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MEASUREMENT IN SCIENCE AND TECHNOLOGY

Measurement is a basic skill which forms an essential part of our day to day activities irrespective of what we do. You would definitely have observed that while cooking food, measured quantities of ingredients are cooked for a measured amount of time. When you go to buy fruits and vegetables, you take them in measured amounts. You can identify which one of your friends runs fastest. This is possible by making them run a known distance say from one end of a playground to the other and noting who is first to reach the destination. In other words, you measure the time. Can you tell by the above measurement how fast does your friend run? For this, you need to precisely measure the distance run and the time taken. Science and technology helps us in making precise measurements for our daily life activities such as stitching, cooking, sports, shopping, travelling etc.

In this lesson we would like to seek answers to several questions. What is the measurement and why do we need it? How do we measure? How do we quantify a measurement, so that it is understood by everyone in the same sense? What is the currently accepted International System of units? We would also learn about commonly used tools for measurement of the physical quantities like length, mass, time, area and volume.

OBJECTIVES

After completing this lesson, you will be able to:

- *define measurement and explain the need for measurement;*
- *give examples of the parts of human body that may be used to measure length of an object and state the limitations of such measurements;*
- *describe the Indian and various other measurement systems used in the ancient times;*
- *explain the need of a common system of units;*
- *define and differentiate base and derived SI units;*

- *derive the SI unit of a physical quantity;*
- *explain the need of SI prefixes;*
- *use SI prefixes for the units and*
- *correctly write the SI units using the rules for writing the same.*

1.1 WHAT IS A MEASUREMENT?

Suppose you are asked to measure the length of a play ground, what would you do? May be you would walk from one end of the field to the other and count the number of steps. The other possibility is that you may arrange for a measuring tape or some scale, say a meter scale. Then again go from one end and count how many times the meter scale was used to reach the other end. Let us take another example. Suppose you need to weigh a carton full of books; you would use a weighing scale and see how many kilogram weights you need to correctly weigh the carton- again a kind of counting. Thus we may define measurement to be **a counting of the number of times a chosen scale is used.**

"When you can measure what you are talking about, and express in numbers, you know what you are talking about; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of a Science"

Lord Kelvin (1824-1907)

1.1.1 Why do we need to make a measurement?

Suppose you go to the market to buy mangoes and they are priced at say Rs.50 per kilogram. What would you expect the shopkeeper to do? Would you be happy if he/she gives you 4 or 5 small mangoes, which are surely less than a kilogram, and asks for the price of one kilogram? Similarly, the shopkeeper will also not like to give you more than a kilogram of mangoes for the price of a kilogram. An accurate measurement is desirable for both buyer and the seller. The absence of a suitable measurement may lead to conflicts between them. Measurement is an essential activity in our everyday life. You may ask why it is essential. Can't we do without it?

Have you ever wondered how space scientists make sure that the space shuttle reaches the desired destination? Or when the shuttle comes back it comes at a predetermined time and place. This is made possible by accurate measurement of many parameters and extensive calculations. For measurement we require specific scale which is called unit.

1.1.2 What is a Unit?

Imagine a situation. Suppose you are blindfolded and handed a bunch of currency notes. On counting them you find that they are 46 in number. Can you tell how much money is in your hand? For knowing the exact amount of money, you need to know the denomination i.e., whether the notes are of Rs.10, Rs.50, Rs100 or of some other denomination?

Similarly, if you are told that two trees are 100 away from each other. How would you interpret it? Are the trees 100 cm, 100 ft or 100 m or….away? These examples suggest that the result of every measurement must be expressed in such a way that it makes a sense and has a unique meaning. For this we need to know two things. Firstly, what is the measuring standard used, say centimetre (cm), metre (m) or foot (ft) in the above example and the number of times it is used.

The result of measurement of a physical quantity is expressed in terms of a **value**. The value of the physical quantity is equal to the product of the number of times the standard is used for the measurement and the quantity (the standard) defined for making the measurement. This defined or standard quantity i.e., the scale used e.g., metre or the foot in above case, is called a unit.

Value of physical quantity = numerical quantity x unit

A unit is a measure, device or a scale in terms of which we make physical measurement. The value of a physical quantity consists of two parts; a numerical quantity and a unit and is equal to their product.

Thus, it is necessary to state the numerical quantity as well as the unit while expressing the result of a measurement. So by now we know that the measurements are essential in every sphere of human activity and also that we need a unit or a standard in terms of which we make the measurement and express the result of such a measurement. Let us learn about the characteristics of such a unit. What qualities should a unit have?

1.1.3 Characteristics of a Unit

Can we measure the distance in kilograms? Obviously not; it is ridiculous to measure distance in terms of kilogram. It has no relevance for measuring distances. So to be useful, a unit should be **relevant** for the quantity being measured. Further, the unit used should be **convenient** also. Would it be convenient to express the distance between two cities in inches? Don’t you think that kilometre would be a better unit? In addition to being relevant and convenient a unit should also be **well defined** i.e. it should be well understood by other people. For example, we may express the distance between my house and a nearby shop as 200 steps. In order to make some sense, we need to define the step - whether it is my step or an adult and child. Is it while walking slowly or while running fast? How long is the step? Thus, to be useful, a unit must be:

- relevant
- convenient
- well defined

In today's world, an accurate measurement is a necessary. We have in numerable devices to make such measurement. You would be surprised to know that an atomic clock is so accurate that it may make an error of just one second in about 15 million years. Have you ever thought how our ancestors made measurements? What were the devices used and what the units of measurement? Let us try to learn about the interesting way measurements were made and also the way the system of measurement has evolved since then. However, why don't you assess your understanding of the meaning and need of measurement and about the units and their characteristics.

INTEXT QUESTIONS 1.1

1. Define the term measurement by giving two examples.
2. What is a unit?
3. List the essential characteristics of a unit.

1.2 HOW DID OUR ANCESTORS MAKE MEASUREMENTS?

The need for measurement and measuring devices dates back to antiquity. When the humans became civilised, started cultivating and living in communities they realised that one cannot do everything and they need to be interdependent. This paved the way for trade and then probably a need of a measure was felt. Various ways of measurements were adopted. The system of measurement has evolved a lot since then. Let us have a brief account of interesting means of measurement used by our forefathers.

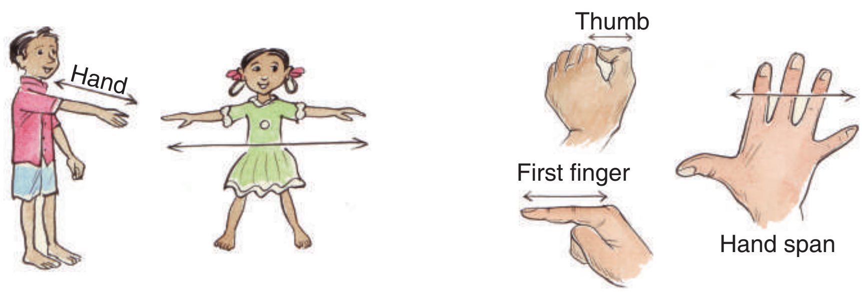

Fig. 1.1 *Use of body parts for measurements*

The recorded history shows ample evidence that the different parts of the human body were used as a point of reference while making measurements. Some of these were, digit : the width of a single finger; foot : the length of a foot; cubit: length of an arm; hand span : the distance between the tip of the thumb and the tip of the little finger when the hand is fully stretched out. similarly fathom meant the distance between the ends of the hands of a Anglo-Saxon farmer when his arms were fully out stretched. It is interesting to note that these are still used sometimes.

Certain historical units were based on the things around us, e. g., Romans used a unit called pace which was equal to the stride of their army contingent and they called the distance travelled by it in 1000 paces to be equal to a mile. Similarly, the grain was used as the unit of mass in sixteenth century and was equal to the weight of a wheat grain.

Based on the criteria given under section 1.1.3, evaluate the above units. What are the limitations you find in above ancient units of measurement? Write your response in the space given below.

....

....

....

....

The following activity may help you to respond to the above query. Perform the following activity and then revisit your response above.

ACTIVITY 1.1

Can you check the accuracy of the measurements using parts of your body as a unit? In your personal contact programme (PCP) you can perform this. Take a black board (or a table, a desk, a wall or any other suitable reasonably long object) with group of 4-5 learners.

This activity can be performed in the class or even at home. In the class a group of 4-5 students can participate in it. (At home the family members or friends can do the same).

First measure the length of the black board using hand span and digits as the units of measurement and record your observations in the table given below.

S. No.	Name of the learner	Length of the black board* in Hand span and digits e.g., 10 Hand spans and 3 digits
1		
2		
3		
4		
5		

* or any other object on which the measurement is made

Now ask your friends (or other learners of the group) to make the same measurement one by one and record their results in the table above. Thus you can record your body **can/cannot** be used for accurate measurements based on your observation. (Tick the right option and delete the incorrect one)

Would you like to revisit your response given above and revise?

1.2.1 Need for a standard unit

As you would have concluded from the activity given above, the units based on parts of human body are arbitrary and inaccurate. The results of the measurements vary from person to person because size of the unit is different for different person. For example, the units like a cubit or a foot would depend on the person making measurement. This created problems in trade between different countries and obviously in the day to day transactions. In order to overcome the limitations of body parts as units, and to bring about uniformity in the measurement system, the need for exact measurement was felt. For this, a standard of measurements had to be developed which is acceptable to everybody.

The problem of measuring lengths acurately was first solved by the Egyptians as far back as in 3000 B.C. It was done by defining the standard cubit. It was defined to be equal to the distance between the elbow and tip of the middle finger of the Pharaoh ruling Egypt at that time. Measuring sticks of length exactly equal to that of standard cubit were made. In this way they made sure that the cubit was the same length all over Egypt. Similar efforts were made by other rulers also. For example, the British King Henry-I (1100-1137) decreed that a yard would exactly be equal to the distance from the top of his nose to the end of his thumb on outstretched arm. Queen Elizabeth-I declared a mile to be exactly equal to eight furlongs. A furlong (furrow long) was the distance a pair of oxen could plough in a field without stopping to rest. It was found to be 220 yards.

These standards proved to be useful but were short lived, as once a given ruler went out of power or died, the system was not followed and a newer system came into being. Further, since different countries and the different provinces in a given country were governed by different rulers; they followed different systems of units. As a consequence, by the eighteenth century a large number of units for mass, length, area and volume came to be in widespread use. Let us now learn about the systems of units followed in India in different historical periods.

1.2.2 Indian measurement system

The measurement system in India also has evolved a great deal from the ancient times.

(a) Indian measurement system in the ancient period

In ancient periods in India, the lengths of the shadows of trees or other objects were used to know the approximate time of the day. Long time durations were expressed

in terms of the lunar cycles, which even now is the basis of some calendars. Excellent examples of measurement practices in different historic periods are available. For example, about 5000 years ago in the Mohenjodaro era, the size of bricks all over the region was same. The length, breadth and width of bricks were always in the ratio of 4:2:1 and taken as a standard .

Similarly around 2400 years ago during the Chandragupta Maurya period there was a well-defined system of weights and measures. The government at that time ensured that everybody used the same weights and measures. According to this system, the smallest unit of length was 1 Parmanu. Small lengths were measured in anguls. For long distances Yojan was used. One Yojan is roughly equal to 10 kilometres..

Different units of measurements used in the period of Chandragupta Maurya

8 Parmanus	=	1 Rajahkan (dust particle from the wheel of a chariot)
8 Rajahkans	=	1 Liksha (egg of lice)
8 Likshas	=	1 Yookamadhya
8 Yookamadhyas	=	1 Yavamadhya
8 Yavamadhyas	=	1 Angul
8 Anguls	=	1 Dhanurmushti

(Reference: Kautilaya's *Arthashastra*)

The Indian medicine system, Ayurveda, also had well-defined units for the measurement of the mass and volume. The measurement system was strongly followed to ensure the proper quantity of medicine for particular disease.

(b) Indian measurement system in the medieval period

In the medieval period also the measurement system was in practice. As described in **Ain-i-Akbari** by Abul Fazl-i-Allami, during the period of Moghul Emperor Akbar, the gaz was used as the unit of measuring length. Each gaz was divided into 24 equal parts and each part was called Tassuj. This system was extensively used to measure land pieces, for construction of buildings, houses, wells, gardens and roads. You should know that, the gaz was widely used as a unit of length till the metric system was introduced in 1956. Even today in many parts of our country, particularly in the rural areas, gaz is being used as a unit of length.

(c) Indian measurement system during British period

In order to bring about uniformity in the system of measurement and the weights used, a number of efforts were made during the British period. The British rulers wanted to connect Indian weights and measures to those being used in Great Britain at that time. During this period the inch, foot, and yard were used to measure length whereas grain, ounce, pounds, etc. were used to measure mass. These units and weights were used in India till the time of Independence in 1947. The essential units of mass used in India included Ratti, Masha, Tola, Chhatank, Seer and Maund. Raatti is a red seed whose mass is approximately 120 mg. It was widely used by goldsmiths and by practitioners of traditional medicine system in India.

Relation between various units of mass used during the British period

8 Ratti	1 Masha
12 Masha	1 Tola
5 Tola	1 Chhatank
16 Chhatank	1 Seer
40 Seer	1 Maund
1 Maund	100 Pounds troy (exact)

INTEXT QUESTIONS 1.2

1. Name the smallest unit of length during the Chandragupta Maurya period.
2. List the parts of human body which can be used for measurements.
3. Why cannot the parts of human body be used for accurate measurement?
4. In which period was 'gaz' introduced as a unit to measure length?

1.3 THE MODERN MEASUREMENT SYSTEMS

Immediately after the French Revolution (1790) the French scientists took lead in establishing a new system of weights and measures. They advocated the establishment of national standards for the purpose and the use of decimal arithmetic system. This led to the birth of metric system which like our Hindu-Arabic counting system is based on the multiples and subdivisions of ten.

After detailed deliberations the basic unit of length and mass were defined and their working standards were prepared. The working standard for meter was prepared by marking two lines a metre apart, on a platinum-iridium bar. Similarly, a platinum - iridium cylinder was constructed, equal to the mass of 1 cubic decimetre of water, as the working standard for mass. These two standards have been preserved at the International Beurau of Weights and Measures at Serves near Paris. The copies of these were prepared and sent to different countries. As regards the time, the concept of hour, minute and second based on

The meter was defined as one ten millionth ($1/10^7$) of the distance between north pole to the equator on the meridian running near Dunkirk in France and Brcelona in Spain.

the rotation of earth was retained. An international treaty, called Metre Convention was signed in 1875 to follow metric system through out the world for trade and commerce.

In the course of development of units a number of systems were adopted. Two systems which were extensively used were the cgs and mks systems. The cgs system was based on centimetre, gram and second as the units for length, mass and time while mks system used metre, kilogram and second for the same. In 1958 it was realised that the units defined as standard needed to be redefined. Since 1983, it is defined as the length of the path travelled by light in vacuum in 1/299,792,458 of a second.The new exercise of redefining the system of units led to the birth of SI system of units which is currently the system in use. Let us learn the SI system in details.

1.4 SI UNITS

An international system of units, called SI units, was adopted at the 11th General Conference on Weights and Measures (CGPM) in 1960. SI is an abbreviation of the French name "Le Systeme Internationale de Unite's".
You know that measurements are concerned with quantities like length, mass, time, density etc. Any quantity which can be measured is called a physical quantity. The SI system of units is based on seven **base units** corresponding to seven base physical quantities. These are the physical quantities, in terms of which other physical quantities can be measured. The names and symbols of the base physical quantities and their corresponding SI units are given in Table 1.1. The precise definitions and the standards for the base SI units are given under Appendix-I.

The base SI units are independent of each other

Table 1.1 Names and symbols of the base physical quantities and the corresponding SI units.

Base physical quantity	Symbol of Physical quantity	Name of SI Unit	Symbol for SI Unit
length	l	metre	m
mass	m	kilogram	kg
time	t	second	s
electric current	I	ampere	A
thermodynamic temperature	T	kelvin	K
amount of substance	n	mole	mol
Luminous intensity	I	candela	cd

Note: The other measurements for temperature are in degree celsius (°C) and Fahrenheit (F).

Perhaps you may be confused by mass and amount of substance and also with luminous intensity as given in Table 1.1. The mass of a body is the amount of matter contained in the body, while a mole is the amount of any substance equal to its molecular mass expressed in grams. For example,

1 mole of HCl = 36.46 g

2 moles of HCl = 36.46 × 2 = 72.92 g

Luminous intensity is the amount of light emitted by a point source per second in a particular direction.

ACTIVITY 1.2

Take a thermometer at your home. Observe the measuring marks on a thermometer along with a parent.

(i) Write down the two types of measuring marks indicating on the thermometer.

(ii) Measure your temperature and record it in °C (degree celsius) and F (Fahrenheit)

(iii) In case you find it difficult to understand, you can contact your nearest Doctor or nurse or ANM

Note: Commonly, body temperature between 98.2°F-98.6°F is expressed in Fahrenheit.

1.4.1 Derived Units

The base or fundamental SI units like length, mass, time, etc. are independent of each other. The SI units for all other physical quantities such as area, density, velocity can be derived in terms of the base SI units and are called **derived units**. In order to find the derived unit for a physical quantity we have to find out the relationship between the physical quantity and the base physical quantities. Then substitute the units of the base physical quantities to find the desired derived unit. Let us take some examples to learn how to derive units for physical quantities in terms of base units.

Example 1. Derive the SI unit for area of a surface.

In order to derive the unit, we need to find out the relationship between area and the base physical quantities. As you know that the area of a surface is the product of its length and breadth. So, as the first step we write area as

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

Since breadth is also a kind of length, we can write,

$$\text{Area} = \text{length} \times \text{length}$$

Then to find the derived unit for area, we substitute the units of the base physical quantities as

$$\text{Unit of area} = \text{metre} \times \text{metre} = (\text{metre})^2 = \text{m}^2$$

Thus, the SI unit of area is m^2 and is pronounced as squared metre. Similarly you can check that volume would have the SI unit as m^3 or cubic metre.

Example 2. Find the derived unit for force.

You know that force is defined as

$$\text{Force} = \text{mass} \times \text{acceleration} = \text{mass} \times (\text{change in velocity/time})$$

Since, change in velocity = Length/time

So, $\text{Force} = \text{mass} \times (\text{length/time}) \times (1/\text{time}) = \text{mass} \times (\text{length/time}^2)$

The SI unit of force can be found by substituting the SI units of the base physical quantities on the right side of the expression.

Thus, $\Rightarrow$ SI unit of force $= \text{kg m/s}^2 = \text{kg ms}^{-2}$

Some commonly encountered physical quantities other than base physical quantities, their relationship with the base physical quantities and the SI units are given in Table 1.2.

Table 1.2 Some examples of derived SI units of the commonly used physical quantities

Derived Quantity	Dimensions	Name of Unit	Symbol of the Unit
area	Length × length	square meter	m^2
volume	Length × length × length	cubic metre	m^3
speed, velocity	Length/time	metre per second	$m\ s^{-1}$
acceleration	(Length/time)/time	metre per second squared	$m\ s^{-2}$
wavenumber	1/length	reciprocal metre	m^{-1}
density	Mass/(length)^3	kilogram per cubic metre	$kg\ m^{-3}$
Work	(Mass × length^2)/(time)^2	kilogram square metre per square second	$kg\ m^2/s^2$

A number of physical quantities like force, pressure, etc. are used very often but their SI units are quite complex. Due to their complex expression it becomes quite inconvenient to use them again and again. The derived SI units for such physical quantities have been assigned special names. Some of the physical quantities whose SI units have been assigned special names are compiled in Table 1.3.

Table 1.3 Names and symbols of the derived SI units with Special names

Physical Quantity	Derived SI unit	Special name assigned to the Unit	Symbol assigned to the special name
frequency	s^{-1}	Hertz	Hz
force	$m.kg.s^{-2}$	Newton	N
Pressure or stress	$m^{-1}.kg.s^{-2}$	Pascal	Pa
Energy or work	$kg.m^2.s^{-2}$	Joule	J
Power	$kg.m^2.s^{-3}$	Watt	W

INTEXT QUESTIONS 1.3

1. Differentiate between base units and derived units.
2. What is the difference between mass and amount of a substance?
3. Derive the unit of Pressure. (Pressure = Force/Area)
4. Which term of measurement is commonly used by the announcer of your favourite radio programme?
5. Observe a bulb/tube light at your home for the unit measurement written on it. From Table 1.3 find out the physical quantity it measure?
6. Veena, Mohindar and Alam went to market. Veena brought milk with a litre measure, Mohindar brought ribbon by a measuring mark on the table and Alam brought vegetables using stones. Which of them did not use the appropriate measurement while purchasing goods? Explain while given the names of right measurement.

1.4.2 SI Prefixes

When we make measurements of physical quantities, quite often the quantity being measured is too large as compared to the base unit of the physical quantity. Look at some of the following examples,

Mass of earth = 5,970,000,000,000,000,000,000,000 kg

Radius of Sun = 6,96,000,000 m

Approximate distance between Mumbai and Delhi = 1,400,000 m

Other possibility is that the physical quantity is too small as compared to the base unit of the physical quantity. Look at some of the examples,

Radius of a hydrogen atom = 0.000,000,000,05 m

Mass of an electron (m_e) = 0.000,000,000,000,000,000,000,911 kg

You can see from the examples given above that when the physical quantity being measured is either too large or too small as compared to the standard unit, then the value of the physical quantity is quite inconvenient to express.

The numbers given above can be simplified by using what is called scientific notation of numbers. In this notation system we represent the numbers as power of ten. In this notation system we can rewrite the above examples as

Mass of Earth = 5.97×10^{24} kg

Radius of Sun = 6.96×10^{8} m

Approximate distance between Mumbai and Delhi = 1.4×10^{6} m

Radius of a hydrogen atom = 5×10^{-11} m

Mass of an electron (m_e) = 9.11×10^{-31} kg

In scientific notation the numbers become relatively easier, but are still not convenient because they carry exponents. In order to simplify the numbers further, the SI system of units has recommended the use of certain prefixes. These prefixes are used along with the SI units in such a way that the physical quantity being measured can be expressed as a convenient number. The SI prefixes have been defined to cover a wide range of 10^{-24} to 10^{+24} of a unit and are given in Table 1.4.

Table1.4: SI Prefixes for multiples and sub multiples of units

Multiple	Prefix	Symbol	Sub multiple	Prefix	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	m
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deca	da	10^{-24}	yocto	y

1.4.3 How do we use SI prefixes?

In order to use SI prefixes, we have to keep a basic rule in mind. The rule is that the prefix is chosen in such a way that the resulting value of the physical quantity has a value between 0.1 and 1000. Let us illustrate it with examples.

Radius of Sun = 6.96×10^8 m = 696×10^6 m = 696 Mm (696 mega metre)

Alternatively = 6.96×10^8 m = 0.696×10^9 m = 0.696 Gm (0.696 giga metre)

INTEXT QUESTIONS 1.4

Rewrite the following measurements of length using suitable SI prefixes.

(i) effective radius of a proton; 1.2×10^{-15}m __________

(ii) radius of human red blood cell; 3.7×10^{-6}m ________

(iii) radius of our galaxy; 6×10^{19}m __________________

You must follow the following rules while using SI prefixes.

Note:

- No space is required between the prefix and the symbol of the unit e.g., nanogram is written as ng and not as n g.
- The prefixes are used only with the units and not alone e.g., 10 µ does not convey anything, it has to be 10 µm, 10 µg, etc.
- You can use only one prefix at a time e.g. 10^{-12} g is represented as 1 pg and not as 1 mmg.
- SI prefix is not used with the unit °C.
- The power to which a prefixed unit is raised applies to the whole unit, including the prefix e.g. 1 km^2 = $(1000\ m)^2$ = 10^6 m^2 and not 1000 m^2.

Having learnt about the base SI units, the method of obtaining the derived SI unit for a given physical quantity and also the need and usage of prefixing SI units, let us now learn about the grammatical rules for using SI units in general.

1.4.4 Rules for Representing SI Units

The SI units are the result of the attempt of scientists to evolve a common international system of units that can be used globally. It is therefore important that the words and the grammar is logical and defined unambiguously i.e. everyone uses the system of units in the same manner. In order to achieve this objective, a number of grammatical rules have been framed. The most commonly used rules are given below:

- While writing the value of physical quantity, the number and the unit are separated by a space. For example, 100 mg is correct but not 100mg.
- No space is given between number and °C, degree, minute and second of plane angle.
- The symbols of the units are not changed while writing them in plural e.g. 10 mg is correct but not 10 mgs.

- The symbols of the units are not followed by a full stop except at the end of a sentence, e.g. 10 mg. of a compound is incorrect.
- In writing the SI unit obtained as a combination of units a space is given between the symbols. Thus m s represents metre second while ms stands for milli-second. That is if the units are written without leaving any space, the first letter may be taken as a prefix.
- For numbers less than unity zero must be inserted to the left of the decimal point e.g. writing 0.928 g is correct but not .928 g.
- Symbols of units derived from proper names are represented by using capital letters. When written in full, the unit should not be written in plural e.g. 30.5 joule or 30.5 J is correct but 30.5 Joules or 30.5 j is not correct.
- When using powers with a unit name the modifier squared or cubed is used after the unit name e.g. second squared, gram cubed etc. Area and volume are exception in such cases the qualifier for the power comes first e.g. square kilometer or cubic centimetre etc.
- For representing unit symbols with negative exponent, the use of the solidus (/) sign should be avoided. If used, no more than one solidus should be used e.g. the unit for gas constant (JK^{-1} mol^{-1}) may be represented as J/K mol but not as J/K/mol.

The rules mentioned earlier for the use of SI prefixes are to be followed along with these rules.

WHAT YOU HAVE LEARNT

- Measurement is a basic skill which forms an essential part of our day to day activities irrespective of what we do.
- It is a process of comparison and involves counting of the number of times a chosen scale is used to make the measurement.
- Measurement is essential for accurate determination of a physical quantity. It is helpful in day to day transactions, trade and scientific endeavours.
- The unit of physical quantity is a standard value in terms of which other quantities of that kind are expressed.
- To be useful, a unit must be relevant to the quantity being measured, be convenient and also well defined so that it is understood by every body in an unambiguous way.
- In the ancient times parts of ‘human body’ were used for measurement but these led to conflicts and confusions because these were arbitrary, non uniform and led to results which were not reproducible.

- Currently, we follow an international system of units, called SI units. This system is based on seven base units which correspond to seven base physical quantities namely length, mass, time, temperature, amount of substances, light intensity and electric current.
- The units for all other physical quantities can be derived in terms of the base SI units and are called derived units. Some of the derived units have been given special names.
- SI prefixes are used in cases where the quantity being measured is too large or too small as compared to the base unit of the physical quantity.
- The grammar of SI units must be followed while writing them.

TERMINAL EXERCISE

1. Which of the following is not an SI unit?

   A. Metre B. Pound
   C. Kilogram D. second

2. If the mass of a solution in 10 μg it is the same as

   A. 10^{-6} g B. 10^{-12} g
   C. 10^{-9} g D. 10^{-3} g

3. Indicate whether the following statements are True or False. Write T for true and F for false

   (i) SI units are arbitrary (ii) $1\ mm^2 = 10^{-3}\ m^2$
   (iii) 10^{-15} g = 1 mpg (iv) SI unit for pressure is Pascal

4. Represent the following measurements by using suitable SI prefixes

   (i) 2×10^{-8} s (ii) 1.54×10^{-10} m
   (iii) 1.98×10^{-6} mol (iv) 200 000 kg

5. Give the SI units used while buying :.

   A. Silk ribbon B. Milk
   C. Potatoes

6. Give the common unit to measure our body temperature and write its SI unit

7. What are the advantages of SI units?

APPENDIX-I

(a) **Mass**: The SI unit of mass is kilogram. One kilogram is the mass of a particular cylinder made of Platinum–Iridium alloy, kept at the International Bureau of Weights and Measures in France. This standard was established in 1887 and there has been no change because this is an unusually stable alloy. Prototype kilograms have been made out of this alloy and distributed to member states. The national prototype of India is the Kilogram no 57. This is preserved at the National Physical Laboratory, New Delhi.

(b) **Length**: The SI unit of length is metre. Earlier the metre (also written as meter) was defined to be $1/10^7$ times the distance from the Equator to the North Pole through Paris. This standard was abandoned for practical reasons. In 1875, the new metre was defined as the distance between two lines on a Platinum-Iridium bar stored under controlled conditions. Such standards had to be kept under severe controlled conditions. Even then their safety against natural disasters is not guaranteed, and their accuracy is also limited for the present requirements of science and technology. In 1983 the metre was redefined as the distance travelled by light in vacuum in a time interval of 1/ 299792458 seconds. This definition establishes that the speed of light in vacuum is 299792458 metres per second.

(c) **Time**: The SI unit of time is second. The time interval second was originally defined in terms of the time of rotation of earth about its own axis. This time of rotation is divided in 24 parts, each part is called an hour. An hour is divided into 60 minutes and each minute is subdivided into 60 seconds. Thus, one second is equal to $1/86400^{th}$ part of the solar day. But it is known that the rotation of the earth varies substantially with time and therefore, the length of a day is a variable quantity, may be very slowly varying.

The XIII General Conference on Weights and Measures in 1967 defined one second as the time required for Cesium–133 atom to undergo 9192631770 vibrations. The definition has its roots in a device, which is named as the atomic clock.

(d) **Temperature**: The SI unit of temperature is kelvin (K). The thermodynamic scale on which temperature is measured has its zero at absolute zero, and has its lower fixed point corresponding to 273.15 K at the triple point of water (0°C). One unit of thermodynamic temperature (1K) is equal to 1/273.15 of the thermodynamic temperature of the triple point of water.

(e) **Electric current**: The SI unit of electric current is the ampere (A). One ampere is defined as the magnitude of current that when flowing through two long parallel wires, each of length equal to 1 m, separated by 1 metre in free space, results in a force of 2×10^{-7} N between the two wires.

(f) **Amount of substance**: The SI unit of amount is mole (mol). One mole is defined as the amount of any substance, which contains, as may elementary units, as there are atoms in exactly 0.012 kg of C-12 isotope of carbon.

(g) **Luminous intensity**: The SI unit of luminous intensity (I) is candela (Cd). The candela is defined as the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 × 1012 hertz and that has a radiant intensity of 1/683 watt per steradian in that direction.

ANSWERS TO INTEXT QUESTIONS

1.1

1. Measurement may be defined as a kind of counting. It refers to counting of the number of times a chosen scale is used to make the measurement. For example :An inch tape to measure length, or a graded cylinder to measure volume.
2. A unit is a measure, device or a scale in terms of which we make physical measurement.
3. A standard unit must have the following characteristics to be useful
   - relevant
   - convenient
   - well defined

1.2

1. Parmanu
2. Arm, Angul, Cubit, etc.
3. Because the parts of human body may vary from person to person and we cannot trust on our senses to measure exactly and accurately.
4. During the period of Moghul emperor Akbar.

1.3

1. (a) Fundamental units are only seven in number whereas derived units are very large in number.

   (b) Fundamental units are independent of each other but derived units are obtained from fundamental units.
2. Mass of a body is the amount of matter contained in a body while the amount of the substance is equal to its molecular mass.
3. Unit of pressure = Unit of force/Unit of area = $kg\ ms^{-2} / m^2 = kg\ m^{-1}s^{-2}$
4. Hz
5. Watt
6. Mohindar and Alam, meter scale, kilogram

1.4

(i) 1.2 fm (ii) 3.7 mm (iii) 60 E m

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MODULE - 2

MATTER IN OUR SURROUNDINGS

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2

MATTER IN OUR SURROUNDINGS

You have learnt about units of measurement in the previous lesson. What we eat, drink or breathe is the matter. Hence all of us are surrounded by matter. *Anything which occupies space and has mass is matter*. In order to understand the world better it is necessary to understand the *nature of matter*.

In this section you shall learn about matter and shall utilise the concepts of measurement in understanding the properties of matter.

OBJECTIVES

After completing this lesson you will be able to:

- *describe what is matter and explain its particulate nature;*
- *clarify and differentiate the three states of matter – solid, liquid and gas;*
- *describe the effect of pressure and temperature on states of matter;*
- *illustrate the inter-conversion of these states with the help of suitable examples;*
- *classify the given matter as an element, a compound or a mixture;*
- *distinguish between homogeneous and heterogeneous mixtures;*
- *define the terms solution, solvent and solute;*
- *calculate the percentage composition of a solution;*
- *describe the properties and uses of suspension, and*
- *describe the common methods used for separation of mixtures or purification of a substance.*

2.1 WHAT IS MATTER?

Matter is any thing which has mass and occupies space. All solids, liquids and gases around us are made of matter. Scientist believe that matter is made of tiny particles that clump together. You cannot see these particles but you can see the matter, for example, a book, a car, a letter, a hand set, a piece of wood, tree, a bag etc. Think and add a few more exmaples from your day to day life.

When we say matter has mass it means matter has weight: the heavier an object, the more mass it has. Matter occupies space it means matter has volume.

A substance is a pure kind of matter having only one kind of constituent particle (atom or molecule). Water, iron, gold, copper, aluminum and oxygen are examples of substances. **All substances are matter but all forms of matter are not substances.** You must be wondering how this is possible. Well, a substance is a pure form of matter, that is, it is the same throughout. Let us take the examples of soft drinks and soil. In what category you would put them. They are not single substance but they are mixture of substances. Now you will find out what is the nature of matter?

2.2 PARTICULATE NATURE OF MATTER

Human beings have been questioning the nature of matter. In ancient times there were two different views about it. One school of thought believed that if we take a piece of matter (for example stone) and break it into smaller pieces and break these smaller pieces into still smaller pieces, the process can be repeated any number of times. This would happen because matter is continuous and its piece of any size can be broken or subdivided into smaller pieces. Greek philosophers Plato and Aristotle belong to this school of thought.

The second school of thought believed that process of subdivision of matter can be repeated only for limited number of times. A stage would be reached when the tiny particles of matter so obtained cannot be further subdivided. They believed that all matter is composed of very tiny particles. In other words, the matter has particulate nature. The smallest indivisible particles of matter were given the name "atom" from the Greek word "atomos" for " indivisible" .

Indian philosopher Kanada and Greek philosophers Leucippus and Democritus belong to this school of thought. The term "atom" was coined by Democritus. Today the idea of atom has changed since it was first proposed. The modern idea of atom originated with John Dalton in 1803. Today we talk of two types of constituent particles-atoms and molecules. Atoms is a basic unit of matter and all chemical

Notes

properties of matter can be explained on its basis. Molecules are important in explaining physical properties of matter. Details about atoms and molecules will be undertaken in the Lesson No. 3. Let us learn about how to classify matter.

INTEXT QUESTIONS 2.1

1. What is matter?
2. Which of the following is not a pure substance?

   (a) Iron (b) Water (c) Soil

3. Who coined the term "atom" and what does it mean?

2.3 STATES OF MATTER

Matter can be classified in many ways. However, the following are the two main ways of classifying the matter:

(i) by the physical state of matter as a solid, liquid, or gas, and

(ii) by the chemical composition of matter as an element, compound or mixture.

We shall discuss these classifications in the next section.

Let us discuss about the classification of matter based on physical states. Matter can ordinarily exist in three states – solid, liquid and gas. These three states of matter have different properties. Water exists in all the three states namely steam or water vapour (gas), water at room temperature (liquid) and ice (solid). This is the only substance which exists naturally in all the three states.

The characteristic properties of different states of matter depend on intermolecular forces. **The forces holding molecules together are called intermolecular forces.** Intermolecular forces (i.e. forces between the constituent molecules) try to keep molecules together but thermal energy always tries to keep them far apart. It is the competition between molecular interaction energy and thermal energy that decides whether a given substance under given conditions will be a solid, liquid or gas. Thermal or heat energy can convert one state of matter into another state. Thus a particular state of a matter depends on both : intermolecular force and the thermal energy which basically depends upon temperature.

Each state of matter has some characteristic properties. Now you shall learn about these properties.

2.3.1 Solids

We are surrounded by innumerable solid objects. A piece of wood, a stone, a pencil, a pen, and a computer all are examples of solids. **A solid has definite size and shape which do not change on their own** (see **Fig.2.1).** However, by using external forces you can change the shape of a solid. For example you can cut a piece of metal into two and you can use hammer to change its shape. Can you think of any other way to change the shape of solids? Yes, you can. Beat it into sheets or pull it into strings.

