apple. Why?

According to the third law of motion, the apple does attract the earth. But according to the second law of motion, for a given force, acceleration is inversely proportional to the mass of an object [Eq. (8.4)]. The mass of an apple is negligibly small compared to that of the earth. So, we do not see the earth moving towards the apple. Extend the same argument for why the earth does not move towards the moon.

In our solar system, all the planets go around the Sun. By arguing the same way, we can say that there exists a force between the Sun and the planets. From the above facts Newton concluded that not only does the earth attract an apple and the moon, but all objects in the universe attract each other. This force of attraction between objects is called the gravitational force.

9.1.1 Universal law of gravitation

Every object in the universe attracts every other object with a force which is proportional to the product of their masses and inversely proportional to the square of the distance between them. The force is along the line joining the centres of two objects.

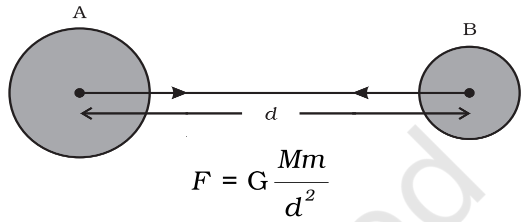


Fig. 9.2: *The gravitational force between two uniform objects is directed along the line joining their centres.*

Let two objects A and B of masses M and m lie at a distance d from each other as shown in Fig. 9.2. Let the force of attraction between two objects be F. According to the universal law of gravitation, the force between two objects is directly proportional to the product of their masses. That is,

$$F \propto M \times m \qquad (9.1)$$

And the force between two objects is inversely proportional to the square of the distance between them, that is,

$$F \propto \frac{1}{d^2} \qquad (9.2)$$

Combining Eqs. (10.1) and (10.2), we get

$$F \propto \frac{M \times m}{d^2} \qquad (9.3)$$

or, $$F = G\,\frac{M \times m}{d^2} \qquad (9.4)$$

where G is the constant of proportionality and is called the universal gravitation constant. By multiplying crosswise, Eq. (9.4) gives

$$F \times d^2 = G\,M \times m$$

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or $$G = \frac{F d^2}{M \times m} \qquad (9.5)$$

The SI unit of G can be obtained by substituting the units of force, distance and mass in Eq. (9.5) as N m^2 kg^{-2}.

The value of G was found out by Henry Cavendish (1731 – 1810) by using a sensitive balance. The accepted value of G is 6.673×10^{-11} N m^2 kg^{-2}.

We know that there exists a force of attraction between any two objects. Compute the value of this force between you and your friend sitting closeby. Conclude how you do not experience this force!

More to know

The law is universal in the sense that it is applicable to all bodies, whether the bodies are big or small, whether they are celestial or terrestrial.

Inverse-square

Saying that F is inversely proportional to the square of d means, for example, that if d gets bigger by a factor of 6, F becomes $\frac{1}{36}$ times smaller.

Example 9.1 The mass of the earth is 6×10^{24} kg and that of the moon is 7.4×10^{22} kg. If the distance between the earth and the moon is 3.84×10^5 km, calculate the force exerted by the earth on the moon. (Take $G = 6.7 \times 10^{-11}$ N m^2 kg^{-2})

Solution:

The mass of the earth, $M = 6 \times 10^{24}$ kg

The mass of the moon,

$m = 7.4 \times 10^{22}$ kg

The distance between the earth and the moon,

$$\begin{aligned} d &= 3.84 \times 10^5 \text{ km} \\ &= 3.84 \times 10^5 \times 1000 \text{ m} \\ &= 3.84 \times 10^8 \text{ m} \\ G &= 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \end{aligned}$$

From Eq. (9.4), the force exerted by the earth on the moon is

$$F = G\frac{M \times m}{d^2}$$

$$= \frac{6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \times 6 \times 10^{24} \text{ kg} \times 7.4 \times 10^{22} \text{ kg}}{(3.84 \times 10^8 \text{ m})^2}$$

$= 2.02 \times 10^{20}$ N.

Thus, the force exerted by the earth on the moon is 2.02×10^{20} N.

Questions

1. *State the universal law of gravitation.*
2. *Write the formula to find the magnitude of the gravitational force between the earth and an object on the surface of the earth.*

9.1.2 Importance of the universal law of gravitation

The universal law of gravitation successfully explained several phenomena which were believed to be unconnected:

(i) the force that binds us to the earth;

(ii) the motion of the moon around the earth;

(iii) the motion of planets around the Sun; and

(iv) the tides due to the moon and the Sun.

9.2 Free Fall

Let us try to understand the meaning of free fall by performing this activity.

Activity 9.2

- Take a stone.
- Throw it upwards.
- It reaches a certain height and then it starts falling down.

We have learnt that the earth attracts objects towards it. This is due to the gravitational force. Whenever objects fall towards the earth under this force alone, we say that the objects are in free fall. Is there any

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change in the velocity of falling objects? While falling, there is no change in the direction of motion of the objects. But due to the earth's attraction, there will be a change in the magnitude of the velocity. Any change in velocity involves acceleration. Whenever an object falls towards the earth, an acceleration is involved. This acceleration is due to the earth's gravitational force. Therefore, this acceleration is called the acceleration due to the gravitational force of the earth (or acceleration due to gravity). It is denoted by g. The unit of g is the same as that of acceleration, that is, m s^{-2}.

We know from the second law of motion that force is the product of mass and acceleration. Let the mass of the stone in activity 9.2 be m. We already know that there is acceleration involved in falling objects due to the gravitational force and is denoted by g. Therefore the magnitude of the gravitational force F will be equal to the product of mass and acceleration due to the gravitational force, that is,

$$F = m\,g \tag{9.6}$$

From Eqs. (9.4) and (9.6) we have

$$m\,g = G\,\frac{M \times m}{d^2}$$

or $$g = G\,\frac{M}{d^2} \tag{9.7}$$

where M is the mass of the earth, and d is the distance between the object and the earth.

Let an object be on or near the surface of the earth. The distance d in Eq. (9.7) will be equal to R, the radius of the earth. Thus, for objects on or near the surface of the earth,

$$mg = G\,\frac{M \times m}{R^2} \tag{9.8}$$

$$g = G\,\frac{M}{R^2} \tag{9.9}$$

The earth is not a perfect sphere. As the radius of the earth increases from the poles to the equator, the value of g becomes greater at the poles than at the equator. For most calculations, we can take g to be more or less constant on or near the earth. But for objects far from the earth, the acceleration due to gravitational force of earth is given by Eq. (9.7).

9.2.1 To calculate the value of g

To calculate the value of g, we should put the values of G, M and R in Eq. (9.9), namely, universal gravitational constant, $G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}, mass of the earth, $M = 6 \times 10^{24}$ kg, and radius of the earth, $R = 6.4 \times 10^6$ m.

$$g = G\,\frac{M}{R^2}$$

$$= \frac{6.7 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2} \times 6 \times 10^{24}\ \text{kg}}{(6.4 \times 10^6\ \text{m})^2}$$

$$= 9.8\ \text{m s}^{-2}.$$

Thus, the value of acceleration due to gravity of the earth, $g = 9.8$ m s^{-2}.

9.2.2 Motion of objects under the influence of gravitational force of the earth

Let us do an activity to understand whether all objects hollow or solid, big or small, will fall from a height at the same rate.

Activity 9.3

- Take a sheet of paper and a stone. Drop them simultaneously from the first floor of a building. Observe whether both of them reach the ground simultaneously.
- We see that paper reaches the ground little later than the stone. This happens because of air resistance. The air offers resistance due to friction to the motion of the falling objects. The resistance offered by air to the paper is more than the resistance offered to the stone. If we do the experiment in a glass jar from which air has been sucked out, the paper and the stone would fall at the same rate.

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We know that an object experiences acceleration during free fall. From Eq. (9.9), this acceleration experienced by an object is independent of its mass. This means that all objects hollow or solid, big or small, should fall at the same rate. According to a story, Galileo dropped different objects from the top of the Leaning Tower of Pisa in Italy to prove the same.

As g is constant near the earth, all the equations for the uniformly accelerated motion of objects become valid with acceleration a replaced by g. The equations are:

$$v = u + at \qquad (9.10)$$

$$s = ut + \frac{1}{2}at^2 \qquad (9.11)$$

$$v^2 = u^2 + 2as \qquad (9.12)$$

where u and v are the initial and final velocities and s is the distance covered in time, t.

In applying these equations, we will take acceleration, a to be positive when it is in the direction of the velocity, that is, in the direction of motion. The acceleration, a will be taken as negative when it opposes the motion.

Example 9.2 A car falls off a ledge and drops to the ground in 0.5 s. Let g = 10 m s^{-2} (for simplifying the calculations).

(i) What is its speed on striking the ground?

(ii) What is its average speed during the 0.5 s?

(iii) How high is the ledge from the ground?

Solution:

Time, t = ½ second

Initial velocity, u = 0 m s^{-1}

Acceleration due to gravity, g = 10 m s^{-2}

Acceleration of the car, a = + 10 m s^{-2} (downward)

(i) speed $v = a\,t$

v = 10 m s^{-2} × 0.5 s

= 5 m s^{-1}

(ii) average speed $= \dfrac{u+v}{2}$

= (0 m s^{-1} + 5 m s^{-1})/2

= 2.5 m s^{-1}

(iii) distance travelled, $s = ½\,a\,t^2$

= ½ × 10 m s^{-2} × $(0.5\ s)^2$

= ½ × 10 m s^{-2} × 0.25 s^2

= 1.25 m

Thus,

(i) its speed on striking the ground = 5 m s^{-1}

(ii) its average speed during the 0.5 s = 2.5 m s^{-1}

(iii) height of the ledge from the ground = 1.25 m.

Example 9.3 An object is thrown vertically upwards and rises to a height of 10 m. Calculate (i) the velocity with which the object was thrown upwards and (ii) the time taken by the object to reach the highest point.

Solution:

Distance travelled, s = 10 m

Final velocity, v = 0 m s^{-1}

Acceleration due to gravity, g = 9.8 m s^{-2}

Acceleration of the object, a = –9.8 m s^{-2} (upward motion)

(i) $v^2 = u^2 + 2a\,s$

$0 = u^2 + 2 \times (-9.8\ \text{m s}^{-2}) \times 10\ \text{m}$

$-u^2 = -2 \times 9.8 \times 10\ \text{m}^2\,\text{s}^{-2}$

$u = \sqrt{196}\ \text{m s}^{-1}$

$u = 14\ \text{m s}^{-1}$

(ii) $v = u + a\,t$

$0 = 14\ \text{m s}^{-1} - 9.8\ \text{m s}^{-2} \times t$

$t = 1.43$ s.

Thus,

(i) Initial velocity, u = 14 m s^{-1}, and

(ii) Time taken, t = 1.43 s.

Questions

1. *What do you mean by free fall?*
2. *What do you mean by acceleration due to gravity?*

9.3 Mass

We have learnt in the previous chapter that the mass of an object is the measure of its inertia . We have also learnt that greater the mass, the greater is the inertia. It remains the same whether the object is on the earth, the moon or even in outer space. Thus, the mass of an object is constant and does not change from place to place.

9.4 Weight

We know that the earth attracts every object with a certain force and this force depends on the mass (m) of the object and the acceleration due to the gravity (g). The weight of an object is the force with which it is attracted towards the earth.

We know that

$$F = m \times a, \tag{9.13}$$

that is,

$$F = m \times g. \tag{9.14}$$

The force of attraction of the earth on an object is known as the weight of the object. It is denoted by W. Substituting the same in Eq. (9.14), we have

$$W = m \times g \tag{9.15}$$

As the weight of an object is the force with which it is attracted towards the earth, the SI unit of weight is the same as that of force, that is, newton (N). The weight is a force acting vertically downwards; it has both magnitude and direction.

We have learnt that the value of g is constant at a given place. Therefore at a given place, the weight of an object is directly proportional to the mass, say m, of the object, that is, $W \propto m$. It is due to this reason that at a given place, we can use the weight of an object as a measure of its mass. The mass of an object remains the same everywhere, that is, on the earth and on any planet whereas its weight depends on its location because g depends on location.

9.4.1 Weight of an object on the moon

We have learnt that the weight of an object on the earth is the force with which the earth attracts the object. In the same way, the weight of an object on the moon is the force with which the moon attracts that object. The mass of the moon is less than that of the earth. Due to this the moon exerts lesser force of attraction on objects.

Let the mass of an object be m. Let its weight on the moon be W_m. Let the mass of the moon be M_m and its radius be R_m.

By applying the universal law of gravitation, the weight of the object on the moon will be

$$W_m = G\frac{M_m \times m}{R_m^2} \tag{9.16}$$

Let the weight of the same object on the earth be W_e. The mass of the earth is M and its radius is R.

Table 9.1

Celestial body	Mass (kg)	Radius (m)
Earth	5.98×10^{24}	6.37×10^{6}
Moon	7.36×10^{22}	1.74×10^{6}

From Eqs. (9.9) and (9.15) we have,

$$W_e = G\frac{M \times m}{R^2} \tag{9.17}$$

Substituting the values from Table 10.1 in Eqs. (9.16) and (9.17), we get

$$W_m = G\frac{7.36 \times 10^{22}\,\text{kg} \times m}{\left(1.74 \times 10^{6}\,\text{m}\right)^2}$$

$$W_m = 2.431 \times 10^{10}\,G \times m \tag{9.18a}$$

and $$W_e = 1.474 \times 10^{11}\,G \times m \tag{9.18b}$$

Dividing Eq. (9.18a) by Eq. (9.18b), we get

$$\frac{W_m}{W_e} = \frac{2.431 \times 10^{10}}{1.474 \times 10^{11}}$$

or $$\frac{W_m}{W_e} = 0.165 \approx \frac{1}{6} \tag{9.19}$$

$$\frac{\text{Weight of the object on the moon}}{\text{Weight of the object on the earth}} = \frac{1}{6}$$

Weight of the object on the moon

= $(1/6) \times$ its weight on the earth.

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Example 9.4 Mass of an object is 10 kg. What is its weight on the earth?

Solution:

Mass, m = 10 kg
Acceleration due to gravity, g = 9.8 m s^{-2}

$W = m \times g$

W = 10 kg × 9.8 m s^{-2} = 98 N

Thus, the weight of the object is 98 N.

Example 9.5 An object weighs 10 N when measured on the surface of the earth. What would be its weight when measured on the surface of the moon?

Solution:

We know,
Weight of object on the moon
= (1/6) × its weight on the earth.
That is,

$$W_m = \frac{W_e}{6} = \frac{10}{6} \text{ N.}$$

$$= 1.67 \text{ N.}$$

Thus, the weight of object on the surface of the moon would be 1.67 N.

Questions

1. *What are the differences between the mass of an object and its weight?*
2. *Why is the weight of an object on the moon $\frac{1}{6}^{th}$ its weight on the earth?*

9.5 Thrust and Pressure

Have you ever wondered why a camel can run in a desert easily? Why an army tank weighing more than a thousand tonne rests upon a continuous chain? Why a truck or a motorbus has much wider tyres? Why cutting tools have sharp edges? In order to address these questions and understand the phenomena involved, it helps to introduce the concepts of the net force in a particular direction (thrust) and the force per unit area (pressure) acting on the object concerned.

Let us try to understand the meanings of thrust and pressure by considering the following situations:

Situation 1: You wish to fix a poster on a bulletin board, as shown in Fig 9.3. To do this task you will have to press drawing pins with your thumb. You apply a force on the surface area of the head of the pin. This force is directed perpendicular to the surface area of the board. This force acts on a smaller area at the tip of the pin.