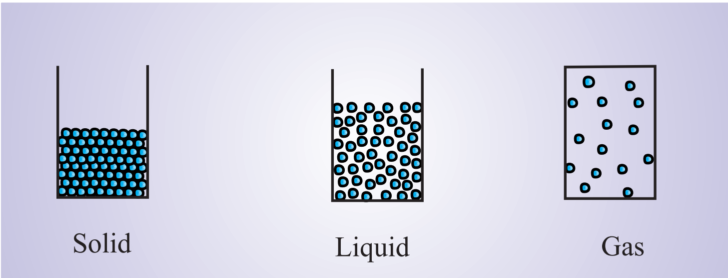


Fig. 2.1: *Shapes of different states of matter*

In solids the constituent particles are present very close to each other and the intermolecular forces operating between the constituent particles are very strong and they are capable of keeping the molecules in fixed positions. This is the reason why solids are rigid and hard. Also, solids cannot be compressed. The attractive intermolecular forces become repulsive when atoms or molecules are forced to come further closer. When a solid is heated there is an increase in thermal energy of the particles which results in conversion of solid into liquid. The temperature at which this happens is the **melting point** of the solid.

2.3.2 Liquids

Water is a liquid. Mustard oil and kerosene oil are other examples of liquids. Can you think of some more examples? **A liquid has a definite volume**. However, a liquid does not have a definite shape. It takes the shape of its container. A liquid can flow. You can pour a liquid or spill it. Can you spill a solid?

Liquids have properties intermediate between solids and gases. The intermolecular forces in liquids are weaker than solids but stronger than gases. In liquids the constituent particles do not occupy fixed position as in solids, but they have freedom of movement as in gases. In liquids intermolecular forces are stronger than those of gases.The constituent particles (atoms and molecules) in a liquid can break away from each other and get attracted while approaching the other molecules. Like in solids,

the intermolecular forces become repulsive when an attempt is made to bring the molecules closer by applying pressure. This is the reason why pressure does not have much effect on volume of liquids.

2.3.3 Gases

We cannot see gases but they are all around us. We can feel the presence of air when the wind blows. **The wind is moving air and is a mixture of many gases like oxygen, nitrogen, argon, carbon dioxide and others.** A gas occupies the entire volume of the container irrespective of its size (see Figure 2.1). In gases, molecules move freely because the intermolecular forces are very weak and are unable to keep the gas molecules together in bulk. The molecules remain far apart from each other due to weak molecular interactions. Since molecules are far away from each other in gases, they can be brought closer when pressure is applied. This is the reason why-gases are highly compressible. We can compress a gas only up to a certain limit. Beyond this limit repulsion between gas molecules becomes very high. Temperature also affects the volume of the gases. When temperature increases, volume of the gas also increases. For example when a closed container is heated it blasts due to rapid increase in volume.

We are lucky that a gas can be compressed easily. If this was not the case then we could not have obtained CNG (Compressed Natural Gas). As you might be aware that CNG is used as a clean fuel for vehicles and you might have noticed that at the back of several Autorikshas and buses, CNG is written. We also have our cooking gas cylinders in kitchen because gas (LPG) is compressible. There are many other examples of uses based on compressibility of gases. Can you think some more examples? Oxygen cylinder in hospital is another example.

The distribution of molecules in solid, liquid and gas is shown in Fig 2.2.

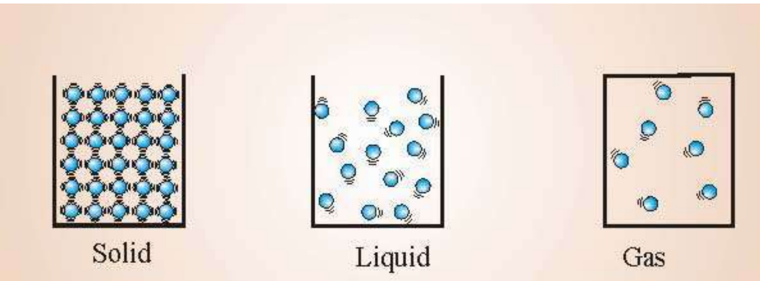


Fig. 2.2: *Schematic representation of distribution of molecules in solid, liquid and gas*

Do you know

Three basic states of matter, described above, are dominant on Earth but they become less relevant in other parts of the universe. You will be surprised to know that 99% of the matter in the entire universe is not a solid, a liquid or a gas. The form of matter that is more dominant is called 'plasma'. The Sun consists of plasma as most of the other stars do. You will learn about "plasma" in your higher classes.

Different characteristics of the three states of matter have been summarized in Table.2.1.

Table 2.1 Different characteristics of the three states of matter

State of matter	Volume	Density	Shape	Fluidity	Compressibility
Solid	Has fixed volume	High	Has definite shape	Does not flow	Negligible
Liquid	Has fixed volume	Lower as compared to solid	Has no definite shape. It takes the shape of container.	Flows smoothly	Very small
Gas	Has no fixed volume	Low	Has no definite shape.	Flows smoothly	Highly compressible

INTEXT QUESTIONS 2.2

1. Which of the three states of matter has no definite volume? Give one reason for your answer.
   (a) Solid, (b) liquid, (c) gas
2. Why do solids have definite shape?
3. Name a substance which exists naturally in all the three states.

Do you know

There are two basic concepts in the physical world around which you can organize everything. These two basic concepts are matter and energy. Both matter and energy are related to each other by the formula $E = mc^2$. Here E is energy, m is mass and c is velocity of light. One of the greatest scientists of all times, Albert Einstein showed that matter can be transformed into energy, and energy can be transformed into matter. No doubt, transforming matter into energy is easy whereas transforming energy into matter is difficult.

2.4 EFFECT OF TEMPERATURE AND PRESSURE ON STATES OF MATTER

Have you ever thought what happens if a solid substance is heated? When heat is supplied to a solid, it expands. This expansion is very small. In fact after receiving thermal energy, particles (atom/molecules) vibrate more rapidly in their position and take up more space. If particles become more energetic on further heating they leave their fixed positions and the solid melts. Once a solid becomes liquid it can be poured into a container. As you learned earlier, a liquid takes the shape of the container in which it is poured. Particles in the liquid state are free to move.

Now let us see what happens when a liquid is heated. On receiving heat (thermal energy) a liquid is converted into a gas. This happens because the kinetic energy of the particles becomes so high that they can overcome the intermolecular force within the liquid. Therefore liquid is converted into gas (vapour).

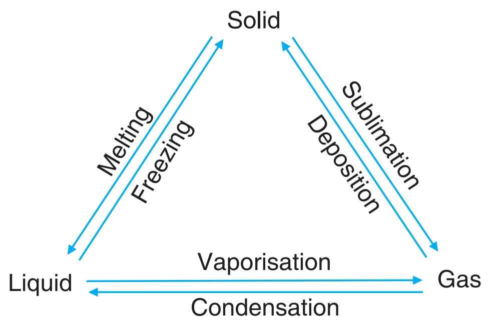


Fig. 2.3: *Interconversion of states of matter*

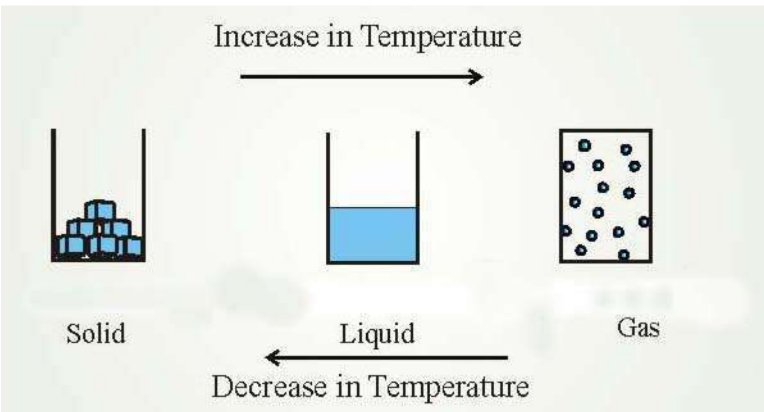


Fig. 2.4: *Inter-conversion of states: from solid to liquid, liquid to gas and vice versa with variation of temperature*

When a gas is heated, kinetic energy of the particles increases. They move more freely and at much higher speed. Intermolecular distance also increases and the volume of the gas increases if pressure is kept constant. Do you know what happens when a balloon filled with air is brought near fire?

A pure solid turns to liquid at a fixed temperature or in other words conversion of pure substance from solid to liquid takes place at one particular temperature. This particular temperature is called **melting point** of that particular solid substance. Similarly when the liquid cools down, it converts into solid at a particular temperature. This temperature is called **freezing point** of that particular liquid substance. The temperature at which a liquid boils and is converted into a gas is **boiling point** of the liquid.

ACTIVITY 2.1

Demonstrating the inter-conversion of the three states of matter

Materials required: Ice, container, gas burner or any other heating device.

How to do it:

Put the ice in the container and gradually heat it. First it will melt into water and if you continue heating it will turn into vapour.

You should remember that the three different states of matter respond differently with changes of temperature and pressure. All the three states expand or show an increase in volume when the temperature is increased. They contract or show a decrease in volume when the temperature is lowered. However, the effect of pressure on solid and liquid is negligible. A gas can be compressed easily by applying pressure.

ACTIVITY 2.2

You can observe the effect of pressure on gases and liquids by performing the following experiment.

Take a syringe and close its nozzle by inserting it in a rubber cork. Remove the piston so that the entire space inside the syringe is filled with air. Now, insert the piston carefully back in the syringe and try to compress the air by pushing the piston. What do you observe? You will find that the piston can be pushed easily. Of course beyond a point you will not be able to push the piston. This shows that air is compressible easily. Now you repeat the experiment with liquid. Can you push the piston as easily as you could push with air? If you try, you will find that it is not possible. This is because the molecules in liquids are much close to each other as compared to gases.

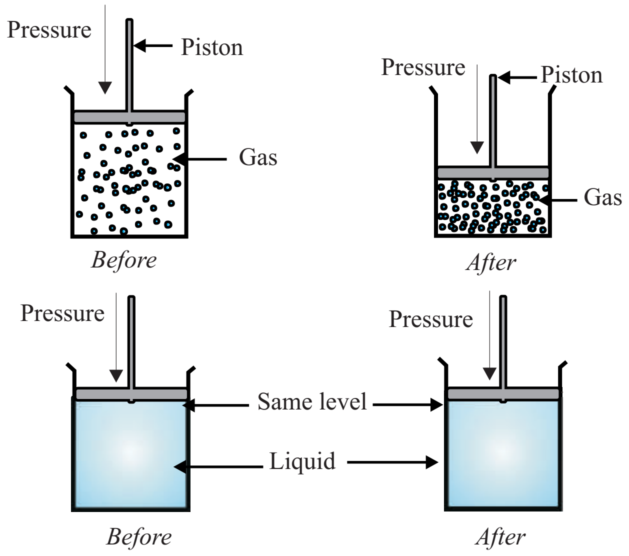


Fig. 2.5 : *Effect of pressure on gas and liquid*

INTEXT QUESTIONS 2.3

1. Why gases are more compressible as compared to solids?
2. How can you change water into ice?

2.5 ELEMENTS, COMPOUNDS AND MIXTURES

2.5.1 Elements

All substances are made up of chemical elements. A chemical element is a basic form of matter that cannot be chemically broken down into simpler substances. **A chemical element is a pure substance and it consists of one type of atom distinguished by its atomic number.** Examples of some elements are : helium, carbon, iron, gold, silver, copper, aluminum, hydrogen, oxygen, nitrogen, sulphur, copper, chlorine, iodine, uranium, and plutonium.

Elements are the building blocks of the Universe. In total, 114 elements have been listed so far. Out of the total 114 known elements, about 90 occur naturally on Earth and the remaining have been synthesized artificially by nuclear reactions. Only two elements namely hydrogen (92%) and helium (7%) make up about 99% of the total mass of the Universe. The remaining elements contribute only 1% to the total mass of the Universe.

Out of about 90 elements found naturally on Earth, two elements silicon and oxygen together make up almost three-quarters of the Earth's crust. Our body is also composed of elements but the composition of elements in human body is very much different from that of the Earth's crust, as it can be seen from Table 2.2.

Notes

Table 2.2: Elements in Earth's crust and human body

Elements		% by mass	
		Earth's Crust	Human Body
1.	Aluminium	6.5	very little
2.	Calcium	3.6	1.5
3.	Carbon	0.03	18.5
4.	Hydrogen	0.14	9.5
5.	Iron	5.0	very little
6.	Magnesium	2.1	0.1
7.	Oxygen	46.6	65.0
8.	Silicon	27.7	very little
9.	Sodium	2.8	0.2
10.	Sulphur	0.03	0.3

Although human beings and Earth share elements in their composition, human being have several advantages like being able to think, feel etc. Don't you think that it is our responsibility to take care of Earth?

2.5.2 Compounds

A compound is a substance formed when two or more than two elements are chemically combined. **A compound can be defined as a pure substance made from two or more elements chemically combined together in a definite proportion by mass.** When elements join to form compounds they lose their individual properties. Compounds have different properties from the elements they are made of. For example, water (a compound) is made up of elements – hydrogen and oxygen but properties of water are different from those of hydrogen and oxygen .The world of compounds is really fascinating because compounds show a great variety in forms and properties.

Some examples of compounds are given below:

Glucose	Glycerol	Calcium oxide
Sodium chloride	Sulphuric acid	Carbon dioxide
Hydrochloric acid	Chloroform	Acetic acid
Sodium carbonate	Ethanol	Carbon monoxide
Phenol	Citric acid	Methane

A pictorial representation of element compound and mixture is shown in Fig. 2.6

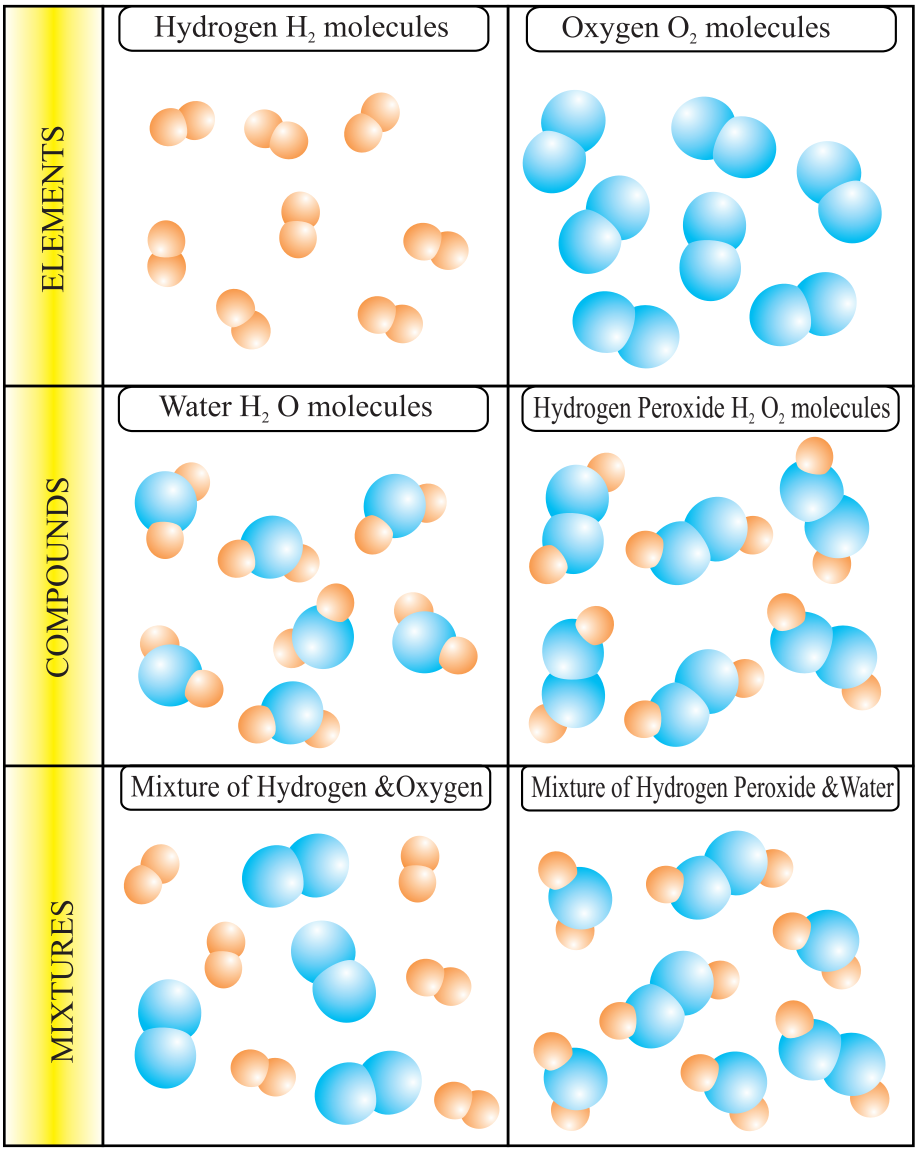


Fig. 2.6: *A Pictorial representation of elements, compounds and mixtures. From the figure we can see that elements combine to form compounds but in the mixture the elements and compounds maintain their separate identities*

2.5.3 Mixture

In our everyday life we deal with a large number of substances but majority of them are not pure substances (elements or compounds). They are mixtures of two or more pure substances. In the next section we shall see that there are two types of mixture depending on whether the parts of the mixtures completely mix or not

The relationship among elements, compounds and other categories of matter are summarized in Fig. 2.7.

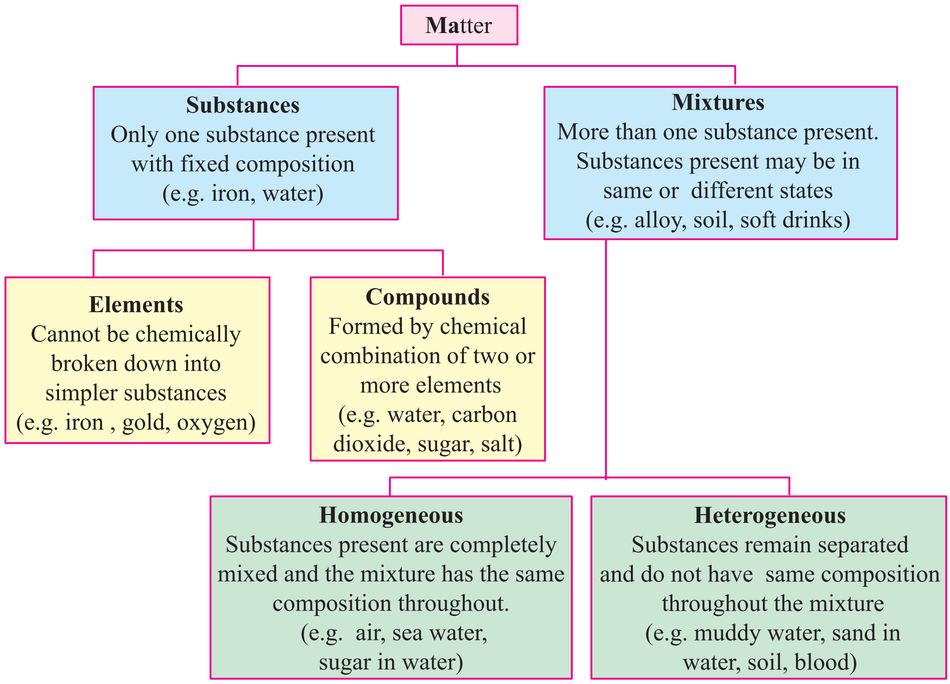


Fig. 2.7: *Classification of matter*

INTEXT QUESTIONS 2.4

1. Classify the following into element, compound and mixture:
   aluminum, carbon, granite, water, silicon, carbon dioxide, air and sugar.
2. How does an element differ from a compound?
3. Which is the most abundant element in the universe?

2.6 HOMOGENEOUS AND HETEROGENEOUS MIXTURES

Mixtures are broadly divided in two major groups – (i) homogeneous mixtures and (ii) heterogeneous mixtures.

2.6.1 Homogeneous Mixture

You have seen that people having loose motion take ORS. What is ORS? You can yourself prepare ORS by putting little amounts of salt and sugar in water. ORS is an example of a homogeneous mixture or solution. So let us learn about homogeneous mixtures.

In some mixtures, constituents are completely mixed in such a way that the entire mixture has the same composition throughout. Such mixtures which have uniform composition are called **homogeneous mixtures**. For example when you prepare *sharbat* by mixing sugar and water in a jug, the entire mixture has the uniform

sweetness. Technically such homogeneous mixtures are called **solutions**. For example common salt, which is solid when dissolved in water, forms a liquid mixture or a salt solution. The salt is totally dispersed into water uniformly and one cannot see it (Fig. 2.8). Two-thirds of the Earth's surface is covered by sea water which is nothing but a homogeneous mixture (solution) of various salts in water. Sea water also contains dissolved gases like oxygen and carbon dioxide. The air we breathe is a homogenous mixture of different gases. Two liquids can also form homogeneous mixture for example water mixes with ethyl alcohol in all proportions. In other words water is miscible with ethyl alcohol or vice versa. Many alloys are also homogeneous mixtures of two or more than two metals. Gold and copper form homogeneous solid *solution*. Do you know a goldsmith can judge the purity of gold by testing any part of it.

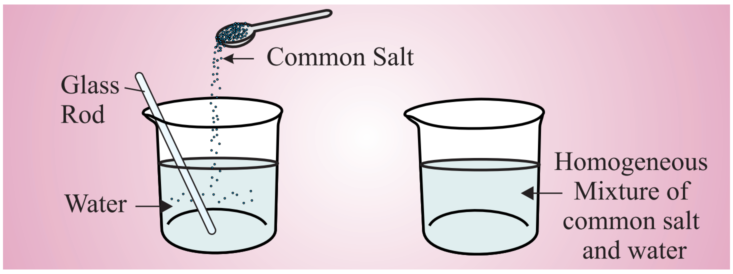


Fig. 2.8 Mixing of common salt into water

A homogeneous mixture is a mixture where the substances are completely mixed together and have uniform composition throughout.

Different types of homogeneous mixtures that may result by mixing different substances have been summarized in **Table 2.3**.

Table 2.3: Different types of homogeneous mixtures

Type of mixture	Description	Examples	Can you think another example(s)?
Solid + liquid	solid dissolves in liquid to form transparent solution	sugar in water or salt in water, iodine in ethyl alcohol (tincture iodine)	
Liquid + liquid	forms a single transparent mixture	Mixture of water and ethyl alcohol.	
Gas + liquid	Gas completely dissolves in a liquid to form a transparent solution	Soda water and any other common soft drink	
Gas + gas	mixture of two or more gases	Air	
Solid + solid	some metallic alloys	Brass, bronze	

You can discuss with your friends and others while carrying out the above exercise.

2.6.2 Heterogeneous Mixture

Have you ever brought a 'mixture' from market? If yes, then you must have noticed that such a mixture contains different constituents and each of these constituents is visible.

Such mixtures where the constituents do not completely mix with each other, and remain separate, are called *heterogeneous mixtures* (Fig. 2.9). In such mixtures one substance is spread throughout the other in the form of small particles, droplets or bubbles.

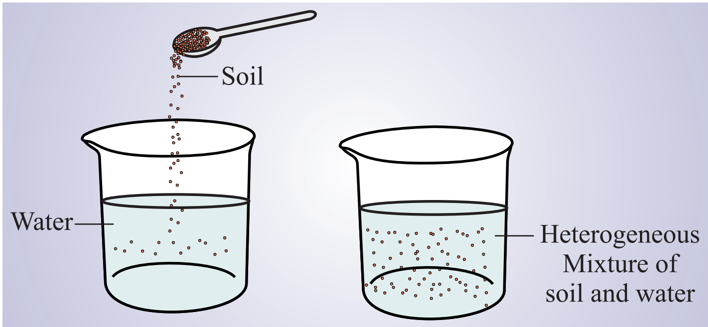


Fig. 2.9 Mixing of soil into water to form heterogeneous solution

A heterogeneous mixture is a mixture where the substances (parts or phases) remain separate and composition is not uniform.

Different types of heterogeneous mixtures that may result by mixing different substances have been summarized in **Table 2.4**.

Table 2.4: Different types of heterogeneous mixtures

Type of mixture	Description	Examples	Can you think of another example(s)?
Suspension	solid + liquid	flour in water, river water carrying mud	
Gel	liquid trapped in solid	fruit jelly, agar gel	
Emulsion	mixture of tiny droplets of one liquid suspended in another	milk	
Aerosol	small droplets of liquid or particles of solid dispersed in a gas	clouds (liquid in gas) smoke (solid in gas)	
Foam	Gas in liquid: small bubbles of gas trapped in liquid	shaving foam	
	Gas in solid: small bubbles of gas trapped in solid	polystyrene foam (Thermocoal)	

You may like to discuss with your mother to know whether any of the above types of mixtures are used in your home.

ACTIVITY 2.3

Collect at least 10 different things from your homes and surroundings and classify them based on their composition and place in the following table:

S.No.	Name of the things/ objects/ material	Element	Compound	Mixture	not known
				Homogeneous or Heterogeneous	
1.	Water				
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

INTEXT QUESTIONS 2.5

1. Say whether ethyl alcohol and water form a homogeneous mixture or heterogeneous mixture.
2. Give an example of homogeneous mixture obtained by mixing two solids.

2.7 SOLUTION AND ITS CONCENTRATION

A solution (a homogeneous mixture) is formed when one or more substances (the **solute**) are completely dissolved in another substance (the **solvent**). When we think about solutions, the most common examples that come to our mind are the solutions that are obtained by dissolving solids in water. Sugar or common salt dissolved in water gives this type of solution. Do you know that two-third of the Earth's surface is covered by a solution? You may be able to guess this solution present in oceans. The sea-water is a solution of water and soluble minerals. It also contains gases like oxygen, nitrogen and carbon dioxide. Such dissolved gases are very important for aquatic life to survive in oceans.

There are some solutions of two or more than two liquids. As you know that ethyl alcohol mixes with water in all proportions to form a solution. Iodine (solid) dissolved in ethyl alcohol gives tincture of iodine which has antiseptic properties.

A solution made of solid dissolved in a liquid has two parts:

- the solid that dissolves is called the **solute**,
- the liquid, in which the solid is dissolved, is called the **solvent.** Fig. 2.10.

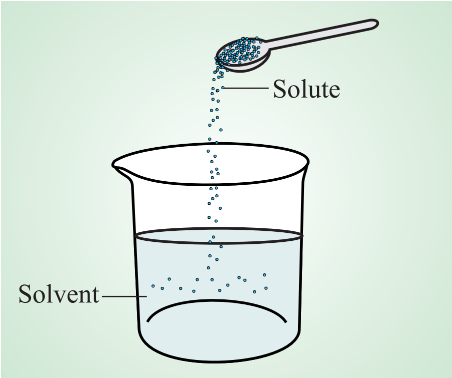


Fig. 2.10 Mixing of NaCl into water

You have just seen that solutions are not confined to only solids dissolved in liquids. There are other types of solutions as described earlier. In each case the **substance which is present in bigger quantity is normally taken as solvent and substance which is present in smaller quantity is normally taken as solute.**

When a substance dissolves in a solvent it is said that that particular solute is **soluble** in that particular solvent. If it does not dissolve then it is **insoluble**. Water is a commonly used solvent as it dissolves a large number of substances. Because of this property water is called a **universal solvent**. Different types of substances dissolve in water. Because of this unique property of water, plants can take minerals from the soil? Being a good solvent, water is used in many ways. However, there are some disadvantages also which result from this unique property of water. Water becomes easily contaminated. Therefore, purifying water for drinking and other uses is a major challenge.

There are other important solvents, for examples organic liquids. The **organic solvents** are important because, unlike water, they dissolve organic substances. Ethyl alcohol and benzene are examples of such organic solvents.

2.7.1 Concentration of a Solution

The term "concentration" is most often used when we talk about solutions. Concentration of a solution is expressed in terms of the amount of solute present in a given mass or in a given volume of a solvent. Usually **concentration** of a solution is defined as the mass of solute present in a definite volume of a **solution** (which is usually taken as 1 litre). Concentration of a solution may also be expressed in terms of per cent by mass of solute (in gram). This gives the mass of solute per 100 mass units (grams) of solution as shown below:

$$\% \text{ of solute} = (\text{mass of solute}/\text{mass of solution}) \times 100.$$

A solution of 10% glucose by mass means that 100 grams of the solution contains 10 gram of glucose. This means 10 grams of glucose is dissolved in 90 grams of water.

When we try to dissolve a particular substance say sugar in water, the solution becomes more concentrated as we add more and more sugar. A concentrated solution contains a high proportion of the solute. A dilute solution contains a small proportion of solute.

If we keep on adding solute to a solvent, keeping the temperature constant we reach a point where no more solute will be dissolved. At this point we say that the solution has become **saturated** with respect to solute. However, if we increase the temperature, more solute will get dissolved. **The concentration of a solute in a saturated solution at a definite temperature is called solubility of that solute in that particular solvent.**

ACTIVITY 2.4

Make a solution of sodium chloride in water with a known concentration of 10g/litre by mass.

1. Take a graduated flask and fill approximately half with distilled water (the solvent).
2. Weigh out 10 g of sodium chloride (the solute).
3. Carefully add the sodium chloride to the water in the container.
4. Gently shake the container to dissolve all the sodium chloride.
5. Add more distilled water to make up the volume of the solution to exactly the 1000 mL (1.0 dm^3) mark on the neck of the graduated flask. Finally shake the flask carefully to make the solution uniform.

INTEXT QUESTIONS 2.6

1. To make one kilogram of 40% sugar solution by mass, how much sugar and water will you need?

   sugar ....

   water ....

2. What is the name given to a liquid which dissolves a solid to make a solution?
3. To make a given solution more concentrated, what will you add?

2.8 SUSPENSIONS

In winter, the fog is a common experience in both urban and rural areas. What is fog? Fog forms when tiny water droplets are suspended in air. So fog is nothing but a type of a suspension. There are large numbers of substances which do not mix with each other. There are some solids that do not dissolve in water or other liquid solvents and there are liquids that do not mix with each other. The mixing of such substances results into heterogeneous mixtures. Depending on the size of the particles suspended, or dispersed in the surrounding medium, heterogeneous mixtures can be divided into colloids and suspension. You will study about colloids in higher classes. Here we shall briefly describe suspension. Materials of smaller particle size, insoluble in a solvent but visible to naked eyes, form suspension.

Unlike a colloid, which contains smaller particles ranging in size from 1 to 1000 nanometres, a suspension contains relatively larger particles. The size of particles in suspension is over 1000 nanometres. When flour is added to water it does not dissolve but forms a slurry, which we call a suspension. However, if less amount of water is added in the flour (200 g of flour and 100 mL of water) we get dough to make chapatti etc. Muddy water is an example of suspension. When a suspension is allowed to stand undisturbed, the dispersed particles settle down (Fig. 2.11).

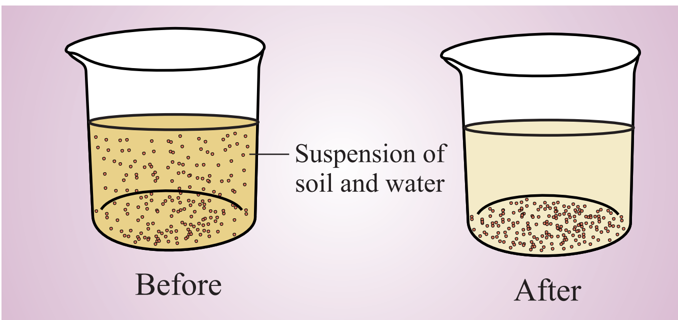


Fig. 2.11 *Settling of suspension when it is allowed to stand undisturbed*

Suspensions are very useful in medical sciences. For example barium sulphate (whose solubility is very low when dispersed in water) is an opaque medium. It is used for diagnostic X-rays (barium meal test). Many medicines, which are insoluble in water, are given in the form of suspension, for example, pencillin and amoxycilin. Please check a few bottles of medicine. Do you find the word suspension written on a bottle.

ACTIVITY 2.5

Prepare a suspension using materials available in your home.

Materials required**:** Wheat flour (1 cup approximate 200g), water, a glass (250 mL), and a spoon.

How to do it

Pour water into a glass and add wheat flour to water. Stir the water with the help of the spoon. Keep the mixture undisturbed for some time . Write your observation and identify whether you have prepared a suspension or a solution. Give at least one reason for your answer..

2.9 SEPARATION OF MIXTURES

Have you seen someone removing unwanted materials from rice or wheat? If so then you have seen separation of heterogeneous mixture into pure components by physical means. Have you eaten *mishri*, the bigger crystal of sugar? Preparation of *mishri* involves separation of sugar from homogeneous mixture of sugar and water. Both in our households and in industries we need to separate mixtures, both homogeneous and heterogeneous, for various purposes. Fortunately we can recover sugar or salt from its water solution by evaporating the water or even sometimes by heating. To separate different components of a mixture variety of physical techniques are available. ***All these separation techniques are based on difference in the physical properties of the components present in the mixture***. The following two factors decide the best possible technique to be adopted for separation:

(i) the type of mixture,

(ii) the component which you want to collect.

Here we shall describe some of the common techniques of separation.

2.9.1 Separation by using Separating Funnels

The mixture of two immiscible liquids (i.e, the liquids that do not mix , as oil and water) can be separated by using a **separating funnel**. The mixture is placed in separating funnel and allowed to stand for some times. When the two layers of liquids are separated, the denser liquid which is in the lower part, is first collected by opening the stop-cock. (See Fig. 2.12) This method is very useful in industries.

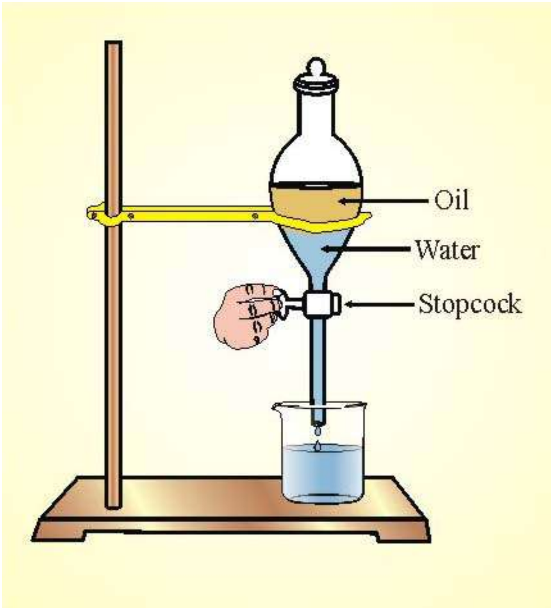


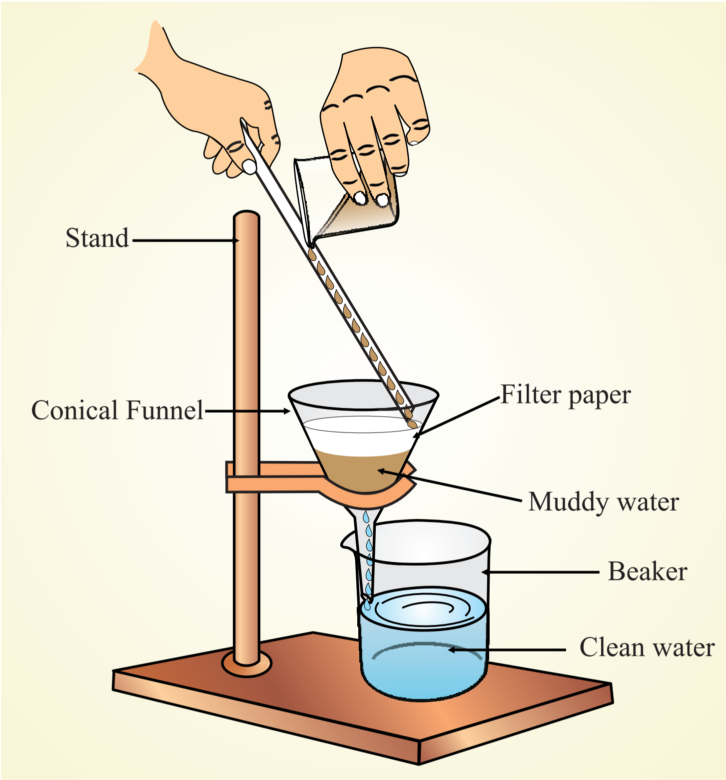
Fig. 2.12: *Separation of oil and water using separating funnel*

2.9.2 Separation by Evaporation

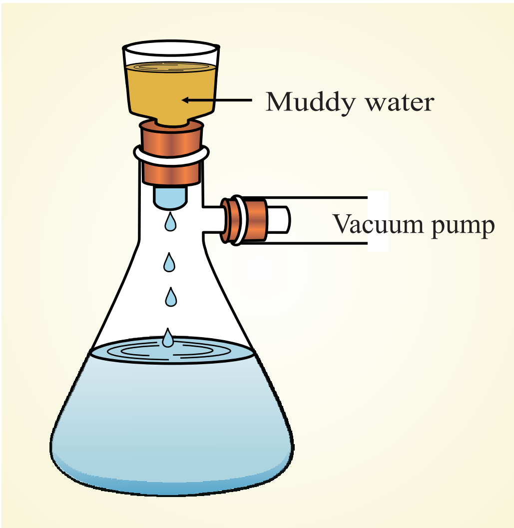
The separation of liquid (solvent) and solid (solute) from a solution is done by removing the liquid (solvent) by heating or by solar evaporation. By evaporation you can recover the solute component only in solid or powder form. If the solvent is inflammable you cannot use flame for heating instead you can use an electrical heating system and an oil or water bath. You might have heard that salt is obtained from sea water by the process of evaporation in shallow beds near the sea shore.

2.9.3 Separation by Filtration

Filtration is a better method for separating solids from liquids in heterogeneous mixtures. In filtration the solid material is collected as a residue on filter paper and the liquid phase is obtained as filtrate. The method of filtration is used on a large scale in industries Fig. 2.13.



(*a*)



(*b*)

Fig. 2.13: *Filtration (a) simple filtration (b) vacuum filtration*

2.9.4 Separation by Crystallization

Crystallization is a process of formation of solid crystals from a solution. The method of crystallization for separating solid from liquid begins by evaporating the liquid.

However, in crystallization, the evaporation is stopped when the solution is concentrated enough. The concentrated solution thus produced, is allowed to cool slowly to form crystals which can be separated by filtration. *Mishri (sugar crystals)* is produced by crystallization from concentrated sugar solution.

2.9.5 Separation by Distillation

The method of distillation is used to separate a liquid from a solution of a homogeneous mixture. The distillation is a process in which a liquid or mixture of liquids is boiled in a distillation flask. The vapour is condensed by passing through a water-cooled tube called **condenser** and collected as liquid called **distillate** Fig. 2.14. In case of a solution of two miscible liquids (the liquids which can be mixed completely) the **separation is based on the fact that the liquids will have different boiling points** and there is a wide difference between the boiling points of the two liquids.

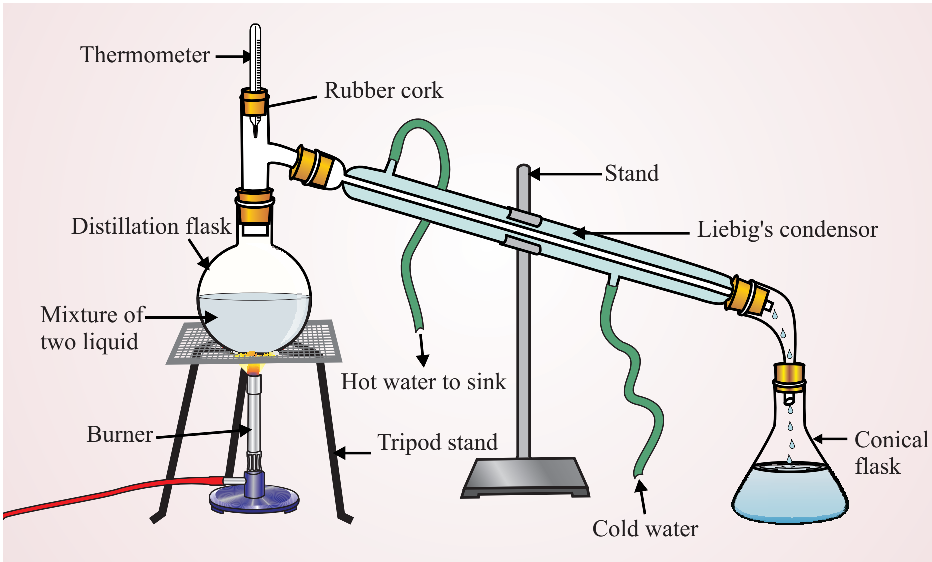


Fig. 2.14 : *The Distillation apparatus*

2.9.6 Separation based on Magnetic Properties

How would you separate a mixture of magnetic and non-magnetic substance? In a mixture of magnetic and non-magnetic substances, the magnetic substance can be separated by using a magnet. For example you will be able to separate iron granules, which are magnetic, from non-magnetic substances like sand, sugar, saw dust etc. (Fig. 2.15). In industry this method is used to separate iron materials from non-magnetic materials by using large electromagnets. e.g. of iron ore.

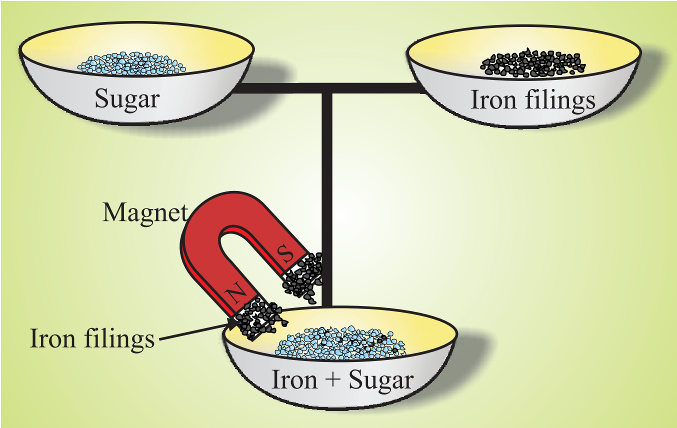


Fig. 2.15 : *Magnetic Separation of a mixture*

ACTIVITY 2.6

Separate iron granules from the mixture-iron granule and sugar.

Materials

Sugar, iron granules and a magnet.

How to do it

Mix the sugar crystals and iron granules and spread a thin layer of the mixture over a piece of paper. Hold the magnet closely over the mixture. The iron granules will be attracted to the magnet. Remove the iron granules from the magnet and repeat the process till no more iron granules remain in the mixture.

ACTIVITY 2.7

Separate water from muddy water by the process of distillation using solar energy

Materials

Large dish pan, a glass container shorter in length than the pan, plastic wrap, 9-10 clean marbles or small pieces of stone, plastic membrane, and (2 litre) muddy water.

How to do it

1. Take muddy water in a large pan and put a glass in the centre of the pan as shown in Fig. 2.16. Put a few small marbles at the bottoms of the glass in order to make it stable in the water.

2. Cover the pan with a plastic wrap in such a way that it doesn't become too tight. The cello tape can be used to keep the plastic wrap in place.
3. Put marble or a small piece of stone in the centre of the plastic wrap to create a slight dip in the plastic over the glass for collecting water. The plastic should not touch glass.
4. Keep the pan in direct sunlight for several hours and you will see water vapour condense on the plastic and drip into the small glass container.

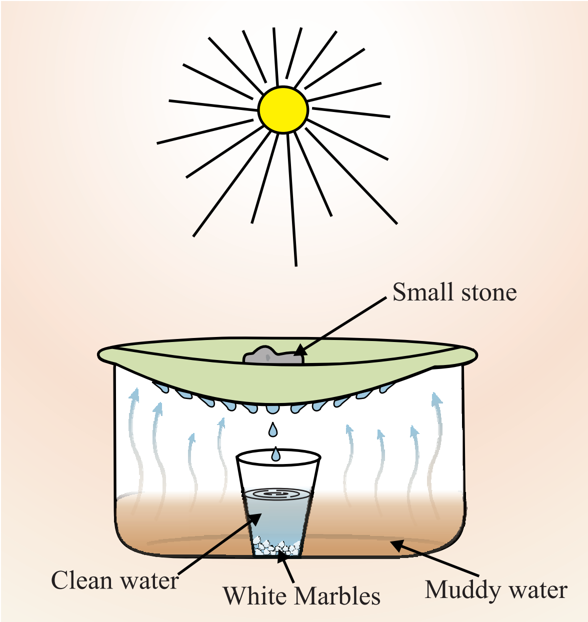


Fig. 2.16: *Solar still for purifying water*

The device prepared by following the steps mentioned above is called a **solar still (see Fig. 2.16.)**, which uses the natural process of evaporation and condensation to purify muddy water. The muddy water kept in the pan gets heated by the sun. The water is turned into vapour, and the mud remains in the bottom of the pan. The vapour on touching the plastic sheet covering the pan gets condensed as the plastic sheet is relatively cool because of the cooler air outside the container. The water collected in the small container is clean water (but not very fit for drinking).

INTEXT QUESTIONS 2.7

1. Which physical property is used to separate iron granules from dust particles?
   (a) Magnetic, (b) Electric, (c) Density
2. The separation of sugar in the form of *Mishree* is called
   (a) evaporation (b) crystallization (c) distillation

WHAT YOU HAVE LEARNT

- Anything that has mass and occupies space is matter. Matter can be detected and measured.
- There are three different physical states of matter in which a substance can exist namely solid, liquid and gas.
- A particular state of matter can be changed into other states by changing the temperature and/or pressure.
- A solid has a definite size and shape which do not change on their own.
- A liquid has a definite size or volume and it takes shape of the container in which the liquid is kept.
- A gas has no shape or size of its own. It occupies entire volume of the container in which it is kept.
- Matter can be classified on the basis of its composition as element, compound or mixture.
- An element is a basic form of matter that cannot be chemically broken down into simpler substances.
- A compound is a pure substance made from two or more than two elements chemically combined together in a definite proportion by mass.
- Pressure and temperature affect states of matter.
- A wide varieties of mixture are possible between substances depending on their nature.
- A homogeneous mixture is a mixture where the substances are completely mixed together and are indistinguishable. A homogeneous mixture is called a solution.
- A heterogeneous mixture is a mixture where the substances remain separate and the composition is not uniform.
- A suspension is a heterogeneous mixture where the dispersed particles are large enough to settle out eventually.
- There are a number of methods available to purify and separate substances from a mixture. Some of the methods are filtration, crystallization and distillation.

TERMINAL EXERCISE

1. Indicate whether each of the following statements is true or false.

   (i) A liquid has a definite shape true/false

   (ii) An element cannot be broken into simpler substances by chemical means. true/false

(iii) A solid cannot be converted into liquid even by increasing temperature. true/false

(iv) A liquid can be converted into solid by lowering temperature true/false

2. Indicate the normal state (i.e. state at room temperature) of each of the following?

(i) iron	(ii) water	(iii) nitrogen
(iv) carbon	(v) gold	(vi) oxygen

3. In the table given below, a list of substances has been provided. Identify whether each of them is an element, compoind, mixture or soluton.

(i) Milk	(ii) Sugar	(iii) Silver
(iv) Air	(v) Water	(vi) Sea water
(vii) Iron	(viii) Sugar	(ix) Carbon dioxide

4. Why is it important to store cooking gas cylinder away from heat and flame?

5. Identify the most appropriate method to separate the following:

Substances	**Method of Separation**
1. Separate water from yogurt	
2. Separate clean water from muddy water	
3. Separate oil from oil water mixture	
4. Separate iron nails from saw dust	
5. Separate sugar from saturated sugar solution	

ANSWERS OF THE INTEXT QUESTIONS

2.1

1. Matter is anything that has mass and occupies space
2. Soil
3. Democritus. The word atom means indivisible.

2.2

1. Gases. A gas has no definite volume because intermolecular forces in gas are so weak that the molecules are far apart and in constant motion. They can fill container of any size.
2. The molecules in solids have fixed positions and strong intermolecular forces are acting between them. Therefore, it solids hae a definite shape.
3. Water

2.3

1. Molecules in solids are closely packed and any attempt to bring them closer results in strong repulsive forces and so solids cannot be compressed. In gases there are large spaces between their molecules and can be brought closer by applying pressure.
2. Water can be converted into ice by lowering the temperature.

2.4

1.

Element	Compound	Mixture
Aluminium	Water	air
Carbon	Carbon dioxide	granite
Silicon	Sugar	

2. An element consists of one type of atom but a compound contains two or more types of atom.
3. Hydrogen

2.5

1. The mixture of ethyl alcohol and water is a homogeneous mixture
2. Alloys eg. brass

2.6

1. 400 g sugar and 600 g water
2. Solvent
3. Solute

2.7

1. Magnetic
2. Crystallisation

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3

ATOMS AND MOLECULES

In the previous chapter you learnt about matter. The idea of divisibility of matter was considered long back in India around 500 B.C. Maharishi Kanad, an Indian Philosopher discussed it in his Darshan (Vaisesik Darshan). He said if we go on dividing matter, we shall get smaller and smaller particles. A stage would come beyond which further division will not be possible. He named these particles as 'PARMANU'. This concept was further elaborated by another Indian philosopher, Pakudha Katyayan. Katyayan said that these particles normally exist in a combined form which gives us various forms of matter.

Around the same era, an ancient Greek philosopher Democritus (460 – 370 BC) and Leucippus suggested that if we go on dividing matter, a stage will come when further division of particles will not be possible. Democritus called these individual particles 'atoms' (which means indivisible). These ideas were based on philosophical considerations. Experimental work to validate these ideas could not be done till the eighteenth century. However, today we know what an atom is and how it is responsible for different properties of substances. In this chapter, we shall study about atoms and molecules and related aspects like atomic and molecular masses, mole concept and molar masses. We shall also learn how to write chemical formula of a compound.

OBJECTIVES

After completing this lesson you will be able to :

- *state the law of conservation of mass and law of constant proportions;*
- *list important features of Dalton's atomic theory;*
- *distinguish between atoms and molecules;*
- *define isotopic mass, atomic mass, and molecular mass;*

- *define the mole concept and molar mass;*
- *represent some molecules with the help of a formula;*
- *apply the mole concept to chemical reaction and show a quantitative relationship between masses of reactants and products and*
- *solve simple problems based on various concepts learnt.*

3.1 LAWS OF CHEMICAL COMBINATIONS

There was tremendous progress in Chemical Sciences after 18th century. It arose out of an interest in the nature of heat and the way things burn. Major progress was made through the careful use of *chemical balance* to determine the change in mass that occurs in chemical reactions. The great French Chemist Antoine Lavoisier used the balance to study chemical reactions. He heated mercury in a sealed flask that contained air. After several days, a red substance mercury (II) oxide was produced. The gas remaining in the flask was reduced in mass. The remaining gas was neither able to support combustion nor life. The remaining gas in the flask was identified as nitrogen. The gas which combined with mercury was oxygen. Further he carefully performed the experiment by taking a weighed quantity of mercury (II) oxide. After strong heating, he found that mercury (II) oxide, red in colour, was decomposed into mercury and oxygen. He weighed both mercury and oxygen and found that their combined mass was equal to that of the mercury (II) oxide taken. Lavoisier finally came to the conclusion that ***in every chemical reaction, total masses of all the reactants is equal to the masses of all the products***. This law is known as the **law of conservation of mass.**

There was rapid progress in science after chemists began accurate determination of masses of reactants and products. French chemist Claude Berthollet and Joseph Proust worked on the ratio (by mass) of two elements which combine to form a compound. Through a careful work, Proust demonstrated the fundamental law of definite or constant proportions in 1808. **In a given chemical compound, the proportions by mass of the elements that compose it are fixed, independent of the origin of the compound or its mode of preparation.**

In pure water, for instance, the ratio of mass of hydrogen to the mass of oxygen is always 1:8 irrespective of the source of water. In other words, pure water contains 11.11% of hydrogen and 88.89% of oxygen by mass whether water is obtained from well, river or from a pond. Thus, if 9.0 g of water are decomposed, 1.0 g of hydrogen and 8.0 g of oxygen are always obtained. Furthermore, if 3.0 g of hydrogen are mixed with 8.0 g of oxygen and the mixture is ignited, 9.0 g of water are formed and 2.0 g of hydrogen remains unreacted. Similarly sodium chloride contains 60.66% of chlorine and 39.34% of sodium by mass whether we obtained it from salt mines or by crytallising it from water of ocean or inland salt seas or synthesizing it from its elements sodium and chlorine. Of course, the key word in this sentence is 'pure'. Reproducible experimental results are highlights of scientific thoughts. In fact modern science is based on experimental findings. **Reproducible results indirectly hint for a truth which is hidden**. Scientists always worked for findings this truth and in this manner many theories and laws were discovered. This search for truth plays an important role in the development of science.

3.2 DALTON'S ATOMIC THEORY

The English scientist John Dalton was by no means the first person to propose the existence of atoms, as we have seen in the previous section, such ideas date back to classical times. Dalton's major contribution was to arrange those ideas in proper order and give evidence for the existence of atoms. He showed that the mass relationship expressed by Lavoisier and Proust (in the form of law of conservation of mass and law of constant proportions) could be interpreted most suitably by postulating the existence of atoms of the various elements.

In 1803, Dalton published a new system of chemical philosophy in which the following statements comprise the atomic theory of matter:

1. Matter consists of indivisible atoms.
2. All the atoms of a given chemical element are identical in mass and in all other properties.
3. Different chemical elements have different kinds of atoms and in particular such atoms have different masses.
4. Atoms are indestructible and retain their identity in chemical reactions.
5. The formation of a compound from its elements occurs through the combination of atoms of unlike elements in small whole number ratio.

Dalton's fourth postulate is clearly related to the law of conservation of mass. Every atom of an element has a definite mass. Also in a chemical reaction there is rearrangement of atoms. Therefore after the reaction, mass of the product should remain the same. The fifth postulate is an attempt to explain the law of definite proportions. A compound is a type of matter containing the atoms of two or more elements in small whole number ratio. Because the atoms have definite mass, the compound must have the elements in definite proportions by mass.

John Dalton (1766-1844)

Fig. 3.1

The Dalton's atomic theory not only explained the laws of conservations of mass and law of constant proportions but also predicted the new ones. He deduced **the law of multiple proportions** on the basis of his theory. The law states that **when two elements form more than one compound, the masses of one element in these compound for a fixed mass of the other element are in the ratio of small whole numbers**. For example, carbon and oxygen form two compounds: Carbon monoxide and carbon dioxide. Carbon monoxide contains 1.3321 g of oxygen for each 1.000g of carbon, whereas carbon dioxide contains 2.6642 g of oxygen for 1.0000 g of carbon. In other words, carbon dioxide contains twice the mass of oxygen as is contained in carbon monoxide (2.6642 g = 2 × 1.3321 g) for a given mass of carbon. Atomic theory explains this by saying that carbon dioxide contains twice as many oxygen atoms for a given number of carbon atoms as does carbon monoxide. The deduction of *law of multiple proportions* from atomic theory was important in convincing chemists of the validity of the theory.

3.2.1 What is an Atom?

As you have just seen in the previous section that an atom is the smallest particle of an element that retains its (elements) chemical properties. An atom of one element is different in size and mass from the atoms of the other elements. These atoms were considered 'indivisible' by Indian and Greek 'Philosophers' in the beginning and the name 'atom' as mentioned earlier, emerged out of this basic philosophy. Today, we know that atoms are not indivisible. They can be broken down into still smaller particles although they lose their chemical identity in this process. But inspite of all these developments atom still remains a **building block** of matter.

3.2.2 What is the size of the atom?

Atoms are very small, they are smaller than anything that we can imagine or compare with. In order to have a feeling of size of an atom you can consider this example: **One teaspoon of water (about 1 mL) contains about three times as many atoms as Atlantic ocean contains teaspoons of water.** Also more than millions of atoms when stacked would make a layer barely as thick as this sheet of paper. Atoms of different elements not only differ in mass as proposed by Dalton but also they differ in size. Now question is why should we bother for the size, mass and other properties of an atom? The reason is simple, every matter we see around us is made of atoms. Is it rectangular, circular or spherical? It is difficult to imagine the real shape of an atom but for all practical purposes it is taken as spherical in size and that is why we talk of its radius. Since size is extremely small and invisible to our eyes, we adopt a scale of nanometer (1nm = 10^{-9} m) to express its size.

You can have a feeling of its size from the following table (Table 3.1).

Table 3.1 : Relative sizes

Radius (in m)	Example
10^{-10}	Atoms of hydrogen
10^{-4}	Grain of sand
10^{-1}	Water melon
0.2×10^{-1}	Cricket ball

You can not see atoms with your naked eyes but by using modern techniques, we can now produce magnified image of surface of elements showing atoms. The technique is known as Scanning Tunneling Microscopy (STM) (Fig. 3.2)

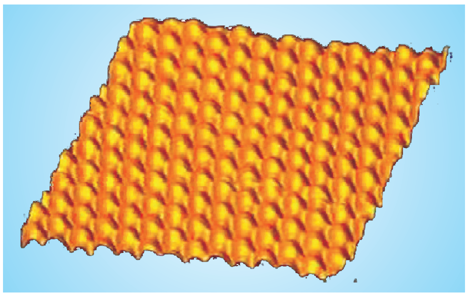


Fig. 3.2: *Image of Copper surface by STM technique. Atom can be seen in magnified image of surfae*

3.2.3 Atomic Mass

Dalton gave the concept of atomic mass. According to him, atoms of the same element have same atomic masses but atoms of different elements have different atomic masses. Since Dalton could not weigh individual atoms, he measured relative masses of the elements required to form a compound. From this, he deduced ***relative atomic masses***. For example, we can determine by experiment that 1.0000 g of hydrogen gas reacts with 7.9367 g of oxygen gas to form water. If we know formula of water, we can easily determine the mass of an oxygen atom relative to that of hydrogen atom.

Dalton did not have a way of determining the proportions of atoms of each element forming water during those days. He assumed the simplest possibility that atoms of oxygen and hydrogen were equal in number. From this assumption, it would follow that oxygen atom would have a mass that was 7.9367 times that of hydrogen atom. This in fact was not correct. We now know that in water number of hydrogen atoms is twice the number of oxygen atoms (formula of water being H_2O). Therefore, relative mass of oxygen atom must be $2\times7.9367 = 15.873$ times that of hydrogen atom. After Dalton, relative atomic masses of several elements were determined by scientists based on hydrogen scale. Later on, ***hydrogen based scale*** was replaced by a scale based on oxygen as it (oxygen) was more reactive and formed a large number of compounds.

In 1961, C-12 (or ${}^{12}_{6}C$) atomic mass scale was adopted. This scale depends on measurement of atomic mass by an instrument called ***mass spectrometer***. Mass spectrometer invented early in 20^{th} century, allows us to determine atomic masses

Notes

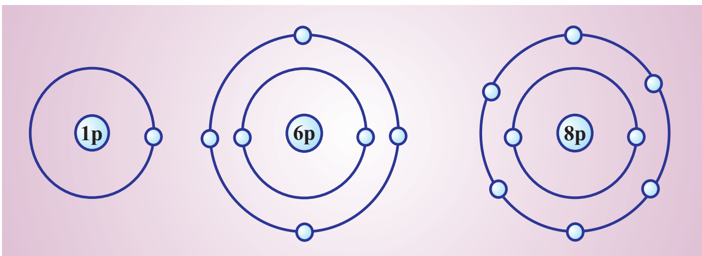
precisely. The masses of atoms are obtained by comparison with ***C-12 atomic mass scale***. In fact C-12 isotope is chosen as standard and arbitrarily assigned a mass of exactly ***12 atomic mass units.*** One atomic mass unit (amu), therefore, equals exactly one twelfth of mass of a carbon–12 atom, Atomic mass unit (amu) is now-a-days is written as unified mass unit and is denoted by the letter 'u'.

The relative atomic mass of an element expressed in atomic mass unit is called its ***atomic weight***. Now-a-days we are using *atomic mass* in place of atomic weight.

Further, you have seen that Dalton proposed that masses of all atoms in an element are equal. But later on it was found that all atoms of naturally occurring elements are not of the same mass. We shall study about such atoms in the following section. Atomic masses that we generally use in our reaction or in chemical calculations are ***average atomic masses*** which depend upon relative abundance of isotopes of elements.

3.2.4 Isotopes and Atomic Mass

Dalton considered an atom as an indivisible particle. Later researches proved that an atom consists of several fundamental particles such as : electrons, protons and neutrons. An electron is negatively charged and a proton is positively charged particle. Number of electrons and protons in an atom is equal. Since charge on an electron is equal and opposite to charge of a proton, therefore ***an atom is electrically neutral***. Protons remain in the nucleus in the centre of the atom, and nucleus is surrounded by negatively charged electrons.



(*a*) (*b*) (*c*)

Fig. 3.3: *Arrangement of electrons around nucleus in (a) hydrogen, (b) carbon and (c) oxygen atoms*

The number of protons in the nucleus is called ***atomic number*** denoted by Z. For example in Fig. 3.3, there are 8 protons in the oxygen nucleus, 6 protons in carbon nucleus and only one proton in hydrogen nucleus. Therefore atomic numbers of oxygen, carbon and hydrogen are 8,6 and 1 respectively. There are also neutral particles in the nucleus and they are called 'neutrons'. Mass of a proton and of a neutron is nearly the same.

Total mass of the nucleus = mass of protons + mass of neutrons

Total number of protons and neutrons is called ***mass number (A)***. By convention atomic number is written at the bottom of left corner of the symbol of the atom of a particular element and mass number is written at the top left corner. For example, symbol ${}^{12}_{6}C$ indicates that there is a total of 12 particles (nucleons) in the nucleus of a carbon atom, 6 of which are protons. Thus, there must be 12-6 = 6 neutrons. Similarly ${}^{16}_{8}O$ indicates 8 protons and 16 nucleons (8 protons + 8 neutrons). Since atom is electrically neutral, oxygen has 8 protons and 8 electrons in it. Further, atomic number (Z) differentiates the atom of one element from the atoms of the other elements.

An element may be defined as a substance where all the atoms have the same atomic number.

But the nuclei of all the atoms of a given element do not necessarily contain the same number of neutrons. For example, atoms of oxygen, found in nature, have the same number of protons which makes it different from other elements, but their neutrons (in nucleus) are different. This is the reason that the masses of atoms of the same element are different. For example, one type of oxygen atom contains 8 protons and 8 neutrons in one atom, second type 8 protons and 9 neutrons and the third type contains 8 protons and 10 neutrons. We represent these oxygen atoms as ${}^{16}_{8}O$, ${}^{17}_{8}O$ and ${}^{18}_{8}O$ respectively. ***Atoms of an element that have the same atomic number (Z) but different mass number (A) are called isotopes***. In view of difference in atomic masses of the same element, we take average atomic masses of the elements. This is calculated on the basis of the *abundance of the isotopes*. Atomic masses of some elements are provided in Table 3.2.

Example 3.1 : Chlorine is obtained as a mixture of two isotopes ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$. These isotopes are present in the ratio of 3:1. What will be the average atomic mass of chlorine?

Solution : ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$ are present in the ratio of 3:1 i.e. out of four atoms, 3 atoms are of mass 35 and one atom of mass 37. Therefore,

$$\text{Average atomic mass} = \frac{35 \times 3 + 37 \times 1}{4} = \frac{142}{4} = 35.5 \text{ u}$$

Thus, average atomic mass of chlorine will be 35.5u.

Table 3.2 : Atomic mass* of some common elements

Elements	Symbol	Mass (u)	Elements	Symbol	Mass (u)
Aluminium	Al	26.93	Magnesium	Mg	24.31
Argon	Ar	39.95	Manganese	Mn	54.94
Arsenic	As	74.92	Mercury	Hg	200.59
Barium	Ba	137.34	Neon	Ne	20.18
Boron	B	10.81	Nickel	Ni	58.71
Bromine	Br	79.91	Nitrogen	N	14.01
Caesium	Cs	132.91	Oxygen	O	16.00
Calcium	Ca	40.08	Phosphorus	P	30.97
Carbon	C	12.01	Platinum	Pt	195.09
Chlorine	Cl	35.45	Potassium	K	39.1
Chromium	Cr	52.00	Radon	Rn	(222)**
Cobalt	Co	58.93	Silicon	Si	23.09
Copper	Cu	63.56	Silver	Ag	107.87
Fluorine	F	19.00	Sodium	Na	23.00
Gold	Au	196.97	Sulphur	S	32.06
Helium	He	4.00	Tin	Sn	118.69
Hydrogen	H	1.008	Titanium	Ti	47.88
Iodine	I	126.90	Tungsten	W	183.85
Iron	Fe	55.85	Uranium	U	238.03
Lead	Pb	207.19	Vanadium	V	50.94
Lithium	Li	6.94	Xenon	Xe	131.30
			Zinc	Zn	65.37

* Atomic masses are average atomic masses covered upto second decimal places. In practice, we use rounded figures.

** Radioactive

INTEXT QUESTIONS 3.1

1. Name the scientists who proposed the law of conservation of mass and law of constant proportions.
2. 12 g of magnesium powder was ignited in a container having 20 g of pure oxygen. After the reaction was over, it was found that 12 g of oxygen was left unreacted. Show that it is according to law of constant proportions.

$$2Mg + O_2 \longrightarrow 2MgO$$

Notes

3.3 WHAT IS A MOLECULE?

Dalton proposed in his hypothesis that atoms react to form a molecule which he said as 'compound atoms'. Today we know what a molecule is. ***A molecule is an aggregate of two or more than two atoms of the same or different elements in a definite arrangement.*** These atoms are held together by chemical forces or *chemical bonds*. (You will study details of molecules in unit of chemical bonding) ***An atom is the smallest particle of a substance but can not exist freely. Contrary to this, a molecules can be considered as the smallest particle of an element or of a compound which can exist alone or freely under ordinary conditions***. A molecule of a substance shows all chemical properties of that substance. To describe the chemical composition of a molecule we take the help of symbols of elements and formulas (described in sec 3.5). Oxygen molecule, with which we are familiar, is made of two atoms of oxygen and therefore it is a *diatomic molecule* (represented by O_2), hydrogen, nitrogen, fluorine, chlorine, bromine and iodine are other examples of diatomic molecules and are represented as H_2, N_2, F_2, Cl_2 , Br_2 and I_2 respectively (Fig. 3.4).

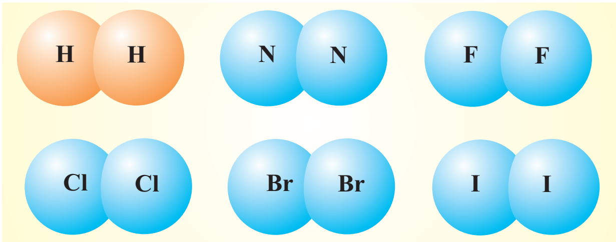
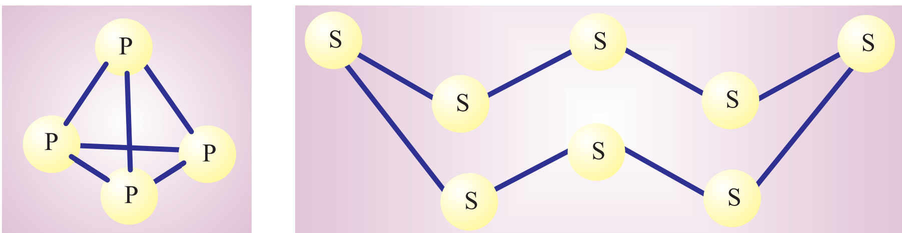


Fig. 3.4 : *Representation of diatomic molecules*

Some other elements exist as more complex molecules. Phosphorus molecule consists of four atoms (denoted by P_4) whereas sulphur exists as eight atom molecule (S_8) at ordinary temperature and pressure Fig. 3.5. A molecule made of four atoms is tetratomic molecule. Normally, molecules consisting of more than three or four atoms are considered under the category of ***polyatomic molecules***. Only a few years back, a form of carbon called buckminsterfullerene having molecular formula C_{60} was discovered which you will study later on in you higher classes.



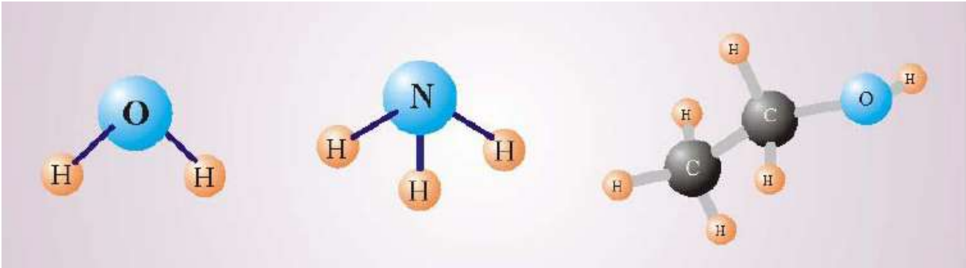
Structure of phosphorus molecule P_4 Structure of a sulphur molecule S_8

Fig. 3.5 : *Molecules of phosphorus and sulphur*

Molecules of compounds are composed of more than one kind of atoms. A familiar example is a water molecule which is composed of more than one kind of atoms.

Notes

In one water molecule, there are two atoms of hydrogen and one atom of oxygen. It is represented as H_2O. A molecule of ammonia consists of one nitrogen atom and three hydrogen atoms. A molecule of ethyl alcohol (C_2H_5OH) is composed of nine atoms (2 atoms of carbon, 6 atoms of hydrogen and one atom of oxygen) Fig. 3.6.



Molecule of water Molecule of ammonia Molecule of ethyl alcohol

Fig. 3.6 : *Molecules of water, ammonia and ethyl alcohol*

3.3.1 Molecular Mass

You have just read that a molecule can be represented in the form of a formula popularly known as ***molecular formula***. Molecular formula may be of an element or of a compound. ***Molecular formula of a compound is normally used for determining the molecular mass of that substance.*** If a substance is composed of molecule (for example : CO_2, H_2O or NH_3), it is easy to calculate the molecular mass. Molecular mass is the sum of atomic masses of all the atoms present in that molecule. Thus the ***molecular mass is the sum of atomic masses of all the atoms present in that molecule.*** The molecular mass of CO_2 is obtained as

C	$1 \times 12.0\ u = 12.0\ u$
2 O	$2 \times 16.0\ u = 32.0\ u$
Mass of CO_2	$= 44.0\ u$

Hence, we write molecular mass of CO_2 = 44.0 u

Similarly, we obtain molecular mass of NH_3 as follows:

N	$1 \times 14.0\ u = 14.0\ u$
3 H	$3 \times 1.08\ u = 3.24\ u$
Mass of NH_3	$= 17.24\ u$

Molecular mass of ammonia, NH_3 = 17.24 u

For substances which are not molecular in nature, we talk of *formula mass*. For example, sodium chloride (denoted by formula, NaCl) is an ionic substance. For this, we will calculate formula mass, similar to molecular mass. In case of sodium chloride, NaCl;

$$\text{Formula mass} = \text{mass of 1 Na atom} + \text{mass of 1 Cl atom}$$
$$= 23\ u + 35.5\ u = 58.5\ u$$

You will learn more about the molecular and ionic compounds in detail later.

INTEXT QUESTIONS 3.2

1. Nitrogen forms three oxides : NO, NO_2 and N_2O_3. Show that it obeys law of multiple proportions.
2. Atomic number of silicon is 14. If there are three isotopes of silicon having 14, 15 and 16 neutrons in their nuclei, what would be the symbol of the isotope?
3. Calculate molecular mass of the compounds whose formulas are provided below:

   C_2H_4, H_2O and CH_3OH

3.4 MOLE CONCEPT

When we mix two substances, we get one or more new substances. For example, when we mix hydrogen and oxygen and ignite the mixture, we get a new substance-water. This can be represented in the form of a chemical equation,

$$2H_2\ (g) + O_2\ (g) \longrightarrow 2H_2O\ (l)$$

In the above equation, 2 molecules (four atoms) of hydrogen react with 1 molecule (2 atoms) of oxygen and give two molecules of water. We always like to know how many atoms/molecules of a particular substance would react with atoms/molecules of another substance in a chemical reaction. No matter how small they are. The solution to this problem is to have a convenient unit. Would you not like to have a convenient unit? Definitely a unit for counting of atoms/molecules present in a substance will be desirable and convenient as well. This chemical counting unit of atoms and molecules is called ***mole***.

The word mole was, apparently introduced in about 1896 by Wilhelm Ostwald who derived the term from the Latin word 'moles' meaning a 'heap' or 'pile'. The mole whose symbol is 'mol' is the SI (international system) base unit for measuring ***amount of substance***. It is defined as follows:

A mole is the amount of substance that contains as many elementary entities (atoms, molecules, formula unit or other fundamental particles) as there are atoms in exactly 0.012 kg of carbon-12 isotope.

In simple words, mole is the number of atoms in exactly 0.012 kg (12 grams) of C-12. Although mole is defined in terms of carbon atoms but the unit is applicable to any substance just as 1 dozen means 12 or one gross means 144 of anything. Mole is scientist's ***counting unit*** like dozen or gross. By using mole, scientists (particularly chemists) count atoms and molecules in a given substance. Now it is experimentally found that the number of atoms contained in exactly 12 g of C-12 is 602,200 000 000 000 000 000 000 or 6.022×10^{23}. This number is called ***Avogadro's number*** in honour of Amedeo Avogadro, an Italian lawyer and physicist. When this number is divided by 'mole' it becomes a constant and is known as *Avogadro's constant* denoted by symbol, $N_A = 6.02 \times 10^{23}\ mol^{-1}$. We have seen that

$$\text{Atomic mass of C} = 12\ u$$

$$\text{Atomic mass of He} = 4\ u$$

We can see that one atom of carbon is three times as heavy as one atom of helium. On the same logic 100 atoms of carbon are three times as heavy as 100 atoms of helium. Similarly 6.02×10^{23} atoms of carbon are three times as heavy as 6.02×10^{23} atoms of helium. But 6.02×10^{23} atoms of carbon weigh 12 g, therefore 6.02×10^{23} atoms of helium will weigh $1/3 \times 12g = 4$ g. We can take a few more examples of elements and can calculate the mass of one mole atoms of that element.