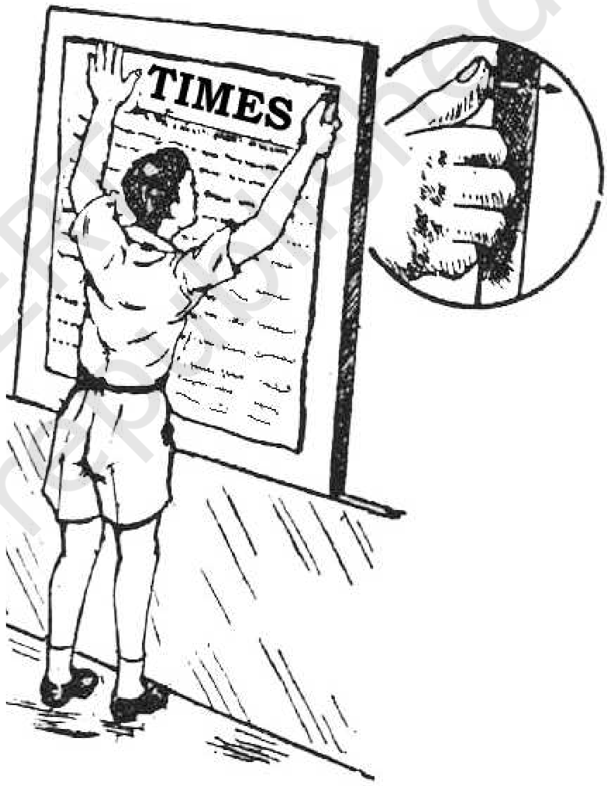

Fig. 9.3: To fix a poster, drawing pins are pressed with the thumb perpendicular to the board.

Situation 2: You stand on loose sand. Your feet go deep into the sand. Now, lie down on the sand. You will find that your body will not go that deep in the sand. In both cases the force exerted on the sand is the weight of your body.

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You have learnt that weight is the force acting vertically downwards. Here the force is acting perpendicular to the surface of the sand. The force acting on an object perpendicular to the surface is called thrust.

When you stand on loose sand, the force, that is, the weight of your body is acting on an area equal to area of your feet. When you lie down, the same force acts on an area equal to the contact area of your whole body, which is larger than the area of your feet. Thus, the effects of forces of the same magnitude on different areas are different. In the above cases, thrust is the same. But effects are different. Therefore the effect of thrust depends on the area on which it acts.

The effect of thrust on sand is larger while standing than while lying. The thrust on unit area is called pressure. Thus,

$$\text{Pressure} = \frac{\text{thrust}}{\text{area}} \tag{9.20}$$

Substituting the SI unit of thrust and area in Eq. (9.20), we get the SI unit of pressure as N/m^2 or N m^{-2}.

In honour of scientist Blaise Pascal, the SI unit of pressure is called pascal, denoted as Pa.

Let us consider a numerical example to understand the effects of thrust acting on different areas.

Example 9.6 A block of wood is kept on a tabletop. The mass of wooden block is 5 kg and its dimensions are 40 cm × 20 cm × 10 cm. Find the pressure exerted by the wooden block on the table top if it is made to lie on the table top with its sides of dimensions (a) 20 cm × 10 cm and (b) 40 cm × 20 cm.

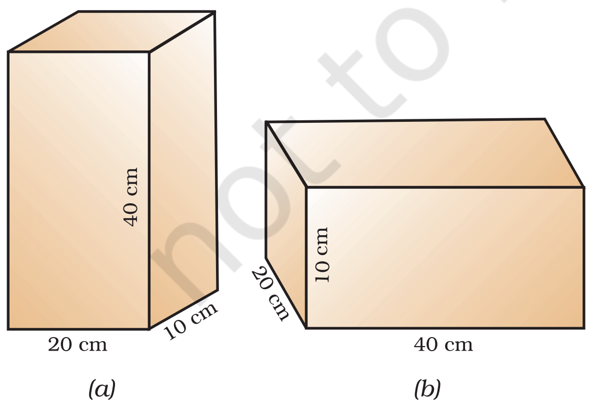

Fig. 9.4

Solution:

The mass of the wooden block = 5 kg

The dimensions

= 40 cm × 20 cm × 10 cm

Here, the weight of the wooden block applies a thrust on the table top.

That is,

$$\begin{aligned} \text{Thrust} = F &= m \times g \\ &= 5\ \text{kg} \times 9.8\ \text{m s}^{-2} \\ &= 49\ \text{N} \end{aligned}$$

$$\begin{aligned} \text{Area of a side} &= \text{length} \times \text{breadth} \\ &= 20\ \text{cm} \times 10\ \text{cm} \\ &= 200\ \text{cm}^2 = 0.02\ \text{m}^2 \end{aligned}$$

From Eq. (9.20),

$$\text{Pressure} = \frac{49\,\text{N}}{0.02\,\text{m}^2}$$

$= 2450$ N m^{-2}.

When the block lies on its side of dimensions 40 cm × 20 cm, it exerts the same thrust.

$$\begin{aligned} \text{Area} &= \text{length} \times \text{breadth} \\ &= 40\ \text{cm} \times 20\ \text{cm} \\ &= 800\ \text{cm}^2 = 0.08\ \text{m}^2 \end{aligned}$$

From Eq. (9.20),

$$\text{Pressure} = \frac{49\,\text{N}}{0.08\,\text{m}^2}$$

$= 612.5$ N m^{-2}

The pressure exerted by the side 20 cm × 10 cm is 2450 N m^{-2} and by the side 40 cm × 20 cm is 612.5 N m^{-2}.

Thus, the same force acting on a smaller area exerts a larger pressure, and a smaller pressure on a larger area. This is the reason why a nail has a pointed tip, knives have sharp edges and buildings have wide foundations.

9.5.1 Pressure in fluids

All liquids and gases are fluids. A solid exerts pressure on a surface due to its weight. Similarly, fluids have weight, and they also exert pressure on the base and walls of the container in which they are enclosed. Pressure exerted in any confined mass of fluid is transmitted undiminished in all directions.

9.5.2 Buoyancy

Have you ever had a swim in a pool and felt lighter? Have you ever drawn water from a well and felt that the bucket of water is heavier when it is out of the water? Have you ever wondered why a ship made of iron and steel does not sink in sea water, but while the same amount of iron and steel in the form of a sheet would sink? These questions can be answered by taking buoyancy in consideration. Let us understand the meaning of buoyancy by doing an activity.

Activity 9.4

- Take an empty plastic bottle. Close the mouth of the bottle with an airtight stopper. Put it in a bucket filled with water. You see that the bottle floats.
- Push the bottle into the water. You feel an upward push. Try to push it further down. You will find it difficult to push deeper and deeper. This indicates that water exerts a force on the bottle in the upward direction. The upward force exerted by the water goes on increasing as the bottle is pushed deeper till it is completely immersed.
- Now, release the bottle. It bounces back to the surface.
- Does the force due to the gravitational attraction of the earth act on this bottle? If so, why doesn't the bottle stay immersed in water after it is released? How can you immerse the bottle in water?

The force due to the gravitational attraction of the earth acts on the bottle in the downward direction. So the bottle is pulled downwards. But the water exerts an upward force on the bottle. Thus, the bottle is pushed upwards. We have learnt that weight of an object is the force due to gravitational attraction of the earth. When the bottle is immersed, the upward force exerted by the water on the bottle is greater than its weight. Therefore it rises up when released.

To keep the bottle completely immersed, the upward force on the bottle due to water must be balanced. This can be achieved by an externally applied force acting downwards. This force must at least be equal to the difference between the upward force and the weight of the bottle.

The upward force exerted by the water on the bottle is known as upthrust or buoyant force. In fact, all objects experience a force of buoyancy when they are immersed in a fluid. The magnitude of this buoyant force depends on the density of the fluid.

9.5.3 Why objects float or sink when placed on the surface of water?

Let us do the following activities to arrive at an answer for the above question.

Activity 9.5

- Take a beaker filled with water.
- Take an iron nail and place it on the surface of the water.
- Observe what happens.

The nail sinks. The force due to the gravitational attraction of the earth on the iron nail pulls it downwards. There is an upthrust of water on the nail, which pushes it upwards. But the downward force acting on the nail is greater than the upthrust of water on the nail. So it sinks (Fig. 9.5).

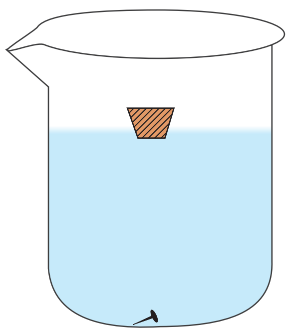

Fig. 9.5: *An iron nail sinks and a cork floats when placed on the surface of water.*

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Activity 9.6

- Take a beaker filled with water.
- Take a piece of cork and an iron nail of equal mass.
- Place them on the surface of water.
- Observe what happens.

The cork floats while the nail sinks. This happens because of the difference in their densities. The density of a substance is defined as the mass per unit volume. The density of cork is less than the density of water. This means that the upthrust of water on the cork is greater than the weight of the cork. So it floats (Fig. 9.5).

The density of an iron nail is more than the density of water. This means that the upthrust of water on the iron nail is less than the weight of the nail. So it sinks.

Therefore objects of density less than that of a liquid float on the liquid. The objects of density greater than that of a liquid sink in the liquid.

Questions

1. *Why is it difficult to hold a school bag having a strap made of a thin and strong string?*
2. *What do you mean by buoyancy?*
3. *Why does an object float or sink when placed on the surface of water?*

9.6 Archimedes' Principle

Activity 9.7

- Take a piece of stone and tie it to one end of a rubber string or a spring balance.
- Suspend the stone by holding the balance or the string as shown in Fig. 9.6 (a).
- Note the elongation of the string or the reading on the spring balance due to the weight of the stone.
- Now, slowly dip the stone in the water in a container as shown in Fig. 9.6 (b).

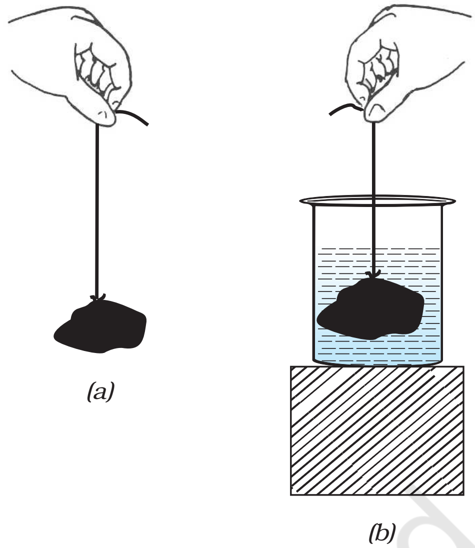

Fig. 9.6: *(a) Observe the elongation of the rubber string due to the weight of a piece of stone suspended from it in air. (b) The elongation decreases as the stone is immersed in water.*

- Observe what happens to elongation of the string or the reading on the balance.

You will find that the elongation of the string or the reading of the balance decreases as the stone is gradually lowered in the water. However, no further change is observed once the stone gets fully immersed in the water. What do you infer from the decrease in the extension of the string or the reading of the spring balance?

We know that the elongation produced in the string or the spring balance is due to the weight of the stone. Since the extension decreases once the stone is lowered in water, it means that some force acts on the stone in upward direction. As a result, the net force on the string decreases and hence the elongation also decreases. As discussed earlier, this upward force exerted by water is known as the force of buoyancy.

What is the magnitude of the buoyant force experienced by a body? Is it the same in all fluids for a given body? Do all bodies in a given fluid experience the same buoyant force? The answer to these questions is contained in Archimedes' principle, stated as follows:

When a body is immersed fully or partially in a fluid, it experiences an upward force that is equal to the weight of the fluid displaced by it.

Now, can you explain why a further decrease in the elongation of the string was not observed in activity 9.7, as the stone was fully immersed in water?

Archimedes was a Greek scientist. He discovered the principle, subsequently named after him, after noticing that the water in a bathtub overflowed when he stepped into it. He ran through the streets shouting "Eureka!", which means "I have got it". This knowledge helped him to determine the purity of the gold in the crown made for the king.

Archimedes

His work in the field of Geometry and Mechanics made him famous. His understanding of levers, pulleys, wheels-and-axle helped the Greek army in its war with Roman army.

Archimedes' principle has many applications. It is used in designing ships and submarines. Lactometers, which are used to determine the purity of a sample of milk and hydrometers used for determining density of liquids, are based on this principle.

Questions

1. *You find your mass to be 42 kg on a weighing machine. Is your mass more or less than 42 kg?*
2. *You have a bag of cotton and an iron bar, each indicating a mass of 100 kg when measured on a weighing machine. In reality, one is heavier than other. Can you say which one is heavier and why?*

What you have learnt

- The law of gravitation states that the force of attraction between any two objects is proportional to the product of their masses and inversely proportional to the square of the distance between them. The law applies to objects anywhere in the universe. Such a law is said to be universal.
- Gravitation is a weak force unless large masses are involved.
- The force of gravity decreases with altitude. It also varies on the surface of the earth, decreasing from poles to the equator.
- The weight of a body is the force with which the earth attracts it.
- The weight is equal to the product of mass and acceleration due to gravity.
- The weight may vary from place to place but the mass stays constant.

- All objects experience a force of buoyancy when they are immersed in a fluid.
- Objects having density less than that of the liquid in which they are immersed, float on the surface of the liquid. If the density of the object is more than the density of the liquid in which it is immersed then it sinks in the liquid.

Exercises

1. How does the force of gravitation between two objects change when the distance between them is reduced to half ?
2. Gravitational force acts on all objects in proportion to their masses. Why then, a heavy object does not fall faster than a light object?
3. What is the magnitude of the gravitational force between the earth and a 1 kg object on its surface? (Mass of the earth is 6×10^{24} kg and radius of the earth is 6.4×10^{6} m.)
4. The earth and the moon are attracted to each other by gravitational force. Does the earth attract the moon with a force that is greater or smaller or the same as the force with which the moon attracts the earth? Why?
5. If the moon attracts the earth, why does the earth not move towards the moon?
6. What happens to the force between two objects, if
   (i) the mass of one object is doubled?
   (ii) the distance between the objects is doubled and tripled?
   (iii) the masses of both objects are doubled?
7. What is the importance of universal law of gravitation?
8. What is the acceleration of free fall?
9. What do we call the gravitational force between the earth and an object?
10. Amit buys few grams of gold at the poles as per the instruction of one of his friends. He hands over the same when he meets him at the equator. Will the friend agree with the weight of gold bought? If not, why? [*Hint*: The value of g is greater at the poles than at the equator.]
11. Why will a sheet of paper fall slower than one that is crumpled into a ball?
12. Gravitational force on the surface of the moon is only $\frac{1}{6}$ as strong as gravitational force on the earth. What is the weight in newtons of a 10 kg object on the moon and on the earth?

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13. A ball is thrown vertically upwards with a velocity of 49 m/s. Calculate
   (i) the maximum height to which it rises,
   (ii) the total time it takes to return to the surface of the earth.
14. A stone is released from the top of a tower of height 19.6 m. Calculate its final velocity just before touching the ground.
15. A stone is thrown vertically upward with an initial velocity of 40 m/s. Taking g = 10 m/s^2, find the maximum height reached by the stone. What is the net displacement and the total distance covered by the stone?
16. Calculate the force of gravitation between the earth and the Sun, given that the mass of the earth = 6×10^{24} kg and of the Sun = 2×10^{30} kg. The average distance between the two is 1.5×10^{11} m.
17. A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Calculate when and where the two stones will meet.
18. A ball thrown up vertically returns to the thrower after 6 s. Find
   (a) the velocity with which it was thrown up,
   (b) the maximum height it reaches, and
   (c) its position after 4 s.
19. In what direction does the buoyant force on an object immersed in a liquid act?
20. Why does a block of plastic released under water come up to the surface of water?
21. The volume of 50 g of a substance is 20 cm^3. If the density of water is 1 g cm^{-3}, will the substance float or sink?
22. The volume of a 500 g sealed packet is 350 cm^3. Will the packet float or sink in water if the density of water is 1 g cm^{-3}? What will be the mass of the water displaced by this packet?

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Chapter 10

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WORK AND ENERGY

In the previous few chapters we have talked about ways of describing the motion of objects, the cause of motion and gravitation. Another concept that helps us understand and interpret many natural phenomena is 'work'. Closely related to work are energy and power. In this chapter we shall study these concepts.

All living beings need food. Living beings have to perform several basic activities to survive. We call such activities 'life processes'. The energy for these processes comes from food. We need energy for other activities like playing, singing, reading, writing, thinking, jumping, cycling and running. Activities that are strenuous require more energy.

Animals too get engaged in activities. For example, they may jump and run. They have to fight, move away from enemies, find food or find a safe place to live. Also, we engage some animals to lift weights, carry loads, pull carts or plough fields. All such activities require energy.

Think of machines. List the machines that you have come across. What do they need for their working? Why do some engines require fuel like petrol and diesel? Why do living beings and machines need energy?

10.1 Work

What is work? There is a difference in the way we use the term 'work' in day-to-day life and the way we use it in science. To make this point clear let us consider a few examples.

10.1.1 NOT MUCH 'WORK' IN SPITE OF WORKING HARD!

Kamali is preparing for examinations. She spends lot of time in studies. She reads books, draws diagrams, organises her thoughts, collects question papers, attends classes, discusses problems with her friends, and performs experiments. She expends a lot of energy on these activities. In common parlance, she is 'working hard'. All this 'hard work' may involve very little 'work' if we go by the scientific definition of work.

You are working hard to push a huge rock. Let us say the rock does not move despite all the effort. You get completely exhausted. However, you have not done any work on the rock as there is no displacement of the rock.

You stand still for a few minutes with a heavy load on your head. You get tired. You have exerted yourself and have spent quite a bit of your energy. Are you doing work on the load? The way we understand the term 'work' in science, work is not done.

You climb up the steps of a staircase and reach the second floor of a building just to see the landscape from there. You may even climb up a tall tree. If we apply the scientific definition, these activities involve a lot of work.

In day-to-day life, we consider any useful physical or mental labour as work. Activities like playing in a field, talking with friends, humming a tune, watching a movie, attending a function are sometimes not considered to be work. What constitutes 'work' depends on the way we define it. We use and define the term work differently in science. To understand this let us do the following activities:

Activity 10.1

- We have discussed in the above paragraphs a number of activities which we normally consider to be work in day-to-day life. For each of these activities, ask the following questions and answer them:

(i) What is the work being done on?
(ii) What is happening to the object?
(iii) Who (what) is doing the work?

10.1.2 Scientific conception of work

To understand the way we view work and define work from the point of view of science, let us consider some situations:

Push a pebble lying on a surface. The pebble moves through a distance. You exerted a force on the pebble and the pebble got displaced. In this situation work is done.

A girl pulls a trolley and the trolley moves through a distance. The girl has exerted a force on the trolley and it is displaced. Therefore, work is done.

Lift a book through a height. To do this you must apply a force. The book rises up. There is a force applied on the book and the book has moved. Hence, work is done.

A closer look at the above situations reveals that two conditions need to be satisfied for work to be done: (i) a force should act on an object, and (ii) the object must be displaced.

If any one of the above conditions does not exist, work is not done. This is the way we view work in science.

A bullock is pulling a cart. The cart moves. There is a force on the cart and the cart has moved. Do you think that work is done in this situation?

Activity 10.2

- Think of some situations from your daily life involving work.
- List them.
- Discuss with your friends whether work is being done in each situation.
- Try to reason out your response.
- If work is done, which is the force acting on the object?
- What is the object on which the work is done?
- What happens to the object on which work is done?

Activity 10.3

- Think of situations when the object is not displaced in spite of a force acting on it.
- Also think of situations when an object gets displaced in the absence of a force acting on it.
- List all the situations that you can think of for each.
- Discuss with your friends whether work is done in these situations.

10.1.3 Work done by a constant force

How is work defined in science? To understand this, we shall first consider the case when the force is acting in the direction of displacement.

Let a constant force, F act on an object. Let the object be displaced through a distance, s in the direction of the force (Fig. 10.1). Let W be the work done. We define work to be equal to the product of the force and displacement.

Work done = force × displacement

$$W = F\,s \qquad (10.1)$$

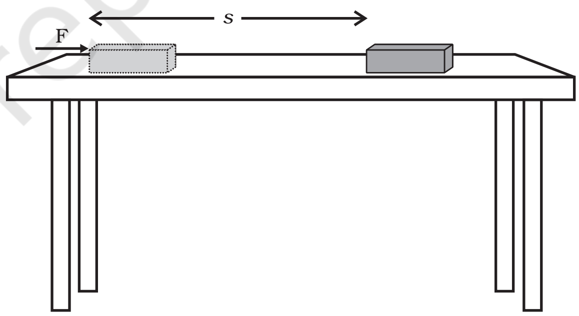

Fig. 10.1

Thus, work done by a force acting on an object is equal to the magnitude of the force multiplied by the distance moved in the direction of the force. Work has only magnitude and no direction.

In Eq. (10.1), if F = 1 N and s = 1 m then the work done by the force will be 1 N m. Here the unit of work is newton metre (N m) or joule (J). Thus 1 J is the amount of work done on an object when a force of 1 N displaces it by 1 m along the line of action of the force.

Look at Eq. (10.1) carefully. What is the work done when the force on the object is zero? What would be the work done when the displacement of the object is zero? Refer to the conditions that are to be satisfied to say that work is done.

Example 10.1 A force of 5 N is acting on an object. The object is displaced through 2 m in the direction of the force (Fig. 10.2). If the force acts on the object all through the displacement, then work done is 5 N × 2 m =10 N m or 10 J.

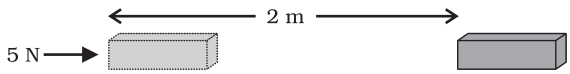

Fig. 10.2

Question

1. *A force of 7 N acts on an object. The displacement is, say 8 m, in the direction of the force (Fig. 10.3). Let us take it that the force acts on the object through the displacement. What is the work done in this case?*

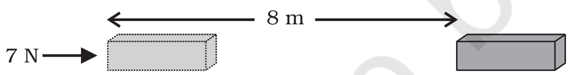

Fig. 10.3

Consider another situation in which the force and the displacement are in the same direction: a baby pulling a toy car parallel to the ground, as shown in Fig. 10.4. The baby has exerted a force in the direction of displacement of the car. In this situation, the work done will be equal to the product of the force and displacement. In such situations, the work done by the force is taken as positive.

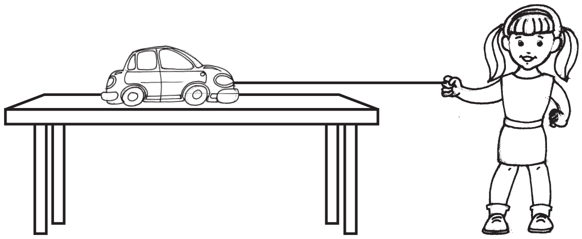

Fig. 10.4

Consider a situation in which an object is moving with a uniform velocity along a particular direction. Now a retarding force, F, is applied in the opposite direction. That is, the angle between the two directions is 180º. Let the object stop after a displacement *s*. In such a situation, the work done by the force, *F* is taken as negative and denoted by the minus sign. The work done by the force is $F \times (-s)$ or $(-F \times s)$.

It is clear from the above discussion that the work done by a force can be either positive or negative. To understand this, let us do the following activity:

Activity 10.4

- Lift an object up. Work is done by the force exerted by you on the object. The object moves upwards. The force you exerted is in the direction of displacement. However, there is the force of gravity acting on the object.
- Which one of these forces is doing positive work?
- Which one is doing negative work?
- Give reasons.

Work done is negative when the force acts opposite to the direction of displacement. Work done is positive when the force is in the direction of displacement.

Example 10.2 A porter lifts a luggage of 15 kg from the ground and puts it on his head 1.5 m above the ground. Calculate the work done by him on the luggage.

Solution:

Mass of luggage, m = 15 kg and displacement, s = 1.5 m.

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Work done, $W = F \times s = mg \times s$
$= 15\,\text{kg} \times 10\,\text{m s}^{-2} \times 1.5\,\text{m}$
$= 225\,\text{kg m s}^{-2}\,\text{m}$
$= 225\,\text{N m} = 225\,\text{J}$

Work done is 225 J.

Questions

1. *When do we say that work is done?*
2. *Write an expression for the work done when a force is acting on an object in the direction of its displacement.*
3. *Define 1 J of work.*
4. *A pair of bullocks exerts a force of 140 N on a plough. The field being ploughed is 15 m long. How much work is done in ploughing the length of the field?*

10.2 Energy

Life is impossible without energy. The demand for energy is ever increasing. Where do we get energy from? The Sun is the biggest natural source of energy to us. Many of our energy sources are derived from the Sun. We can also get energy from the nuclei of atoms, the interior of the earth, and the tides. Can you think of other sources of energy?

Activity 10.5

- A few sources of energy are listed above. There are many other sources of energy. List them.
- Discuss in small groups how certain sources of energy are due to the Sun.
- Are there sources of energy which are not due to the Sun?

The word energy is very often used in our daily life, but in science we give it a definite and precise meaning. Let us consider the following examples: when a fast moving cricket ball hits a stationary wicket, the wicket is thrown away. Similarly, an object when raised to a certain height gets the capability to do work. You must have seen that when a raised hammer falls on a nail placed on a piece of wood, it drives the nail into the wood. We have also observed children winding a toy (such as a toy car) and when the toy is placed on the floor, it starts moving. When a balloon is filled with air and we press it we notice a change in its shape. As long as we press it gently, it can come back to its original shape when the force is withdrawn. However, if we press the balloon hard, it can even explode producing a blasting sound. In all these examples, the objects acquire, through different means, the capability of doing work. An object having a capability to do work is said to possess energy. The object which does the work loses energy and the object on which the work is done gains energy.

How does an object with energy do work? An object that possesses energy can exert a force on another object. When this happens, energy is transferred from the former to the latter. The second object may move as it receives energy and therefore do some work. Thus, the first object had a capacity to do work. This implies that any object that possesses energy can do work.

The energy possessed by an object is thus measured in terms of its capacity of doing work. The unit of energy is, therefore, the same as that of work, that is, joule (J). 1 J is the energy required to do 1 joule of work. Sometimes a larger unit of energy called kilo joule (kJ) is used. 1 kJ equals 1000 J.

10.2.1 Forms of Energy

Luckily the world we live in provides energy in many different forms. The various forms include mechanical energy (potential energy + kinetic energy), heat energy, chemical energy, electrical energy and light energy.

Think it over !

How do you know that some entity is a form of energy? Discuss with your friends and teachers.

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James Prescott Joule (1818 – 1889)

James Prescott Joule was an outstanding British physicist. He is best known for his research in electricity and thermodynamics. Amongst other things, he formulated a law for the heating effect of electric current. He also verified experimentally the law of conservation of energy and discovered the value of the mechanical equivalent of heat. The unit of energy and work called joule, is named after him.

10.2.2 Kinetic energy

Activity ____________ 10.6

- Take a heavy ball. Drop it on a thick bed of sand. A wet bed of sand would be better. Drop the ball on the sand bed from height of about 25 cm. The ball creates a depression.
- Repeat this activity from heights of 50 cm, 1m and 1.5 m.
- Ensure that all the depressions are distinctly visible.
- Mark the depressions to indicate the height from which the ball was dropped.
- Compare their depths.
- Which one of them is deepest?
- Which one is shallowest? Why?
- What has caused the ball to make a deeper dent?
- Discuss and analyse.

Activity ____________ 10.7

- Set up the apparatus as shown in Fig. 10.5.
- Place a wooden block of known mass in front of the trolley at a convenient fixed distance.
- Place a known mass on the pan so that the trolley starts moving.

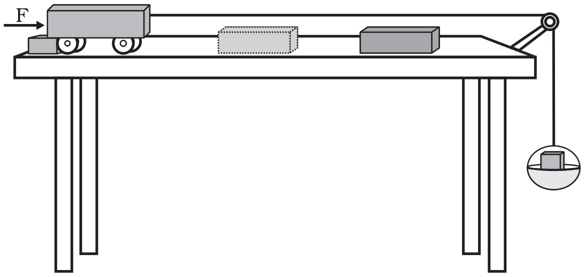

Fig. 10.5

- The trolley moves forward and hits the wooden block.
- Fix a stop on the table in such a manner that the trolley stops after hitting the block. The block gets displaced.
- Note down the displacement of the block. This means work is done on the block by the trolley as the block has gained energy.
- From where does this energy come?
- Repeat this activity by increasing the mass on the pan. In which case is the displacement more?
- In which case is the work done more?
- In this activity, the moving trolley does work and hence it possesses energy.

A moving object can do work. An object moving faster can do more work than an identical object moving relatively slow. A moving bullet, blowing wind, a rotating wheel, a speeding stone can do work. How does a bullet pierce the target? How does the wind move the blades of a windmill? Objects in motion possess energy. We call this energy kinetic energy.

A falling coconut, a speeding car, a rolling stone, a flying aircraft, flowing water, blowing wind, a running athlete etc. possess kinetic energy. In short, kinetic energy is the energy possessed by an object due to its motion. The kinetic energy of an object increases with its speed.

How much energy is possessed by a moving body by virtue of its motion? By definition, we say that the kinetic energy of a body moving with a certain velocity is equal to the work done on it to make it acquire that velocity.

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Let us now express the kinetic energy of an object in the form of an equation. Consider an object of mass, m moving with a uniform velocity, u. Let it now be displaced through a distance s when a constant force, F acts on it in the direction of its displacement. From Eq. (10.1), the work done, W is $F\,s$. The work done on the object will cause a change in its velocity. Let its velocity change from u to v. Let a be the acceleration produced.

We studied three equations of motion. The relation connecting the initial velocity (u) and final velocity (v) of an object moving with a uniform acceleration a, and the displacement, s is

$$v^2 - u^2 = 2a\,s$$

This gives

$$s = \frac{v^2 - u^2}{2a} \tag{10.2}$$

From section 9.4, we know $F = m\,a$. Thus, using (Eq. 10.2) in Eq. (10.1), we can write the work done by the force, F as

$$W = m\,a \times \left(\frac{v^2 - u^2}{2a}\right)$$

or

$$W = \frac{1}{2} m \left(v^2 - u^2\right) \tag{10.3}$$

If the object is starting from its stationary position, that is, $u = 0$, then

$$W = \frac{1}{2} m\,v^2 \tag{10.4}$$

It is clear that the work done is equal to the change in the kinetic energy of an object.

If $u = 0$, the work done will be $\frac{1}{2} m\,v^2$.

Thus, the kinetic energy possessed by an object of mass, m and moving with a uniform velocity, v is

$$E_k = \frac{1}{2} m\,v^2 \tag{10.5}$$

Example 10.3 An object of mass 15 kg is moving with a uniform velocity of 4 m s^{-1}. What is the kinetic energy possessed by the object?

Solution:

Mass of the object, m = 15 kg, velocity of the object, v = 4 m s^{-1}.

From Eq. (10.5),

$$E_k = \frac{1}{2} m\,v^2$$

$$= \frac{1}{2} \times 15 \text{ kg} \times 4 \text{ m s}^{-1} \times 4 \text{ m s}^{-1}$$

$$= 120 \text{ J}$$

The kinetic energy of the object is 120 J.

Example 10.4 What is the work to be done to increase the velocity of a car from 30 km h^{-1} to 60 km h^{-1} if the mass of the car is 1500 kg?

Solution:

Mass of the car, m =1500 kg,
initial velocity of car, u = 30 km h^{-1}

$$= \frac{30 \times 1000 \text{ m}}{60 \times 60 \text{ s}}$$

$$= 25/3 \text{ m s}^{-1}.$$

Similarly, the final velocity of the car,

$$v = 60 \text{ km h}^{-1}$$
$$= 50/3 \text{ m s}^{-1}.$$

Therefore, the initial kinetic energy of the car,

$$E_{ki} = \frac{1}{2} m\,u^2$$

$$= \frac{1}{2} \times 1500 \text{ kg} \times (25/3 \text{ m s}^{-1})^2$$

$$= 156250/3 \text{ J}.$$

The final kinetic energy of the car,

$$E_{kf} = \frac{1}{2} \times 1500 \text{ kg} \times (50/3 \text{ m s}^{-1})^2$$

$$= 625000/3 \text{ J}.$$

Thus, the work done = Change in kinetic energy

$$= E_{kf} - E_{ki}$$

$$= 156250 \text{ J}.$$

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Questions

1. *What is the kinetic energy of an object?*
2. *Write an expression for the kinetic energy of an object.*
3. *The kinetic energy of an object of mass, m moving with a velocity of 5 m s^{-1} is 25 J. What will be its kinetic energy when its velocity is doubled? What will be its kinetic energy when its velocity is increased three times?*

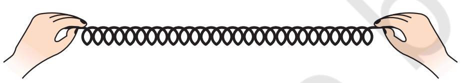
10.2.3 Potential energy

Activity 10.8

- Take a rubber band.
- Hold it at one end and pull from the other. The band stretches.
- Release the band at one of the ends.
- What happens?
- The band will tend to regain its original length. Obviously the band had acquired energy in its stretched position.
- How did it acquire energy when stretched?