3.4.1 Molar Mass

Mass of one mole of a substance is called its molar mass. A substance may be an element or a compound. Mass of one mole atoms of oxygen means mass of 6.02×10^{23} atoms of oxygen. It is found that one mole atoms of oxygen weighs 16.0 g. When we say one mole molecules of oxygen that means 6.02×10^{23} molecules of oxygen (O_2). One mole molecules of oxygen will weigh 32.0 g. Thus,

$$\text{Mass of one mole atoms of oxygen} = 16\ g\ mol^{-1}$$

$$\text{Mass of one mole molecules of oxygen} = 32\ g\ mol^{-1}$$

When it is not clear whether we are asking for one mole of atoms or one mole of molecules then we take natural form of that substance. For example, one mole of oxygen means one mole of oxygen molecules as oxygen occurs in the form of molecules in nature. In case of compounds, the same logic is applicable. For example, one mole of water means one mole molecules of water which weighs 18 g. Numerically one mole of a substance is equal to atomic or molecular mass of that substance expressed in grams.

Remember, molar mass is always expressed in the unit of g/mol or $g\ mol^{-1}$.

For example,

$$\text{Molar mass of nitrogen } (N_2) = 28\ g\ mol^{-1}$$

$$\text{Molar mass of chlorine } (Cl_2) = 71\ g\ mol^{-1}$$

Table 2.3 Provides molecular and molar mass of a few common substances.

Table 3.3 : Molecular and molar masses

Formula	Molecular Mass (u)	Molar mass (g/mol)
O_2(oxygen)	32.0	32.0
Cl_2(chlorine)	71.0	71.0
P_4 (phosphorus)	123.9	123.9
CH_4 (methane)	16.00	16.0
NH_3 (ammonia)	17.0	17.0
HCl (hydrochloric acid gas)	36.5	36.5
CO_2 (carbon dioxide)	44.0	44.0
SO_2 (sulphur dioxide)	64.0	64.0
C_2H_5OH (ethyl alcohol)	46.0	46.0
C_6H_6 (benzene)	78.0	78.00

Example 3.2 : How many grams are there in 3.5 mol of oxygen?

Solution : For converting mole into mass in grams and vice-versa, we always need a relationship between mass and mole.

Molar mass of oxygen (O_2) = 32 g mol^{-1}

Therefore, number of grams of oxygen in 3.5 mol of it

$$= 3.5 \text{ mol of oxygen} \times 32.0 \text{ g mol}^{-1}$$

$$= 112.0 \text{ g of oxygen}$$

Example 3.3 : Find out number of molecules in 27 g of water.

Solution: Mole concept provides a relationship between number of particles and their mass. Thus it is possible to calculate the number of particles in a given mass.

$$\text{Number of mole of } H_2O = \frac{\text{Mass of water } (H_2O)}{\text{Molar mass of } H_2O}$$

$$= \frac{27\text{g}}{18 \text{ g mol}^{-1}} = \frac{3}{2} \text{ mol} = 1.5 \text{ mol}$$

Since 1 mol of water contains 6.02×10^{23} molecules.

Therefore, 1.5 mol of water contains = 6.02×10^{23} molecules mol^{-1} $\times 1.5$ mol

$$= 9.03 \times 10^{23} \text{ molecules of water}$$

INTEXT QUESTIONS 3.3

1. Work out a relationship between number of molecules and mole.
2. What is molecular mass? In what way it is different from the molar mass?
3. Consider the reaction

   $C\ (s) + O_2\ (g) \longrightarrow CO_2\ (g)$

   18 g of carbon was burnt in oxygen. How many moles of CO_2 is produced?
4. What is the molar mass of NaCl?

3.5 WRITING CHEMICAL FORMULA OF COMPOUNDS

As you are aware, a compound is made of two or more than two elements combined in a definite proportion by mass (law of constant proportions). Thus, the number of combining atoms in a compound is fixed. The elements are represented by their symbols (e.g. H for hydrogen, Na for sodium). Similarly a compound is also represented by a shorthand notation known as formula or ***chemical formula***. The formula of a compound indicates **(i) elements constituting the compound and (ii) the number of each constituent element. In other word, the formula of a compound also represents its chemical composition.** The atoms of elements constituting a compound are indicated by their symbols and their number is indicated as a **subscript** on the right hand bottom of the symbol. For example, in the formula of water, H_2O, two atoms of hydrogen are indicated as subscript '2', while oxygen is shown without writing any subscript, which means that the number of oxygen atom is just one.

3.5.1 Valency and Formulation

Every element has a definite capacity to combine with other elements. ***This combining capacity of an element is called its valency.*** You will learn very soon that this combining capacity of elements depends on the electronic configuration of elements. Valencies of a few elements are given in Table 3.4.

Table 3.4 : Valency of elements

Elements	Symbol	Valency	Elements	Symbol	Valency
Hydrogen	H	1	Phosphorus	P	5
Oxygen	O	2	Sodium	Na	1
Carbon	C	4	Magnesium	Mg	2
Nitrogen	N	3	Calcium	Ca	2
Chlorine	Cl	1	Aluminium	Al	3
Bromine	Br	1	Iron	Fe	2
Iodine	I	1	Barium	Ba	2

Most of the simple compounds are made of two elements. Such compounds are called ***binary compounds***. It is easy to write formula of such compounds. When a metal combines with a non-metal, the symbol of the metal-element is written on the left hand side and that of the non-metal element on right hand side. (If both are non-metal, we write more electronegative* element on the right hand side). In naming a compound, the first element is written as such and the name of the second element i.e. more electronegative element, changes its ending to 'ide'. For writing chemical formula, we have to write valencies as shown below and then cross over the valencies of the combining atoms. Formula of the compounds resulting from carbon and chlorine, hydrogen and oxygen, and hydrogen and chlorine can be written as follows:

Element	C	Cl	H	O	H	Cl
Valency	4	1	1	2	1	1
Formula	CCl_4		H_2O		HCl	

Some other examples for writing formula of compounds CaO, NaCl and NH_3 can also be taken for more clarity.

Element	Ca	O	Na	Cl	N	H
Valency	2	2	1	1	3	1
Formula	CaO		NaCl		NH_3	

Thus, we can write formulas of various compounds if we know elements constituting them and their valencies.

Valency, as mentioned, depends on the electronic configuration and nature of the elements. Sometimes an element shows more than one type of valency. We say element has ***variable valency.*** For example nitrogen forms several oxides : N_2O, N_2O_2, N_2O_3, N_2O_4 and N_2O_5. If we take valency of oxygen equal to 2, then valency of nitrogen in the oxides will be 1,2,3,4 and 5 respectively. Valencies are not always fixed. Similar to nitrogen, phosphorus also shows valencies 3 and 5 as reflected in compounds PBr_3 and P_2O_5. In these compounds, there are more than one atom. In such cases, number of atoms is indicated by attaching a numerical prefix (mono, di, tri, etc) as mentioned in Table 2.5.

Table 3.5 : Numerical Prefixes

Number of atoms	Prefix	Example
1	Mono	carbon monoxide, CO
2	Di	carbon dioxide, CO_2
3	Tri	phosphorus trichloride, PCl_3
4	Tetra	carbon tetrachloride, CCl_4
5	Penta	Dinitrogen pentoxide, N_2O_5

Here you would notice that '–o' or '–a' at the end of the prefix is often dropped before another vowel, e.g. monoxide, pentoxide. There is no gap between numerical prefix and the name of the element. The prefix mono is usually dropped for the first element. When hydrogen is the first element in the formula, no prefix is added before hydrogen irrespective of the number. For example, the compound H_2S is named as hydrogen sulphide and not as dihydrogen sulphide.

Thus, we have seen that writing formula of a binary compound is relatively easy. However, when we have to write formula of a compound which involves more than two elements (i.e. of a polyatomic molecule), it is somewhat a cumbersome task. In the following section we shall consider formulation of more difficult compounds.

You will learn later on that there are basically two types of compounds: covalent compounds and ionic or electrovalent compounds. H_2O and NH_3 are covalent compounds. NaCl and MgO are ionic compounds. An ionic compound is made of two charged constituents. One positively charged and other negatively charged. In case of NaCl, there are two ions : Na^+ and Cl^- ion. Charge of these ions in case of electrovalent compound is used for writing formula. It is easy to write formula of an ionic compound only if there is one metal and one non-metal as in the case of NaCl and MgO. If there are more than two elements in an ionic compound, formulation will be a little difficult and in that situation we should know charge of cations and anions.

3.5.2 Formulation of Ionic compounds

Formulation of an ionic compound is easy when we know charge of cation and anion. Remember, in an ionic compound, sum of the charge of cation and anion should be equal to zero. A few examples of cations and anions with their charges are provided in Table 3.6.

Table 3.6 : Charges of some common cations and anions which form ionic compounds

Anions	Charge	Cations	Charge
Chloride ion, Cl^-	–1	Potassium ion, K^+	+1
Nitrate ion, NO_3^-	–1	Sodium ion, Na^+	+1
Hydroxide ion, OH^-	–1	Ammonium ion, NH_4^+	+1
Bicarbonate ion, HCO_3^-	–1	Magnesium ion, Mg^{2+}	+2
Nitrite ion, NO_2^-	–1	Calcium ion, Ca^{2+}	+2
Acetate ion, CH_3COO^-	–1	Lead ion, Pb^{2+}	+2
Bromide ion, Br^-	–1	Iron ion (ous), Fe^{2+}	+2
Iodide ion, I^-	–1	Zinc ion, Zn^{2+}	+2

Sulphite ion, SO_3^{2-}	–2	Copper ion (cupric), Cu^{2+}	+2
Carbonate ion, CO_3^{2-}	–2	Mercury ion (Mercuric), Hg^{2+}	+2
Sulphate ion, SO_4^{2-}	-2	Iron (ic) ion, Fe^{3+}	+3
Sulphide ion, S^{2-}	–2	Aluminium ion, Al^{3+}	+3
Phosphate ion, PO_4^{3-}	–3	Potassium ion, K^+	+1
		Sodium ion, Na^+	+1

Suppose you have to write formula of sodium sulphate which is made of Na^+ and SO_4^{2-} ions. For this the positive and negative charge can be crossed over to give subscripts. The purpose of this crossing over of charges is to find the number of ions required to equate the number of positive and negative charges.

Ion	Na^+	SO_4^{2-}
Charge	1 (positive)	2 (negative)

This gives the formula of sodium sulphate as Na_2SO_4 . We can check the charge balance as follows

$$\left.\begin{array}{lll} 2Na^+ & = & 2\times(+1) = +2 \\ 1SO_4^{2-} & = & 1\times(-2) = -2 \end{array}\right] = 0$$

Thus the compound, Na_2SO_4 is electrically neutral.

Now it is clear that digit showing charge of cation goes to anion and digit showing charge of anion goes to cation. For writing formula of calcium phosphate we take charge of each ion into consideration and write the formula as discussed above.

$$\left(Ca^{2+}\right)_3 \left(PO_4^{3-}\right)_2 = Ca_3\left(PO_4\right)_2$$

Writing formula of a compound comes only by practice, therefore write formulas of as many ionic compounds as possible based on the guidelines given above.

INTEXT QUESTIONS 3.4

1. Write the name of the expected compound formed between
   (i) hydrogen and sulphur
   (ii) nitrogen and hydrogen
   (iii) magnesium and oxygen

2. Propose the formulas and names of the compounds formed between
   - (i) potassium and iodide ions
   - (ii) sodium and sulphate ions
   - (iii) aluminium and chloride ions
3. Write the formula of the compounds formed between
   - (i) Hg^{2+} and Cl^{-}
   - (ii) Pb^{2+} and PO_4^{3-}
   - (iii) Ba^{2+} and SO_4^{2-}

WHAT YOU HAVE LEARNT

- According to ***law of constant proportions***, a sample of a pure substance always consists of the same elements combined in the same proportion by mass.
- When an element combines with another element and forms more than one compound, then different masses of the one element that combine with the fixed mass of another element are in the ratio of simple whole number or integer. This is the ***law of multiple proportions***.
- John Dalton introduced the idea of an atom as an indivisible particle. An atom is the smallest particle of an element which shows all the properties of that element. An atom can not exist freely and therefore remains in a combined state.
- A molecule is the smallest particle of an element or of a compound which shows all properties of that substance and can exist freely under ordinary conditions.
- A molecule can be represented in the form of a chemical formula using symbols of elements that constitute it.
- Composition of any compound can be represented by its chemical formula.
- Atom of the isotope C-12 is assigned atomic mass unit of 12 and the relative atomic masses of all other atoms of elements are obtained by comparing them with it.
- **The mole is the amount of a substance which contains the same number of particles (atoms, ions or molecule)** as there are atoms in exactly 0.012 kg of carbon-12.
- Avogadro's number is defined as the number of atoms in exactly 0.012 kg (or 12 g) of C-12 and is equal to 6.02×10^{23}. Avogadro's constant is written as 6.02×10^{23} mol^{-1}.

- Mass of one mole atoms or one mole molecules or one mole of formula unit of a substance is its **molar mass**.
- The composition of any compound can be represented by its formula. For writing the formula of a compound, valence or valency of an element is used. This is normally done in case of covalent compounds.
- Valency is the combining capacity of an element and is related to its electronic configuration.
- In ionic compounds, the charge on each ion is used to determine the chemical formula of the compound.

TERMINAL EXERCISE

1. Describe the following:
   (a) Law of conservation of mass
   (b) Law of constant proportions
   (c) Law of multiple proportions
2. What is the atomic theory proposed by John Dalton? What changes have taken place in the theory during the last two centuries?
3. Write the number of protons, neutrons and electron in each of the following isotopes :

   $^{2}_{1}H$, $^{18}_{8}O$, $^{19}_{9}F$, $^{40}_{20}Ca$
4. Boron has two isotopes with masses 10.13 u and 11.01 u and abundance of 19.77% and 80.23% respectively. What is the average atomic mass of boron?
   (Ans. 10.81 u)
5. Give symbol for each of the following isotopes:
   (a) Atomic number 19, mass number 40
   (b) Atomic number 7, mass number 15
   (c) Atomic number 18, mass number 40
   (d) Atomic number 17, mass number 37
6. How does an element differ from a compound? Explain with suitable examples.
7. Charge of one electron is 1.6022×10^{-19} coulomb. What is the total charge on 1 mol of electrons?

8. How many molecules of O_2 are in 8.0 g of oxygen? If the O_2 molecules were completely split into O (Oxygen atoms), how many mole of atoms of oxygen would be obtained?

9. Assume that human body is 80% water. Calculate the number of molecules of water that are present in the body of a person whose weight is 65 kg.

10. Refer to atomic masses given in the Table (3.2) of this chapter. Calculate the molar masses of each of the following compounds :

    HCl, NH_3, CH_4, CO and $NaCl$

11. Average atomic mass of carbon is 12.01 u. Find the number of moles of carbon in (a) 2.0 g of carbon. (b) 8.0 g of carbon.

12. Classify the following molecules as di, tri, tetra, penta and hexa atomic molecules:

    H_2, P_4, SF_4, SO_2, PCl_3, CH_3OH, PCl_5, HCl

13. What is the mass of

    (a) 6.02×10^{23} atoms of oxygen

    (b) 6.02×10^{23} molecules of P_4

    (c) 3.01×10^{23} molecules of O_2

14. How many atoms are present in:

    (a) 0.1 mol of sulphur

    (b) 18.g of water (H_2O)

    (c) 0.44 g of carbon dioxide (CO_2)

15. Write various postulates of Dalton's atomic theory.

16. Convert into mole:

    (a) 16 g of oxygen gas (O_2)

    (b) 36 g of water (H_2O)

    (c) 22 g of carbon dioxide (CO_2)

17. What does a chemical formula of a compound represents?

18. Write chemical formulas of the following compounds:

    (a) Copper (II) sulphate

    (b) Calcium fluoride

    (c) Aluminium bromide

    (d) Zinc sulphate

    (e) Ammonium sulphate

ANSWERS TO INTEXT QUESTIONS

3.1

(i) Lavoisier proposed the law of conservation of mass and Proust proposed the law of constant proportions

(ii) In container, 12g of Oxygen was left unreacted. Therefore, amount of unreacted Oxygen = (20 – 12)g = 08g. Thus 12g of magnesium reacted with 8g of oxygen in the ratio 12:8. This is what we expected for MgO i.e 24g of Mg reacted with 16g of Oxygen or 12g of Mg will react with 8g of Oxygen.

3.2

(i) Atomic mass of nitrogen is 14u and that of oxygen is 16u.

In NO, 14g of nitrogen reacted with 16g of oxygen

In NO_2, 14g of nitrogen reacted with 32g of oxygen

In N_2O_3, 28g of nitrogen reacted with 48g of oxygen

or

14g of nitrogen reacted with 24g of Oxygen.

Threfore, amount of oxygen which reacts with 12g of nitrogen in case of NO, NO_2 and N_2O_3 will be in the ratio of 16:32:24 or 2:4:3. This proves the law of multiple proportions.

(ii) Atomic number of Si is 14

Mass number of silicon atoms having 14,15 and 16 neutrons will be 28,29 and 30 respectively and therefore symbols of istopes of silicon will be

$${}^{28}_{14}Si \qquad {}^{29}_{14}Si \qquad \text{and} \qquad {}^{30}_{14}Si$$

(iii) Molecular mass of C_2H_4 = mass of two atom of carbon + mass of 4 atom of hydrogen

$$= 2 \times 12u + 4 \times 1u = 28u$$

Molecular mass of H_2O = mass of two atoms of hydrogen + mass of one atom of oxygen

$$= 2 \times 1u + 1 \times 16u = 18u$$

Molecular mass of CH_3OH = mass of one atom of carbon + mass of 4 atoms of hydrogen + mass of one atom of oxygen

$$= 1 \times 12u + 4 \times 1u + 1 \times 16u = 32u$$

3.3

1. 1 mole of a substance contains 6.023×10^{23} molecules of that substance i.e 1 mole of a substance = 6.023×10^{23} molecules of that substance.

2. Molecular mass is the sum of atomic masses of all the atoms present in that molecule.

Molecular mass is the mass of one molecule whereas molar mass is the mass of 1 mol or 6.023×10^{23} elementary entities (atoms, molecules, ions)

3.

$$\begin{array}{ccccc} C(s) & + & O_2 & \longrightarrow & CO_2 \\ \text{1 mol of C (12g)} & & \text{1 mol of } O_2 \text{(32g)} & & \text{1 mol of } CO_2 \text{ (44g)} \end{array}$$

12 g of carbon gives 1 mole of CO_2

18g of carbon will give 1.5 mole of CO_2

4. Molar mass of NaCl = $(23.0 + 35.5)\,g\,mol^{-1}$

$= \mathbf{58.5}\ g\ mol^{-1}$

3.4

1. (i) H_2S

(ii) NH_3

(iii) MgO

2. (i) KI, Potassium iodide

(ii) Na_2SO_4, Sodium Sulphate

(iii) $AlCl_3$, Aluminium Chloride

3. (i) $HgCl_2$

(ii) $Pb_3(PO_4)_2$

(iii) $BaSO_4$

212en04

4

CHEMICAL REACTION AND EQUATIONS

Everyday we observe different types of changes in our surroundings. Some of these changes are very simple and are of *temporary nature*. Some others are really complex and of *permanent nature*. When ice kept in a tumbler is exposed to the atmosphere, it melts and is converted into water. When the tumbler containing this water is kept in a freezer it is converted again into ice. Thus, this is a temporary change and the substance comes to its original form. Such changes are ***physical changes***. However, milk once converted into curd can not be converted into milk again. Such changes are ***chemical changes***. These changes are of permanent nature. Both physical and chemical changes are integral part of our daily life. We can present these changes in the form of an equation.

In this lesson we shall discuss how to write and balance chemical equations.We shall also describe different types of chemical reactions.

OBJECTIVES

After completing this lesson, you will be able to:

- *write and balance simple chemical equations;*
- *describe the significance of a balanced chemical equation;*
- *explore the relationship between mole, mass and volume of various reactants and products;*
- *classify chemical reactions as combination, decomposition, displacement and double displacement reactions and*
- *define oxidation and reduction processes (redox reactions) and correlate these with corrosion and rancidity and other aspects of daily life.*

4.1 CHEMICAL EQUATIONS

You must have observed many chemical changes in nature, in your surroundings and in your daily lives. Let us perform a few activities to observe changes.

ACTIVITY 4.1

A. Take a 2 cm long magnesium ribbon. Clean it with a piece of sand paper. Hold it firmly with a pair of tongs. Heat it over a spirit lamp or a burner until it burns. Keep the ribbon as far as possible from your eyes. What do you observe? The magnesium ribbon burns with a dazzling light and liberates a lot of heat. It is soon converted into a white powdery substance.

Fig. 4.1: *Burning of magnesium ribbon*

B. Take a few zinc granules in a conical flask or in a test tube. Add dilute sulphuric or hydrochloric acid to it. What do you observe? There is evolution of gas from the test tube. If you touch the bottom of the test tube, you will find that it has become quite warm.

You can perform many more such activities in the laboratory or in the activity room.

4.1.1 How does one describe these Chemical Changes?

The two reactions mentioned above can be written in words as follows :

$$\underset{reactants}{\text{Magnesium} + \text{Oxygen}} \longrightarrow \underset{product}{\text{Magnesium oxide}} \qquad ...(1)$$

$$\text{Zinc} + \text{dil Sulphuric acid} \longrightarrow \text{Zinc sulphate} + \text{Hydrogen} \qquad ...(2)$$

A substance which undergoes a chemical change is called the ***reactant*** and the substance which is formed as a result of a chemical change is called the ***product***. In reaction (1) magnesium and oxygen undergo chemical change and they are the reactants. In reaction (2) zinc and dilute sulphuric acid are the reactants. Similarly in reaction (1) magnesium oxide is a new substance formed. It is the product. Can you now say what is the product in reaction (2)? Yes, it is zinc sulphate and hydrogen. In chemical reaction, the reactant (s) is (are) written on the left hand side and the product(s) is (are) written on the right hand side. The change of the reactant into the product is shown through an arrow. Use of + sign is made when there are more than one reactant or there are more than one product. Let us see if you can complete the reaction given below:

Calcium Chlorine Calcium chloride

4.1.2 Writing a Chemical Equation

Is there any other shorter way for representing a chemical change? Yes this can be done through a chemical equation. A chemical equation can be made more concise and useful if we use chemical formulae instead of words. In the previous lesson you have already studied how to represent compound with the help of a chemical formula. Now if you substitute formulae of magnesium, oxygen and magnesium oxide for the words in equation (1), we get

$$Mg + O_2 \longrightarrow MgO \qquad ...(3)$$

Similarly substituting formulae for words in equation B, we get,

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2 \qquad ...(4)$$

Do you remember the ***Law of conservation of mass*** studied in the previous lesson? According to it, the mass and the number of atoms present in the reactant(s) should be equal to the mass and number of atoms present in product(s). Let us count the number of atoms on both sides (left hand side and right hand side) of the chemical equations (3) and (4). We find that in equation (3), the numbers of oxygen atoms on the right hand side and the left hand side are not equal. However in (4), the number of atoms on both the sides is equal. Such chemical equations in which the number of atoms is not equal on both sides of the arrow but still represent chemical reactions are called ***skeletal chemical equations***. Skeletal chemical equations can be balanced by using suitable *coefficients* in the equation. We shall study the balancing of chemical equation in the following section.

4.2 BALANCED CHEMICAL EQUATIONS

According to the law of conservation of mass, matter can neither be created nor destroyed. Thus, ***mass of each element present in the products of a chemical reaction must be equal to its mass present in the reactants***. In other words, the number of atoms of each element remains the same before and after a chemical reaction. In a balanced chemical equation number of atoms of a particular element present in the reactants and products must be equal. If not, equation is said to be 'not balanced.' Let us reconsider the above two equations (3) and (4).

i.e. $$Mg + O_2 \longrightarrow MgO \qquad ...(3)$$

and $$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2 \qquad ...(4)$$

Which one of the above two is balanced? It is quite obvious that equation (4) is balanced, as the number of Zn, H and S (sulphur) atoms are equal on both sides of the equation. Therefore equation (4) is said to be a *balanced chemical equation*. Now what about equation (3)? By simple inspection we can see that the number of atoms of magnesium in the reactant side is equal to the number of atoms of magnesium in the product side. However, the number of atoms of oxygen on the reactant side is two (in O_2) but only one atom of oxygen is in the product side in (MgO). To make the same number of atoms of oxygen in the product side, we shall have to write 2MgO. Now the equation becomes;

$$Mg + O_2 \longrightarrow 2MgO$$

In the above equation there is a shortage of one atom of magnesium on the left hand side. For balancing the number of magnesium atoms, we need to put 2 before Mg and the equation becomes,

$$2Mg + O_2 \longrightarrow 2MgO$$

Now the number of magnesium and oxygen atoms is equal on both sides of the arrow and the chemical equation is said to be balanced. This method of balancing of a chemical equation is called the ***Hit and Trial method***.

Let us consider another reaction for writing and balancing of a chemical reaction. When steam is passed over red hot iron, hydrogen gas (H_2) is evolved and magnetic oxide of iron (Fe_3O_4) is obtained. This can be expressed as:

$$Fe + H_2O \longrightarrow Fe_3O_4 + H_2$$

If we examine the above equation we find that the equation is not balanced. Let us try to balance it using the following steps:

Step I: Study the equation carefully and write the number of atoms of different elements in the imbalanced equation:

$$Fe \quad + \quad H_2O \longrightarrow Fe_3O_4 \quad + \quad H_2$$

Table 4.1 Comparing number of atoms of different elements in reactants and products

Element	Number of atoms on reactants side (LHS)	Number of atoms on products side (RHS)
Fe	1	3
H	2	2
O	1	4

Step II: We should start balancing with the compound that contains the maximum number of atoms. The compound may be a reactant or a product. In the compound, select the element which has maximum number of atoms. Based on this select Fe_3O_4 in the above equation. In Fe_3O_4 the element oxygen has the maximum number of atoms. There are four oxygen atoms on the right hand side and only one oxygen atom on the left hand side of the arrow. For balancing the oxygen atoms, we can put the coefficient '4' as '$4H_2O$'. Now the equation becomes:

$$Fe \quad + \quad 4H_2O \longrightarrow Fe_3O_4 \quad + \quad H_2 \text{ (partially balanced)}$$

Step III: Here Fe and H atoms are still not balanced. Let us balance the hydrogen atoms. For this, make the number of molecules of hydrogen as four on the RHS of the arrow. The equation now becomes:

$$Fe \quad + \quad 4H_2O \longrightarrow Fe_3O_4 \quad + \quad 4H_2 \text{ (partially balanced)}$$

Step IV: Now, out of the three elements, only Fe remains imbalanced. For balancing iron, we write 3 atoms of iron on left hand side and the equation becomes:

$$3Fe \quad + \quad 4H_2O \longrightarrow Fe_3O_4 \quad + \quad 4H_2$$

Step V: Finally count the number of atoms of all the three elements on both sides of the arrow. You will find that the number of atoms of oxygen, hydrogen and iron on both sides of the arrow are equal and thus the balanced equation is obtained as:

$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2 \quad \text{(balanced equation)}$$

4.2.1 How can we make a Chemical Equation more Informative?

In the balanced equation

$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + H_2$$

we have no information about the physical states of the reactants and the products i.e. whether they are solid, liquid or gas. By using (s) for solids, (l) for liquids and (g) for gases along with reactants and products, we can make a chemical equation more informative. Thus, the above equation can be written as:

$$3Fe\ (s) + 4H_2O\ (g) \longrightarrow Fe_3O_4\ (s) + 4H_2\ (g) \qquad ...(5)$$

Here, (g) by the side of H_2O clearly indicates that water used in the reaction is in the form of steam or gas. Further, if a reactant or a product is taken as solution in water, we denote it by writing (aq). For example.

$$\underset{\text{(quick lime)}}{CaO(s)} + H_2O\ (l) \longrightarrow \underset{\text{(slacked lime)}}{Ca(OH)_2\ (aq)} \qquad ...(6)$$

Sometimes the reaction conditions such as temperature, pressure, catalyst, etc. for the reaction are also indicated above and/or below the arrow in the equation. For example,

$$CO\ (g) + 2H_2\ (g) \xrightarrow{\text{340 atm}} CH_3OH\ (l) \qquad ...(7)$$

$$6CO_2\ (aq) + 6H_2O\ (l) \xrightarrow[\text{Chlorophyl}]{\text{Sunlight}} C_6H_{12}O_{16}\ (aq) + 6O_2\ (g) \qquad ...(8)$$

Important Tips for balancing a chemical equation

- Use the simplest possible set of whole number coefficients to balance a chemical equation. Normally we do not write fractional coefficients in such equations as molecules are not available in fractions. We multiply the equation by an appropriate number to ensure the entire equation has whole number coefficients.
- Do not change subscripts in formulae of reactants or of products during balancing, as that may change the identity of the substances. For example, $2NO_2$ means two molecules of nitrogen dioxide but if we double the subscript we get N_2O_4 which is the formula of dinitrogen tetroxide, a completely different compound.

4.3 SIGNIFICANCE OF A BALANCED CHEMICAL EQUATION

Qualitatively a chemical equation simply describes what the reactants and products are. However, *a balanced chemical equation gives a lot of quantitative information about a chemical reaction*. A balanced chemical equation tells us:

(i) the number of atoms and molecules taking part in the reaction and the corresponding masses in atomic mass unit (amu or u).

(ii) the number of moles taking part in the reaction, with the corresponding masses in grams or in other convenient units.

(iii) relationship between the volume of the reactants and the products if all of them are in the gaseous state.

4.3.1 Mole and Mass Relationships

Let us consider a chemical reaction between nitrogen and hydrogen in the presence of a catalyst.

$$\underset{\substack{\text{(1 molecule of}\\ \text{nitrogen)}}}{N_2\ (g)} + \underset{\substack{\text{(3 molecules}\\ \text{of hydrogen)}}}{3H_2\ (g)} \xrightarrow{\text{catalyst}} \underset{\substack{\text{(2 molecules of}\\ \text{ammonia)}}}{2NH_3\ (g)} \quad ...(9)$$

We may multiply the entire equation by any number, say 100, we obtain

$$\underset{\text{of nitrogen}}{1 \times 100 \text{ molecules}} + \underset{\text{of hydrogen}}{3 \times 100 \text{ molecules}} \longrightarrow \underset{\text{of ammonia}}{2 \times 100 \text{ molecules}}$$

Suppose, we multiply the entire equation by 6.022×10^{23}, (Avogadro's number) we get

$$\underset{\substack{\text{molecules of}\\ \text{nitrogen}}}{1 \times 6.022 \times 10^{23}} + \underset{\substack{\text{molecules of}\\ \text{hydrogen}}}{3 \times 6.022 \times 10^{23}} \longrightarrow \underset{\substack{\text{molecules of}\\ \text{ammonia}}}{2 \times 6.00 \times 10^{23}}$$

Since 6.022×10^{23} molecules of any substance constitute its one mole, therefore, we can write

1 mole of nitrogen + 3 moles of hydrogen $\longrightarrow$ 2 moles of ammonia

Taking molar mass into consideration, we can write

(1×28.0) g of nitrogen + $(3 \times 2.0$ g of hydrogen $\longrightarrow$ (2×17) g of ammonia

or 28.0 g of nitrogen + 6.0 g of hydrogen $\longrightarrow$ 34.0 g of ammonia

Let us write the equation (9) once again,

$$N_2\ (g) + 3H_2\ (g) \xrightarrow{\text{catalyst}} 2NH_3\ (g)$$

$$\underset{\text{of nitrogen}}{\text{1 molecule}} \quad \underset{\text{of hydrogen}}{\text{3 molecules}} \longrightarrow \underset{\text{of ammonia}}{\text{2 molecules}}$$

$$\underset{\text{nitrogen}}{\text{1 mol of}} \quad \underset{\text{of hydrogen}}{\text{3 moles}} \longrightarrow \underset{\text{of ammonia}}{\text{2 moles}}$$

28.0 g of nitrogen + 6.0 g of hydrogen $\longrightarrow$ 34.0 g of ammonia

Remember

Quantity of a substance consumed or produced can be determined only if we use a balanced chemical equation.

4.3.2 Volume Relationship for Reactions involving gases

The French chemist, Gay Lussac found that the volume of reactants and products in gaseous state are related to each other by small integers, provided the volumes are measured at the same temperature and pressure.

Gay Lussac's discovery of integer ratio in volume relationship is actually the *law of definite proportion by volume*. Remember, the law of definite proportion studied in lesson 3: Atoms and Molecules, was with respect to masses.

Let us take the following example

$$\underset{\text{2 volumes}}{2H_2\,(g)} + \underset{\text{1 volume}}{O_2\,(g)} \longrightarrow \underset{\text{2 volumes}}{2H_2O\,(g)}$$

$$\text{2 mol of } H_2 + \text{1 mol of } O_2 \longrightarrow \text{2 mol of } H_2O$$ [According to Avogadro's Law]

Here, hydrogen, oxygen and water vapours are at the same temperature and pressure (say 100°C and 1 atmospheric pressure). From this basic concept we can conclude that, if we take 100 mL of hydrogen and 50 mL of oxygen, we shall get 100 mL water vapour provided all volumes are measured at the same temperature and pressure. Thus, from a balanced chemical equation, we get relationship between mole, mass and volume of the reactants and products. This quantitative relationship has been found very useful in chemical calculations.

INTEXT QUESTION 4.1

1. Write a chemical equation for each of the following reactions:
   (i) Zinc metal reacts with aqueous hydrochloric acid to produce a solution of zinc chloride and hydrogen gas.
   (ii) When solid mercury(II) oxide is heated, liquid mercury and oxygen gas are produced.
2. Balance the following chemical equations:
   (i) $H_2SO_4\,(aq) + NaOH\,(aq) \longrightarrow Na_2SO_4\,(aq) + H_2O\,(l)$
   (ii) $Al\,(s) + HCl\,(aq) \longrightarrow AlCl_3\,(aq) + H_2\,(g)$
3. What is a balanced chemical equation? Why should a chemical equation be balanced?

4.4 TYPES OF CHEMICAL REACTIONS

So far we have studied how to express a chemical change in the form of an equation. We have also studied how to balance a chemical equation in order to derive useful quantitative information. We can classify chemical reactions into the following categories (i) combination reactions, (ii) decomposition reactions (iii) displacement reactions (iv) double displacement reactions.

4.4.1 Combination Reactions

In combination reactions, as the name indicates, two or more substances (elements or compounds) simply combine to form a new substance. For example, when a substance burns it combines with oxygen present in the air. In activity 4.1 we have seen that magnesium ribbon burns with dazzling light. During burning it combines with oxygen as

$$2Mg\ (s) + O_2\ (g) \longrightarrow 2MgO\ (s)$$

Now try the same with carbon.

$$C\ (s) + O_2\ (g) \longrightarrow CO_2\ (g)$$

Further, let us take a few activities.

ACTIVITY 4.2

Take a small amount of calcium oxide (CaO) or quick lime in a beaker. Now slowly add water to it (Fig. 4.2). Touch the side of the beaker with your hand. Do you feel any change in the temperature? Yes, it is warm to touch. You might have seen that for white-washing we put white solid material in water and after some time it starts boiling. This white material is calcium oxide and it reacts with water to form calcium hydroxide. Temperature rises due to evolution of heat in the reaction between quick lime and water. This reaction can be expressed in the form of the following equation:

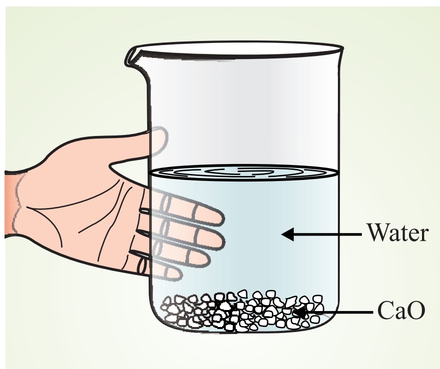


Fig. 4.2: *Reaction between quick lime and water*

$$\underset{\substack{\text{quick lime}\\(\text{Choona Patthar})}}{CaO\ (s)} + H_2O\ (l) \longrightarrow \underset{\text{slaked lime}}{Ca(OH)_2\ (aq)} \qquad ...(10)$$

In the above reaction calcium oxide (quick lime) and water combine and form a single product-calcium hydroxide (slaked lime). Such ***a reaction in which a single product is formed from two or more reactants is known as combination reaction***.