Activity 10.9

- Take a slinky as shown below.
- Ask a friend to hold one of its ends. You hold the other end and move away from your friend. Now you release the slinky.



- What happened?
- How did the slinky acquire energy when stretched?
- Would the slinky acquire energy when it is compressed?

Activity 10.10

- Take a toy car. Wind it using its key.
- Place the car on the ground.
- Did it move?
- From where did it acquire energy?
- Does the energy acquired depend on the number of windings?
- How can you test this?

Activity 10.11

- Lift an object through a certain height. The object can now do work. It begins to fall when released.
- This implies that it has acquired some energy. If raised to a greater height it can do more work and hence possesses more energy.
- From where did it get the energy? Think and discuss.

In the above situations, the energy gets stored due to the work done on the object. The energy transferred to an object is stored as potential energy if it is not used to cause a change in the velocity or speed of the object.

You transfer energy when you stretch a rubber band. The energy transferred to the band is its potential energy. You do work while winding the key of a toy car. The energy transferred to the spring inside is stored as potential energy. The potential energy possessed by the object is the energy present in it by virtue of its position or configuration.

Activity 10.12

- Take a bamboo stick and make a bow as shown in Fig. 10.6.
- Place an arrow made of a light stick on it with one end supported by the stretched string.
- Now stretch the string and release the arrow.
- Notice the arrow flying off the bow. Notice the change in the shape of the bow.
- The potential energy stored in the bow due to the change of shape is thus used in the form of kinetic energy in throwing off the arrow.

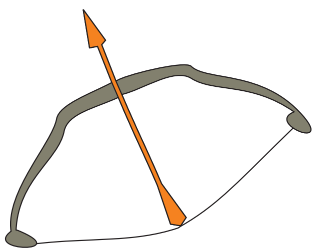


Fig. 10.6: *An arrow and the stretched string on the bow.*

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10.2.4 Potential energy of an object at a height

An object increases its energy when raised through a height. This is because work is done on it against gravity while it is being raised. The energy present in such an object is the gravitational potential energy.

The gravitational potential energy of an object at a point above the ground is defined as the work done in raising it from the ground to that point against gravity.

It is easy to arrive at an expression for the gravitational potential energy of an object at a height.

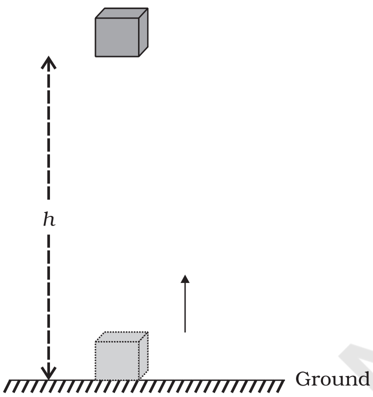

Fig. 10.7

Consider an object of mass, m. Let it be raised through a height, h from the ground. A force is required to do this. The minimum force required to raise the object is equal to the weight of the object, mg. The object gains energy equal to the work done on it. Let the work done on the object against gravity be W. That is,

work done, W = force × displacement

$= mg \times h$

$= mgh$

Since work done on the object is equal to mgh, an energy equal to mgh units is gained by the object. This is the potential energy (E_p) of the object.

$$E_p = mgh \qquad (10.6)$$

More to know

The potential energy of an object at a height depends on the ground level or the zero level you choose. An object in a given position can have a certain potential energy with respect to one level and a different value of potential energy with respect to another level.

It is useful to note that the work done by gravity depends on the difference in vertical heights of the initial and final positions of the object and not on the path along which the object is moved. Fig. 10.8 shows a case where a block is raised from position A to B by taking two different paths. Let the height AB = h. In both the situations the work done on the object is mgh.

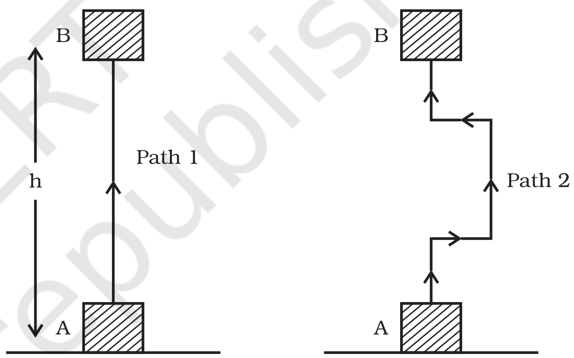

Fig. 10.8

Example 10.5 Find the energy possessed by an object of mass 10 kg when it is at a height of 6 m above the ground. Given, g = 9.8 m s^{-2}.

Solution:

Mass of the object, m = 10 kg, displacement (height), h = 6 m, and acceleration due to gravity, g = 9.8 m s^{-2}.

From Eq. (10.6),

Potential energy = mgh

= 10 kg × 9.8 m s^{-2} × 6 m

= 588 J.

The potential energy is 588 J.

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Example 10.6 An object of mass 12 kg is at a certain height above the ground. If the potential energy of the object is 480 J, find the height at which the object is with respect to the ground. Given, $g = 10\ \mathrm{m\ s^{-2}}$.

Solution:

Mass of the object, $m = 12$ kg,
potential energy, $E_p = 480$ J.

$$E_p = mgh$$
$$480\ \mathrm{J} = 12\ \mathrm{kg} \times 10\ \mathrm{m\ s^{-2}} \times h$$
$$h = \frac{480\ \mathrm{J}}{120\ \mathrm{kg\ m\,s^{-2}}} = 4\ \mathrm{m}.$$

The object is at the height of 4 m.

10.2.5 Are various energy forms interconvertible?

Can we convert energy from one form to another? We find in nature a number of instances of conversion of energy from one form to another.

Activity 10.13

- Sit in small groups.
- Discuss the various ways of energy conversion in nature.
- Discuss following questions in your group:
  (a) How do green plants produce food?
  (b) Where do they get their energy from?
  (c) Why does the air move from place to place?
  (d) How are fuels, such as coal and petroleum formed?
  (e) What kinds of energy conversions sustain the water cycle?

Activity 10.14

- Many of the human activities and the gadgets we use involve conversion of energy from one form to another.
- Make a list of such activities and gadgets.
- Identify in each activity/gadget the kind of energy conversion that takes place.

10.2.6 Law of conservation of energy

In activities 10.13 and 10.14, we learnt that the form of energy can be changed from one form to another. What happens to the total energy of a system during or after the process? Whenever energy gets transformed, the total energy remains unchanged. This is the law of conservation of energy. According to this law, energy can only be converted from one form to another; it can neither be created or destroyed. The total energy before and after the transformation remains the same. The law of conservation of energy is valid in all situations and for all kinds of transformations.

Consider a simple example. Let an object of mass, m be made to fall freely from a height, h. At the start, the potential energy is mgh and kinetic energy is zero. Why is the kinetic energy zero? It is zero because its velocity is zero. The total energy of the object is thus mgh. As it falls, its potential energy will change into kinetic energy. If v is the velocity of the object at a given instant, the kinetic energy would be $\frac{1}{2}mv^2$. As the fall of the object continues, the potential energy would decrease while the kinetic energy would increase. When the object is about to reach the ground, $h = 0$ and v will be the highest. Therefore, the kinetic energy would be the largest and potential energy the least. However, the sum of the potential energy and kinetic energy of the object would be the same at all points. That is,

potential energy + kinetic energy = constant

or

$$mgh + \frac{1}{2}mv^2 = \text{constant}. \qquad (10.7)$$

The sum of kinetic energy and potential energy of an object is its total mechanical energy.

We find that during the free fall of the object, the decrease in potential energy, at any point in its path, appears as an equal amount of increase in kinetic energy. (Here the effect of air resistance on the motion of the object has been ignored.) There is thus a continual transformation of gravitational potential energy into kinetic energy.

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Activity 10.15

- An object of mass 20 kg is dropped from a height of 4 m. Fill in the blanks in the following table by computing the potential energy and kinetic energy in each case.

Height at which object is located m	Potential energy ($E_p = mgh$) J	Kinetic energy ($E_k = mv^2/2$) J	$E_p + E_k$ J
4			
3			
2			
1			
Just above the ground			

- For simplifying the calculations, take the value of g as 10 m s^{-2}.

Think it over !

What would have happened if nature had not allowed the transformation of energy? There is a view that life could not have been possible without transformation of energy. Do you agree with this?

10.3 Rate of Doing Work

Do all of us work at the same rate? Do machines consume or transfer energy at the same rate? Agents that transfer energy do work at different rates. Let us understand this from the following activity:

Activity 10.16

- Consider two children, say A and B. Let us say they weigh the same. Both start climbing up a rope separately. Both reach a height of 8 m. Let us say A takes 15 s while B takes 20 s to accomplish the task.
- What is the work done by each?
- The work done is the same. However, A has taken less time than B to do the work.
- Who has done more work in a given time, say in 1 s?

A stronger person may do certain work in relatively less time. A more powerful vehicle would complete a journey in a shorter time than a less powerful one. We talk of the power of machines like motorbikes and motorcars. The speed with which these vehicles change energy or do work is a basis for their classification. Power measures the speed of work done, that is, how fast or slow work is done. Power is defined as the rate of doing work or the rate of transfer of energy. If an agent does a work W in time t, then power is given by:

Power = work/time

or $$P = \frac{W}{t} \qquad (10.8)$$

The unit of power is watt [in honour of James Watt (1736 – 1819)] having the symbol W. 1 watt is the power of an agent, which does work at the rate of 1 joule per second. We can also say that power is 1 W when the rate of consumption of energy is 1 J s^{-1}.

1 watt = 1 joule/second or 1 W = 1 J s^{-1}.

We express larger rates of energy transfer in kilowatts (kW).

1 kilowatt = 1000 watts
1 kW = 1000 W
1 kW = 1000 J s^{-1}.

The power of an agent may vary with time. This means that the agent may be doing work at different rates at different intervals of time. Therefore the concept of average power is useful. We obtain average power by dividing the total energy consumed by the total time taken.

Example 10.7 Two girls, each of weight 400 N climb up a rope through a height of 8 m. We name one of the girls A and the other B. Girl A takes 20 s while B takes 50 s to accomplish this task. What is the power expended by each girl?

Solution:

(i) Power expended by girl A:
Weight of the girl, mg = 400 N
Displacement (height), h = 8 m

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Time taken, $t = 20$ s
From Eq. (10.8),

$$\text{Power, } P = \text{Work done/time taken} = \frac{mgh}{t} = \frac{400 \text{ N} \times 8 \text{ m}}{20 \text{ s}} = 160 \text{ W.}$$

(ii) Power expended by girl B:
Weight of the girl, $mg = 400$ N
Displacement (height), $h = 8$ m
Time taken, $t = 50$ s

$$\text{Power, } P = \frac{mgh}{t} = \frac{400 \text{ N} \times 8 \text{ m}}{50 \text{ s}} = 64 \text{ W.}$$

Power expended by girl A is 160 W.
Power expended by girl B is 64 W.

Example 10.8 A boy of mass 50 kg runs up a staircase of 45 steps in 9 s. If the height of each step is 15 cm, find his power. Take $g = 10 \text{ m s}^{-2}$.

Solution:

Weight of the boy,
$mg = 50 \text{ kg} \times 10 \text{ m s}^{-2} = 500 \text{ N}$
Height of the staircase,
$h = 45 \times 15/100 \text{ m} = 6.75 \text{ m}$
Time taken to climb, $t = 9$ s
From Eq. (10.8),

$$\text{power, } P = \text{Work done/time taken} = \frac{mgh}{t} = \frac{500 \text{ N} \times 6.75 \text{ m}}{9 \text{ s}} = 375 \text{ W.}$$

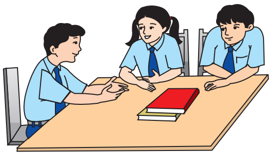
Power is 375 W.

Questions

1. *What is power?*
2. *Define 1 watt of power.*
3. *A lamp consumes 1000 J of electrical energy in 10 s. What is its power?*
4. *Define average power.*

Activity 10.17

- Take a close look at the electric meter installed in your house. Observe its features closely.
- Take the readings of the meter each day at 6.30 am and 6.30 pm.
- Do this activity for about a week.
- How many 'units' are consumed during day time?
- How many 'units' are used during night?
- Tabulate your observations.
- Draw inferences from the data.
- Compare your observations with the details given in the monthly electricity bill (One can also estimate the electricity to be consumed by specific appliances by tabulating their known wattages and hours of operation).



What you have learnt

- Work done on an object is defined as the magnitude of the force multiplied by the distance moved by the object in the direction of the applied force. The unit of work is joule: 1 joule = 1 newton × 1 metre.
- Work done on an object by a force would be zero if the displacement of the object is zero.
- An object having capability to do work is said to possess energy. Energy has the same unit as that of work.
- An object in motion possesses what is known as the kinetic energy of the object. An object of mass, m moving with velocity v has a kinetic energy of $\frac{1}{2}mv^2$.
- The energy possessed by a body due to its change in position or shape is called the potential energy. The gravitational potential energy of an object of mass, m raised through a height, h from the earth's surface is given by $m\ g\ h$.
- According to the law of conservation of energy, energy can only be transformed from one form to another; it can neither be created nor destroyed. The total energy before and after the transformation always remains constant.
- Energy exists in nature in several forms such as kinetic energy, potential energy, heat energy, chemical energy etc. The sum of the kinetic and potential energies of an object is called its mechanical energy.
- Power is defined as the rate of doing work. The SI unit of power is watt. 1 W = 1 J/s.

Exercises

1. Look at the activities listed below. Reason out whether or not work is done in the light of your understanding of the term 'work'.
   - Suma is swimming in a pond.
   - A donkey is carrying a load on its back.
   - A wind-mill is lifting water from a well.
   - A green plant is carrying out photosynthesis.
   - An engine is pulling a train.

- Food grains are getting dried in the sun.
- A sailboat is moving due to wind energy.

2. An object thrown at a certain angle to the ground moves in a curved path and falls back to the ground. The initial and the final points of the path of the object lie on the same horizontal line. What is the work done by the force of gravity on the object?
3. A battery lights a bulb. Describe the energy changes involved in the process.
4. Certain force acting on a 20 kg mass changes its velocity from 5 m s^{-1} to 2 m s^{-1}. Calculate the work done by the force.
5. A mass of 10 kg is at a point A on a table. It is moved to a point B. If the line joining A and B is horizontal, what is the work done on the object by the gravitational force? Explain your answer.
6. The potential energy of a freely falling object decreases progressively. Does this violate the law of conservation of energy? Why?
7. What are the various energy transformations that occur when you are riding a bicycle?
8. Does the transfer of energy take place when you push a huge rock with all your might and fail to move it? Where is the energy you spend going?
9. A certain household has consumed 250 units of energy during a month. How much energy is this in joules?
10. An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy? If the object is allowed to fall, find its kinetic energy when it is half-way down.
11. What is the work done by the force of gravity on a satellite moving round the earth? Justify your answer.
12. Can there be displacement of an object in the absence of any force acting on it? Think. Discuss this question with your friends and teacher.
13. A person holds a bundle of hay over his head for 30 minutes and gets tired. Has he done some work or not? Justify your answer.
14. An electric heater is rated 1500 W. How much energy does it use in 10 hours?
15. Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob

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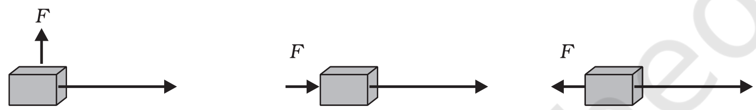
eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?

16. An object of mass, m is moving with a constant velocity, v. How much work should be done on the object in order to bring the object to rest?
17. Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km/h?
18. In each of the following a force, F is acting on an object of mass, m. The direction of displacement is from west to east shown by the longer arrow. Observe the diagrams carefully and state whether the work done by the force is negative, positive or zero.



19. Soni says that the acceleration in an object could be zero even when several forces are acting on it. Do you agree with her? Why?
20. Find the energy in joules consumed in 10 hours by four devices of power 500 W each.
21. A freely falling object eventually stops on reaching the ground. What happenes to its kinetic energy?

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Chapter 11

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SOUND

Everyday we hear sounds from various sources like humans, birds, bells, machines, vehicles, televisions, radios etc. Sound is a form of energy which produces a sensation of hearing in our ears. There are also other forms of energy like mechanical energy, light energy, etc. We have talked about mechanical energy in the previous chapters. You have been taught about conservation of energy, which states that we can neither create nor destroy energy. We can just change it from one form to another. When you clap, a sound is produced. Can you produce sound without utilising your energy? Which form of energy did you use to produce sound? In this chapter we are going to learn how sound is produced and how it is transmitted through a medium and received by our ears.

11.1 Production of Sound

Activity 11.1

- Take a tuning fork and set it vibrating by striking its prong on a rubber pad. Bring it near your ear.
- Do you hear any sound?
- Touch one of the prongs of the vibrating tuning fork with your finger and share your experience with your friends.
- Now, suspend a table tennis ball or a small plastic ball by a thread from a support [Take a big needle and a thread, put a knot at one end of the thread, and then with the help of the needle pass the thread through the ball]. Touch the ball gently with the prong of a vibrating tuning fork (Fig. 11.1).
- Observe what happens and discuss with your friends.

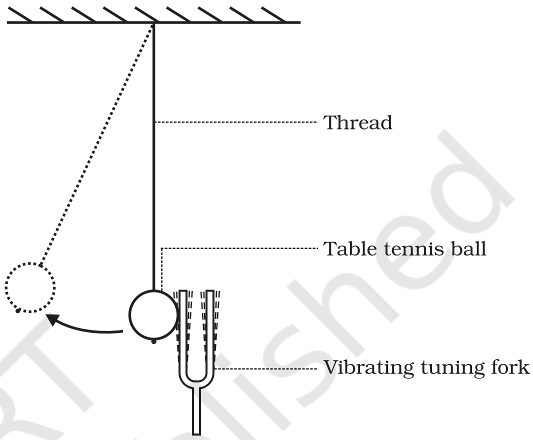

Fig. 11.1: Vibrating tuning fork just touching the suspended table tennis ball.

Activity 11.2

- Fill water in a beaker or a glass up to the brim. Gently touch the water surface with one of the prongs of the vibrating tuning fork, as shown in Fig. 11.2.
- Next dip the prongs of the vibrating tuning fork in water, as shown in Fig. 11.3.
- Observe what happens in both the cases.
- Discuss with your friends why this happens.

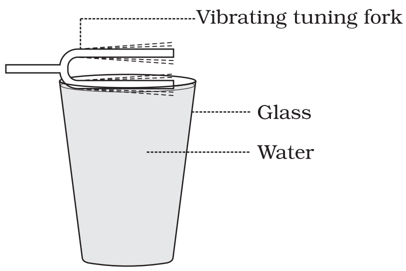

Fig. 11.2: One of the prongs of the vibrating tuning fork touching the water surface.

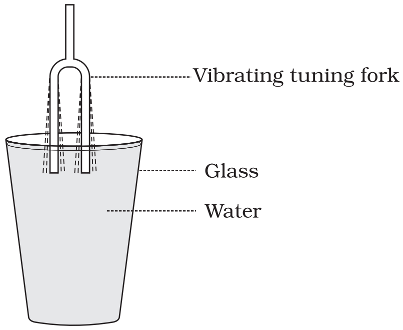

Fig. 11.3: Both the prongs of the vibrating tuning fork dipped in water

From the above activities what do you conclude? Can you produce sound without a vibrating object?

In the above activities we have produced sound by striking the tuning fork. We can also produce sound by plucking, scratching, rubbing, blowing or shaking different objects. As per the above activities what do we do to the objects? We set the objects vibrating and produce sound. Vibration means a kind of rapid to and fro motion of an object. The sound of the human voice is produced due to vibrations in the vocal cords. When a bird flaps its wings, do you hear any sound? Think how the buzzing sound accompanying a bee is produced. A stretched rubber band when plucked vibrates and produces sound. If you have never done this, then do it and observe the vibration of the stretched rubber band.

Activity 11.3

- Make a list of different types of musical instruments and discuss with your friends which part of the instrument vibrates to produce sound.

11.2 Propagation of Sound

Sound is produced by vibrating objects. The matter or substance through which sound is transmitted is called a medium. It can be solid, liquid or gas. Sound moves through a medium from the point of generation to the listener. When an object vibrates, it sets the particles of the medium around it vibrating. The particles do not travel all the way from the vibrating object to the ear. A particle of the medium in contact with the vibrating object is first displaced from its equilibrium position. It then exerts a force on the adjacent particle. As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. This process continues in the medium till the sound reaches your ear. The disturbance created by a source of sound in the medium travels through the medium and not the particles of the medium.

A wave is a disturbance that moves through a medium when the particles of the medium set neighbouring particles into motion. They in turn produce similar motion in others. The particles of the medium do not move forward themselves, but the disturbance is carried forward. This is what happens during propagation of sound in a medium, hence sound can be visualised as a wave. Sound waves are characterised by the motion of particles in the medium and are called mechanical waves.

Air is the most common medium through which sound travels. When a vibrating object moves forward, it pushes and compresses the air in front of it creating a region of high pressure. This region is called a compression (C), as shown in Fig. 11.4. This compression starts to move away from the vibrating object. When the vibrating object moves backwards, it creates a region of low pressure called rarefaction (R), as shown in Fig. 11.4. As the object moves back and forth rapidly, a series of compressions and rarefactions is created in the air. These make the sound wave that

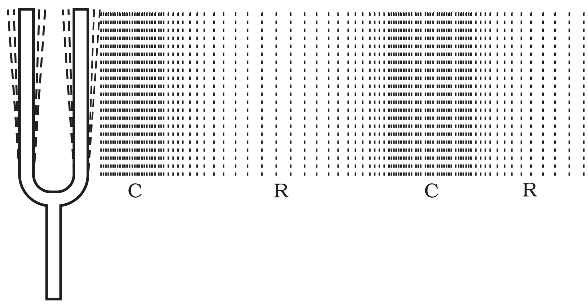

Fig. 11.4: A vibrating object creating a series of compressions (C) and rarefactions (R) in the medium.

propagates through the medium. Compression is the region of high pressure and rarefaction is the region of low pressure. Pressure is related to the number of particles of a medium in a given volume. More density of the particles in the medium gives more pressure and vice versa. Thus, propagation of sound can be visualised as propagation of density variations or pressure variations in the medium.

Question

1. *How does the sound produced by a vibrating object in a medium reach your ear?*
2. *Explain how sound is produced by your school bell.*
3. *Why are sound waves called mechanical waves?*
4. *Suppose you and your friend are on the moon. Will you be able to hear any sound produced by your friend?*

11.2.1 Sound waves are longitudinal waves

Activity 11.4

- Take a slinky. Ask your friend to hold one end. You hold the other end. Now stretch the slinky as shown in Fig. 11.5(a). Then give it a sharp push towards your friend.
- What do you notice? If you move your hand pushing and pulling the slinky alternatively, what will you observe?
- If you mark a dot on the slinky, you will observe that the dot on the slinky will move back and forth parallel to the direction of the propagation of the disturbance.

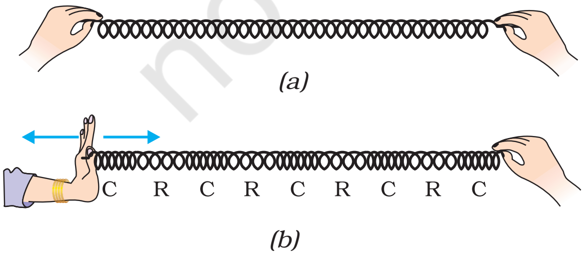

***Fig. 11.5:** Longitudinal wave in a slinky.*

The regions where the coils become closer are called compressions (C) and the regions where the coils are further apart are called rarefactions (R). As we already know, sound propagates in the medium as a series of compressions and rarefactions. Now, we can compare the propagation of disturbance in a slinky with the sound propagation in the medium. These waves are called longitudinal waves. In these waves the individual particles of the medium move in a direction parallel to the direction of propagation of the disturbance. The particles do not move from one place to another but they simply oscillate back and forth about their position of rest. This is exactly how a sound wave propagates, hence sound waves are longitudinal waves.

There is also another type of wave, called a transverse wave. In a transverse wave particles do not oscillate along the direction of wave propagation but oscillate up and down about their mean position as the wave travels. Thus, a transverse wave is the one in which the individual particles of the medium move about their mean positions in a direction perpendicular to the direction of wave propagation. When we drop a pebble in a pond, the waves you see on the water surface is an example of transverse wave. Light is a transverse wave but for light, the oscillations are not of the medium particles or their pressure or density— it is not a mechanical wave. You will come to know more about transverse waves in higher classes.

11.2.2 Characteristics of a sound wave

We can describe a sound wave by its

- frequency
- amplitude and
- speed.

A sound wave in graphic form is shown in Fig. 11.6(c), which represents how density and pressure change when the sound wave moves in the medium. The density as well as the pressure of the medium at a given time varies with distance, above and below the average value of density and pressure. Fig. 11.6(a) and

Fig. 11.6(b) represent the density and pressure variations, respectively, as a sound wave propagates in the medium.

Compressions are the regions where particles are crowded together and represented by the upper portion of the curve in Fig. 11.6(c). The peak represents the region of maximum compression. Thus, compressions are regions where density as well as pressure is high. Rarefactions are the regions of low pressure where particles are spread apart and are represented by the valley, that is, the lower portion of the curve in Fig. 11.6(c). A peak is called the crest and a valley is called the trough of a wave.

The distance between two consecutive compressions (C) or two consecutive rarefactions (R) is called the wavelength, as shown in Fig. 11.6(c), The wavelength is usually represented by λ (Greek letter lambda). Its SI unit is metre (m).

H. R. Hertz

Heinrich Rudolph Hertz was born on 22 February 1857 in Hamburg, Germany and educated at the University of Berlin. He confirmed J.C. Maxwell's electromagnetic theory by his experiments. He laid the foundation for future development of radio, telephone, telegraph and even television. He also discovered the photoelectric effect which was later explained by Albert Einstein. The SI unit of frequency was named as hertz in his honour.

Frequency tells us how frequently an event occurs. Suppose you are beating a drum. How many times you are beating the drum in unit time is called the frequency of your beating the drum. We know that when sound is propagated through a medium, the

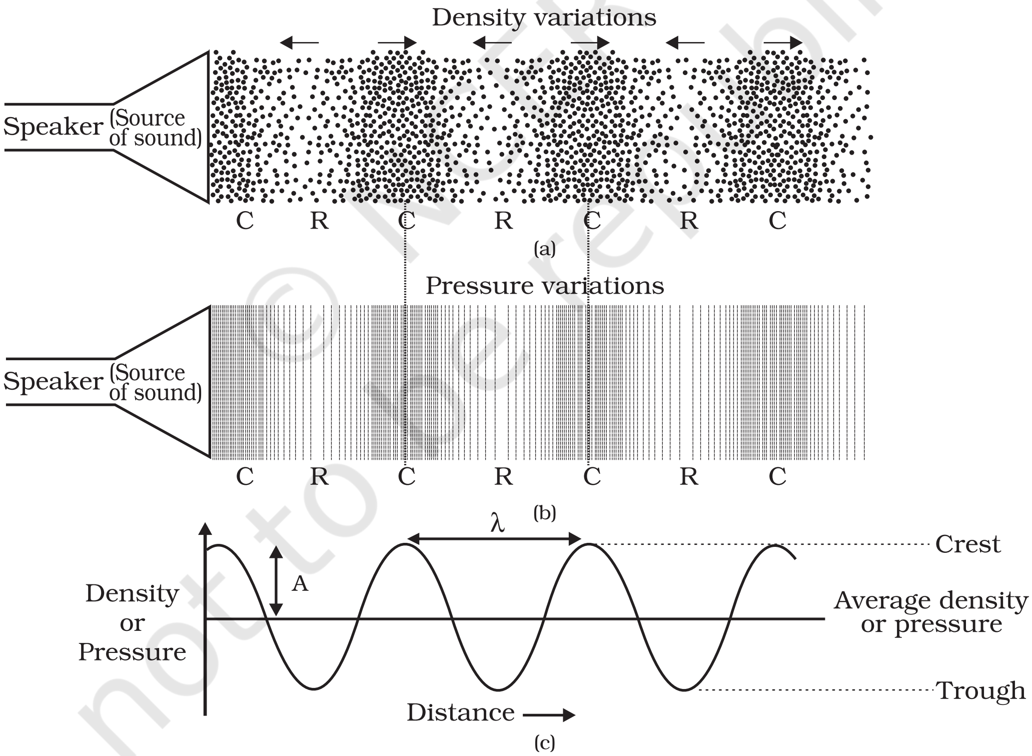

Fig. 11.6: *Sound propagates as density or pressure variations as shown in (a) and (b), (c) represents graphically the density and pressure variations.*

density of the medium oscillates between a maximum value and a minimum value. The change in density from the maximum value to the minimum value, then again to the maximum value, makes one complete oscillation. The number of such oscillations per unit time is the frequency of the sound wave. If we can count the number of the compressions or rarefactions that cross us per unit time, we will get the frequency of the sound wave. It is usually represented by ν (Greek letter, nu). Its SI unit is hertz (symbol, Hz).

The time taken by two consecutive compressions or rarefactions to cross a fixed point is called the time period of the wave. In other words, we can say that the time taken for one complete oscillation is called the time period of the sound wave. It is represented by the symbol *T*. Its SI unit is second (s). Frequency and time period are related as follows:

$$\upsilon = \frac{1}{T}$$

A violin and a flute may both be played at the same time in an orchestra. Both sounds travel through the same medium, that is, air and arrive at our ear at the same time. Both sounds travel at the same speed irrespective of the source. But the sounds we receive are different. This is due to the different characteristics associated with the sound. Pitch is one of the characteristics.

How the brain interprets the frequency of an emitted sound is called its pitch. The faster the vibration of the source, the higher is the frequency and the higher is the pitch, as shown in Fig. 11.7. Thus, a high pitch sound corresponds to more number of compressions and rarefactions passing a fixed point per unit time.

Objects of different sizes and conditions vibrate at different frequencies to produce sounds of different pitch.

The magnitude of the maximum disturbance in the medium on either side of the mean value is called the amplitude of the wave. It is usually represented by the letter A,

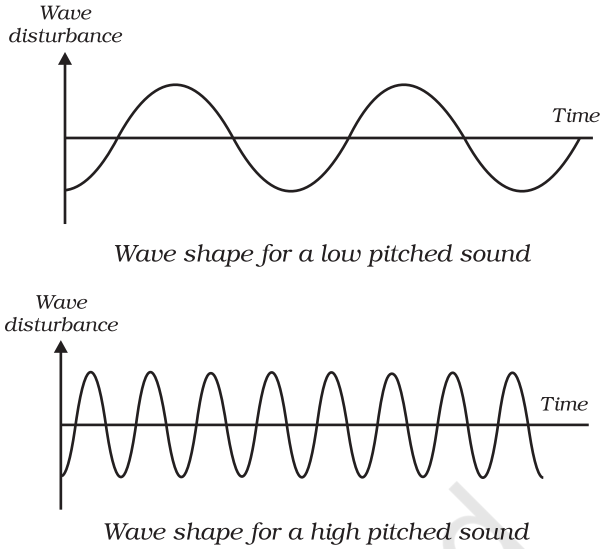

Fig. 11.7: *Low pitch sound has low frequency and high pitch of sound has high frequency.*

as shown in Fig. 11.6(c). For sound its unit will be that of density or pressure.