In white washing, when slaked lime is applied on the walls it gradually reacts with carbon dioxide from the atmosphere. The bluish coloured calcium hydroxide (slaked lime) is converted into white calcium carbonate. After drying, it gives a white shiny finish. This reaction can be written as follows:

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2\ (aq)} + CO_2\ (g) \longrightarrow \underset{\text{Calcium carbonate}}{CaCO_3\ (s)} + H_2O\ (l) \quad ...(11)$$

It is interesting to note that chemical formula of marble is also $CaCO_3$.

In activities 4.1 and 4.2 you have seen that a lot of heat is evolved during the course of the reaction. Such reactions in which heat is released along with the formation of the products are called ***exothermic reactions***.

Other examples of exothermic reactions are:

(i) Burning of natural gas (CH_4) used for cooking.

$$CH_4(g) + 2O_2\ (g) \longrightarrow CO_2\ (g) + 2H_2O\ (g) \quad ...(12)$$

(ii) Respiration and digestion both are exothermic process. This heat energy comes from the food that we eat. Do you know what types of food give us energy? Food which we take in the form of rice, potatoes and bread contains ***carbohydrates***. Carbohydrates are broken down to glucose during digestion. The glucose combines with oxygen in the cells of our body and provides energy to our body.

$$C_6H_{12}O_6\ (aq) + 6O_2\ (aq) \longrightarrow 6CO_2\ (aq) + \text{energy} \quad ...(13)$$

People who do physical work, require a lot of energy and therefore, require carbohydrates in the form of sugar, potato, rice, bread, etc.

(iii) The decomposition of vegetable matter or *biomass* into compost is also an example of an exothermic reaction. If you have a compost pit in your surroundings, you can observe this yourself.

4.4.2 Decomposition Reactions

You have seen earlier that quick lime (*choona patthar*) solution is used for whitewashing of our houses. Have you ever thought how this quick lime is obtained? It is obtained by heating lime stone in a furnace (*bhatti*). Lime stone when heated gives lime and carbon dioxide.

$$\underset{\text{lime stone}}{CaCO_3\ (s)} \xrightarrow{\text{heat}} \underset{\text{quick lime}}{CaO\ (s)} + \underset{\text{carbon dioxide}}{CO_2\ (g)} \quad ...(14)$$

This reaction is an example of a decomposition reaction. **A decomposition reaction is the one in which a compound decomposes into two or more than two substances (elements or compounds).** Let us now carry out some activities.

ACTIVITY 4.3

Take about 2 g of ferrous sulphate in a hard glass test tube as shown in Fig. 4.3. Hold the test tube with a test tube holder and gently heat it over the flame. After heating for about one minute, observe the change in colour of ferrous sulphate. Smell the odour of the gas carefully. What do you observe? The green colour of the ferrous sulphate crystals gradually fades away and a smell of burning sulphur is found.

$$FeSO_4.7H_2O\ (s) \xrightarrow{\text{heat}} FeSO_4\ (s) + 7H_2O\ (g)$$

$$\underset{\text{ferrous sulphate}}{2FeSO_4\ (s)} \xrightarrow{\text{heat}} \underset{\text{ferric oxide}}{Fe_2O_3\ (s)} + \underset{\text{sulphur dioxide}}{SO_2\ (g)} + \underset{\text{sulphur trioxide}}{SO_3\ (g)} \qquad ...(15)$$

Here ferrous sulphate ($FeSO_4.7H_2O$) crystal first loses water and then decomposes to SO_2 and SO_3 gases.

Another example of a decomposition reaction is given below:

$$\underset{\text{lead nitrate}}{2Pb(NO_3)_2\ (s)} \xrightarrow{\text{heat}} \underset{\text{lead oxide}}{2PbO\ (s)} + \underset{\text{nitrogen dioxide}}{4NO_2\ (g)} + O_2\ (g) \qquad ...(16)$$

In the reactions given above, decomposition occurs by application of heat. Such reactions fall in the category of ***thermal decomposition***.

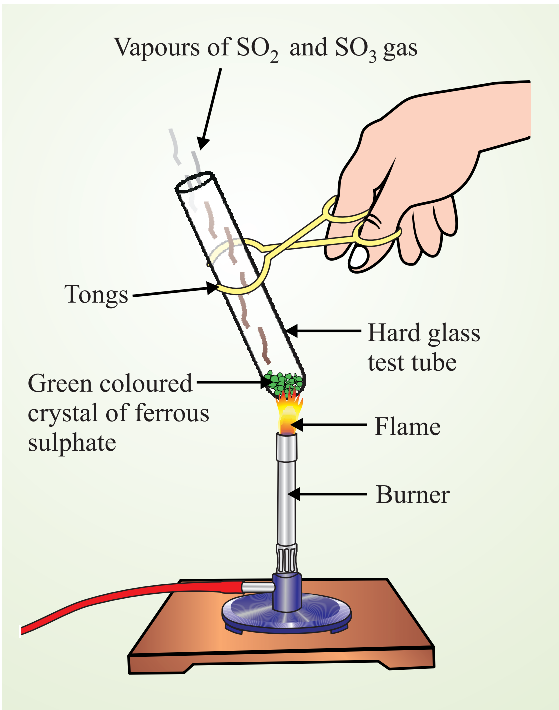


Fig. 4.3: *Thermal decomposition of ferrous sulphate*

ACTIVITY 4.4

Take a plastic mug. Drill two holes at its base and fit rubber stoppers in these holes. Insert graphite electrodes in these rubber stoppers as shown in Fig. 4.4. Connect these electrodes to a 6 volt battery.

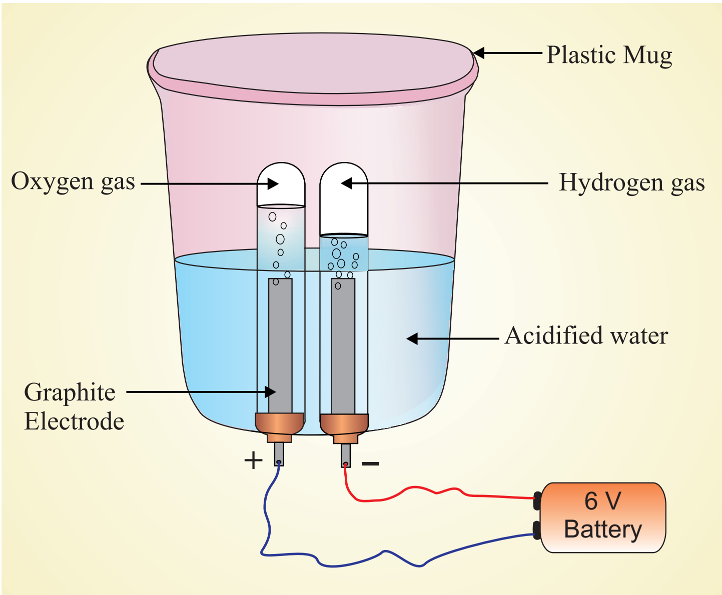


Fig. 4.4: *Electrolysis of water*

Now observe carefully what happens. You will find bubbles of gases over both the electrodes. Take two test tubes. Fill them with water and invert them over two graphite electrodes. Bubbles formed at the electrodes are found to replace water filled in the two test tubes. After sometime observe the volume of the two gases. You will find that the volume ratio of the two gases (oxygen and hydrogen) is 1:2. Carefully remove both the test tubes containing these gases one by one and test them with the help of your tutor at the study centre.

The two gases are hydrogen and oxygen and their volumes are in the ratio of 2:1 respectively (Gay Lussac's Law). The decomposition of water in this experiment takes place due to the electrical current that is passed through the water. A r***eaction in which a compound decomposes due to electrical energy into two or more than two substances (elements or compounds) is called electrolytic decomposition reaction***.

4.4.3 Displacement Reaction

For understanding this types of reaction, perform the following activity.

ACTIVITY 4.5

Take about 10 mL of dilute copper sulphate solution in each of the two test tubes and mark them as A and B. Now take two iron nails and clean them with sand paper. In test tube A, immerse one iron nail with the help of a thread as shown in Fig. 4.5. After nearly 20 minutes, observe the changes taking place on the surface of the iron nail and also in the colour of copper sulphate solutions. Compare the colour of the solution in test tube A with the colour of the solution in test tube B. What do you observe? The blue colour of copper sulphate solution fades. Similarly, compare the colour of the iron nail dipped in solution A with the other iron nail. You will see that the surface of the nail has become brownish. Do you know why the iron nail becomes brownish and the blue colour of copper sulphate solution fades?

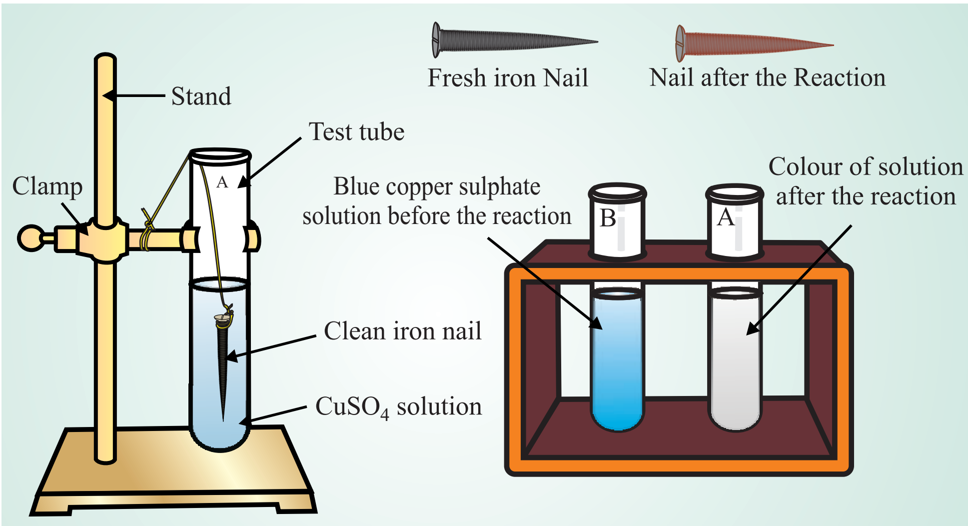


Fig. 4.5: *Reaction between iron and copper sulphate*

All this happens due to the following chemical reaction,

$$\underset{\text{iron}}{Fe\ (s)} + \underset{\text{copper sulphate}}{CuSO_4\ (aq)} \longrightarrow \underset{\text{ferrous sulphate}}{FeSO_4\ (aq)} + \underset{\text{copper}}{Cu\ (s)} \qquad ...(17)$$

In this reaction, one element i.e. iron has displaced another element i.e. copper from copper sulphate solution. These types of reactions fall in the category of ***displacement reactions. The displacement reaction is one in which one element displaces another element from its compounds.***

Other examples of displacement reactions are:

$$Zn\ (s) + CuSO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + Cu\ (s) \qquad ...(18)$$

$$Pb\ (s) + CuCl_2\ (aq) \longrightarrow PbCl_2\ (aq) + Cu\ (s) \quad ...(19)$$

Since zinc and lead are more reactive metals than copper therefore they displace copper from its compound.

4.4.4 Double Displacement Reactions

For understanding this type of reactions, perform the following activity.

ACTIVITY 4.6

Take two test tubes and mark them A and B. In test tube A take nearly 4 mL of sodium sulphate solution and in test tube B take nearly 4 mL of barium chloride solution. Now add solution of test tube A to solution of test tube B. What do you observe? A white substance is formed which is known as a ***precipitate***. The reaction can be written as,

$$\underset{\text{sodium sulphate}}{Na_2SO_4\ (aq)} + \underset{\text{barium chloride}}{BaCl_2\ (aq)} \longrightarrow \underset{\substack{\text{barium sulphate}\\ \text{(white ppt)}}}{BaSO_4\ (s)\downarrow} + \underset{\text{sodium chloride}}{2NaCl\ (aq)} \quad ...(20)$$

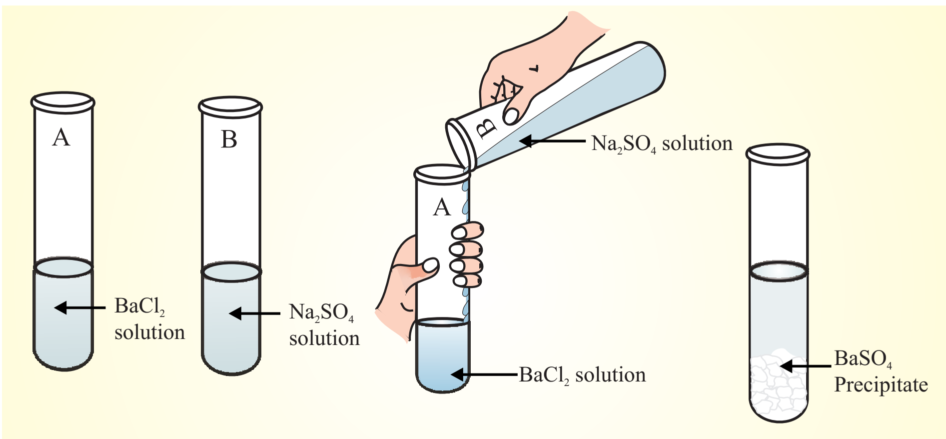


Fig. 4.6: *Precipitation reaction between sodium sulphate and barium chloride*

The white precipitate of $BaSO_4$ is formed by the reaction of Ba^{2+} ions and SO_4^{2-} ions. The other product formed is sodium chloride which remains in solution. ***Reactions in which there is an exchange of ions between the reactants, are called double displacement reactions.***

Find out different types of reaction occuring in your compounds.

4.5 OXIDATON AND REDUCTION (REDOX REACTION)

In order to understand the redox reactions, let us perform the following activity.

ACTIVITY 4.7

Take a china dish containing nearly 2 g of copper powder and heat it strongly as shown in Fig. 4.7. What do you observe? Copper powder becomes black. Why? This is because when oxygen combined with copper, copper oxide is formed which is black in colour. This reaction can be written as,

$$\underset{\text{brown}}{2Cu\ (s)} + O_2\ (g) \xrightarrow{\text{heat}} \underset{\text{black}}{2CuO\ (s)} \qquad ...(21)$$

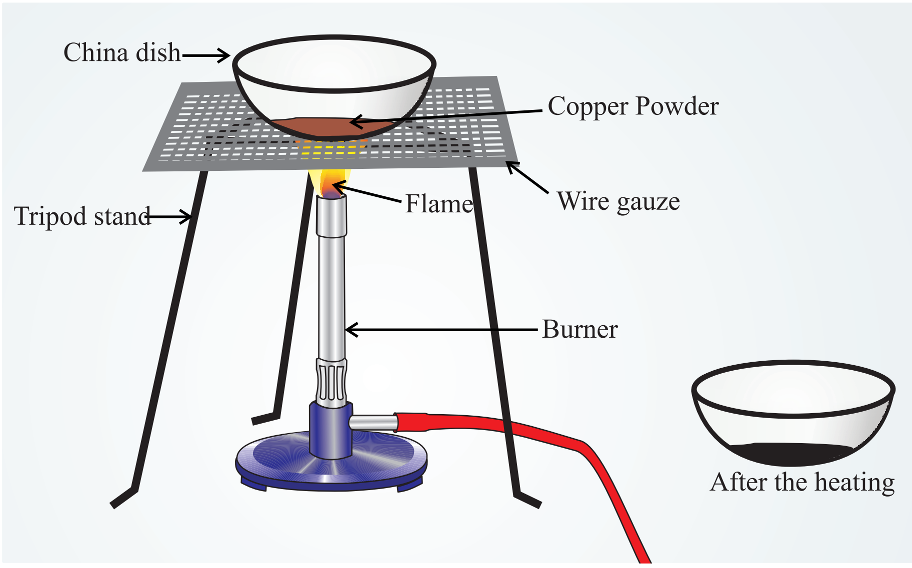


Fig. 4.7: *Heating of copper powder in air*

Now if you pass hydrogen gas over this black powder (CuO) you will observe that the surface of the black powder becomes brown, which is the original colour of the copper. This reaction can be written as,

$$\underset{\text{black}}{CuO\ (s)} + H_2\ (g) \longrightarrow \underset{\text{brown}}{Cu\ (s)} + H_2O\ (l) \qquad ...(22)$$

In reaction (21) copper gains oxygen and is said to be oxidized. In reaction (22) copper oxides loses oxygen and is said to be reduced. Hydrogen in this reaction is gaining oxygen and is thus being oxidized. ***When a substance gains oxygen during a reaction, it is said to be oxidized and when a substance loses oxygen during a reaction, it is said to be reduced.***

Thus in this reaction, during the reaction process, one reactant gets oxidized while the other gets reduced. Such reactions are called ***oxidation reduction reaction or Redox Reactions***. This can be depicted in the following way:

Reduction

$$CuO\ (s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$$

Oxidation

In the above scheme, CuO provides oxygen and therefore is an oxidizing agent and hydrogen takes this oxygen and therefore is a reducing agent. In a redox reaction, an oxidizing agent is reduced and a reducing agent is oxidized.

Some other examples of redox reaction are :

$$ZnO\ (s) + C\ (s) \xrightarrow{\text{heat}} Zn\ (s) + CO\ (g) \qquad ...(23)$$

$$MnO_2\ (s) + 4HCl\ (aq) \longrightarrow MnCl_2\ (aq) + 2H_2O\ (l) + Cl_2\ (g) \qquad ...(24)$$

In all redox reactions, you have seen that one species is oxidized and the other is reduced. ***There is no oxidation without reduction and there is no reduction without oxidation.*** This aspect of redox reactions will be explained broadly in terms of ***electron gain*** and ***electron loss*** in the following section.

4.5.1 Redox Reactions in terms of Electron gain and Electron Loss

You just learnt oxidation and reduction in terms of gain and loss of oxygen and hydrogen. However, defining a redox reaction in this way is confined to only a few reactions.

Let us consider the reactions

$$Cu\ (s) + I_2\ (s) \xrightarrow{\text{heat}} CuI_2\ (s) \qquad ...(25)$$

$$Fe\ (s) + S\ (s) \xrightarrow{\text{heat}} FeS\ (s) \qquad ...(26)$$

These reactions do not involve any gain or loss of oxygen or hydrogen. Yet these are oxidation-reduction reactions. The reaction (25),

$$Cu\ (s) + I_2\ (s) \longrightarrow CuI_2\ (s)$$

can be written in two steps as follows:

Step (i):

$$\underset{\text{copper atom}}{Cu} \longrightarrow \underset{\text{copper ion}}{Cu^{2+}} + \underset{\text{electrons}}{2e^-}$$

Step (ii):

$$\underset{\text{iodine}}{I_2} + \underset{\text{electrons}}{2e^-} \longrightarrow \underset{\text{iodide ion}}{2I^-}$$

In step (i) one copper atom loses two electrons to become a cupric ion, Cu^{2+} and in step (ii) iodine gains two electrons and gets converted into two iodide ions. Here we say, copper is oxidized by losing electrons and iodine is reduced by gaining electrons. Thus ***a reaction in which a species loses electrons is called an oxidation reaction and a reaction in which a species gains electrons is called a reduction reaction.*** The substance which oxidizes the other substance is known as an ***oxidizing agent***. An oxidizing agent gets reduced during the reaction. Likewise, the substance which reduces the other substance is known as a ***reducing agent***. A reducing agent gets oxidized during the reaction. In reaction (25), copper acts as a reducing agent and iodine as an oxidizing agent.

Similarly, in reaction (26) iron acts as a reducing agent and sulphur as an oxidising agent.

Step (i):

Fe	$\longrightarrow$	Fe^{2+}	+	$2e^-$
iron atom		ferrous ion		electrons

Step (ii):

S	+	$2e^-$	$\longrightarrow$	S^{2-}
sulphur atom		electrons		sulphide ion

Now, you can answer the following in the space provided

(i) Reducing agent: ....

(ii) Oxidising agent: ....

(iii) element which is oxidised: ....

(iv) Element which is reduced ....

[**Hint:** Your answer should be as per rule given below]

Gain of electron is reduction and loss of electron is oxidation.

As mentioned earlier, oxidation and reduction processes occur simultaneously.

Consider the following displacement reaction

$$Zn\ (s) + CuSO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + Cu\ (s)$$

or $$Zn\ (s) + Cu^{2+}\ (aq) \longrightarrow Zn^{2+}\ (aq) + Cu\ (s) \qquad ...(28)$$

Here, Zn loses electrons and gets converted into Zn^{2+} (aq). These electrons lost by Zn are gained by Cu^{2+} ion which gets converted into Cu. This broad definition of reduction-oxidation can be applied to many more reactions.

A few more examples of redox reaction are given below:

$$Fe_2O_3\ (s) + 2Al\ (s) \longrightarrow Al_2O_3\ (s) + 2Fe\ (s)$$

$$2Na\ (s) + Cl_2\ (g) \longrightarrow 2NaCl\ (s)$$

$$2Mg\ (s) + O_2\ (g) \longrightarrow 2MgO\ (s)$$

Notes

INTEXT QUESTIONS 4.2

1. Examine the following reaction(s) and identify which of them are **not** example(s) of a redox reaction?

   (i) $AgNO_3\ (aq) + HCl\ (aq) \longrightarrow AgCl\ (s) + HNO_3\ (aq)$

   (ii) $MnO_2\ (s) + 4HCl\ (aq) \longrightarrow MnCl_2\ (aq) + 2H_2O\ (l) + Cl_2\ (g)$

   (iii) $4Na\ (s) + O_2\ (g) \longrightarrow 2Na_2O\ (s)$

2. Identify the substances which are oxidized and the substances that are reduced in the following reactions:

   (i) $H_2\ (g) + Cl_2\ (g) \longrightarrow 2HCl\ (g)$

   (ii) $H_2\ (g) + CuO\ (s) \longrightarrow Cu\ (s) + H_2O\ (l)$

   (iii) $Zn\ (s) + 2AgNO_3\ (aq) \longrightarrow Zn(NO_3)_2\ (aq) + 2Ag\ (s)$

4.5.2 Effect of Redox Reaction in Everyday Life

We have studied different types of chemical reactions in the previous sections. Out of these reactions, redox reactions are very important in our lives. We would like to discuss corrosion in view of its economic importance. Rancidity is also important in view of its direct link with our foods and edibles. Both of these i.e. corrosion and rancidity are results of redox reactions.

- Corrosion
- Rancidity

A substance capable of destroying bacteria is called a disinfectant or a bactericide or an antiseptic. Most effective disinfectants are strong oxidizers

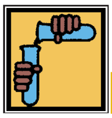
A bleach oxidises colored compounds to other substance which are not coloured.

Many disinfectants including chlorine which are available in different forms as solid compounds such as calcium hypochlorite, $Ca(ClO)_2$, are oxidising agents.

In an oxy-acetylene torch used for welding and cutting metals, acetylene is oxidised and produces very high temperature.

A. Corrosion

Corrosion is a destructive chemical process in which metals are oxidized in presence of air and moisture. The rusting of iron, tarnishing of silver, development of green coatings on copper, brass and bronze are a few examples of corrosion. It causes enormous damage to bridges, ships, cars and to all machines which are made of iron or steel. The damage and efforts taken to prevent it costs several crores of rupees a year. Preventing corrosion is a big challenge for an industrially developing country like ours.



ACTIVITY 4.8

Take 3 small beakers and mark them as A, B and C. In each beaker put 3 g of iron nail. In beaker A nothing is added but its mouth is covered with a watch glass. In beaker B add a few drops of water and make the iron nail wet. Leave the beaker B open, i.e. exposed to the atmosphere. In beaker C, add enough water to cover the nail completely (Fig. 4.8). Leave all the beakers for about three days. Observe the changes in all the beakers. Iron nail in beaker A are not affected, in beaker B the iron nail are rusted and in beaker C again the iron nail are not affected. Now write the condition for rusting on the basis of your findings.

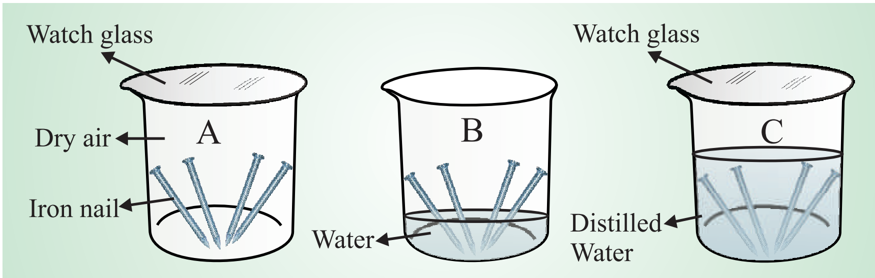


Fig. 4.8

How does one prevent corrosion?

There are several methods for protecting metals from corrosion, especially iron from rusting:

- plating the metal (iron) with a thin layer of less easily oxidized metal like nickel or chromium. This plating keeps out air (oxygen) and moisture which are main causes of corrosion.
- coating/connecting the metal with more reactive metal or with a metal which is more easily oxidized. For example, iron is connected to magnesium or coated with zinc for protecting it from corrosion. Iron rods are dipped in molten zinc to create a layer on their surface. This process of zinc coating over iron is called ***galvanization***.
- applying a protective coating such as paint.

Fig. 4.9: *Rusted nuts and bolts of iron*

B. Rancidity

You might have tasted or smelt fat/oil containing food material left for a long time. What do you find? You will find a lot of difference in the smell of fresh and stale oil or ghee. Why does this happen? This happens because fats and oils undergo oxidation and become rancid. This change is called ***rancidity***. Oxidation of fats/oils results into the formation of acids. These acids give unpleasant smell and bad taste.

Many food items which are cooked/fried in oil/fat are kept in air tight containers for sale. Keeping food items in air tight containers helps to slow down the oxidation process. Usually substances which prevent oxidation (anti-oxidants) are added to food items containing fats and oils. Do you know that the chips manufacturers usually flush bags of chips with a gas such as nitrogen to prevent oxidation of oil present in chips?

WHAT YOU HAVE LEARNT

- A chemical equation is a shorthand description of a reaction. It symbolically represents the reactants, products and their physical states.
- In a balanced chemical equation, number of atoms of each type involved in the chemical reaction is equal on the reactants and products sides of the equation.
- If charged species are involved, the sum of the charges on reactants should be equal to sum of charges on the products.
- During balancing of a chemical equation, no change in the formula of reactant(s) and product(s) is allowed.
- A balanced chemical equation obeys the law of conservation of mass and the law of constant proportions.
- In a combination reaction two or more substances combine to form a new single substance.
- In a decomposition reaction, a single substance decomposes to give two or more substances. Thus decomposition reactions are opposite to combination reactions.
- Reactions in which heat is given out during product formation are called **exothermic reactions** and reactions in which heat is absorbed during product formation are called **endothermic reactions**.
- A displacement reaction is one in which an element displaces another element from its compound.
- When two different ions are exchanged between two reactants double displacement reaction occurs.
- Precipitation reactions are the result of ion exchange between two substances, producing insoluble salts.

- Oxidation is the gain of oxygen or loss of hydrogen and reduction is loss of oxygen or gain of hydrogen. Oxidation and reduction reactions occur simultaneously and are jointly called ***redox reactions***.
- Redox reactions can broadly be defined in terms of loss and gain of electrons. Gain of electron(s) is reduction and loss of electrons is oxidation.
- Redox reactions are very important in our life situations as well as in industries.

TERMINAL EXERCISE

1. A. Write chemical equations of the following and balance them:

   (a) Carbon + oxygen $\longrightarrow$ Carbon dioxide

   (b) Hydrogen + Chlorine $\longrightarrow$ Hydrogen chloride

   (c) Barium chloride + Sodium sulphate $\longrightarrow$ Barium sulphate + sodium chloride

   B. Write balanced chemical equations with physical state symbols and necessary conditions, if any:

   (a) Nitrogen reacts with hydrogen in the presence of iron as a catalyst at 200 atmospheric pressure and 600°C temperature, and the product obtained is ammonia.

   (b) Aqueous solution of sodium hydroxide reacts with hydrochloric acid and produces sodium chloride and water.

   (c) Phosphorus burns in chlorine gas to form phosphorous pentachloride.

   C. Balance the following chemical reactions:

   (a) $Ca(OH)_2 + HNO_3 \longrightarrow Ca(NO_3)_2 + H_2O$

   (b) $BaCl_2\ (aq) + H_2SO_4\ (aq) \longrightarrow BaSO_4\ (s) + HCl\ (aq)$

   (c) $CuSO_4\ (aq) + Zn\ (s) \longrightarrow ZnSO_4\ (aq) + Cu\ (s)$

   (d) $H_2S\ (g) + SO_2\ (g) \longrightarrow S\ (s) + H_2O\ (l)$

   (e) $BaCl_2\ (aq) + Al_2(SO_4)_3\ (aq) \longrightarrow AlCl_3\ (aq) + BaSO_4\ (s)$

   (f) $Pb\ (NO_3)_2\ (aq) + Fe_2(SO_4)\ (aq) \longrightarrow Fe(NO_3)_3\ (aq) + PbSO_4\ (s)$

   (g) Calcium hydroxide + carbon dioxide $\longrightarrow$ Calcium carbonate + water

   (h) Aluminium + Copper (II) chloride $\longrightarrow$ Aluminium chloride + copper

   (i) Calcium carbonate + hydrochloric acid $\longrightarrow$ Calcium chloride + water + carbon dioxide

2. What is a balanced chemical equation? Write 3 characteristics of a balanced chemical equations?

3. In what way is a displacement reaction different from a double-displacement reaction? Explain with two suitable examples.

4. What happens when dilute hydrochloric acid is added to iron filings? Mark (√) at the correct answer from the following:

   (a) Hydrogen gas and iron chloride are produced and is classified as a displacement reaction.

   (b) Iron chloride and chlorine gas are produced and is classified as a decomposion reaction.

   (c) Iron hydroxide and water are produced and is classified as a combination reaction.

   (d) No reaction takes place but is classified as a double displacement reaction.

7. What do you mean by an exothermic reaction? Give a suitable example.

8. Classify each of the following reactions as combination, decomposition, displacement or double displacement reactions:

   (a) $Zn\ (s) + 2AgNO_3\ (aq) \longrightarrow Zn(NO_3)_2 + 2Ag\ (s)$

   (b) $2KNO_3\ (s) \xrightarrow{heat} 2KNO_2 + O_2\ (g)$

   (c) $Ni\ (NO_3)_2\ (aq) + 2NaOH\ (aq) \longrightarrow Ni(OH)_2\ (s) + 2NaNO_3\ (aq)$

   (d) $2KClO_3\ (s) \xrightarrow{heat} 2KCl\ (s) + 3O_2\ (g)$

   (e) $MgO\ (s) + C\ (s) \longrightarrow CO\ (g) + Mg\ (s)$

9. What is the difference between a combination and a decomposition reaction? Illustrate with suitable examples.

10. Is there any oxidation without reduction? Justify your answer.

11. 'Both combination reaction and displacement reaction fall in the category of redox reactions'. Do you agree? If so discuss this aspect with suitable examples.

12. Give two examples from everyday life situation where redox reaction takes place. How will you prove it?

13. In the following reactions name the substances which are oxidized and reduced and also mention the oxidizing and reducing agents:

    (a) $Ca\ (s) + Cl_2\ (g) \xrightarrow{heat} CaCl_2\ (s)$

(b) $3MnO_2\ (s) + 4Al\ (s) \xrightarrow{\text{heat}} 3Mn\ (l) + 2Al_2O_3\ (s)$

(c) $Fe_2O_3\ (s) + 3CO\ (g) \xrightarrow{\text{heat}} 2Fe\ (s) + 3CO_2\ (g)$

14. Explain the following in terms of electron transfer:

    (a) Oxidation (b) Reduction

17. What is the law of definite proportion by volume? Explain.

ANSWERS TO INTEXT QUESTIONS

4.1

1. (i) $Zn(s) + 2HCl\ (aq) \longrightarrow ZnCl_2(aq)\ + H_2(g) +\ H_2$

   (ii) $2HgO\ (s) \longrightarrow 2Hg\ (l) + O_2$

2. (i) $H_2SO_4\ (aq) + 2NaOH\ (aq) \longrightarrow Na_2SO_4\ (aq) + 2H_2O\ (l)$

   (ii) $2Al\ (s) + 6HCl\ (aq) \longrightarrow 2AlCl_3\ (aq) + 3\ H_2\ (g)$

3. Volume of reactant and products in gaseous chemical reactions are related to each other by small integers, provided the volume are measured at the same temperature and pressure. In a balanced gaseous chemical equation we get relation between volume and between the moles of the reactants and products.

4.2

1. Following equation is not example of a redox reaction :

   (i) $AgNO_3(aq)\ + HCl\ (aq) \longrightarrow AgCl(s)\ + HNO_3(aq)$

2. (i) H_2 is oxidized and Cl_2 is reduced.

   (ii) H_2 is oxidized and CuO is reduced.

   (iii) Zn is oxidized and Ag^+ (in $AgNO_3$) is reduced.

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5

ATOMIC STRUCTURE

In lesson 3, you have studied about atoms and molecules as the constituents of matter. You have also learnt that the atoms are the smallest constituents of matter. In lesson 4 you studied about the chemical reactions, their types and the ways to represent them. You know that according to Dalton's atomic theory, the atoms of different elements are different and in chemical reactions the atoms are rearranged between different reacting substances. However, today we know that the atom is not indivisible as it was thought by Dalton. The atom has a structure and contains smaller constituents in it. In this unit, we would attempt to find out the answers to some of the questions like, "What is the structure of an atom?", "What are the constituents of atoms?", "Why the atoms of different elements are different?" and so on.

We will begin this unit with the study of the discoveries of sub-atomic particles such as electron, proton etc. Then, we will take up various atomic models proposed on the basis of these discoveries. We will discuss how various models for the structure of atom were developed and also explain the success as well as the shortcomings of these models. This will be followed by the description of the arrangement or the distribution of electrons in the atom. This arrangement is known as *electronic configuration*. These electronic configurations are useful in explaining various properties of the elements. These also determine the nature of chemical bonds formed by it. This aspect is dealt with in lesson 7 on chemical bonding.

OBJECTIVES

After completing this lesson, you will be able to:

- *recall the evidences showing the presence of charged particles in matter;*
- *describe the discovery of electron and proton;*
- *explain Dalton's atomic theory and its failure;*
- *discuss Thomson's and Rutherford's models of atom and explain their limitations;*

- *explain the Bohr's model of atom (in brief);*
- *describe the discovery of neutron;*
- *compare the characteristic properties of proton, electron and neutron;*
- *explain various rules for filling of electrons and write the distribution of electrons in different shells upto atomic number 20;*
- *define valency and correlate the electronic configuration of an atom with its valency;*
- *define atomic number and mass number of an atom;*
- *describe isotopes and isobars;*
- *define and compute average atomic mass and explain its fractional value.*

5.1 CHARGED PARTICLES IN ATOM

You have read about Dalton's atomic theory in lesson 3. The theory proposed in the year 1803 considered the atom to be the smallest indivisible constituent of all matter. The Dalton's theory could explain the law of conservation of mass, law of constant composition and law of multiple proportions known at that time. However, towards the end of nineteenth century, certain experiments showed that an atom is neither the smallest nor indivisible particle of matter as stated by Dalton. It was shown to be made up of even smaller particles. These particles were called electrons, protons and neutrons. The electrons are negatively charged whereas the protons are positively charged. The neutrons on the other hand are uncharged in nature. You will now learn about the discovery of the charged subatomic particles.

5.1.1 Discovery of Electron

In 1885, Sir William Crookes carried out a series of experiments to study the behaviour of metals heated in a vacuum using cathode ray tubes. A cathode ray tube

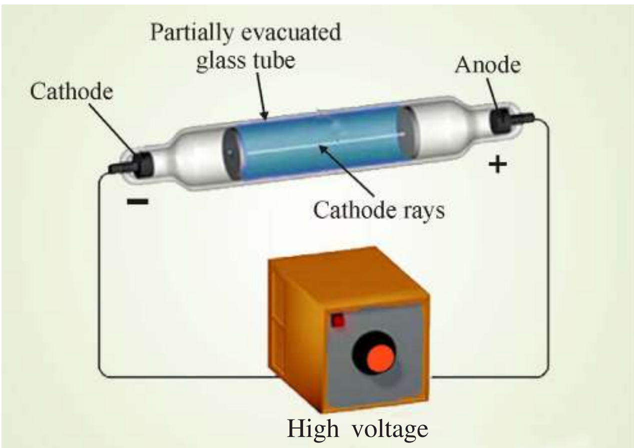


Fig. 5.1: *A cathode ray tube; cathode rays are obtained on applying high voltage across the electrodes in an evacuated glass tube*

consists of two metal electrodes in a partially evacuated glass tube. An evacuated tube is the one from which most of the air has been removed. The negatively charged electrode is called cathode whereas the positively charged electrode is called anode. These electrodes are connected to a high voltage source. Such a cathode ray tube has been shown in Fig. 5.1.