The loudness or softness of a sound is determined basically by its amplitude. The amplitude of the sound wave depends upon the force with which an object is made to vibrate. If we strike a table lightly, we hear a soft sound because we produce a sound wave

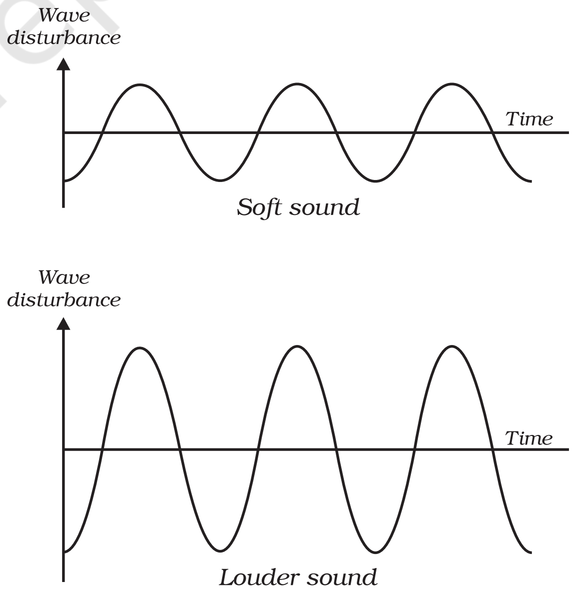

Fig. 11.8: *Soft sound has small amplitude and louder sound has large amplitude.*

of less energy (amplitude). If we hit the table hard we hear a louder sound. Can you tell why? A sound wave spreads out from its source. As it moves away from the source its amplitude as well as its loudness decreases. Louder sound can travel a larger distance as it is associated with higher energy. Fig. 11.8 shows the wave shapes of a loud and a soft sound of the same frequency.

The quality or timber of sound is that characteristic which enables us to distinguish one sound from another having the same pitch and loudness. The sound which is more pleasant is said to be of a rich quality. A sound of single frequency is called a tone. The sound which is produced due to a mixture of several frequencies is called a note and is pleasant to listen to. Noise is unpleasant to the ear! Music is pleasant to hear and is of rich quality.

Questions

1. *Which wave property determines (a) loudness, (b) pitch?*
2. *Guess which sound has a higher pitch: guitar or car horn?*

The speed of sound is defined as the distance which a point on a wave, such as a compression or a rarefaction, travels per unit time.

We know,

speed, v = distance / time

$$= \frac{\lambda}{T}$$

Here λ is the wavelength of the sound wave. It is the distance travelled by the sound wave in one time period (T) of the wave. Thus,

$$v = \lambda \nu \left(\because \frac{1}{T} = \nu \right)$$

or $\quad v = \lambda \nu$

That is, speed = wavelength × frequency.

The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

Example 11.1 A sound wave has a frequency of 2 kHz and wave length 35 cm. How long will it take to travel 1.5 km?

Solution:

Given,

Frequency, ν = 2 kHz = 2000 Hz

Wavelength, λ = 35 cm = 0.35 m

We know that speed, v of the wave

= wavelength × frequency

$v = \lambda \nu$

= 0.35 m 2000 Hz = 700 m/s

The time taken by the wave to travel a distance, d of 1.5 km is

$$t = \frac{d}{v} = \frac{1.5 \times 1000 \text{ m}}{700 \text{ m s}^{-1}} = \frac{15}{7} \text{ s} = 2.1 \text{ s}.$$

Thus sound will take 2.1 s to travel a distance of 1.5 km.

Questions

1. *What are wavelength, frequency, time period and amplitude of a sound wave?*
2. *How are the wavelength and frequency of a sound wave related to its speed?*
3. *Calculate the wavelength of a sound wave whose frequency is 220 Hz and speed is 440 m/s in a given medium.*
4. *A person is listening to a tone of 500 Hz sitting at a distance of 450 m from the source of the sound. What is the time interval between successive compressions from the source?*

The amount of sound energy passing each second through unit area is called the intensity of sound. We sometimes use the terms "loudness" and "intensity" interchangeably, but they are not the same. Loudness is a measure of the response of the ear to the sound. Even when two sounds are of equal intensity, we may hear one as louder than the other simply because our ear detects it better.

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Question

1. *Distinguish between loudness and intensity of sound.*

11.2.3 Speed of sound in different media

Sound propagates through a medium at a finite speed. The sound of a thunder is heard a little later than the flash of light is seen. So, we can make out that sound travels with a speed which is much less than the speed of light. The speed of sound depends on the properties of the medium through which it travels. You will learn about this dependence in higher classes. The speed of sound in a medium depends on temperature of the medium. The speed of sound decreases when we go from solid to gaseous state. In any medium as we increase the temperature, the speed of sound increases. For example, the speed of sound in air is 331 m s^{-1} at 0 ºC and 344 m s^{-1} at 22 ºC. The speeds of sound at a particular temperature in various media are listed in Table 11.1. You need not memorise the values.

Table 11.1: Speed of sound in different media at 25 ºC

State	Substance	Speed in m/s
Solids	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

Question

1. *In which of the three media, air, water or iron, does sound travel the fastest at a particular temperature?*

11.3 Reflection of Sound

Sound bounces off a solid or a liquid like a rubber ball bounces off a wall. Like light, sound gets reflected at the surface of a solid or liquid and follows the same laws of reflection as you have studied in earlier classes. The directions in which the sound is incident and is reflected make equal angles with the normal to the reflecting surface at the point of incidence, and the three are in the same plane. An obstacle of large size which may be polished or rough is needed for the reflection of sound waves.

Activity 11.5

- Take two identical pipes, as shown in Fig. 11.9. You can make the pipes using chart paper. The length of the pipes should be sufficiently long as shown.
- Arrange them on a table near a wall.
- Keep a clock near the open end of one of the pipes and try to hear the sound of the clock through the other pipe.
- Adjust the position of the pipes so that you can best hear the sound of the clock.
- Now, measure the angles of incidence and reflection and see the relationship between the angles.
- Lift the pipe on the right vertically to a small height and observe what happens.

(In place of a clock, a mobile phone on vibrating mode may also be used.)

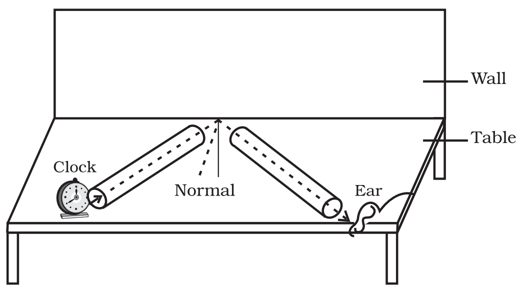

Fig. 11.9: Reflection of sound

11.3.1 Echo

If we shout or clap near a suitable reflecting object such as a tall building or a mountain,we will hear the same sound again a little later. This sound which we hear is called an echo. The sensation of sound persists in our brain for about 0.1 s. To hear a distinct echo the time interval between the original sound and the reflected one must be at least 0.1s. If we take the speed of sound to be 344 m/s at a given temperature, say at 22 ºC in air, the sound must go to the obstacle and reach back the ear of the listener on reflection after 0.1s. Hence, the total distance covered by the sound from the point of generation to the reflecting surface and back should be at least (344 m/s) × 0.1 s = 34.4 m. Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance, that is, 17.2 m. This distance will change with the temperature of air. Echoes may be heard more than once due to successive or multiple reflections. The rolling of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds and the land.

11.3.2 Reverberation

A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation. In an auditorium or big hall excessive reverberation is highly undesirable. To reduce reverberation, the roof and walls of the auditorium are generally covered with sound-absorbent materials like compressed fibreboard, rough plaster or draperies. The seat materials are also selected on the basis of their sound absorbing properties.

Example 11.2 A person clapped his hands near a cliff and heard the echo after 2 s. What is the distance of the cliff from the person if the speed of the sound, v is taken as 346 m s^{-1}?

Solution:

Given,
Speed of sound, $v = 346$ m s^{-1}
Time taken for hearing the echo,
$t = 2$ s
Distance travelled by the sound
$= v \times t = 346$ m $s^{-1} \times 2$ s $= 692$ m
In 2 s sound has to travel twice the distance between the cliff and the person. Hence, the distance between the cliff and the person
$= 692$ m/2 $= 346$ m.

Question

1. *An echo is heard in 3 s. What is the distance of the reflecting surface from the source, given that the speed of sound is 342 m s^{-1}?*

11.3.3 Uses of multiple reflection of sound

1. Megaphones or loudhailers, horns, musical instruments such as trumpets and *shehanais*, are all designed to send sound in a particular direction without spreading it in all directions, as shown in Fig 11.10.

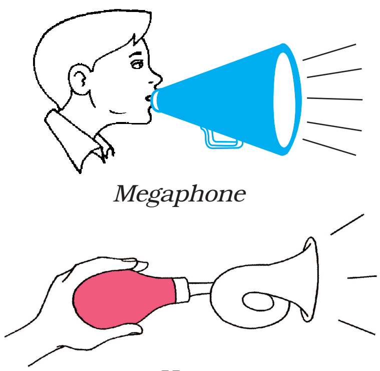

Fig 11.10: A megaphone and a horn.

In these instruments, a tube followed by a conical opening reflects sound successively to guide most of the sound waves from the source in the forward direction towards the audience.

2. Stethoscope is a medical instrument used for listening to sounds produced within the body, mainly in the heart or lungs. In stethoscopes the sound of the patient's heartbeat reaches the doctor's ears by multiple reflection of sound, as shown in Fig.11.11.

Fig.11.11: Stethoscope

3. Generally the ceilings of concert halls, conference halls and cinema halls are curved so that sound after reflection reaches all corners of the hall, as shown in Fig 11.12. Sometimes a curved soundboard may be placed behind the stage so that the sound, after reflecting from the sound board, spreads evenly across the width of the hall (Fig 11.13).

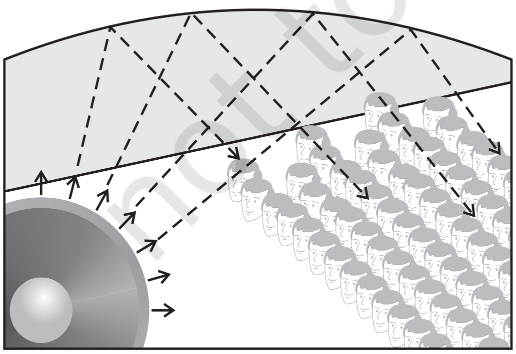

Fig. 11.12: Curved ceiling of a conference hall.

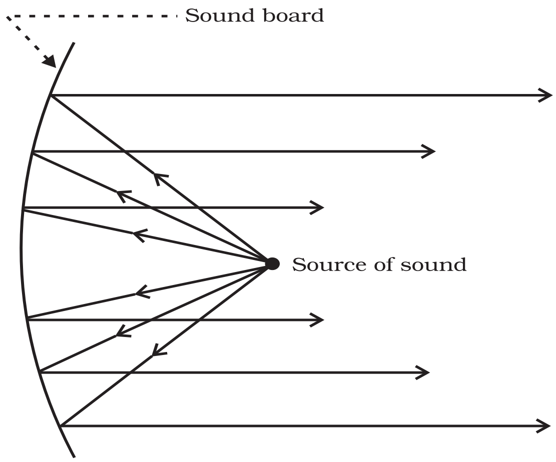

Fig. 11.13: Sound board used in a big hall.

Question

1. *Why are the ceilings of concert halls curved?*

11.4 Range of Hearing

The audible range of sound for human beings extends from about 20 Hz to 20000 Hz (one Hz = one cycle/s). Children under the age of five and some animals, such as dogs can hear up to 25 kHz (1 kHz = 1000 Hz). As people grow older their ears become less sensitive to higher frequencies. Sounds of frequencies below 20 Hz are called infrasonic sound or infrasound. If we could hear infrasound we would hear the vibrations of a pendulum just as we hear the vibrations of the wings of a bee. Rhinoceroses communicate using infrasound of frequency as low as 5 Hz. Whales and elephants produce sound in the infrasound range. It is observed that some animals get disturbed before earthquakes. Earthquakes produce low-frequency infrasound before the main shock waves begin which possibly alert the animals. Frequencies higher than 20 kHz are called ultrasonic sound or ultrasound. Ultrasound is produced by animals such as dolphins, bats and porpoises. Moths of certain families have very sensitive hearing equipment. These moths can hear the high frequency

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squeaks of the bat and know when a bat is flying nearby, and are able to escape capture. Rats also play games by producing ultrasound.

Hearing Aid: People with hearing loss may need a hearing aid. A hearing aid is an electronic, battery operated device. The hearing aid receives sound through a microphone. The microphone converts the sound waves to electrical signals. These electrical signals are amplified by an amplifier. The amplified electrical signals are given to a speaker of the hearing aid. The speaker converts the amplified electrical signal to sound and sends to the ear for clear hearing.

Questions

1. *What is the audible range of the average human ear?*
2. *What is the range of frequencies associated with*
   (a) *Infrasound?*
   (b) *Ultrasound?*

11.5 Applications of Ultrasound

Ultrasounds are high frequency waves. Ultrasounds are able to travel along well-defined paths even in the presence of obstacles. Ultrasounds are used extensively in industries and for medical purposes.

- Ultrasound is generally used to clean parts located in hard-to-reach places, for example, spiral tube, odd shaped parts, electronic components, etc. Objects to be cleaned are placed in a cleaning solution and ultrasonic waves are sent into the solution. Due to the high frequency, the particles of dust, grease and dirt get detached and drop out. The objects thus get thoroughly cleaned.
- Ultrasounds can be used to detect cracks and flaws in metal blocks. Metallic components are generally used in construction of big structures like buildings, bridges, machines and also scientific equipment. The cracks or holes inside the metal blocks, which are invisible from outside reduces the strength of the structure. Ultrasonic waves are allowed to pass through the metal block and detectors are used to detect the transmitted waves. If there is even a small defect, the ultrasound gets reflected back indicating the presence of the flaw or defect, as shown in Fig. 11.14.

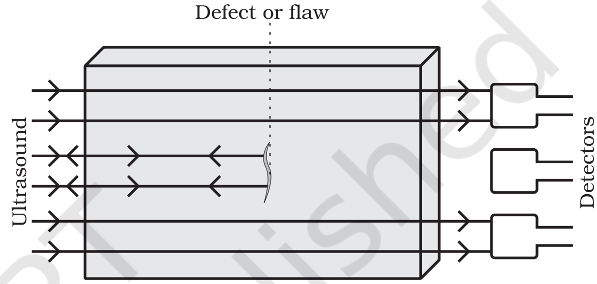

Fig 11.14: *Ultrasound is reflected back from the defective locations inside a metal block.*

Ordinary sound of longer wavelengths cannot be used for such purpose as it will bend around the corners of the defective location and enter the detector.

- Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called 'echocardiography'.
- Ultrasound scanner is an instrument which uses ultrasonic waves for getting images of internal organs of the human body. A doctor may image the patient's organs, such as the liver, gall bladder, uterus, kidney, etc. It helps the doctor to detect abnormalities, such as stones in the gall bladder and kidney or tumours in different organs. In this technique the ultrasonic waves travel through the tissues of the body and get reflected from a region where there is a change of tissue density.

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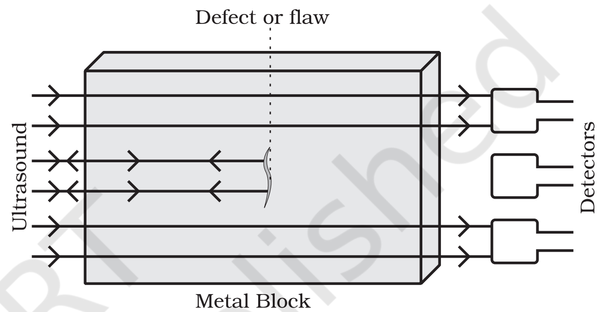

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These waves are then converted into electrical signals that are used to generate images of the organ. These images are then displayed on a monitor or printed on a film. This technique is called 'ultrasonography'. Ultrasonography is also used for examination of the foetus during pregnancy to detect congenial defects and growth abnormalities.

- Ultrasound may be employed to break small 'stones' formed in the kidneys into fine grains. These grains later get flushed out with urine.

What you have learnt

- Sound is produced due to vibration of different objects.
- Sound travels as a longitudinal wave through a material medium.
- Sound travels as successive compressions and rarefactions in the medium.
- In sound propagation, it is the energy of the sound that travels and not the particles of the medium.
- The change in density from one maximum value to the minimum value and again to the maximum value makes one complete oscillation.
- The distance between two consecutive compressions or two consecutive rarefactions is called the wavelength, λ.
- The time taken by the wave for one complete oscillation of the density or pressure of the medium is called the time period, T.
- The number of complete oscillations per unit time is called the frequency (ν), $\nu = \frac{1}{T}$.
- The speed v, frequency ν, and wavelength λ, of sound are related by the equation, $v = \lambda\nu$.
- The speed of sound depends primarily on the nature and the temperature of the transmitting medium.
- The law of reflection of sound states that the directions in which the sound is incident and reflected make equal angles with the normal to the reflecting surface at the point of incidence and the three lie in the same plane.
- For hearing a distinct sound, the time interval between the original sound and the reflected one must be at least 0.1 s.
- The persistence of sound in an auditorium is the result of repeated reflections of sound and is called reverberation.

- Sound properties such as pitch, loudness and quality are determined by the corresponding wave properties.
- Loudness is a physiological response of the ear to the intensity of sound.
- The amount of sound energy passing each second through unit area is called the intensity of sound.
- The audible range of hearing for average human beings is in the frequency range of 20 Hz – 20 kHz.
- Sound waves with frequencies below the audible range are termed "infrasonic" and those above the audible range are termed "ultrasonic".
- Ultrasound has many medical and industrial applications.

Exercises

1. What is sound and how is it produced?
2. Describe with the help of a diagram, how compressions and rarefactions are produced in air near a source of sound.
3. Why is sound wave called a longitudinal wave?
4. Which characteristic of the sound helps you to identify your friend by his voice while sitting with others in a dark room?
5. Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?
6. A person has a hearing range from 20 Hz to 20 kHz. What are the typical wavelengths of sound waves in air corresponding to these two frequencies? Take the speed of sound in air as 344 m s^{-1}.
7. Two children are at opposite ends of an aluminium rod. One strikes the end of the rod with a stone. Find the ratio of times taken by the sound wave in air and in aluminium to reach the second child.
8. The frequency of a source of sound is 100 Hz. How many times does it vibrate in a minute?
9. Does sound follow the same laws of reflection as light does? Explain.
10. When a sound is reflected from a distant object, an echo is produced. Let the distance between the reflecting surface and the source of sound production remains the same. Do you hear echo sound on a hotter day?
11. Give two practical applications of reflection of sound waves.
12. A stone is dropped from the top of a tower 500 m high into a pond of water at the base of the tower. When is the splash heard at the top? Given, g = 10 m s^{-2} and speed of sound = 340 m s^{-1}.

13. A sound wave travels at a speed of 339 m s^{-1}. If its wavelength is 1.5 cm, what is the frequency of the wave? Will it be audible?
14. What is reverberation? How can it be reduced?
15. What is loudness of sound? What factors does it depend on?
16. How is ultrasound used for cleaning?
17. Explain how defects in a metal block can be detected using ultrasound.

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Chapter 12

Improvement in Food Resources

We know that all living organisms need food. Food supplies proteins, carbohydrates, fats, vitamins and minerals, all of which we require for body development, growth and health. Both plants and animals are major sources of food for us. We obtain most of this food from agriculture and animal husbandry.

We read in newspapers that efforts are always being made to improve production from agriculture and animal husbandry. Why is this necessary? Why we cannot make do with the current levels of production?

India is a very populous country. Our population is more than one billion people, and it is still growing. As food for this growing population, we will soon need more than a quarter of a billion tonnes of grain every year. This can be done by farming on more land. But India is already intensively cultivated. As a result, we do not have any major scope for increasing the area of land under cultivation. Therefore, it is necessary to increase our production efficiency for both crops and livestock.

Efforts to meet the food demand by increasing food production have led to some successes so far. We have had the green revolution, which contributed to increased food-grain production. We have also had the white revolution, which has led to better and more efficient use as well as availability of milk.

However, these revolutions mean that our natural resources are getting used more intensively. As a result, there are more chances of causing damage to our natural resources to the point of destroying their balance completely. Therefore, it is important that we should increase food production without degrading our environment and disturbing the balances maintaining it. Hence, there is a need for sustainable practices in agriculture and animal husbandry.

Also, simply increasing grain production for storage in warehouses cannot solve the problem of malnutrition and hunger. People should have money to purchase food. Food security depends on both availability of food and access to it. The majority of our population depends on agriculture for their livelihood. Increasing the incomes of people working in agriculture is therefore necessary to combat the problem of hunger. Scientific management practices should be undertaken to obtain high yields from farms. For sustained livelihood, one should undertake mixed farming, intercropping, and integrated farming practices, for example, combine agriculture with livestock/poultry/fisheries/bee-keeping.

The question thus becomes – how do we increase the yields of crops and livestock?

12.1 Improvement in Crop Yields

Cereals such as wheat, rice, maize, millets and sorghum provide us carbohydrate for energy requirement. Pulses like gram (*chana*), pea (*matar*), black gram (*urad*), green gram (*moong*), pigeon pea (*arhar*), lentil (*masoor*), provide us with protein. And oil seeds including soyabean, ground nut, sesame, castor, mustard, linseed and sunflower provide us with necessary fats (Fig. 12.1). Vegetables, spices and fruits provide a range of vitamins and minerals in addition to small amounts of proteins, carbohydrates and fats. In addition to these food crops, fodder crops like *berseem*, *oats* or *sudan grass* are raised as food for the livestock.

Fig. 12.1: Different types of crops

Question

1. *What do we get from cereals, pulses, fruits and vegetables?*

Different crops require different climatic conditions, temperature and photoperiods for their growth and completion of their life cycle. Photoperiods are related to the duration of sunlight. Growth of plants and flowering are dependent on sunlight. As we all know, plants manufacture their food in sunlight by the process of photosynthesis. There are some crops, which are grown in rainy season, called the *kharif* season from the month of June to October, and some of the crops are grown in the winter season, called the *rabi* season from November to April. Paddy, soyabean, pigeon pea, maize, cotton, green gram and black gram are *kharif* crops, whereas wheat, gram, peas, mustard, linseed are *rabi* crops.

In India there has been a four times increase in the production of food grains from 1952 to 2010 with only 25% increase in the cultivable land area. How has this increase in production been achieved? If we think of the practices involved in farming, we can see that we can divide it into three stages. The first is the choice of seeds for planting. The second is the nurturing of the crop plants. The third is the protection of the growing and harvested crops from loss. Thus, the major groups of activities for improving crop yields can be classified as:

- Crop variety improvement
- Crop production improvement
- Crop protection management.

12.1.1 Crop variety improvement

This approach depends on finding a crop variety that can give a good yield. Varieties or strains of crops can be selected by breeding for various useful characteristics such as disease resistance, response to fertilisers, product quality and high yields. One way of incorporating desirable characters into crop varieties is by hybridisation. Hybridisation refers to crossing between genetically dissimilar plants. This crossing may be intervarietal (between different varieties), interspecific (between two different species of the same genus) or intergeneric (between different genera). Another way of improving the crop is by introducing a gene that would provide the desired characteristic. This results in genetically modified crops.

For new varieties of crops to be accepted, it is necessary that the variety produces high yields under different conditions that are found in different areas. Farmers would need to be provided with good quality seeds of a particular variety, that is, the seeds should all be of the same variety and germinate under the same conditions.

Cultivation practices and crop yield are related to weather, soil quality and availability of water. Since weather conditions such as drought and flood situations are unpredictable, varieties that can be grown in diverse climatic conditions are useful. Similarly, varieties tolerant to high soil salinity have been developed. Some of the factors for which variety improvement is done are:

- Higher yield: To increase the productivity of the crop per acre.
- Improved quality: Quality considerations of crop products vary from crop to crop. Baking quality is important in wheat, protein quality in pulses, oil quality in oilseeds and preserving quality in fruits and vegetables.
- Biotic and abiotic resistance: Crops production can go down due to biotic (diseases, insects and nematodes) and abiotic (drought, salinity, water logging, heat, cold and frost) stresses under different situations. Varieties resistant to these stresses can improve crop production.
- Change in maturity duration: The shorter the duration of the crop from sowing to harvesting, the more economical is the variety. Such short durations allow farmers to grow multiple rounds of crops in a year. Short duration also reduces the cost of crop production. Uniform maturity makes the harvesting process easy and reduces losses during harvesting.
- Wider adaptability: Developing varieties for wider adaptability will help in stabilising the crop production under different environmental conditions. One variety can then be grown under different climatic conditions in different areas.
- Desirable agronomic characteristics: Tallness and profuse branching are desirable characters for fodder crops. Dwarfness is desired in cereals, so that less nutrients are consumed by these crops. Thus developing varieties of desired agronomic characters help give higher productivity.

Questions

1. *How do biotic and abiotic factors affect crop production?*
2. *What are the desirable agronomic characteristics for crop improvements?*

12.1.2 Crop Production Management

In India, as in many other agriculture-based countries, farming ranges from small to very large farms. Different farmers thus have more or less land, money and access to information and technologies. In short, it is the money or financial conditions that allow farmers to take up different farming practices and agricultural technologies. There is a correlation between higher inputs and yields. Thus, the farmer's purchasing capacity for inputs decides cropping system and production practices. Therefore, production practices can be at different levels. They include 'no cost' production, 'low cost' production and 'high cost' production practices.

12.1.2 (i) Nutrient Management

Just as we need food for development, growth and well-being, plants also require nutrients for growth. Nutrients are supplied to plants by air, water and soil. There are several nutrients which are essential for plants. Air supplies carbon and oxygen, hydrogen comes from water, and soil supplies the other thirteen nutrients to plants. Amongst these, some are required in large quantities and are therefore called macro-nutrients. The other nutrients are used by plants in small quantities and are therefore called micro-nutrients (Table 12.1).

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Table 12.1: Nutrients supplied by air, water and soil

Source	Nutrients
Air	carbon, oxygen
Water	hydrogen, oxygen
Soil	(i) *Macronutrients*: nitrogen, phosphorus, potassium, calcium, magnesium, sulphur (ii) *Micronutrients:* iron, manganese, boron, zinc, copper, molybdenum, chlorine

Deficiency of these nutrients affects physiological processes in plants including reproduction, growth and susceptibility to diseases. To increase the yield, the soil can be enriched by supplying these nutrients in the form of manure and fertilizers.

Questions

1. *What are macro-nutrients and why are they called macro-nutrients?*
2. *How do plants get nutrients?*

Manure

Manure contains large quantities of organic matter and also supplies small quantities of nutrients to the soil. Manure is prepared by the decomposition of animal excreta and plant waste. Manure helps in enriching soil with nutrients and organic matter and increasing soil fertility. The bulk of organic matter in manure helps in improving the soil structure. This involves increasing the water holding capacity in sandy soils. In clayey soils, the large quantities of organic matter help in drainage and in avoiding water logging.

In using manure we use biological waste material, which is advantageous in protecting our environment from excessive use of fertilizers. Using biological waste material is also a way of recycling farm waste. Based on the kind of biological material used, manure can be classified as:

(i) Compost and vermi-compost: The process in which farm waste material like livestock excreta (cow dung, etc.), vegetable waste, animal refuse, domestic waste, sewage waste, straw, eradicated weeds etc. is decomposed in pits is known as composting. The compost is rich in organic matter and nutrients. Compost is also prepared by using earthworms to hasten the process of decomposition of plant and animal refuse. This is called vermi-compost.

(ii) Green manure: Prior to the sowing of the crop seeds, some plants like sun hemp or guar are grown and then mulched by ploughing them into the soil. These green plants thus turn into green manure which helps in enriching the soil in nitrogen and phosphorus.

Fertilizers

Fertilizers are commercially produced plant nutrients. Fertilizers supply nitrogen, phosphorus and potassium. They are used to ensure good vegetative growth (leaves, branches and flowers), giving rise to healthy plants. Fertilizers are a factor in the higher yields of high-cost farming.

Fertilizers should be applied carefully in terms of proper dose, time, and observing pre- and post-application precautions for their complete utilisation. For example, sometimes fertilizers get washed away due to excessive irrigation and are not fully absorbed by the plants. This excess fertilizer then leads to water pollution.

Also, as we have seen in the previous class, continuous use of fertilizers in an area can destroy soil fertility because the organic matter in the soil is not replenished and micro-organisms in the soil are harmed by the fertilizers used. Short-term benefits of using fertilizers and long-term benefits of using

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manure for maintaining soil fertility have to be considered while aiming for optimum yields in crop production.

Question

1. *Compare the use of manure and fertilizers in maintaining soil fertility.*

Organic farming is a farming system with minimal or no use of chemicals as fertilizers, herbicides, pesticides, etc., and with a maximum input of organic manures, recycled farm-wastes (straw and livestock excreta), use of bio-agents such as culture of blue green algae in preparation of biofertilizers, *neem* leaves or turmeric specifically in grain storage as bio-pesticides, with healthy cropping systems [mixed cropping, inter-cropping and crop rotation as discussed below in 12.1.2.(iii)]. These cropping systems are beneficial in insect, pest and wheat control besides providing nutrients.

12.1.2 (ii) IRRIGATION

Most agriculture in India is rain-fed, that is, the success of crops in most areas is dependent on timely monsoons and sufficient rainfall spread through most of the growing season. Hence, poor monsoons cause crop failure. Ensuring that the crops get water at the right stages during their growing season can increase the expected yields of any crop. Therefore, many measures are used to bring more and more agricultural land under irrigation.

More to know

Droughts occur because of scarcity or irregular distribution of rains. Drought poses a threat to rain-fed farming areas, where farmers do not use irrigation for crop production and depend only on rain. Light soils have less water retention capacity. In areas with light soils, crops get adversely affected by drought conditions. Scientists have developed some crop varieties which can tolerate drought conditions.

India has a wide variety of water resources and a highly varied climate. Under such conditions, several different kinds of irrigation systems are adopted to supply water to agricultural lands depending on the kinds of water resources available. These include wells, canals, rivers and tanks.

- Wells: There are two types of wells, namely dug wells and tube wells. In a dug well, water is collected from water bearing strata. Tube wells can tap water from the deeper strata. From these wells, water is lifted by pumps for irrigation.
- Canals: This is usually an elaborate and extensive irrigation system. In this system canals receive water from one or more reservoirs or from rivers. The main canal is divided into branch canals having further distributaries to irrigate fields.
- River Lift Systems: In areas where canal flow is insufficient or irregular due to inadequate reservoir release, the lift system is more rational. Water is directly drawn from the rivers for supplementing irrigation in areas close to rivers.
- Tanks: These are small storage reservoirs, which intercept and store the run-off of smaller catchment areas.

Fresh initiatives for increasing the water available for agriculture include rainwater harvesting and watershed management. This involves building small check-dams which lead to an increase in ground water levels. The check-dams stop the rainwater from flowing away and also reduce soil erosion.

12.1.2 (iii) CROPPING PATTERNS

Different ways of growing crops can be used to give maximum benefit.

Mixed cropping is growing two or more crops simultaneously on the same piece of land, for example, wheat + gram, or wheat + mustard, or groundnut + sunflower. This reduces risk and gives some insurance against failure of one of the crops.

Inter-cropping is growing two or more crops simultaneously on the same field in a definite pattern (Fig.12.2). A few rows of one crop alternate with a few rows of a second crop, for example, soyabean + maize, or finger millet (*bajra*) + cowpea (*lobia*). The crops are selected such that their nutrient requirements are different. This ensures maximum utilisation of the nutrients supplied, and also prevents pests and diseases from spreading to all the plants belonging to one crop in a field. This way, both crops can give better returns.

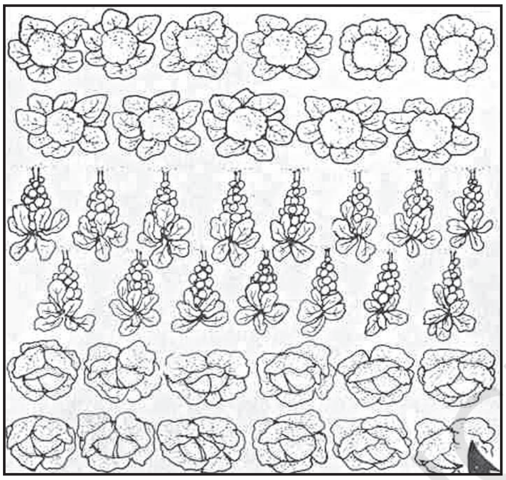

Fig. 12.2 : *Intercropping*

The growing of different crops on a piece of land in a pre-planned succession is known as crop rotation. Depending upon the duration, crop rotation is done for different crop combinations. The availability of moisture and irrigation facilities decide the choice of the crop to be cultivated after one harvest. If crop rotation is done properly then two or three crops can be grown in a year with good harvests.