It was observed that when very high voltage was passed across the electrodes in evacuated tube, the cathode produced a stream of particles. These particles were shown to travel from cathode to anode and were called **cathode rays**. In the absence of external magnetic or electric field these rays travel in straight line. In 1897, an English physicist Sir J.J. Thomson showed that the rays were made up of a stream of negatively charged particles. This conclusion was drawn from the experimental observations when the experiment was done in the presence of an external electric field. Following are the important properties of cathode rays:

- Cathode rays travel in straight line
- The particles constituting cathode rays carry mass and possess kinetic energy
- The particles constituting cathode rays have negligible mass but travel very fast
- Cathode ray particles carry negative charge and are attracted towards positively charged plate when an external electric field is applied (Fig. 5.2)
- The nature of cathode rays generated was independent of the nature of the gas filled in the cathode ray tube as well as the nature of metal used for making cathode and anode. In all the cases the charge to mass ratio (e/m) was found to be the same.

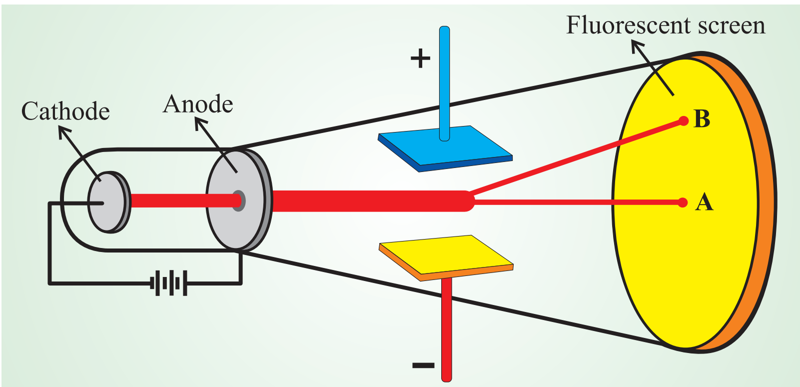


Fig. 5.2: *The cathode rays are negatively charged; these travel in straight line from cathode to the anode (A), however in the presence of an external electrical field these bend towards the positive plate (B)*

These particles constituting the cathode rays were later called **electrons**. Since it was observed that the nature of cathode rays was the same irrespective of the metal used for the cathode or the gas filled in the cathode ray tube. This led Thomson to conclude that all atoms must contain electrons. *This meant that the atom is not indivisible as was believed by Dalton and others*. In other words, we can say that the Dalton's theory of atomic structure failed partially.

This conclusion raised a question, "If the atom was divisible, then what were its constituents?". Today a number of smaller particles are found to constitute atoms. These particles constituting the atom are called **subatomic particles**. You have learnt above that electron is one of the constituents of the atom, let us study the next section to learn about another constituent particle present in an atom. As the atom is neutral, we expect the presence of positively charged particles in the atom so as to neutralise the negative charge of the electrons.

5.1.2 Discovery of Proton

Much before the discovery of electron, Eugen **Goldstein** (in 1886) performed an experiment using a perforated cathode (a cathode having holes in it) in the discharge tube filled with air at a very low pressure. When a high voltage was applied across the electrodes in the discharge tube, a faint red glow was observed behind the perforated cathode. Fig. 5.3

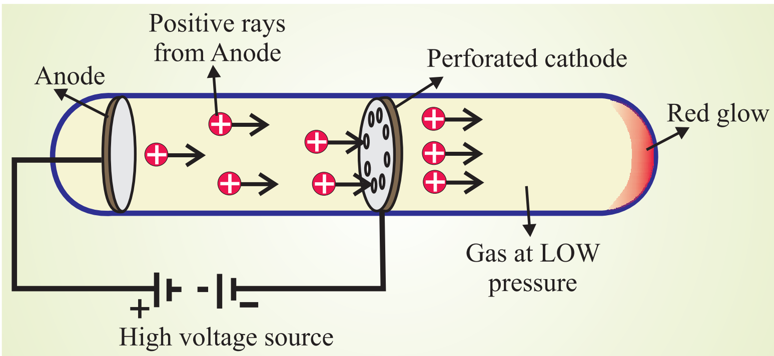


Fig. 5.3 *Goldstein's cathode ray tube with perforated cathode*

This glow was due to another kind of rays flowing in a direction opposite to that of the cathode rays. These rays were called as **anode rays** or positive rays. These were positively charged and were also called **canal rays** because they passed through the holes or the canals present in the perforated cathode. The following observations were made about anode rays (canal rays):

- Like cathode rays, the anode rays also travel in straight lines.
- The particles constituting anode rays carry mass and have kinetic energy.
- The particles constituting canal rays are much heavier than electrons and carry positive charges

- The positive charge on the particles was whole number multiples of the amount of charge present on the electron.
- The nature and the type of the particles constituting the anode rays were dependent on the gas present in the discharge tube.

The origin of anode rays can be explained in terms of interaction of the cathode rays with the gas present in the vacuum tube. It can be explained as given below:

The electrons emitted from the cathode collide with the neutral atoms of the gas present in the tube and remove one or more electrons present in them. This leaves behind positive charged particles which travel towards the cathode. When the cathode ray tube contained hydrogen gas, the particles of the canal rays obtained were the lightest and their charge to mass ratio (e/m ratio) was the highest. Rutherford showed that these particles were identical to the hydrogen ion (hydrogen atom from which one electron has been removed). These particles were named as **protons** and were shown to be present in all matter. Thus, we see that the experiments by Thomson and Goldstein had shown that an atom contains two types of particle which are oppositely charged and an atom is electrically neutral. What do you think is the relationship between the numbers of these particles in a given atom?

In addition to the two charged particles namely the electron and the proton, a neutral particle called neutron was also discovered about which you would learn later in this lesson. Now, it is the time to check your understanding. For this, take a pause and solve the following intext questions:

INTEXT QUESTIONS 5.1

1. Name two charged particles which constitute all matter.
2. Describe a cathode ray tube.
3. Name the negatively charged particles emitted from the cathode in the cathode ray tube?
4. Why do the canal rays obtained by using different gases have different e/m values?

> In addition to the discovery of electrons and protons as the constituents of atom, the phenomenon of **radioactivity** that is the spontaneous emission of rays from atoms of certain elements also proved that the atom was divisible.

5.2 EARLIER MODELS OF ATOM

In section 5.1 you have learnt that the atom is divisible and contains three smaller particles in it. The question that arises is, "In what way are the subatomic particles arranged in the atom?". On the basis of experimental observations, different models have been proposed for the structure of an atom. In this section, we will discuss two such models namely Thomson model and Rutherford model.

5.2.1 Thomson Model

In lesson 3 you have learnt that all matter is made of atoms and all the atoms are electrically neutral. Having discovered electron as a constituent of atom, Thomson concluded that there must be an equal amount of positive charge present in an atom. On this basis he proposed a model for the structure of atom. According to his model, atoms can be considered as a large sphere of uniform positive charge with a number of small negatively charged electrons scattered throughout it, Fig. 5.4. This model was called as **plum pudding** model. The electrons represent the plums in the pudding made of negative charge. This model is similar to a water-melon in which the pulp represents the positive charge and the seeds denote the electrons. However, you may note that a water melon has a large number of seeds whereas an atom may not have as many electrons.

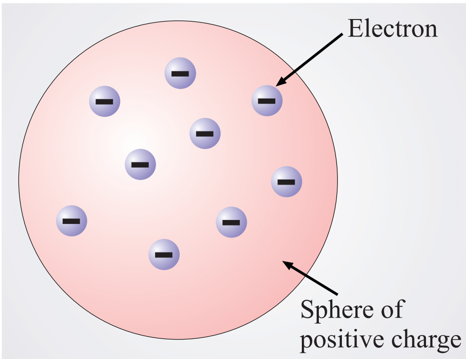


Fig. 5.4: *Thomson's plum-pudding model*

5.2.2 Rutherford's model

Ernest Rutherford and his co-workers were working in the area of radioactivity. They were studying the effect of alpha (α) particles on matter. The alpha particles are helium nuclei, which can be obtained by the removal of two electrons from the helium atom. In 1910, Hans Geiger (Rutherford's technician) and Ernest Marsden (Rutherford's student) performed the famous α-ray scattering experiment. This led to the failure of Thomson's model of atom. Let us learn about this experiment.

α-Ray scattering experiment

In this experiment a stream of α particles from a radioactive source was directed on a thin (about 0.00004 cm thick) piece of gold foil. On the basis of Thomson's model it was expected that the alpha particles would just pass straight through the gold foil and could be detected by a photographic plate placed behind the foil. However, the actual results of the experiment, Fig. 5.5, were quite surprising. It was observed that:

(i) Most of the α-particles passed straight through the gold foil.

(ii) Some of the α-particles were deflected by small angles.

(iii) A few particles were deflected by large angles.

(iv) About 1 in every 12000 particles experienced a rebound.

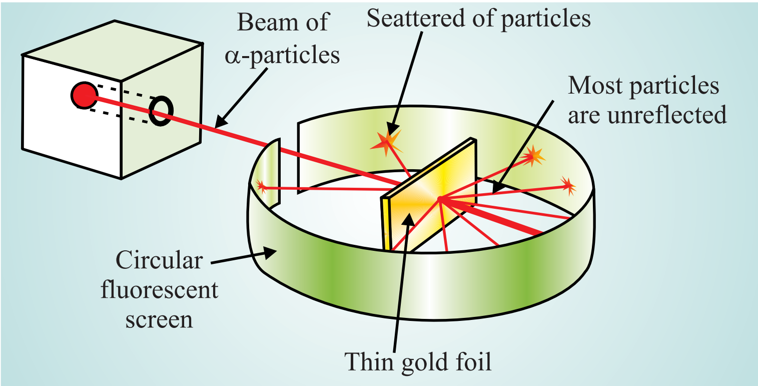
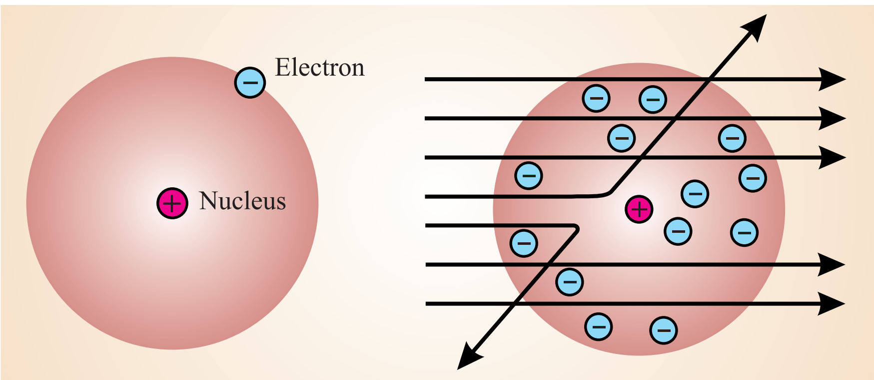


Fig. 5.5: *The experimental set-up and observations in the α- ray scattering experiment performed by Geiger and Marsden*

The results of α-ray scattering experiment were explained by Rutherford in 1911 and another model of the atom was proposed. According to Rutherford's model, Fig. 5.6(a).

- An atom contains a dense and positively charged region located at its centre; it was called as **nucleus**,
- All the positive charge of an atom and most of its mass was contained in the nucleus,
- The rest of an atom must be empty space which contains the much smaller and negatively charged electrons,



(a) (b)

Fig 5.6: *(a) Rutherford's model of atom (b) Explanation of the results of scattering experiment by Rutherford's model.*

On the basis of the proposed model, the experimental observations in the scattering experiment could be explained. This is illustrated in Fig. 5.6(b). The α particles passing through the atom in the region of the electrons would pass straight without any deflection. Only those particles that come in close vicinity of the positively charged nucleus get deviated from their path. Very few α-particles, those that collide with the nucleus, would face a rebound.

On the basis of his model, Rutherford was able to predict the size of the nucleus. He estimated that the radius of the nucleus was at least 1/10000 times smaller than that of the radius of the atom. We can imagine the size of the nucleus with the following analogy. If the size of the atom is that of a cricket stadium then the nucleus would have the size of a fly at the centre of the stadium.

INTEXT QUESTIONS 5.2

1. Describe Thomson's model of atom. What is it called?
2. What would have been observed in the α-ray scattering experiment if the Thomson's model was correct?
3. Who performed the α-ray scattering experiment and what were the observations?
4. Describe the model of atom proposed by Rutherford.

5.3 DRAWBACKS OF RUTHERFORD'S MODEL

According to Rutherford's model the negatively charged electrons revolve in circular orbits around the positively charged nucleus. However, according to Maxwell's electromagnetic theory (about which you may learn in higher classes), if a charged particle accelerates around another charged particle then it would continuously lose energy in the form of radiation. The loss of energy would slow down the speed of the electron. Therefore, the electron is expected to move in a spiral fashion around the nucleus and eventually fall into it as shown in Fig. 5.7. In other words, the atom will not be stable. However, we know that the atom is stable and such a collapse does not occur. Thus, Rutherford's model is unable to explain the stability of the atom. You know that an atom may contain a number of electrons. The Rutherford's model also does not say anything about the way the electrons are distributed around the nucleus. Another drawback of the Rutherford's model was its inability to explain the

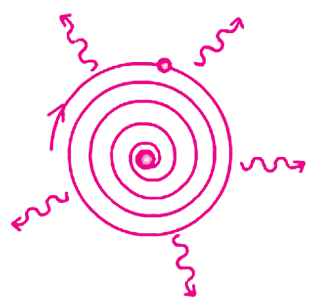


Fig. 5.7: *The electron in the Rutherford's model is expected to spiral into the nucleus*

relationship between the atomic mass and atomic number (the number of protons). This problem was solved later by Chadwick by discovering neutron, the third particle constituting the atom. You would learn about it in section 5.5.

The problem of the stability of the atom and the distribution of electrons in the atom was solved by Neils Bohr by proposing yet another model of the atom. This is discussed in the next section.

5.4 BOHR'S MODEL OF ATOM

In 1913, Niels Bohr,a student of Rutherford proposed a model to account for the shortcomings of Rutherford's model. Bohr's model can be understood in terms of two postulates proposed by him. The postulates are:

Postulate 1: *The electrons move in definite circular paths of fixed energy around a central nucleus*; just like our solar system in which different planets revolve around the Sun in definite trajectory. Similar to the planets, only certain circular paths around the nucleus are allowed for the electrons to move. These paths are called **orbits**, or **energy levels**. The electron moving in the orbit does not radiate. In other words, it does not lose energy; therefore, these orbits are called **stationary orbits or stationary states**. The bold concept of stationary state could answer the problem of stability of atom faced by Rutherford's model.

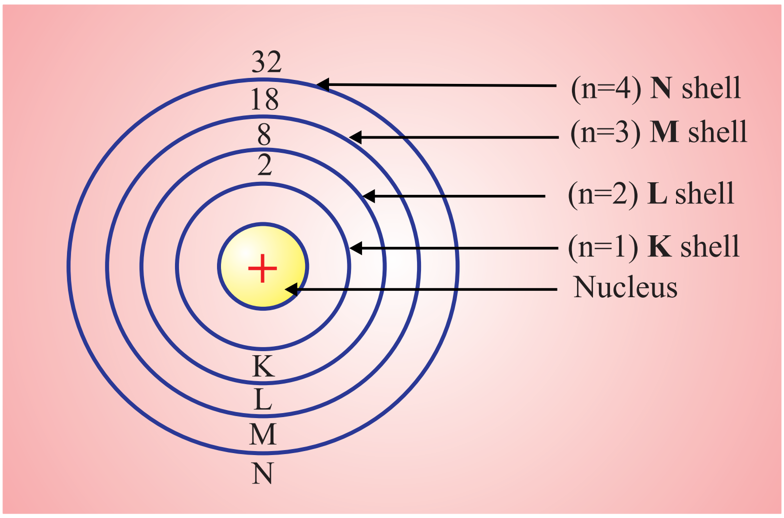


Fig. 5.8: *Illustration showing different orbits or the energy levels of fixed energy in an atom according to Bohr's model*

It was later realised that the concept of circular orbit as proposed by Bohr was not adequate and it was modified to energy shells with definite energy. While a circular orbit is two dimensional, a shell is a three dimensional region. The shells of definite energy are represented by letters (K, L, M, N etc.) or by positive integers (1, 2, 3, …. etc.) Fig. 5.8. The energies of the shells increase with the number n; n = 1, level is of the lowest energy. Further, the maximum number of electrons that can be accommodated in each shell is given by $2n^2$, where n is the number of the level. Thus, the first shell (n=1) can have a maximum of two electrons whereas the second shell can have 8 electrons and so on. Each shell is further divided into various sublevels called **subshells** about which you would study in your higher classes.

Postulate 2: The electron can change its shells or energy level by absorbing or releasing energy. An electron at a lower state of energy E_i can go to a final higher state of energy E_f by absorbing a single photon of energy given by:

$$E = h\nu = E_f - E_i$$

Similarly, when electron changes its shell from a higher initial level of energy E_i to a lower final level of energy E_f, a single photon of energy $h\nu$ is released (Fig. 5.9).

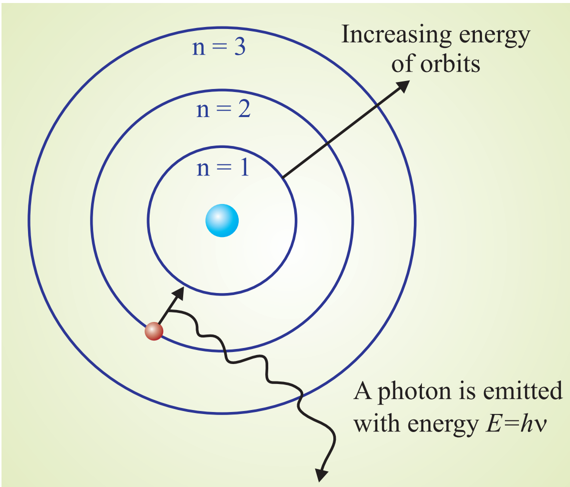


Fig. 5.9: *The electrons in an atom can change their energy level by absorbing suitable amounts of energy or by emitting energy.*

INTEXT QUESTIONS 5.3

1. Give any two drawbacks of Rutherford's model of atom.
2. State the postulates of Bohr's model.
3. How does Bohr model of an atom explain the stability of the atom?

Thus, the Bohr's model of atom removes two of the limitations of Rutherford's model. These are related to the stability of atom and the distribution of electrons around the nucleus. You would recall that the third limitation of Rutherford's model was its inability to explain the relationship between the atomic mass, and the atomic number (the number of protons) of an atom. Let us learn how this problem was solved with the discovery of neutron.

5.5 DISCOVERY OF NEUTRON

You would recall that when we discussed about the failure of Rutherford's model we mentioned that it was unable to explain the relationship between the atomic mass and the atomic number (the number of protons). According to the Rutherford's model, the mass of helium atom (containing 2 protons) should be double that of a hydrogen atom (with only one proton). [Ignoring the mass of electron as it is very light]. However, the actual ratio of the masses of helium atom to hydrogen atom is 4:1. It was suggested that there must be one more type of subatomic particle present in the nucleus which may be neutral but have mass.

Such a particle was discovered by James Chadwick in 1932. This was found to be electrically neutral and was named **neutron**. Neutrons are present in the nucleus of all atoms, except hydrogen. A neutron is represented as 'n' and is found to have a mass slightly higher than that of a proton. Thus, if the helium atom contained 2 protons and 2 neutrons in the nucleus, the mass ratio of helium to hydrogen (4:1) could be explained. The characteristics of the three fundamental particles constituting the atom are given in Table 5.1.

Table 5:1 Characteristics of the fundamental subatomic particles

Particle	Symbol	Mass (in kg)	Actual Charge (in Coulombs)	Relative charge
Electron	e	$9.109\ 389 \times 10^{-31}$	$1.602\ 177 \times 10^{-19}$	–1
Proton	p	$1.672\ 623 \times 10^{-27}$	$1.602\ 177 \times 10^{-19}$	1
Neutron	n	$1.674\ 928 \times 10^{-27}$	0	0

INTEXT QUESTIONS 5.4

1. What is a neutron and where is it located in the atom?
2. How many neutrons are present in the α-particle?
3. How will you distinguish between an electron and a proton?

5.6 ATOMIC NUMBER AND MASS NUMBER

You have learnt that the nucleus of atom contains positively charged particles called protons and neutral particles called neutrons. **The number of protons in an atom is called the atomic number and is denoted by the symbol 'Z'**. All atoms of an element have the same atomic number. The electrons occupy the space outside the nucleus. In order to account for the electrically neutral nature of the atom, the number of protons in the nucleus is exactly equal to the number of electrons. Thus,

Atomic number = number of protons = number of electrons

You would recall that according to Dalton's theory, the atoms of different elements are different from each other. We can now say that this difference is due to difference in the numbers of protons present in the nucleus of the element. In other words, different elements differ in terms of their **atomic number**. For example, the atoms of hydrogen and helium are different because hydrogen has one proton in its nucleus whereas the nucleus of helium atom contains two protons. Their atomic numbers are 1 and 2, respectively. You have learnt in the Rutherford's model that the mass of the atom is concentrated in its nucleus. This is due to the presence of two heavy particles namely protons and neutrons in the nucleus. These particles are called **nucleons**. *The number of nucleons in the nucleus of an atom is called its* ***mass number***. It is denoted by 'A' and is equal to the total number of protons and neutrons present in the nucleus of an element. Thus,

Mass number (A) = number of protons(Z) + number of neutrons(n)

Atomic number and mass number are represented on the symbol of an element. An element, X with an atomic number, Z and the mass number, A is denoted as follows:

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

For example, $^{12}_{6}C$ means that the carbon has an atomic number of 6 and the mass number of 12. This can be used to compute the number of different fundamental particles in the atom. Let us calculate it for carbon.

As the atomic number is 6 this means:

Number of protons = number of electrons = 6

As Mass number = number of protons + number of neutrons

$\Rightarrow$ 12 = 6 + number of neutrons

$\Rightarrow$ number of neutrons = 12 – 6 = 6

Thus, an atom of $^{12}_{6}C$ has 6 protons, 6 electrons and 6 neutrons.

INTEXT QUESTIONS 5.5

1. A sodium atom has an atomic number of 11 and a mass number of 23. Calculate the number of protons, electrons and neutrons in a sodium atom.

2. What is the mass number of an atom which has 7 protons and 8 neutrons?
3. Calculate the number of electrons, protons and neutrons in $^{40}_{18}Ar$ and $^{49}_{19}K$.

5.7 ELECTRONIC CONFIGURATION: DISTRIBUTION OF ELECTRONS IN DIFFERENT ORBITS

As discussed in section 5.4, the electrons move in definite paths called orbits or shells around a central nucleus. These orbits or shells have different energies and can accommodate different number of electrons in them. The question arises that how are the electrons distributed amongst these shells? The answer to this question was provided by Bohr and Bury. According to their scheme, the electron distribution is governed by the following rules:

I. These orbits or shells in an atom are represented by the letters K, L, M, N,… or the positive integral numbers, n = 1,2,3,4,….

II. The orbits are arranged in the order of increasing energy. The energy of M shell is more than that of the L shell which in turn is more than that of the K shell.

III. The maximum number of electrons present in a shell is given by the formula $2n^2$, where 'n' is the number of the orbit or the shell. Thus, the maximum number of electrons that can be accommodated in different shells are as follows:

Maximum number of electrons in K shell (or n = 1 level) = $2n^2 = 2 \times (1)^2 = 2$

Maximum number of electrons in L shell (or n = 2 level) = $2n^2 = 2 \times (2)^2 = 8$

Maximum number of electrons in M shell (or n = 3 level) = $2n^2 = 2 \times (3)^2 = 18$ and so on. See table 5.2

Table 5.2: Electron accommodation capacity of different shells

Value of n	Shell name	Maximum capacity
1	K-Shell	2
2	L- Shell	8
3	M- Shell	18
4	N- Shell	32

IV. The shells are occupied in the increasing order of their energies.

V. Electrons are not accommodated in a given shell, unless the inner shells are completely filled.

The arrangement of electrons in the various shells or orbits of an atom of the element is known as electronic configuration. Keeping these points in mind, let us now study the filling of electrons in various shells of atoms of different elements.

- Hydrogen (H) atom has only one electron. It would occupy the first shell and electronic configuration of hydrogen can be represented as 1.
- The next element helium (He) has two electrons in its atom. Since the first shell can accommodate two electrons; hence, this second electron will also be placed in the first shell. The electronic configuration of helium is written as 2.
- The third element, Lithium (Li) has three electrons. Now the two electrons occupy the first shell whereas the third electron goes to the next shell of higher energy level, i.e. second shell. Thus, the electronic configuration of Li is 2, 1.

Similarly, the electronic configurations of other elements can be written. The structures of the atoms of elements with atomic number 1 to 18 are given in Fig. 5.10.

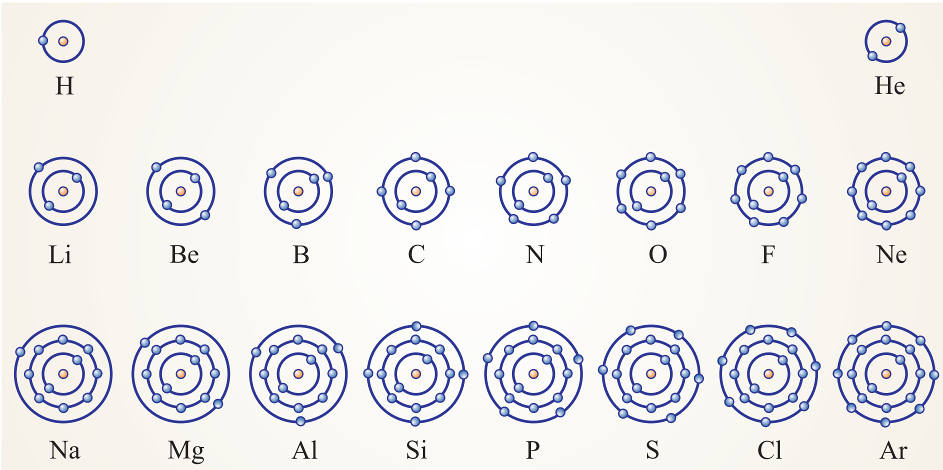


Fig. 5.10: *The structures, according to Bohr's model of atoms, of elements with atomic number 1 to 18.*

5.7.1 Concept of Valence or Valency

We have just discussed the electronic configuration of first 18 elements. You can see from the Fig. 5.10 that different elements have different number of electrons in the outermost or the valence shell. These electrons in the outermost shell are known as valence electrons. **The number of valence electrons determines the combining capacity of an atom in an element.** Valence is the number of chemical bonds that an atom can form with univalent atoms. Since hydrogen is a univalent atom, the valence of an element can be taken by the number of atoms of hydrogen with which one atom of the element can combine. For example, in H_2O, NH_3, and CH_4 the valencies of oxygen, nitrogen and carbon are 2, 3 and 4 respectively.

The elements having a completely filled outermost shell in their atoms show little or no chemical activity. In other words, their combining capacity or valency is zero. The elements with completely filled valence shells are said to have stable electronic

configuration. The main group elements can have a maximum of eight electrons in their valence shell. This is called **octet rule**; you will learn more about it in lesson 7. You will learn that the combining capacity or the tendency of an atom to react with other atoms to form molecules depends on the ease with which it can achieve octet in its outermost shell. The valencies of the elements can be calculated from the electronic configuration by applying the octet rule. It can be seen as follows:

- If the number of valence electrons is four or less then the valency is equal to the number of the valence electrons.
- In cases when the number of valence electrons is more than four then generally the valency is equal to 8 minus the number of valence electrons.

Thus,

Valency = Number of valence electrons (for 4 or lesser valence electrons)

Valency = 8 - Number of valence electrons (for more than 4 valence electrons)

The composition and electronic configuration of the elements having the atomic numbers from 1 to 18, along with their valencies is given in Table 5.3.

Table 5.3: The composition, electron distribution and common valency of the elements with atomic number from 1 to 18

Name of Element	Symbol	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Distribution of Electrons				Valency
						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

In next lesson, you will study about the importance of electronic configurations in understanding the periodic arrangement of elements. These electronic configurations are also helpful in studying the nature of bonding between various elements which will be dealt with in lesson 7.

INTEXT QUESTIONS 5.6

1. How many shells are occupied in the nitrogen (atomic number =7) atom?
2. Name the element which has completely filled first shell.
3. Write the electronic configuration of an element having atomic number equal to 11.

WHAT HAVE YOU LEARNT

- According to Dalton's atomic theory, the atom is considered to be the smallest indivisible constituent of all matter. This theory could explain the law of conservation of mass, law of constant composition and law of multiple proportions. However, certain experiments towards the end of nineteenth century showed that the atom is neither the smallest nor indivisible particle of matter. It was shown to be made up of even smaller particles called electrons, protons and neutrons.
- Sir J.J.Thomson discovered that when very high voltage was passed across the electrodes in the cathode ray tube, the cathode produced rays that travel from cathode to anode and were called **cathode rays**. It showed that the rays were made up of a stream of negatively charged particles called electrons. The discovery of electrons *meant that the atom is not indivisible as was believed by Dalton and others*.
- Eugen **Goldstein** discovered anode rays by using a perforated cathode (a cathode having holes in it) in the discharge tube filled with air at a very low pressure. The discovery of anode rays established the presence of positively charged proton in the atom.
- According to Thomson's plum-pudding model, atoms can be considered as a large sphere of uniform positive charge with a number of small negatively charged electrons scattered throughout it.
- The α-ray scattering experiment performed by Geiger and Marsden led to the failure of Thomson's model of atom. In this experiment, a stream of α-particles from a radioactive source was directed on a thin piece of gold foil. Most of the α-particles passed straight through the gold foil, some α-particles were deflected by small angles, a few particles by large angles and very few experienced a rebound.

- The results of α-ray scattering experiment were explained in terms of Rutherford's model. According to which the atom contains a dense and positively charged region called **nucleus** at its centre and the negatively charged electrons move around it. All the positive charge and most of the mass of atom is contained in the nucleus.
- The Rutherford's model however failed as it could not explain the stability of the atom, the distribution of electrons and the relationship between the atomic mass and atomic number (the number of protons).
- The problem of the stability of the atom and the distribution of electrons in the atom was solved by Neils Bohr in terms of Bohr's model of the atom. Bohr's model can be understood in terms of two postulates, the first being, ' *The electrons move in definite circular paths of fixed energy around a central nucleus*' and the second, '*The electron can change its orbit or energy level by absorbing or releasing energy*.'
- In 1932, James Chadwick discovered an electrically neutral particle in atom and named it as **neutron**.
- The number of protons in an atom is called the atomic number and is denoted as 'Z'. On the other hand the number of nucleons(protons plus neutrons) in the nucleus of an atom is called its mass number and is denoted as 'A'
- The electrons are distributed in different shells in the order of increasing energy. The distribution is called electronic configuration. The maximum number of electrons present in a shell is given by the formula $2n^2$, where 'n' is the number of the orbit or the shell.
- The valence is the number of chemical bonds that an atom can form with univalent atoms. If the number of valence electrons is four or less, then the valency is equal to the number of the valence electrons. On the other hand, if the number of valence electrons is more than four, then generally the valency is equal to 8 minus the number of valence electrons.

TERMINAL EXERCISE

1. How did J.J.Thomson discover the electron? Explain his "plum pudding" model of the atom.
2. What made Thomson conclude that all atoms must contain electrons?
3. Identify the following subatomic particles:
   (a) The number of these in the nucleus is equal to the atomic number
   (b) The particle that is not found in the nucleus
   (c) The particle that has no electrical charge
   (d) The particle that has a much lower mass than the others subatomic particles

4. Which of the following are usually found in the nucleus of an atom?
   (a) Protons and neutrons only
   (b) Protons, neutrons and electrons
   (c) Neutrons only
   (d) Electrons and neutrons only
5. Describe Ernest Rutherford's experiment with alpha particles and gold foil. How did this lead to the discovery of the nucleus?
6. What does the atomic number tell us about an atom?
7. What is the relationship between the numbers of electrons and protons in an atom?
8. How did Neils Bohr revise Rutherford's atomic model?
9. What is understood by a stationary state?
10. What is a shell? How many electrons can be accomodate in L-shell?
11. State the rules for writing the electronic configuration of elements.

ANSWERS TO INTEXT QUESTIONS

5.1

1. Electrons and protons
2. A cathode ray tube consists of two metal electrodes in a partially evacuated glass tube. The negatively charged electrode is called cathode while the positively charged electrode is called anode. These electrodes are connected to a high voltage source.
3. Electron
4. When the electrons emitted from the cathode collide with the neutral atoms of the gas present in the tube, these remove one or more electrons present in them. This leaves behind positive charged particles which travel towards the cathode. As the atoms of different gases have different number of protons present in them, these give positively charged ions with different e/m values.

5.2

1. According to Thomson's model, atoms can be considered as a large sphere of uniform positive charge with a number of small negatively charged electrons scattered throughout it. This model was called as **plum pudding** model.

2. If the Thomson's model was correct, then most of the α-particles in the α-ray scattering experiment would have passed straight through the atom

3. The α-ray scattering experiment was performed by Geiger and Marsden. When a stream of α-particles from a radioactive source was directed on a thin piece of gold foil, most of the α-particles passed straight through the gold foil, some α-particles were deflected by small angles, a few particles by large angles and very few experienced a rebound.

4. According to Rutherford's model, the atom contains a dense and positively charged region called **nucleus** at its centre and the negatively charged electrons move around it. All the positive charge and most of the mass of atom is contained in the nucleus.

5.3

1. The Rutherford's model could not explain the stability of the atom, the distribution of electrons and the relationship between the atomic mass and atomic number (the number of protons).

2. The two postulates of Bohr's model are :

   I. The electrons move in definite circular paths of fixed energy around a central nucleus.

   II. The electron can change its orbit or energy level by absorbing or releasing energy.

3. The Bohr's model explains the stability of atom by proposing that the electron does not lose energy when present in a given energy level.

5.4

1. It is a neutral subatomic particle present in the nucleus of the atom.

2. An α-particle contains two neutrons.

3. The electron and proton can be distinguished in terms of their charge and mass. While the electron is negatively charged, the proton is positively charged. Secondly, the proton is much heavier than the electron; it is about 1840 times heavier.

5.5

1. No of protons = 11

   No. of electrons = 11

   No. of neutrons = 12

2. Mass number = number of protons + number of neutrons

   Therefore, mass number = 7 + 8 = 15

3. $^{40}_{18}Ar$: Number of protons = atomic number = 18

   Number of electrons = number of protons = 18

   Number of neutrons = mass number – number of protons = 40 – 18 = 22

   $^{40}_{19}K$ Number of protons = atomic number = 19

   Number of electrons = number of protons = 19

   Number of neutrons = mass number – number of protons = 40 – 19 = 21

5.6

1. The electronic configuration of nitrogen is 2, 5. Thus, two shells are occupied. The first shell (capacity = 2) is completely filled while the second shell (capacity = 8) is partially filled.
2. Helium
3. The electronic configuration of an element having atomic number 11 is 2, 8, 1.

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6

PERIODIC CLASSIFICATION OF ELEMENTS

In the last lesson, you have studied about the structure of atoms and their electronic configurations. You have also learnt that the elements with similar electronic configurations show similar chemical properties. By the middle of the nineteenth century quite a large number of elements (nearly 60) were known. In order to study these elements systematically, it was considered necessary to classify them. In this lesson, you will undertake the journey through the development of classification of elements from ancient to modern. You will also study how some properties of elements vary in the modern periodic table.

OBJECTIVES

After studying this lesson you will be able to:

- *describe briefly the development of classification of elements;*
- *state main features of Mendeleev's periodic table;*
- *explain the defects of Mendeleev's periodic table;*
- *state modern periodic law;*
- *describe the features of the long form of periodic table;*
- *explain modern periodic classification and*
- *describe the trends in variation of atomic size and metallic character in the periodic table.*

6.1 CLASSIFICATION OF ELEMENTS

6.1.1 Need for Classification of Elements

You must have visited a chemist's shop. Several hundred medicines are stored in it. In spite of this, when you ask for a particular medicine, the chemist is able to locate it easily. How is it possible? It is because the medicines have been *classified* into various categories and sub categories and arranged accordingly. This makes their location an easy task.