12.1.3 Crop protection management

Field crops are infested by a large number of weeds, insect pests and diseases. If weeds and pests are not controlled at the appropriate time then they can damage the crops so much that most of the crop is lost.

Weeds are unwanted plants in the cultivated field, for example, *Xanthium* (*gokhroo*), *Parthenium* (*gajar ghas*), *Cyperus rotundus* (*motha*). They compete for food, space and light. Weeds take up nutrients and reduce the growth of the crop. Therefore, removal of weeds from cultivated fields during the early stages of crop growth is essential for a good harvest.

Generally insect pests attack the plants in three ways: (i) they cut the root, stem and leaf, (ii) they suck the cell sap from various parts of the plant, and (iii) they bore into stem and fruits. They thus affect the health of the crop and reduce yields.

Diseases in plants are caused by pathogens such as bacteria, fungi and viruses. These pathogens can be present in and transmitted through the soil, water and air.

Weeds, insects and diseases can be controlled by various methods. One of the most commonly used methods is the use of pesticides, which include herbicides, insecticides and fungicides. These chemicals are sprayed on crop plants or used for treating seeds and soil. However, excessive use of these chemicals creates problems, since they can be poisonous to many plant and animal species and cause environmental pollution.

Weed control methods also include mechanical removal. Preventive methods such as proper seed bed preparation, timely sowing of crops, intercropping and crop rotation also help in weed control. Some other preventive measures against pests are the use of resistant varieties, and summer ploughing, in which fields are ploughed deep in summers to destroy weeds and pests.

Question

1. *Which of the following conditions will give the most benefits? Why?*
   (a) *Farmers use high-quality seeds, do not adopt irrigation or use fertilizers.*
   (b) *Farmers use ordinary seeds, adopt irrigation and use fertilizer.*
   (c) *Farmers use quality seeds, adopt irrigation, use fertilizer and use crop protection measures.*

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Table 12.2: Nutritional values of animal products

Animal Products	*Per cent (%) Nutrients*					
	Fat	**Protein**	**Sugar**	**Minerals**	**Water**	**Vitamins**
Milk (Cow)	3.60	4.00	4.50	0.70	87.20	B1, B2, B12, D, E
Egg	12.00	13.00	*	1.00	74.00	B2, D
Meat	3.60	21.10	*	1.10	74.20	B2, B12
Fish	2.50	19.00	*	1.30	77.20	Niacin, D, A

*Present in very small amounts

Activity 12.1

- Visit a nearby garden/agricultural field and make a list of the weeds and the flowers/crops found in the area. Also, make a list of insect pests, if any, infesting the flowers/crops.

Storage of grains

Storage losses in agricultural produce can be very high. Factors responsible for such losses are biotic— insects, rodents, fungi, mites and bacteria, and abiotic— inappropriate moisture and temperatures in the place of storage. These factors cause degradation in quality, loss in weight, poor germinability, discolouration of produce, all leading to poor marketability. These factors can be controlled by proper treatment and by systematic management of warehouses.

Preventive and control measures are used before grains are stored for future use. They include strict cleaning of the produce before storage, proper drying of the produce first in sunlight and then in shade, and fumigation using chemicals that can kill pests.

Questions

1. *Why should preventive measures and biological control methods be preferred for protecting crops?*
2. *What factors may be responsible for losses of grains during storage?*

Activity 12.2

- *Collect grains/seeds of cereals, pulses and oil seeds and gather information about the seasons in which they are sown and harvested.*

12.2 Animal Husbandry

Animal husbandry is the scientific management of animal livestock. It includes various aspects such as feeding, breeding and disease control. Animal-based farming includes cattle, goat, sheep, poultry and fish farming. As the population increases and as living standards increase, the demand for milk, eggs and meat is also going up. Also, the growing awareness of the need for humane treatment of livestock has brought in new limitations in livestock farming. Thus, livestock production also needs to be improved.

12.2.1 Cattle farming

Cattle husbandry is done for two purposes— milk and draught labour for agricultural work such as tilling, irrigation and carting. Indian cattle belong to two different species, *Bos indicus*, cows, and *Bos bubalis*, buffaloes. Milk-producing females are called milch animals (dairy animals), while the ones used for farm labour are called draught animals.

Milk production depends, to some extent, on the duration of the lactation period, meaning the period of milk production after

Fig. 12.3: Indigenous milch breed of cattle

the birth of a calf. So, milk production can be increased by increasing the lactation period. Exotic or foreign breeds (for example, Jersey, Brown Swiss) are selected for long lactation periods, while local breeds (for example, Red Sindhi, Sahiwal) show excellent resistance to diseases. The two can be cross-bred to get animals with both the desired qualities.

Question

1. *Which method is commonly used for improving cattle breeds and why?*

Activity 12.3

- Visit a livestock farm. Note the following:
  (1) Number of cattle and number of different breeds.
  (2) The amount of daily milk production from the different breeds.

Proper cleaning and shelter facilities for cows and buffaloes are required for humane farming, for the health of the animals and for production of clean milk as well. Animals require regular brushing to remove dirt and loose hair. They should be sheltered under well-ventilated roofed sheds that protect them from rain, heat and cold. The floor of the cattle shed needs to be sloping so as to stay dry and to facilitate cleaning.

The food requirements of dairy animals are of two types: (a) maintenance requirement, which is the food required to support the animal to live a healthy life, and (b) milk producing requirement, which is the type of food required during the lactation period. Animal feed includes: (a) roughage, which is largely fibre, and (b) concentrates, which are low in fibre and contain relatively high levels of proteins and other nutrients. Cattle need balanced rations containing all nutrients in proportionate amounts. Besides such nutritious food material, certain feed additives containing micronutrients promote the health and milk output of dairy animals.

Cattle suffer from a number of diseases. The diseases, besides causing death, reduce milk production. A healthy animal feeds regularly and has a normal posture. The parasites of cattle may be both external parasites and internal parasites. The external parasites live on the skin and mainly cause skin diseases. The internal parasites like worms, affect stomach and intestine while flukes damage the liver. Infectious diseases are also caused by bacteria and viruses. Vaccinations are given to farm animals against many major viral and bacterial diseases.

12.2.2 Poultry farming

Poultry farming is undertaken to raise domestic fowl for egg production and chicken meat. Therefore, improved poultry breeds are developed and farmed to produce layers for eggs and broilers for meat.

The cross-breeding programmes between Indian (indigenous, for example, *Aseel*) and foreign (exotic, for example, Leghorn) breeds for variety improvement are focused on to develop new varieties for the following desirable traits—

(i) number and quality of chicks;

(ii) dwarf broiler parent for commercial chick production;
(iii) summer adaptation capacity/ tolerance to high temperature;
(iv) low maintenance requirements;
(v) reduction in the size of the egg-laying bird with ability to utilise more fibrous cheaper diets formulated using agricultural by-products.

Aseel

Leghorn

Fig. 12.4

Question

1. *Discuss the implications of the following statement:*
"It is interesting to note that poultry is India's most efficient converter of low fibre food stuff (which is unfit for human consumption) into highly nutritious animal protein food."

EGG AND BROILER PRODUCTION

Broiler chickens are fed with vitamin-rich supplementary feed for good growth rate and better feed efficiency. Care is taken to avoid mortality and to maintain feathering and carcass quality. They are produced as broilers and sent to market for meat purposes.

For good production of poultry birds, good management practices are important. These include maintenance of temperature and hygienic conditions in housing and poultry feed, as well as prevention and control of diseases and pests.

The housing, nutritional and environmental requirements of broilers are somewhat different from those of egg layers. The ration (daily food requirement) for broilers is protein rich with adequate fat. The level of vitamins A and K is kept high in the poultry feeds.

Poultry fowl suffer from a number of diseases caused by virus, bacteria, fungi, parasites, as well as from nutritional deficiencies. These necessitate proper cleaning, sanitation, and spraying of disinfectants at regular intervals. Appropriate vaccination can prevent the occurrence of infectious diseases and reduce loss of poultry during an outbreak of disease.

Questions

1. *What management practices are common in dairy and poultry farming?*
2. *What are the differences between broilers and layers and in their management?*

Activity 12.4

- Visit a local poultry farm. Observe types of breeds and note the type of ration, housing and lighting facilities given to them. Identify the growers, layers and broilers.

12.2.3 FISH PRODUCTION

Fish is a cheap source of animal protein for our food. Fish production includes the finned true fish as well as shellfish such as prawns and molluscs. There are two ways of obtaining fish. One is from natural resources, which is called capture fishing. The other way is by fish farming, which is called culture fishery.

The water source of the fish can be either seawater or fresh water, such as in rivers and ponds. Fishing can thus be done both by capture and culture of fish in marine and freshwater ecosystems.

12.2.3 (i) MARINE FISHERIES

India's marine fishery resources include 7500 km of coastline and the deep seas beyond it. Popular marine fish varieties include pomphret, mackerel, tuna, sardines, and Bombay duck. Marine fish are caught using many kinds of fishing nets from fishing boats. Yields are increased by locating large schools of fish in the open sea using satellites and echo-sounders.

Some marine fish of high economic value are also farmed in seawater. This includes finned fishes like mullets, *bhetki*, and pearl spots, shellfish such as prawns (Fig. 12.5), mussels and oysters as well as seaweed. Oysters are also cultivated for the pearls they make.

Macrobrachium rosenbergii *(fresh water)*

Peneaus monodon *(marine)*

Fig. 12.5 : *Fresh water and marine prawns*

As marine fish stocks get further depleted, the demand for more fish can only be met by such culture fisheries, a practice called mariculture.

12.2.3 (ii) Inland fisheries

Fresh water resources include canals, ponds, reservoirs and rivers. Brackish water resources, where seawater and fresh water mix together, such as estuaries and lagoons are also important fish reservoirs. While capture fishing is also done in such inland water bodies, the yield is not high. Most fish production from these resources is through aquaculture.

Fish culture is sometimes done in combination with a rice crop, so that fish are grown in the water in the paddy field. More intensive fish farming can be done in composite fish culture systems. Both local and imported fish species are used in such systems.

In such a system, a combination of five or six fish species is used in a single fishpond. These species are selected so that they do not compete for food among them having different types of food habits. As a result, the food available in all the parts of the pond is used. As Catlas are surface feeders, Rohus feed in the middle-zone of the pond, Mrigals and Common Carps are bottom feeders, and Grass Carps feed on the weeds, together these species (Fig. 12.6) can use all the food in the pond without competing with each other. This increases the fish yield from the pond.

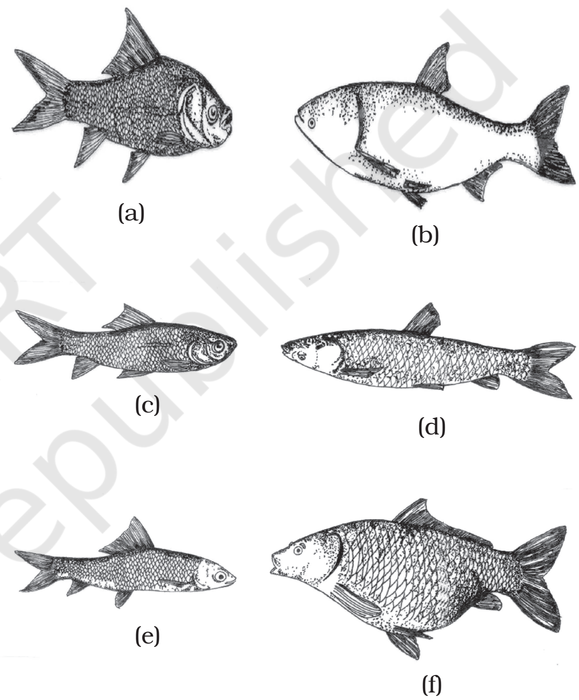

Fig. 12.6: *(a) Catla (b) Silver carp (c) Rohu (d) Grass Carp (e) Mrigal (f) Common Carp*

One problem with such composite fish culture is that many of these fish breed only during monsoon. Even if fish seed is collected from the wild, it can be mixed with that of other species as well. So, a major problem in fish farming is the lack of availability of good-quality seed. To overcome this problem, ways have now been worked out to breed these fish in ponds using hormonal stimulation. This has ensured the supply of pure fish seed in desired quantities.

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Questions

1. *How are fish obtained?*
2. *What are the advantages of composite fish culture?*

Activity 12.5

- Visit a fish farm in fish breeding season and note the following:
  (1) Varieties of fish in fish farm
  (2) Types of ponds
  (3) Feed ingredients used
  (4) Production capacity of the farm
  If there are no fish farms close to your locality, gather the above information from Internet, by referring books or talking to people who are engaged in fishery.

12.2.4 Bee-keeping

Honey is widely used and therefore bee-keeping for making honey has become an agricultural enterprise. Since bee-keeping needs low investments, farmers use it as an additional income generating activity. In addition to honey, the beehives are a source of wax which is used in various medicinal preparations.

The local varieties of bees used for commercial honey production are *Apis cerana indica*, commonly known as the Indian bee, *A. dorsata,* the rock bee and *A. florae,* the little bee. An Italian bee variety, *A. mellifera*, has also been brought in to increase yield of honey.

(a)

(b)

Fig. 12.7: (a) Arrangement of beehive in an apiary (b) honey extractor

This is the variety commonly used for commercial honey production.

The Italian bees have high honey collection capacity. They sting somewhat less. They stay in a given beehive for long periods, and breed very well. For commercial honey production, bee farms or apiaries are established.

The value or quality of honey depends upon the pasturage, or the flowers available to the bees for nectar and pollen collection. In addition to adequate quantity of pasturage, the kind of flowers available will determine the taste of the honey.

Questions

1. *What are the desirable characters of bee varieties suitable for honey production?*
2. *What is pasturage and how is it related to honey production?*

What you have learnt

- There are several nutrients essential for crops. Of these, some are required in large quantities and are known as macro-nutrients whereas rest of the nutrients are required in small quantities and are known as micro-nutrients.
- Manure and fertilizers are the main sources of nutrient supply to crops.
- Organic farming is a farming system with minimal or no use of chemicals as fertilizers, herbicides, pesticides etc. and

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with a maximum input of organic manures, recyled farm wastes, and bio-agents, with healthy cropping systems.

- Mixed farming is a system of farming on a particular farm which includes crop production, raising of livestock etc.
- Mixed cropping is growing of two or more crops simultaneously on the same piece of land.
- Growing two or more crops in definite row patterns is known as inter-cropping.
- The growing of different crops on a piece of land in pre-planned succession is called crop rotation.
- Varietal improvement is required for higher yield, good quality, biotic and abiotic resistance, shortening the maturity duration, wider adaptability and desirable agronomic characteristics.
- Farm animals require proper care and management such as shelter, feeding, breeding and disease control. This is called animal husbandry.
- Poultry farming is done to raise domestic fowls. Poultry production includes egg production and broiler production for poultry meat.
- To enhance poultry production, cross breeding is done between Indian and exotic breeds for variety improvement.
- Fish may be obtained from marine resources as well as inland resources.
- To increase production of fish, they can be cultured in marine and inland ecosystems.
- Marine fish capture is done by fishing nets guided by echo-sounders and satellites.
- Composite fish culture system is commonly used for fish farming.
- Bee-keeping is done to get honey and wax.

Exercises

1. Explain any one method of crop production which ensures high yield.
2. Why are manure and fertilizers used in fields?
3. What are the advantages of inter-cropping and crop rotation?
4. What is genetic manipulation? How is it useful in agricultural practices?
5. How do storage grain losses occur?
6. How do good animal husbandry practices benefit farmers?
7. What are the benefits of cattle farming?
8. For increasing production, what is common in poultry, fisheries and bee-keeping?
9. How do you differentiate between capture fishing, mariculture and aquaculture?

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