Before the beginning of the eighteenth century, only a few elements were known, so it was quite easy to study and remember the properties of those elements and their compounds individually. However, by the middle of the nineteenth century, more the than sixty elements had been discovered. The number of compounds formed by them was also enormous. With the increasing number of elements, it was becoming more and more difficult to study their properties individually. Therefore, the need for their classification was felt. This led to the classifications of various elements into groups which helped in the systematic study of elements.

6.1.2 Development of Classification

Scientists after many attempts were successful in arranging various elements into groups. They realised that even though every element is different from others, yet there are a few similarities among some elements. Accordingly, similar elements were arranged into groups which led to classification. Various types of classification were proposed by different scientists. The first classification of elements was into 2 groups- **metals** and **non-metals**. This classification served only limited purpose mainly because some elements like germanium and antimony showed the properties of both – metals and non-metals. They could not be placed in any of the two classes.

Scientists were in search of such characteristics of an element which would never change. After the work of William Prout in 1815, it was found that the atomic mass of an element remains constant, so it could form the basis for a satisfactory classification. Now, you will learn about the *four* major attempts made for classification of elements. They are as follows :

1. Dobereiner's Triads
2. Newlands' Law of Octaves
3. Mendeleev's Periodic Law & Periodic Tables
4. Modern Periodic Table

6.1.3 Dobereiner's Triads

In 1829, J.W. Dobereiner, a German chemist made groups of three elements each and called them **triads** (Table 6.1). All three elements of a triad were similar in their physical and chemical properties. He proposed a law known as **Dobereiner's law of triads**. According to this law, *when elements are arranged in order of increasing atomic mass, the atomic mass of the middle element was nearly equal to the arithmetic mean of the other two and its properties were intermediate between those of the other two.*

J.W. Dobereiner
(1780-1849)

Table 6.1: Dobereiner's triads of elements

S. No.	Element	Atomic Mass	Mean of I and III
1.	I. Lithium	7	$\frac{7+39}{2}=23$
	II. Sodium	23	
	III. Potassium	39	
2.	I. Calcium	40	$\frac{40+137}{2}=88.5$
	II. Strontium	88	
	III. Barium	137	
3.	I. Chlorine	35.5	$\frac{35.5+127}{2}=81.25$
	II. Bromine	80	
	III. Iodine	127	

This classification did not receive wide acceptance since only a few elements could be arranged into triads.

6.1.4 Newlands' Law of Octaves

In 1864, an English chemist John Alexander Newlands arranged the elements in the increasing order of their atomic masses (then called *atomic weight*). He observed that *every eighth element had properties similar to the first element*. Newlands called it the **Law of Octaves**. It was due to its similarity with musical notes where every eighth note is the repetition of the first one as shown below :

1	2	3	4	5	6	7	8
सा	रे	गा	मा	पा	धा	नी	सा

The arrangement of elements given by Newlands is given in Table 6.2.

Starting from *lithium* (Li), the eighth element is *sodium* (Na) and its properties are similar to those of the lithium. Similarly, *beryllium* (Be), *magnesium* (Mg) and *calcium* (Ca) show similar properties. *Fluorine* (F) and *chlorine* (Cl) are also similar chemically.

Table 6.2 : Arrangement of some elements with their atomic masses according to the Law of Octaves.

Li (7)	Be (9)	B (11)	C (12)	N (14)	O (16)	F (19)
Na (23)	Mg (24)	Al (27)	Si (28)	P (31)	S (32)	Cl (35.5)
K (39)	Ca (40)					

The **merits of Newlands**' Law of Octaves classification are:

(i) Atomic mass was made the basis of classification.

(ii) Periodicity of properties (the repetition of properties after a certain interval) was recognised for the first time.

The demerits of Newlands' law of Octaves are:

(i) It was not applicable to elements of atomic masses higher than 40 u. Hence, all the 60 elements known at that time, could not be classified according to this criterion.

(ii) With the discovery of noble gases, it was found that it was the *ninth* element which had the properties similar to the first one and *not the eighth* element. This resulted in the rejection of the very idea of octaves.

The basic idea of Newlands for using the atomic mass as the fundamental property for classification of elements was pursued further by two scientists Lother Meyer and D. Mendeleev. Their main achievement was that they both included almost all the known elements in their work. We shall, however, discuss the classification proposed by Mendeleev which was accepted more widely and is the basis of the modern classification.

6.1.5 Mendeleev's Periodic Law and Periodic Table

D'mitri Mendeleev (also spelled as Mendeleef or Mandeleyev) , a Russian chemist studied the properties of all the 63 elements known at that time and their compounds. On arranging the elements in the increasing order of atomic masses, he observed that the elements with similar properties occur periodically. In 1869, he stated this observation in the form of the following statement which is known as the **Mendeleev's Periodic Law**.

The chemical and physical properties of elements are a periodic function of their atomic masses.

A *periodic function* is the one which repeats itself after a certain interval. Mendeleev arranged the elements in the form of a table which is known as the **Mendeleev's Periodic Table.**

Mendeleev's Periodic Table

Mendeleev arranged the elements in the increasing order of their atomic masses in horizontal rows till he came across an element whose properties were similar to those of the first element. Then he placed this element below the first element and thus started the second row of elements.


D. Mendeleev
(1834-1907)

The success of Mendeleev's classification was due to the fact that he laid more emphasis on the properties of elements rather than on atomic masses. Occasionally, he could not find an element that would fit in a particular position. He left such positions vacant for the elements that were yet to be discovered. He even predicted the properties of such elements and of some of their compounds fairly accurately. In some cases, he even reversed the order of some elements, if it better matched their properties. Proceeding in this manner, he could arrange all the known elements in his periodic table.

When more elements were discovered, this periodic table was modified and updated to include them. One more group (zero group) had to be added when noble gases were discovered.

Table 6.3: Mendeleev's updated periodic table

Groups	I	II	III	IV	V	VI	VII	VIII
Oxides Hydrides	RO RH	RO RH_2	R_2O_3 RH_3	RO_2 RH_4	R_2O_5 RH_3	RO_3 RH_2	R_2O_7 RH	RO_4
Periods ↓	A B	A B	A B	A B	A B	A B	A B	Transition series
1	H 1.008							
2	Li 6.939	Be 9.012	B 10.81	C 12.011	N 14.007	O 15.999	F 18.998	
3	Na 22.99	Mg 24.31	Al 29.98	Si 28.09	P 30.974	S 32.06	Cl 35.453	
4 First series:	K 39.102	Ca 40.08	Sc 44.96	Ti 47.90	V 50.94	Cr 50.20	Mn 54.94	Fe 55.85 Co 58.93 Ni 58.71
Second series:	Cu 63.54	Zn 65.37	Ga 69.72	Ge 72.59	As 74.92	Se 78.96	Br 79.909	
5 First series:	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	Tc 99	Ru 101.07 Rh 102.91 Pd 106.4
Second series:	Ag 107.87	Cd 112.40	In 114.82	Sn 118.69	Sb 121.75	Te 127.60	I 126.90	
6 First series:	Cs 132.90	Ba 137.34	La 138.91	Hf 178.49	Ta 180.95	W 183.85		Os 190.2 Ir 192.2 Pt 195.09
Second series:	Au 196.97	Hg 200.59	Tl 204.37	Pb 207.19	Bi 208.98			

Main Features of Mendeleev's Periodic Table

The following are the main features of this periodic table :

1. The elements are arranged in **rows** and **columns** in the periodic table.
2. The horizontal rows are called periods. There are six periods in the periodic table. These are numbered from 1 to 6 (Arabic numerals). Each one of the 4th, 5th and 6th periods have two series of elements.
3. Properties of elements in a given period show regular gradation (*i.e*. increase or decrease) from left to right.
4. The vertical columns present in it are called **groups**. There are eight groups numbered from **I** to **VIII** (Roman numerals).
5. Groups I to VII are further divided into A and B **subgroups**. However, group VIII contains three elements in each of the three periods.
6. All the elements present in a particular group are chemically similar in nature. They also show a regular gradation in their physical and chemical properties from top to bottom.

Merits of Mendeleev's Periodic Classification

1. Classification of all elements

Mendeleev's classification included *all the 63 elements known* at that time on the basis of their atomic mass and facilitated systematic study of elements.

2. Correction of atomic masses

Atomic masses of some elements like Be (*beryllium*), Au (*gold*), In (*indium*) were corrected based on their positions in the table. (See box 1)

3. Prediction of new elements

Mendeleev arranged the elements in the periodic table in increasing order of atomic mass but whenever he could not find out an element with expected properties, he left a blank space. He left this space blank for an element yet to be discovered. He even predicted the properties of such elements and also of some of their compounds. For example, he predicted the existence of unknown element for the vacant space below silicon and thus belonging to the same group IV B, of the periodic table. He called it **eka-silicon** (meaning, *one position below silicon*). Later, in 1886, *C.A. Winkler* of Germany discovered this element and named it as **germanium**. The predicted and the actual properties of this element were remarkably similar (see Box 2). **Ekaboron** (scandium) **and eka-aluminium** (gallium) are two more examples of unknown elements predicted by Mendeleev.

Box 1

Indium had been assigned an atomic mass of 76 and valency of *two*. On the basis of its position in the periodic table, Mendeleef predicted its atomic mass to be 113.1 and its valency to be *three*. The accepted atomic mass today is 114.82 and valency is *three*.

Box 2

Predictions for eka-silicon by Mendeleef

Property	Predicted eka-silicon	Actual Germanium
Atomic Mass	72	72·6
Density/g cm^{-3}	5·5	5·36
Melting point	High	1231K
Action of acid	Likely to be slightly attacked	No action with HCl, reacts with hot nitric acid
Action of alkali	No reaction	No action with dil. NaOH
Oxide	MO_2	GeO_2
Sulphide	MS_2	GeS_2
Chloride	MCl_4	$GeCl_4$
Boiling point of chloride	373 K	356 K

4. Valency of elements

Mendeleev's classificaiton helped in understanding the valency of elements. The valency of elements is given by the group number. For example, all the elements in group 1 i.e. lithium, hydrogen, sodium, potassium, rubidium, caesium have valency 1.

Defects of Mendeleev's Periodic Table

Mendeleev's periodic table was a great success, yet it had the following defects :

1. Position of Hydrogen

The position of hydrogen which is placed in group IA along with alkali metals is ambiguous as it resembles alkali metals as well as halogens (group VII A).

2. Position of Isotopes

All the isotopes of an element have different atomic masses therefore, each one of them should have been assigned a separate position. On the other hand, they are all chemically similar; hence they should all be placed at the same position. In fact, Mendeleev's periodic table did not provide any space for different isotopes. For example, two isotopes of carbon are represented as ${}_{6}C^{12}$, ${}_{6}C^{14}$ but placed at the same position.

3. Anomalous* Pairs of Elements

At some places, an element with greater atomic mass had been placed before an element with lower atomic mass due to their properties. For example, cobalt with higher atomic mass (58.9) was placed before nickel with lower atomic mass (58.7). Other such pairs are :

(i) Tellurium (127.6) is placed before iodine (126.9) and

(ii) Argon (39.9) is placed before potassium (39.1).

4. Grouping of chemically dissimilar elements

Elements such as copper and silver have no resemblance with alkali metals (lithium, sodium etc.), but have been grouped together in the first group.

5. Separation of chemically similar elements

Elements which are chemically similar such as gold and platinum have been placed in separate groups.

INTEXT QUESTIONS 6.1

1. Elements A, B and C constitute a Dobereiner's triad. The atomic mass of A is 20 and that of C is 40. Predict the atomic mass of B.
2. Which property of atoms was used by Mendeleev to classify the elements?
3. In Mendeleev's periodic classification, whether chemically similar elements are placed in a group or in a period?

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*Anomaly means deviation from common rule, irregularity, abnormal, exception

4. Mendeleev's periodic table had some blank spaces. What did they signify?
5. Explain any three defects of Mendeleev's periodic table.

6.2 MODERN PERIODIC LAW

Though Mendeleev's periodic table included all the elements, yet at many places a heavier element had to be placed before a lighter one. Such pairs of elements (*called anomalous pairs*) violated the periodic law. Also, there was no place for different isotopes of an element in the periodic table. Due to these reasons, it was felt that the arrangement of elements in the periodic table should be based on some other property which is more fundamental than the atomic mass.

In 1913, Henry Moseley, an English physicist discovered that the **atomic number** and not the atomic mass is the most fundamental property of an element.

***Atomic number** (Z) of an element is the number of protons in the nucleus of its atom.*

Since atom is as electrically neutral entity, the number of electrons is also equal to its atomic number i.e.the number of protons. After this development, it was felt necessary to change the periodic law and modify the periodic table.

6.2.1 Modern Periodic Law

*The **Modern Periodic Law** states that the chemical and physical properties of elements are periodic functions of their atomic numbers i.e. if elements are arranged in the order of their increasing atomic number, the elements with similar properties are repeated after certain regular intervals.*

Fortunately, even with the revised periodic law, the Mendeleev's classification did not require any major revision as it was based on properties of the elements. In fact, taking atomic number as the basis for classification, removed major defects from it such as a*nomalous pairs* and *position of isotopes.*

After changes in the periodic law, many modifications were suggested in the periodic table. Now, we shall learn about the modern periodic table in its final shape that is being used now..

Cause of Periodicity

Let us now understand the cause of periodicity in the properties of elements. Consider the electronic configuration of alkali metals *i.e.*, the first group elements with atomic numbers 3, 11, 19, 37, 55 and 87 (*i.e.*, lithium, sodium, potassium, rubidium, caesium and francium) in the table given below:

Table 6.4 : Electronic configuration of group 1 elements

Element	Electronic configuration
$_3Li$	2, 1
$_{11}Na$	2, 8, 1
$_{19}K$	2, 8, 8, 1
$_{37}Rb$	2, 8, 18, 8, 1
$_{55}Cs$	2, 8, 18, 18, 8, 1
$_{87}Fr$	2, 8, 18, 32, 18, 8, 1

All these elements have one electron in the outer most shell and so they have similar properties which are as follows :

(i) They are good reducing agents.

(ii) They form monovalent cations.

(iii) They are soft metals.

(iv) They are very reactive and, therefore, found in nature in combined state.

(v) They impart colour to the flame.

(vi) They form hydrides with hydrogen.

(vii) They form basic oxides with oxygen.

(viii) They react with water to form metal hydroxides and liberate hydrogen.

It is noticed that all the elements having similar electronic configuration have similar properties. Thus, *the re-occurrence of similar electronic configuration is the cause of periodicity in properties of elements.*

6.3 MODERN PERIODIC TABLE

The periodic table based on the modern periodic law is called the **Modern Periodic Table**. Presently, the accepted modern periodic table is the **Long Form of Periodic Table**.

It may be regarded as an extended form of Mendeleev's table in which the sub-groups A and B have been separated.

Now, you will learn the main features of the long form of periodic table which is shown in Table 6.5.

Table 6.5 : Modern Periodic Table

Group → / Period ↓	1 I	2 II	3	4	5	6	7	8	9	10	11	12	13 III	14 IV	15 V	16 VI	17 VII	18 VIII
1	hydrogen 1 H																	helium 2 He
2	lithium 3 Li	beryllium 4 Be											boron 5 B	carbon 6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	neon 10 Ne
3	sodium 11 Na	magnesium 12 Mg											aluminium 13 Al	silicon 14 Si	phosphorus 15 P	sulfur 16 S	chlorine 17 Cl	argon 18 Ar
4	potassium 19 K	calcium 20 Ca	scandium 21 Sc	titanium 22 Ti	vanadium 23 V	chromium 24 Cr	manganese 25 Mn	iron 26 Fe	cobalt 27 Co	nickel 28 Ni	copper 29 Cu	zinc 30 Zn	gallium 31 Ga	germanium 32 Ge	arsenic 33 As	selenium 34 Se	bromine 35 Br	krypton 36 Kr
5	rubidium 37 Rb	strontium 38 Sr	yttrium 39 Y	zirconium 40 Zr	niobium 41 Nb	molybdenum 42 Mo	technetium 43 Tc	ruthenium 44 Ru	rhodium 45 Rh	palladium 46 Pd	silver 47 Ag	cadmium 48 Cd	indium 49 In	tin 50 Sn	antimony 51 Sb	tellurium 52 Te	iodine 53 I	xenon 54 Xe
6	caesium 55 Cs	barium 56 Ba	57-71 *	hafnium 72 Hf	tantalum 73 Ta	tungsten 74 W	thenium 75 Re	osmium 76 Os	iridium 77 Ir	platinum 78 Pt	gold 79 Au	mercury 80 Hg	thallium 81 Tl	lead 82 Pb	bismuth 83 Bi	polonium 84 Po	astatine 85 At	radon 86 Rn
7	francium 87 Fr	radium 88 Ra	89-103 **	rutherfordium 104 Rf	dubnium 105 Db	seaborgium 106 Sg	bohrium 107 Bh	hassium 108 Hs	meitnerium 109 Mt	darmstadtium 110 Ds	roentgenium 111 Rg	ununbium 112 Uub	ununtrium 113 Uut	ununquadium 114 Uuq	ununpentium 115 Uup	ununhexium 116 Uuh	ununseptium 117 Uus	ununoctium 118 Uuo

* Lanthanoids	lanthanum 57 La	cerium 58 Ce	praseodymium 59 Pr	neodymium 60 Nd	promethium 61 Pm	samarium 62 Sm	europium 63 Eu	gadolinium 64 Gd	terbium 65 Tb	dysprosium 66 Dy	holmium 67 Ho	erbium 68 Er	thulium 69 Tm	ytterbium 70 Yb	lutetium 71 Lu
** Actinoids	actinium 89 Ac	thorium 90 Th	protactinium 91 Pa	uranium 92 U	neptunium 93 Np	plutonium 94 Pu	americium 95 Am	curium 96 Cm	berkelium 97 Bk	californium 98 Cf	einsteinium 99 Es	fermium 100 Fm	mendelevium 101 Md	nobelium 102 No	lawrencium 103 Lr

Chemical series of the periodic table

Alkali metals	Alkaline earth metals	Lanthanides	Actinides	Transition metals	
Poor metals	Metalloids	Nonmetals	Halogens	Noble gases	

6.3.1 Features of Long Form of Periodic Table

The long form of periodic table helps us to understand the reason why certain elements resemble one another and why they differ from other elements in their properties. The arrangement of elements in this table is also in keeping with their electronic structures (configuration). In table 6.5, you must have noticed that it is divided into columns and rows. The columns represent the **groups** or family and the rows represent the **periods**.

1. **Groups:** There are 18 vertical columns in the periodic table. Each vertical column is called a **group**. The groups have been numbered from 1 to 18 (in Arabic numerals).

   All elements present in a group have similar electronic configurations and have same number of valence electrons. You can see in case of group 1 (alkali metals) and group 17 elements (halogens) that as one moves down a group, more and more shells are added as shown in Table 6.6.

Table 6.6

Group 1		Group 17	
Element	**Electronic configuration**	**Element**	**Electronic configuration**
Li	2,1	F	2,7
Na	2,8,1	Cl	2,8,7
K	2,8,8,1	Br	2,8,8,7
Rb	2,8,18,8,1	I	2,8,18,18,7

   All elements of group 1 have only one valence electron. Li has electrons in two shells, Na in three, K in four and Rb has electrons in five shells. Similarly all the elements of group 17 have seven valence electrons however the number of shells is increasing from two in fluorine to five in iodine.

2. **Periods:** There are *seven* horizontal rows in the periodic table. Each row is called a **period.** The elements in a period have consecutive atomic numbers. The periods have been numbered from 1 to 7 (in Arabic numerals).

   In each period a new shell starts filling up. The period number is also the number of the shell which starts filling up as we move from left to right across that particular period. For example, in elements of 3rd period (N = 3), the third shell (*M* shell) starts filling up as we move from left to right*. The first element of this period, sodium (Na 2,8,1) has only one electron in its valence shell (third shell) while the last element of this period, argon (Ar 2,8,8) has eight electrons in its valence shell. The gradual filling of the third shell can be seen below.

Element Period →	Na	Mg	Al	Si	P	S	Cl	Ar
Electronic configuration	2,8,1	2,8,2	2,8,3	2,8,4	2,8,5	2,8,6	2,8,7	2,8,8

* However, it should be noted here that more and more electrons are added to valence shell only in case of normal elements. In transition elements, the electrons are added to incomplete inner shells.

(a) The first period is the *shortest period* of all. It contains only two elements; H and He.

(b) The second and third periods are called *short periods* containing 8 elements each.

(c) The fourth and fifth periods are *long periods* containing 18 elements each.

(d) The sixth and seventh periods are *very long periods* containing 32 elements each.

6.3.2 Types of Elements

1. **Main Group Elements:** The elements present in groups 1 and 2 on left side and groups 13 to 17 on the right side of the periodic table are called *representative* or *main group elements*. Their outermost shells are incomplete,which means their outermost shell has less than eight electrons.

2. **Noble Gases:** Group 18 on the extreme right side of the periodic table contains *noble gases*. Their outermost shells contain 8 electrons except He which contains only 2 electrons.

   Their main characteristics are :

   (a) They have 8 electrons in their outermost shell (except **He** which has 2 electrons).

   (b) Their combining capacity or valency is zero.

   (c) They do not react and so are almost inert.

   (d) All the members are gases.

3. **Transition Elements:** The middle block of periodic table (groups 3 to 12) contains *transition elements.* Their two outermost shells are incomplete.

   Since these elements represent a transition (change) from the most electropositive element to the most electronegative element, they are named as *transition elements*.

   Their important characteristics are as follows:

   (a) All these elements are metals and have high melting and boiling points.

   (b) They are good conductors of heat and electricity.

   (c) Some of these elements get attracted towards magnet.

   (d) Most of these elements are used as catalyst.

   (e) They exhibit variable valencies.

4. **Inner Transition Elements:** These elements, also called *rare-earth elements,* are shown separately below the main periodic table. These are *two series of*

14 elements each. The first series called ***lanthanoids*** consists of elements 58 to 71 (Ce to Lu). They all are placed along with the element 57, *lanthanum* (La) in the same position (group 3, period 6) because of very close resemblance between them. It is only for the sake of convenience that they are shown separately below the main periodic table.

The second series of 14 rare-earth elements is called ***actinoids***. It consists of elements 90 to 103 (Th to Lr) and they are all placed along with the element 89, *actinium* (Ac) in the same position (group 3, period 7) but for convenience they are shown below the main periodic table.

In all rare-earths (lanthanoids and actinoids), *three outermost* shells are incomplete. They are therefore called *inner transition elements*.

It is interesting to note that the element lanthanum *is not* a lanthanoid and the element actinium *is not* an actinoid.

5. **Metals:** *Metals* are present in the left hand portion of the periodic table. The strong metallic elements; *alkali metals* (Li, Na, K, Rb, Cs, Fr) and *alkaline earth metals* (Be, Mg, Ca, Sr, Ba, Ra) occupy groups 1 and 2 respectively.
6. **Non-metals:** *Non-metals* occupy the right hand portion of the periodic table. Strong non-metallic elements *i.e.*, *halogens* (F, Cl, Br, I, At) and *chalkogens* (O, S, Se, Te, Po) occupy groups 17 and 16 respectively.
7. **Metalloids:** *Metalloids* are the elements that show mixed properties of both metals and non-metals. They are present along the diagonal line starting from group 13 (Boron) and going down to group 16 (Polonium).

ACTIVITY 6.1

Rearrange the alphabets to get the correct name of the element in the space provided and mention its position in the modern periodic table

(a) RGANO .... is a noble gas which is placed in group .... and third period of the modern periodic table.

(b) HULIMIT .... is an alkali metal which is placed in group 1 and .... period of the modern periodic table.

(c) MILCUAC .... is an alkaline earth metal which is placed in group .... and fourth period of the modern periodic table.

(d) POHSROSUHP .... is a metalloid which is placed in group 15 and .... period of the modern periodic table.

6.3.3 Merits of the Modern Periodic Table

The following points overcame the defects of Mendeleev's periodic table, that is why, it was accepted by scientists across the world

1. **Position of isotopes:** All isotopes of an element have the same atomic number and therefore, occupy the same position in the modern periodic table.
2. **Anomalous pairs:** The anomaly regarding all these pairs disappears when *atomic number* is taken as the basis for classification. For example, cobalt (at. no. 27) would naturally come before nickel (at. no. 28) even though its atomic mass is little more than that of nickel.
3. **Electronic configuration:** This classification is according to the electronic configuration of elements, *i.e.,* the elements having a certain pattern of electronic configuration are placed in the same group of the periodic table. It relates the properties of elements to their electronic configurations. This point will be further elaborated in the next section.
4. **Separation of metals and non-metals:** The position of metals, non-metals and metalloids are clearly established in the modern periodic table.
5. **Position of transition metals:** It makes the position of the transition elements quite clear.
6. **Properties of elements:** It reflects the differences, the trends and the variations in the properties of the elements in the periodic table.
7. This table is simple, systematic and easy way of remembering the properties of dfifferent metals.

INTEXT QUESTIONS 6.2

1. Give any two defects of Mendeleev's periodic table which has been removed in modern periodic table. How were they removed?
2. Metalloids are present along the diagonal line starting from group 13 and going down to group 16. Do they justify their position in the modern periodic table?

6.4 PERIODIC TRENDS IN PROPERTIES

You have learnt about the main features of the long form of the periodic table in the previous section.and you know that it consists of groups and periods. Let us recall their two important features:

1. In a given group, the number of filled shells increases. The number of valence electrons is the same in all the elements of a given group. However, these valence

electrons but they are present in higher shells which are farther away from the nucleus. In view of this, decreases the force of attraction between the outermost shell and the nucleus as we move downwards in a group.

2. In a given period, the nuclear charge and the number of valence electrons in a particular shell increase from left to right. This increases the force of attraction between the valence electron and nucleus as we move across a period from left to right.

The above given changes affect various properties which show gradual variations in groups and periods, and they repeat themselves after certain intervals of atomic number. They are called *periodic properties*. Now you are going to learn the variations of two of such properties in the periodic table.

A. Atomic Size

Atomic size is the distance between the centre of nucleus and the outermost shell of an isolated atom. It is also known as *atomic radius*. It is measured in picometre, pm (1 pm = 10^{-12} m). Atomic size is a very important property of atoms because it is related to many other properties.

Variation of atomic size in periodic table.

The size of atoms *decreases from left to right* **in a period** but *increases from top to bottom* **in a group**. For example, the atomic radii of the elements of the second period and of group 1 are given below in the tables 6.7 and 6.8 respectively.

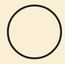
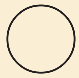
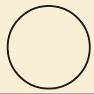
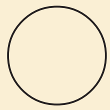
Table 6.7 : Atomic radii of period 2 elements

Atomic Number	3	4	5	6	7	8	9
Elements : (in second period)	Li	Be	B	C	N	O	F
Atom radius/pm :	134	90	82	77	75	73	72
Atomic Size	◯	◯	○	○	○	∘	∘

In a period the atomic number and therefore the positive charge on the nucleus increases gradually. As a result, the electrons are attracted more strongly and they come closer to the nucleus. This decreases the atomic size in a period from left to right.

In a group as one goes down, a new shell is added to the atom which is farther away from the nucleus. Hence electrons move away from the nucleus. This increases the atomic size in a group from top to bottom.

Table 6.8 : Atomic radii of group 1 elements

Atomic Number	Elements (in groups I)	Atom radius/pm	Atomic Size
3	Li	134	
11	Na	154	
19	K	196	
37	Rb	211	
55	Cs	225	

B. Metallic and Non-metallic Character

The tendency of an element to lose electrons to form cations is called *electropositive or metallic character* of an element. Alkali metals are most electropositive. The tendency of an element to accept electrons to form anions is called *electronegative or non-metallic character* of an element.

(a) Variation of Metallic Character in a Group

Metallic character increases from top to bottom in a group as tendency to lose electrons increases. This increases the electropositive character and metallic nature. The variation can best be seen in group 14 as shown below.

Table 6.9: Metallic character of groups 14 elements

Element	Nature
C	Non-metal
Si	Metalloid
Ge	Metalloid
Sn	Metal
Pb	Metal

(b) Variation of Metallic Character in a Period

Metallic character decreases in a period from left to right. It is because the ionization energy increases in a period. This decreases the electropositive character and metallic nature. The variation of metallic character in the elements of 3rd period is shown below.

Table 6.10 : Metallic character of 3rd period elements

Element	Na	Mg	Al	Si	P	S	Cl
Nature	Metal	Metal	Metal	Metalloid	Non-Metal	Non-Metal	Non-Metal

In this section, you have learnt about variation of some properties in periodic table. Some important trends in periodic table may be summarized in a general way as given below :

Table 6.11 : Variation of various periodic properties in periods and groups

Property	**In a Period (From left to right)**	**In a Group (From top to Bottom)**
Atomic number	increases	increases
Atomic size	decreases	increases
Metallic character	decreases	increases
Non-metallic character	increases	decreases

INTEXT QUESTIONS 6.3

1. Fill in the blanks with appropriate words

   (a) The force of attraction between nucleus and valence electrons .... in a period from left to right.

   (b) Atomic radii of elements .... in a period from left to right.

   (c) Atomic radii of elements .... in a group from top to bottom.

   (d) Metallic character of elements .... from top to bottom in a group.

2. In the following crossword puzzle, elements are present horizontally, vertically downwards and diagonally downwards. Let us find out how many elements you are able to get within 5 minutes.

Z	N	H	Y	D	R	O	G	E	N
M	B	I	C	A	R	B	O	N	O
A	D	E	T	B	A	R	I	U	M
G	X	Y	H	R	M	U	S	A	S
N	A	D	E	O	O	A	O	O	I
E	I	U	J	P	X	G	I	S	L
S	O	D	I	U	M	Y	E	L	I
I	D	M	U	X	A	I	G	N	C
U	I	O	M	O	G	E	Y	E	O
M	N	D	P	S	B	O	R	O	N
A	E	C	H	L	O	R	I	N	E

Please check in the intext answers to find if you missed out any.

3. Let us find how many riddles you can solve.
   (i) I am the only noble gas whose outermost shell has 2 electrons. Who am I?
   (ii) I am placed in group 16 of the modern periodic table and essential for your respiration. Who am I?
   (iii) I combine with chlorine to form your table salt. Who am I?

   (**Hint:** Answers are present in the grid]

WHAT YOU HAVE LEARNT

- The first classification of elements was as metals and non-metals.
- After the discovery of atomic mass (old term, atomic weight) it was thought to be the fundamental property of elements and attempts were made to correlate it to their other properties.
- John Dobereiner grouped elements into triads. The atomic mass and properties of the middle element were mean of the other two. He could group only a few elements into triads. For example (i) Li, Na and K (ii) Ca, Sr and Ba (iii) Cl, Br and I.

- Newlands tried to see the periodicity of properties and stated his law of octaves as "*When elements are arranged in the increasing order of their atomic weights every eighth element has properties similar to the first*". He could arrange elements up to calcium only out of more than sixty elements then known.
- Mendeleev observed the correlation between atomic weight and other properties and stated his periodic law as, "*The chemical and physical properties of elements are a periodic function of their atomic weights*".
- Mendeleev gave the first periodic table which is named after him which included all the known elements. It consists of seven horizontal rows called **periods** and numbered them from 1 to 7. It has eight vertical columns called **groups** and numbered them from I to VIII.
- Main achievements of Mendeleev's periodic table were (i) inclusion of all the known elements and (ii) prediction of new elements.
- Main defects of Mendeleev's periodic table were (i) position of isotopes, (ii) anomalous pairs of elements like Ar and K and (iii) grouping of dissimilar elements and separation of similar elements.
- Moseley discovered that atomic number and not atomic mass is the fundamental property of elements. In the light of this the periodic law was modified to "The *chemical and physical properties of elements are periodic functions of their atomic numbers*". This is the Modern Periodic Law.
- Modern Periodic Table is based upon atomic number. Its long form has been accepted by IUPAC. It has seven periods (1 to 7) and 18 groups (1 to 18). It is free of main defects of Mendeleev's periodic table. Elements belonging to same group have same number of valence electrons and thus show same valency and similar chemical properties.
- Arrangement of elements in the periodic table shows periodicity. Atomic radii and metallic character increase in a group from top to bottom and in a period decrease from left to right.

TERMINAL EXERCISE

A. *Objective questions*

I. Mark the correct choice:

1. *Which one of the following was the earliest attempt of classification of elements?*

   (a) Classification of elements into metals and non-metals

   (b) Newlands' Law of Octaves

(c) Dobereiner's Triads
(d) Mendeleef's Periodic Table

2. *The 'law of octaves' was given by*
   (a) Mendeleev (b) Newlands
   (c) Lother Meyer (d) Dobereiner

3. *According to the periodic law given by Mendeleev, the properties of an element are a periodic function of its*
   (i) atomic volume (ii) atomic size
   (iii) atomic number (iv) atomic mass

4. *The particle which is universally present in the nuclei of all elements is*
   (a) neutron (b) proton
   (c) electron (d) α-particle

5. Potassium is more metallic than sodium because
   (a) both have 1 electron in their outermost shell.
   (b) both are highly electropositive.
   (c) sodium is larger in size than potassium.
   (d) potassium is larger in size than sodium.

7. Which one of the following elements in its chloride does not show the valence equal to its valence electrons?
   (a) $NaCl$ (b) $MgCl_2$
   (c) $AlCl_3$ (d) PCl_3

8. Which one of the following elements has the least tendency to form cation?
   (a) Na (b) Ca
   (c) B (d) Al

9. Which one of the following does not belong to the family of the alkali metals?
   (a) Li (b) Na
   (c) Be (d) K

10. The number of elements in the 5^{th} period of the periodic table is
   (a) 2 (b) 8
   (c) 32 (d) 18

11. The elements with atomic number 9 resembles with the element having atomic number
   (a) 35 (b) 27
   (c) 17 (d) 8

Notes

12. In which period of the periodic table, an element with atomic number 20 is placed?
    (a) 4 (b) 3
    (c) 2 (d) 1

II. Mark the following statements *True* (T) or *False* (F) :

1. The properties of the middle element in a Dobereiner's triads are intermediate between those of the other two.
2. The vertical columns in the periodic table are called periods.
3. Mendeleev depended only on the atomic mass of elements for his classification.
4. All elements present in a group are chemically similar.
5. The modern periodic law is based upon atomic mass.
6. The importance of atomic number as the fundamental property was realised by Henry Mosely.
7. There are 18 groups in the modern periodic table.
8. Non-metals are present in the middle portion of the periodic table.
9. Each period in modern periodic classification begins with filling of electrons in a new shell.

III. Fill in the blanks:

1. According to the modern periodic law, the properties of elements are periodic function of their ....
2. The .... number is same as the number of shell which in gradually filled up in the elements of this period.
3. In normal elements of a particular period the electrons are gradually filled in .... shell.
4. All elements of a particular group have .... electronic configurations.
5. In the modern periodic table, groups are numbered from .... to ....
6. The second and third periods of the periodic table are called .... periods.
7. The main group elements are present in group 1 and 2 on the left side and .... to .... on the right side of the periodic table.

8. All the group eighteen elements (except the first one) contain .... valence electrons.
9. All transition elements are metals with .... melting and boiling points.
10. The group of 14 rare-earth elements belonging to the group 3 and 7^{th} period are called ....
11. All elements present in a given .... have the same valency.
12. Atomic size .... in a period from left to right.
13. Magnesium is .... metallic than calcium.
14. Carbon belongs to group .... of the Periodic table.
15. All the elements of group 15 have .... valence electrons.

B. *Subjective Questions*

I. Very short Answer Questions (Answer in one word or one sentence).

1. What was the earliest classification of elements?
2. State Newlands' law of octaves.
3. Which classification of elements failed after the discovery of noble gases?
4. State Mendeleev's Periodic Law.
5. How were the groups numbered in the Mendeleev's periodic table?
6. Name the fundamental properties of element on which the modern periodic law is based.
7. How many groups are there in the modern periodic table?
8. How have groups been numbered in the modern periodic table?
9. What are normal elements?
10. What are the elements present in the middle portion of the modern periodic table called?
11. What is atomic size?
12. How does atomic size vary in a period and in a group?
13. Where would the element with largest atomic size be placed in any group?
14. Give the number of a group in which metallic, metalloid and non-metallic, all three types of elements, are present.

II. Short Answer Questions (Answer in 30-40 words).

1. State Dobereiner's law of triads.
2. Show that chlorine, bromine and iodine (atomic masses 35·5, 80 and 127 respectively) constitute a triad.

3. What were the reasons for the failure of Newlands' law of octaves ?
4. Describe Mendeleev's periodic table briefly in terms of rows and columns and their raw being.
5. Give any two achievements of the Mendeleev's Periodic classification.
6. What were the defects in Mendeleev's periodic classification.
7. State modern periodic law.
8. Briefly describe the modern periodic table in term of groups and period.
9. Give names of four classes into which the elements have been classified and mention to which groups of the modern period table they belong.
10. List the merits of the long form of the modern periodic table and explain any two of them.
11. How are the electronic configurations of all the elements belonging to a particular group related? Explain with the help of group 17 elements.
12. How does the electronic configuration of elements belonging to a particular period vary? Explain with the example of second period elements.
13. Define atomic radius.
14. How and why does metallic character vary in a group from top to bottom?

III. Long Answer Questions (Answer in 60–70 words).

1. State Mendeleev's Periodic Law and describe the periodic table constructed on this basis.
2. What are the merits and demerits of the Mendeleev's Periodic classification?
3. Describe the modern periodic table in terms of groups and periods.
4. What are the following types of elements and where are they located in the periodic table?

   (a) Main group elements (b) Noble gases

   (c) Transition elements (d) Inner transition elements.
5. Discuss the merits of the modern periodic table.
6. What is the relationship between the electronic configuration and the modern periodic table?
8. Explain the variation of atomic size in a group and in a period.
9. How is metallic character related to ionization energy ? Explain the variation of metallic character in the periodic table.

ANSWERS TO INTEXT QUESTIONS

6.1

1. Atomic mass of B = $\frac{20 + 40}{2} = 30$
2. Atomic mass
3. Group
4. These were the positions of elements which were yet to be discovered.
5. Any three of the following: (i) position of hydrogen (ii) position of isotopes (iii) anomalous pairs of elements (iv) grouping of chemically dissimilar element (v) separation of chemically similar element (vi) no explanation for electronic configuration

6.2

1. Anomalous pairs when elements are arranged in the order of their increasing atomic numbers, these anomalies are automatically removed, since the atomic number of the first element is less than that of the second although their atomic masses show revrse trends.
2. Position of isotopes. Since all the isotopes of an element have the same atomic number, they all will occupy the same position in the periodic table.

6.3

1. (a) increases (b) decreases
   (c) increases (d) increases
2. Hydrogen, Carbon, Barium, Sodium, Boron, Chlorine (horizontally)
   Magnesium, Iodine, Helium, Neon, Silicon, (vertically downwards)
   Nitrogen, Oxygen(diagonally downwards)
3. (i) Helium (ii) Oxygen (iii) Sodium

Activity 6.1

(a) Argon (b) Lithium (c) Calcium (d) Phosphorous

7

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CHEMICAL BONDING

In lesson 5, you have read about the electronic configuration of atoms of various elements and variation in the periodic properties of elements. We see various substances around us which are either elements or compounds. You also know that atoms of the same or different elements may combine. When atoms of the same elements combine, we get molecules of the elements. But we get compounds when atoms of different elements combine. Have you ever thought why atoms combine at all?

In this lesson, we will find an answer to this question. We will first explain what a chemical bond is and then discuss various types of chemical bonds which join the atoms together to give various types of substances. The discussion would also highlight how these bonds are formed.

The properties of substances depend on the nature of bonds present between their atoms. In this lesson you will learn that sodium chloride, the common salt and washing soda dissolve in water whereas methane gas or napthalene do not. This is because the type of bonds present between them are different. In addition to the difference in solubility, these two types of compounds differ in other properties as well about which you will study in this lesson.

OBJECTIVES

After completing this lesson you will be able to :

- *recognize the stability of noble gas configuration and tendency of other elements to attain this configuration through formation of chemical bonds;*
- *explain the attainment of stable noble gas electronic configuration through transfer of electrons resulting in the formation of ionic bonds;*

- *describe and justify some of the common properties of ionic compounds;*
- *explain the alternate mode of attainment of stable noble gas configuration through sharing of electrons resulting in the formation of covalent bonds;*
- *describe the formation of single, double and triple bonds and depict these with the help of Lewis-dot method;*
- *describe and justify some of the common properties of covalent substances.*

7.1 WHY DO ATOMS COMBINE?

The answer to this question is hidden in the electronic configurations of the noble gases. It was found that noble gases namely helium, neon, argon, krypton, xenon and radon did not react with other elements to form compounds i.e. they were non -reactive. In the initial stages they were also called inert gases due to their non-reactive nature. Thus it was, thought that these noble gases lacked reactivity because of their specific electronic arrangements which were quite stable. When we write the electronic configurations of the noble gases (see table below), we find that except helium all of them have 8 electrons in their outermost shell.

Table 7.1 : Electronic configuration of Noble gases

Name	Symbol	Atomic Number	Electronic Configuration	No. of electrons in the outermost shell
Helium	He	2	2	2
Neon	Ne	10	2,8	8
Argon	Ar	18	2,8,8	8
Krypton	Kr	36	2,8,18,8	8
Xenon	Xe	54	2,8,18,18,8	8
Radon	Ra	86	2,8,18,32,18,8	8

It was concluded that atoms having 8 electrons in their outermost shell are very stable and they did not form compounds. It was also observed that other atoms such as hydrogen, sodium, chlorine etc. which do not have 8 electrons in their outermost shell undergo chemical reactions. They can stabilize by combining with each other and attain the above configurations of noble gases i.e. 8 electrons (or 2 electrons in case of helium) in their outermost shells. Thus, atoms tend to attain a configuration in which they have 8 electrons in their outermost shells. This is the basic cause of chemical bonding. This attainment of eight electrons for stable structure is called the **octet rule**. The octet rule explains the chemical bonding in many compounds.

Atoms are held together in compounds by the forces of attraction which result in formation of **chemical bonds**. The formation of chemical bonds results in the lowering of energy which is less than the energy the individual atoms. The resulting compound is lower in energy as compared to sum of energies of the reacting atom/molecule and hence is more stable. Thus stability of the compound formed is an important factor in the formation of chemical bonds. In rest of the lesson you will study about the nature of bonds present in various substances. We would explain *ionic bonding and covalent bonding in this lesson*. Before you start learning about ionic bonding in the next section you can answer the following questions to check your understanding.

INTEXT QUESTIONS 7.1

1. State octet rule
2. Why noble gases are non-reactive?
3. In the table given below three elements and their atomic numbers are given. Which of them are stable and will not form compound?

Element	At. No.	Stable/Unstable
A	10	
B	36	
C	37	

7.2 IONIC BONDING

The chemical bond formed by transfer of electron from a metal to a non- metal is known as *ionic* or *electrovalent bond*.

For example, when sodium metal and chlorine gas are brought into contact, they react violently and we obtain sodium chloride. This reaction is shown below:

$$2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$$

The bonding in sodium chloride can be understood as follows:

Sodium (Na) has the atomic number 11 and we can write its electronics configuration as 2,8,1 i.e. it has one electron in its outermost (M) shell. If it loses this electron, it is left with 10 electrons and becomes positively charged. Such a positively charged ion is called a cation. The cation in this case is called sodium cation, Na^+. This is shown below in Fig. 7.1.

$$\underset{2,\,8,1}{Na(s)} \;+\; \underset{2,\,8,\,7}{Cl(g)} \longrightarrow \underset{2,\,8}{Na^+} \;+\; \underset{2,\,8,\,8}{Cl^-} \longrightarrow NaCl(s)$$

Fig. 7.1 *Formation of NaCl*

Note that the sodium cation has 11 protons but 10 electrons only. It has 8 electrons in the outermost (L) shell. Thus, sodium atom has attained the noble gas configuration by losing an electron present in its outermost shell. Loss of electron results into formation of an ion and this process is called *ionization*. Thus, according to octet rule, sodium atom can acquire stability by changing to sodium ion (Na^+).

The ionization of sodium atom to give sodium ion requires an energy of 496 kJ mol^{-1}.

Now, chlorine atom having the atomic number 17, has the electronic configuration 2,8,7. It completes its octet by gaining one electron from sodium atom (at. no. 11) with electronic configuration 2, 8, 1.

Both sodium ion (Na^+) and chloride ion (Cl^-) combine together by ionic bond and become solid sodium chloride (NaCl).

Note that in the above process, the chlorine atom has gained an additional electron hence it has become a negatively charged ion (Cl^-). Such, a negatively charged ion is called an **anion**. Chloride ion has 8 electrons in its outermost shell and it therefore, has a stable electronic configuration according to the octet rule. The formation of chloride ion from the chlorine atom releases 349 kJ mol^{-1} of energy.

Since the **cation** (Na^+) and the **anion** (Cl^-) formed above are electrically charged species, they are held together by Coulombic force or electrostatic force of attraction. This **electrostatic force of attraction which holds the cation and anion together is known as electrovalent bond or ionic bond**. This is represented as follows:

$$Na^+(g) \;+\; Cl^-(g) \longrightarrow Na^+Cl^- \;\text{ or }\; NaCl(s)$$

Note that only outermost electrons are shown above. Such structures are also called **Lewis Structures**.

If we compare the energy required for the formation of sodium ion and that released in the formation of chloride ion, we note that there is a net difference of 147 kJ mol^{-1} of energy. If only these two steps are involved, the formation of sodium chloride is not favourable energetically. But sodium chloride exists as a crystalline solid. This is because the energy is released when the sodium ions and the chloride ions come together to form the crystalline structure. The energy so released compensates for the above deficiency of energy.

You can see that *each sodium ion is surrounded by six chloride ions and each chloride ion is surrounded by six sodium ions* in its solid state structure. The force of attraction between sodium and chloride ions is uniformly felt in all directions. Thus, no particular sodium ion is bonded to a particular chloride ion. Hence, there is no species such as NaCl. Here NaCl is empirical formula and shows that there is one Na^+ for every Cl^- Fig. 7.2.

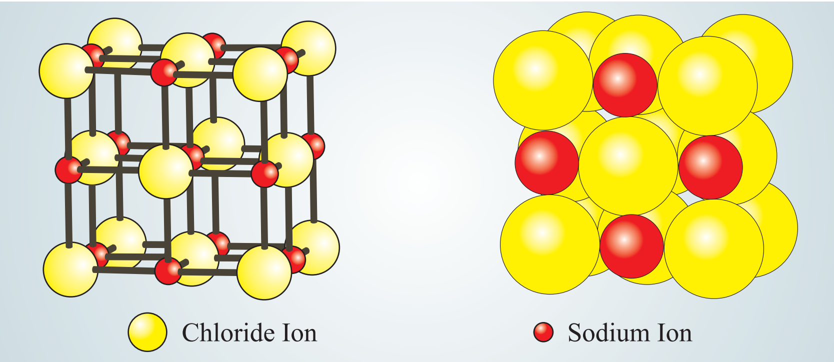


Fig. 7.2 Structure of sodium chloride

Similarly, we can explain the formation of cations resulting from lithium and potassium atoms and the formation of anions resulting from fluorine, oxygen and sulphur atoms.

Let us now study the formation of another ionic compound namely magnesium chloride. Mg has atomic number 12. Thus, it has 12 protons. The number of electrons present in it is also 12. Hence the electronic configuration of Mg atom is 2, 8, 2.

Let us consider the formation of magnesium ion from a magnesium atom. We see that it has 2 electrons in its outermost shell. If it loses these two electrons, then we can achieve the stable configuration of 2, 8 (that of noble gas neon). This can be represented in Fig. 7.3.

$$\underset{2,\ 8,\ 2}{Mg} \longrightarrow \underset{2,\ 8}{Mg^{2+}} + 2e^-$$

Fig. 7.3 Formation of magnesium ion

You can see that the resulting magnesium ion has only 10 electrons and hence it has 2+ charge. It is a dipositive ion and can be represented as Mg^{2+} ion.

The two electrons lost by the magnesium are gained -one each by two chlorine atoms to give two chloride ions.

$$2[Cl(g) + e^- \longrightarrow Cl^-(g)]$$

or

$$2Cl(g) + 2e^- \longrightarrow 2Cl^-(g)$$

Thus, one magnesium ion and two chloride ion join together to give magnesium chloride, $MgCl_2$. Hence we can write as in Fig. 7.4.

$$\begin{array}{ccccccccc} & & Cl & & & & & & \\ Mg & + & 2,8,7 & \longrightarrow & Mg^{2+} & + & 2Cl^{-} & \longrightarrow & MgCl_2(s) \\ 2,8,2 & & Cl & & & & & & \\ & & 2,8,7 & & & & & & \end{array}$$

Fig. 7.4 Formation of magnesium chloride

Let us now see what would happen if instead of chloride ion, the magnesium ion combines with another anion say oxide anion. The oxygen atom having atomic number eight has 8 electrons. Its electronic configuration is 2,6. It can attain a stable electronic arrangement (2,8) of the noble gas neon if it gains two more electrons. The two electrons, which are lost by the magnesium atom, are gained by the oxygen atom. On gaining these two electrons, the oxygen atom gets converted into the oxide anion. This is shown below in Fig. 7.5.

$$\begin{array}{ccc} O + 2e^{-} & \longrightarrow & O^{2-} \\ 2,\ 6 & & 2,\ 8 \end{array}$$

Fig. 7.5 Formation of oxide ion

The oxide has 2 more electrons as compared to the oxygen atom. Hence, it has 2 negative charges on it. Therefore, it can be represented as O^{2-} ion

The magnesium ion (Mg^{2+}) and the oxide ion (O^{2-}) are held together by electrostatic force of attraction. This leads to the formation of magnesium oxide Fig. 7.6.

$$\begin{array}{ccccccccc} Mg & + & O & \longrightarrow & Mg^{2+} & + & O^{2-} & \longrightarrow & MgO(s) \\ 2,8,2 & & 2,6 & & 2,8 & & 2,8 & & \end{array}$$

Fig. 7.6 Formation of magnesium oxide

Thus, magnesium oxide is an ionic compound in which a dipositive cation (Mg^{2+}) and a dinegative anion (O^{2-}) are held together by electrostatic force.

Similar to the case of sodium chloride, the formation of magnesium oxide is also accompanied by lowering of energy which leads to the stability of magnesium oxide as compared to individual magnesium and oxygen atoms.

Similarly, the ionic bonding present in many other ionic compounds can be explained. The ionic compounds show many characteristic properties which are discussed below.

7.2.1 Properties of Ionic Compounds

Since the ionic compounds contain ions (cations and anions) which are held together by the strong electrostatic forces of attraction, they show the following general characteristic properties:

(a) Physical State

Ionic compounds are crystalline solids. In the crystal, the ions are arranged in a regular fashion. The ionic compounds are hard and brittle in nature.

(b) Melting and boiling points

Ionic compounds have high melting and boiling points. The melting point of sodium chloride is 1074 K (801°C) and its boiling point is 1686K (1413°C). The melting and boiling points of ionic compounds are high because of the strong electrostatic forces of attraction present between the ions. Thus, it requires a lot of thermal energy to overcome these forces of attraction. The thermal energy given to the ionic compounds is used to overcome the interionic attractions present between the cations and anions in an ionic crystal. Remember that the crystal has a three dimensional regular arrangement of cations and anions which is called **crystal lattice**. On heating, the breaking of this crystal lattice leads to the molten state of the ionic compound in which the cations and anions are free to move.

(c) Electrical Conductivity

Ionic compounds conduct electricity in their molten state and in aqueous solutions. Since ions are free to move in the molten state, they can carry current from one electrode to another in a cell. Thus ions can conduct electricity in molten state. However, in solid state, such a movement of ions is not possible as they occupy fixed positions in the crystal lattice. Hence in solid state, ionic compounds do not conduct electricity.

In aqueous solution, water is used as a solvent to dissolve ionic compounds. It weakens the electrostatic forces of attraction present among the ions. When these forces are weakened, the ions become free to move, hence they can conduct electricity.

ACTIVITY 7.1

Prepare a solution of NaCl by dissolving 1 tablespoon of it in 100 mL water. Take this solution in a 200 mL beaker and introduce two graphite electrode (obtained from used dry cell battery), Now connect the electrode with a 3 V dry cell and a bulb in a circuit as shown in Fig. 7.7. Initially take plane water in a beaker (200 mL) and see the glow of bulb. Now replace the plane water by the solution of NaCl, what difference in glow of the bulb is observed? Interpret the result on the basis of ionic bond you have just studied.

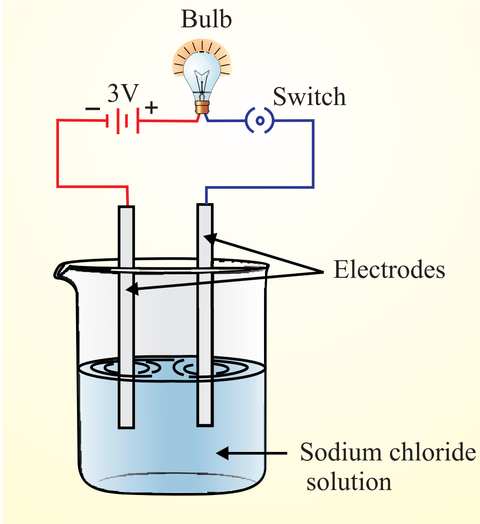
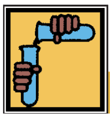


Fig. 7.7 Aqueous solution of sodium chloride conducts electricity

(d) Solubility

Ionic compounds are generally soluble in water but are insoluble in organic solvents such as ether, alcohol, carbon tetrachloride etc. However, a few ionic compounds are insoluble in water due to strong electrostatic force between cation and anion. For example barium sulphate, silver chloride and calcium fluoride.



ACTIVITY 7.2

Take nearly 10 g of NaCl, and two boiling tubes. In boiling tube (1) take 10 mL of water and add nearly 4 g of powdered NaCl. In test tube (2) take nearly 10 mL of ethyl alcohol and add nearly 4 g of powered NaCl. Shake both the test tube vigorously and see change in the amount of NaCl added in each case Fig. 7.8. Write your observation

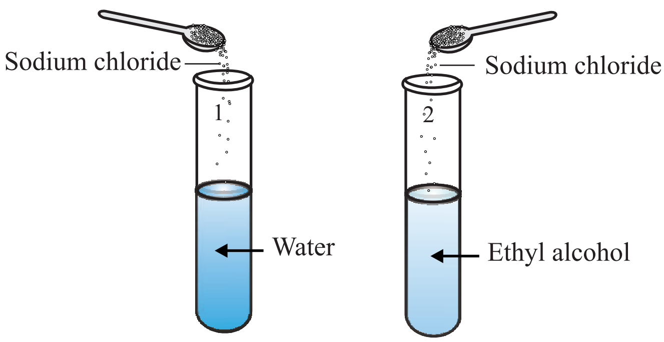


Fig. 7.8 *Showing solubility of NaCl in water and ethyl alcohol*

Before proceeding to the next section in which covalent bonding is discussed, why don't you answer the following questions to test your understanding about the ionic bonding?

INTEXT QUESTIONS 7.2

1. Name the two types of ions present in NaCl.
2. How many shells are present in Na^+ ion?
3. What is the number of electrons present in Cl^- ion?
4. Name the type of force of attraction present in ionic compounds.
5. In sodium chloride lattice, how many Cl^- ions surround each Na^+ ion?
6. Show the formation of Na_2O, $CaCl_2$ and MgO.
7. Why NaCl is bad conductor of electricity in solid state?

7.3 COVALENT BONDING

In this section, we will study about another kind of bonding called *covalent bonding*. Covalent bonding is helpful in understanding the formation of molecules. In lesson 2, you studied that molecules having similar atoms such as H_2, Cl_2, O_2, N_2 etc. are molecules of elements whereas those containing different atom like HCl, NH_3, CH_4, CO_2 etc. are molecule of compounds. Let us now see how are these molecules formed?

Let us consider the formation of hydrogen molecule (H_2). The hydrogen atom has one electron. It can attain the electronic configuration of the noble gas helium by sharing one electron of another hydrogen atom. When the two hydrogen atoms come closer, there is an attraction between the electrons of one atom and the proton of another and there are repulsions between the electrons as well as the protons of the two hydrogen atoms. In the beginning, when the two hydrogen atoms approach each other, the potential energy of the system decreases due to the force of attraction. (Fig. 7.9) The value of potential energy reaches a minimum at some particular distance

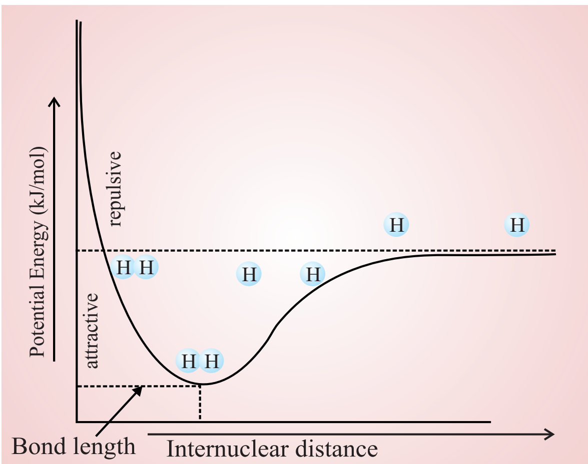


Fig. 7.9 *Potential energy diagram for formation of a hydrogen molecule*

between the two atoms. If the distance between the two atoms further decreases, the potential energy increases because of the forces of repulsion. **The covalent bond forms when the forces of attraction and repulsion balance each other and the potential energy is minimum.** It is this lowering of energy which leads to the formation of the covalent bond.

Formation of covalent bond in H_2 can be shown as

$$H\cdot + \cdot H \longrightarrow H : H \longrightarrow H_2$$

We will next consider the formation of chlorine molecule (Cl_2). A molecule of chlorine contains two atoms of chlorine. Now how are these two chlorine atoms held together in a chlorine molecule?

You know that the electronic configuration of Cl atom is 2,8,7. Each chlorine atom needs one more electron to complete its octet. If the two chlorine atoms share one of their electrons as shown below, then both of them can attain the stable noble gas configuration of argon.

$$:\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}\cdot \quad + \quad \cdot\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}: \quad \xrightarrow[\text{one electron}]{\text{sharing of}} \quad :\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}:\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}:$$

chlorine atom	chlorine atom	shared electrons
2, 8, 7	2, 8, 7	

Note that the sharing pair of electrons is shown to be present between the two chlorine atoms. Each chlorine atom thus acquires 8 electrons. The shared pair of electrons keeps the two chlorine atoms bonded together. *Such a bond, which is formed by sharing of electrons between the atoms is called a* ***covalent bond****.* Thus, we can say that a covalent bond is present between two chlorine atoms. This bond is represented by drawing a line between the two chlorine atoms as follows:

$$:\underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}} - \underset{\cdot\cdot}{\overset{\cdot\cdot}{Cl}}:$$

covalent bond

Sometimes the electrons shown above on the chlorine atoms are omitted and the chlorine-chlorine bond is shown as follows:

$$Cl — Cl$$

Similarly, we can understand the formation of oxygen molecule (O_2) from the oxygen atoms. The oxygen atom has atomic number 8. It has 8 protons and also 8 electrons. The electronic configuration of oxygen atoms is 2,6. Now each oxygen atom needs two electrons to complete its octet. The two oxygen atoms share two electrons and complete their octet as is shown below:

$$:\overset{\cdot\cdot}{O}: \quad + \quad :\overset{\cdot\cdot}{O}: \quad \longrightarrow \quad :\overset{\cdot\cdot}{O}::\overset{\cdot\cdot}{O}:$$

oxygen atom	oxygen atom	sharing of 4 electrons
2, 6	2, 6	or 2 pairs of electrons

The 4 electrons (or 2 pairs of electrons) which are shared between two atoms of oxygen are present between them. Hence these two pairs of shared electrons can be represented by two bonds between the oxygen atoms. Thus, an oxygen molecule can be represented as follows:

$$:\ddot{O}=\ddot{O}:$$

The two oxygen atoms are said to be bonded together by two covalent bonds. Such a bond consisting of two covalent bonds is also known as a **double bond.**

Let us next take the example of nitrogen molecule (N_2) and understand how the two nitrogen atoms are bonded together. The atomic number of nitrogen is 7. Thus it has 7 protons and 7 electrons present in its atom. The electronic configuration can be written as 2,5. To have 8 electrons in the outermost shell, each nitrogen atom requires 3 more electrons. Thus, a sharing of 3 electrons each between the two nitrogen atoms is required. This is shown below:

$$:N\vdots \quad + \quad \vdots N: \longrightarrow :N\vdots\,\vdots N:$$

:N⁝	+	⁝N:	→	:N⁝ ⁝N:
nitrogen atom electronic configuration (2, 5)		nitrogen atom electronic configuration (2, 5)		(2, 8) (2, 8) sharing of 6 electrons or 3 pairs of electrons

Each nitrogen atom provides 3 electrons for sharing. Thus, 6 electrons or 3 pairs of electrons are shared between the two nitrogen atoms. Hence, each nitrogen atom is able to complete its octet.

Since 6 electrons (or 3 pairs of electrons) are shared between the nitrogen atoms, we say that three covalent bonds are formed between them. These three bonds are represented by drawing three lines between the two nitrogen atoms as shown below:

$$:N\equiv N:$$

Such a bond which consists of three covalent bonds is known as a **triple bond**. So far, we were discussing covalent bonds formation between atoms of the same elements. But covalent bonds can be formed by sharing of electrons between atoms of different elements also. Let us take the example of HCl to understand it.

A hydrogen atom has one electron in its outermost shell and a chlorine atom has seven electrons in its outermost shell. Each of these atoms has one electron less than the electronic configuration of the nearest noble gas. If they share one electron pair, then hydrogen can acquire two electrons in its outer most shell whereas chlorine will have eight electrons in its outermost shell. The formation of HCl molecule by sharing of one electron pair is shown below:

$H\cdot$	+	$\cdot\underset{\cdot\cdot}{\ddot{Cl}}:$	→	$H:\underset{\cdot\cdot}{\ddot{Cl}}:$
hydrogen atom electronic configuration (1)		chlorine atom electronic configuration (2, 8, 7)		shared electron pair

Similarly, we can explain bond formation in other covalent compounds.

After knowing the nature of bonding present in covalent compounds, let us now study what type of properties these covalent compounds have.

7.3.1 Properties of Covalent Substances

The covalent compounds consist of molecules which are electrically neutral in nature. The forces of attraction present between the molecules are less strong as compared to the forces present in ionic compounds. Therefore, the properties of the covalent compounds are different from those of the ionic compounds. The characteristic properties of covalent compounds are given below:

(a) Physical State

Because of the weak forces of attraction present between discrete molecules, called intermolecular forces, the covalent compounds exist as a gas or a liquid or a solid. For example O_2, N_2, CO_2 are gases; water and CCl_4 are liquids and iodine is a solid.

(b) Melting and Boiling Points

As the forces of attraction between the molecules are weak in nature, a small amount of energy is sufficient to overcome them. Hence, the melting points and boiling points of covalent compounds are lower than those of ionic compounds. For example, melting point of nephthalene which is a covalent compound is 353 K (80°C). Similarly, the boiling point of carbon tetrachloride which is another covalent liquid compound is 350 K (77°C).

(c) Electrical Conductivity

The covalent compounds contain neutral molecules and do not have charged species such as ions or electrons which can carry charge. Therefore, these compounds do not conduct electricity and are called poor conductors of electricity Fig. 7.10.

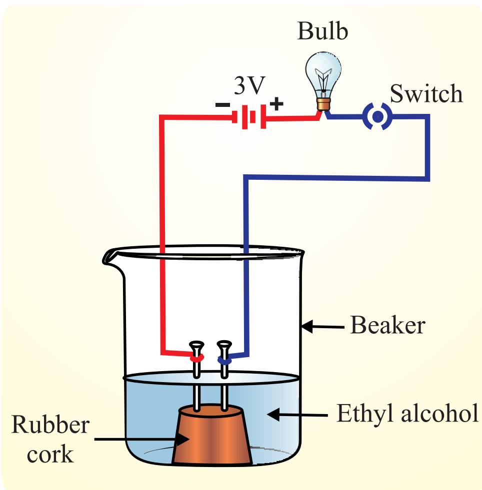


Fig. 7.10 *Ethyl alcohol (a covalent compound) is non-conductor of electricity*

(d) Solubility

Covalent compounds are generally not soluble in water but are soluble in organic solvents such as alcohol, chloroform, benzene, ether etc.

ACTIVITY 7.3

Take about 5 mL of ethyl alcohol in a test tube. Add few crystal of iodine. Shake the test tube well. What do you find. The colour of the ethyl alcohol becomes dark brown. What inference you draw from this. Iodine is soluble in ethyl alcohol. Write your observation. Dissolve the same amount of iodine in the same volume of water. (Soluton of iodine in ethyl alcohol is popularly known as tincture iodine and is used as a antiseptic solution.)

After understanding the nature of covalent bond and properties of covalent compounds. Why don't you answer the following questions to test your understaning about the covalent bonding.

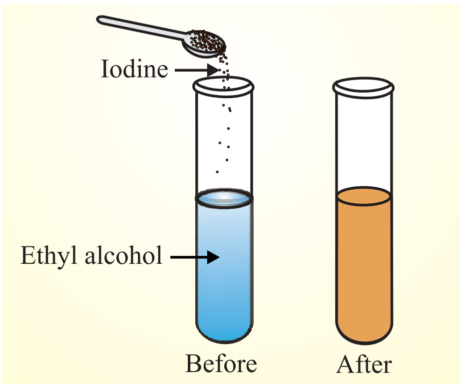


Fig. 7.11 *Showing solubility of iodine in ethyl alcohol*

INTEXT QUESTIONS 7.3

1. How covalent bonds are formed?
2. Show the formation of O_2, HCl, Cl_2 and N_2.
3. How many covalent bond(s) is/are present in following compounds:

   (i) H_2O (ii) HCl (iii) O_2 (iv) N_2
4. State loss or gain of elactrons (giving their number) in the following changes :

   (i) $N \longrightarrow N^{3-}$ (ii) $Cl \longrightarrow Cl^{-}$

   (iii) $Cu \longrightarrow Cu^{2+}$ (iv) $Cr \longrightarrow Cr^{3+}$
5. Why ethyl alcohol is bad conductor of electricity in its aqueous solutions?

WHAT YOU HAVE LEARNT

- The basic cause of chemical bonding is to attain noble gas configuration either by transfer of electron from a metal to non- metal or by sharing of electrons between two non-metal atoms.
- Atoms of elements don't exist freely in the nature. In all, the atoms of all the elements except of noble gases , have less than eight electrons in the valence shell. Normally gases do not react with other elements in normal conditions as they have stable electronic configuration i.e. they have eight electrons in the valence shell or outer most shell.
- All the atoms have a tendency to acquire stable state or noble gas configuration. Therefore, they combine with atoms of other elements to acquire 08 electrons in the valence shell by giving , taking or sharing of electrons. This is the basic cause of Chemical bonding and is called **Octet Rule.**
- Atoms of elements in a molecule are held together by **Chemical Bonding.** The formation of chemical bonds result in the lowering of energy which is less than the energy of the individual atoms. The resulting compound is lower in energy and hence more stable.
- There are two types of chemical bonding : ionic bonding and covalent bonding.
- Ionic Bonding: The chemical bond formed by transfer of electrons from a metal to a non- metal is known as Ionic Bond or Electrovalent bond.
- The ionic bond formation takes place in three steps.
  - (i) Formation of Cations by metals with loss of electrons.
  - (ii) Formation of Anions by non- metal with gain of electrons.
  - (iii) Combination of Cations and Anions by electrostatic force of attraction to form Ionic bond
- Ionic compounds are solid, hard, have high melting and boiling points. They are soluble in water but insoluble in organic solvents .They are good conductor of electricity in molten state and in aqueous solution.
- Covalent Bonding: The chemical bond formed by mutual sharing of equal no. of electrons between two atoms. Covalent bonding is helpful in understanding the formation of the molecules.H_2, Cl_2, O_2 and N_2 are such molecules formed by sharing of electrons between similar atoms, while H_2O and HCl compounds formed by sharing of electrons between dissimilar atoms.
- On the basis of sharing of number of electrons by each atom, covalent compounds are classified as single bonded, double bonded and triple bonded. When sharing of one electron takes place from both the atoms , single bond is formed. Like Cl-Cl or Cl_2 and H-H or H_2.

- Double bond is formed when two similar atoms share two pair of electrons e.g. O=O or O_2 and triple bond is formed when there is sharing of three electrons from each atom. e.g. N≡N or N_2.
- The dissimilar atoms also share electrons but shared pair of electrons shift towards more reactive atom as in HCl and H_2O.
- Covalent compounds mostly have liquid or gaseous state. Some are solid also. They have low melting point, low boiling point. They are insoluble in water but soluble in organic compounds. They are non- conductor of electricity.

TERMINAL EXERCISE

1. Why ionic compounds conduct electricity in aqueous solution?
2. Covalent compounds have low melting point than an ionic compound why?
3. Explain the formation of Na^+ ion from Na atom.
4. How would you explain the bonding in $MgCl_2$?
5. Which of the following statements are correct for ionic compounds:
   (i) They are insoluble in water.
   (ii) They are neutral in nature.
   (iii) They have high melting points.
6. State three characteristic properties of ionic compounds.
7. How does a covalent bond form?
8. What is the number of solvent bonds present in the following molecules?
   (i) Cl_2 (ii) N_2 (iii) O_2 (iv) H_2
9. Classify the following statements as true or false:
   (i) Ionic compounds contain ions which are held together by weak electro-static forces.
   (ii) Ionic compounds have high melting and boiling points.
   (iii) Covalent compounds are good conductors of electricity.
   (iv) Solid sodium chloride is a good conductor of electricity.
10. Classify the following compounds as ionic or covalent:
    (i) sodium chloride (ii) calcium chloride
    (iii) oxygen (iv) hydrogen chloride
    (v) magnesium oxide (vi) nitrogen

11. An element 'X' has atomic no. 11 and 'Y' has atomic no. 8. What type of bond they will form? Write the formula of the compound formed by reacting X and Y.

12. Name the type of bonds present in H_2O molecule.

ANSWER TO INTEXT QUESTIONS

7.1

1. Every atom has tendency to attain 2 or 8 e^- in their outermost shell to get stability like noble gases.
2. Because they have inert gas configuration which makes it very stable.
3. A and B

7.2

1. Sodium ion Na^+ and chloride ion Cl^-.
2. Two (2)
3. 18
4. Electrostatic force of attraction
5. Six
6.

$$\begin{array}{c}\underset{2,\,8,\,1}{Na}(g)\\ \underset{2,\,8,\,1}{Na}(g)\end{array} + \underset{2,\,6}{O}(g) \longrightarrow \underset{2,\,8}{2Na^+(g)} + \underset{2,\,8}{O^{2-}(g)}$$

$$\downarrow$$

$$Na_2O(s)$$

$$\underset{2,\,8,\,8,\,2}{Ca\,(g)} + \begin{array}{c}\underset{2,\,6,\,7}{Cl}\,(g)\\ \underset{2,\,6,\,7}{Cl\,(g)}\end{array} \longrightarrow \underset{2,\,8,\,8}{Ca^{2+}(g)} + \underset{2,\,8,\,8}{2Cl^-\,(g)}$$

$$\downarrow$$

$$CaCl_2\,(s)$$

$$\underset{2,\,8,\,2}{Mg\,(g)} + \underset{2,\,6}{O\,(g)} \longrightarrow \underset{2,\,8}{Mg^{2+}(g)} + \underset{2,\,8}{O^{2-}(g)}$$

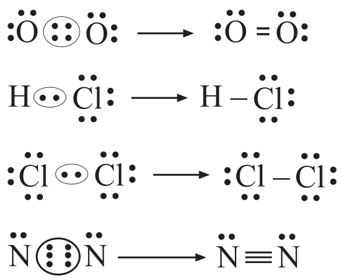
$$\downarrow$$

$$MgO\,(s)$$

7. Due to absence of free Na^+ and Cl^- ion.

7.3

1. A covalent bond is formed by sharing of equal no. of electrons between two atoms.

2. 

3. (i) 2 (ii) 1 (iii) 2 (iv) 3

4. (i) Gain of $3e^-$
   (ii) Gain of $1e^-$
   (iii) Loss of $2e^-$
   (iv) Loss of $3e^-$

5. Ethyl alcohol do not produce H^+ ion in its aqueous solution, hence does not conduct electricity.

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8

ACIDS, BASES AND SALTS

From generations, our parents have been using tamarind or lemon juice to give shiny look to the copper vessels. Our mothers never store pickles in metal containers. Common salt and sugar has often been used as an effective preservative. How did our ancestors know that tamarind, lemon, vinegar, sugar etc. works effectively? This was common collective wisdom which was passed from generation to generation. These days, bleaching powder, baking soda etc. are commonly used in our homes. You must have used various cleaners to open drains and pipes and window pane cleaners for sparkling glass. How do these chemicals work? In this lesson we will try to find answers to these questions. Most of these examples can be classified as acids, bases or salts. In this unit we shall categorize these substances. We shall study about their characteristic properties. We will also be learning about pH – a measure of acidity and its importance in our life.

OBJECTIVES

After completing this lesson you will be able to:

- *define the terms acid, base, salt and indicator;*
- *give examples of some common household acids, bases, salts and suggest suitable indicators;*
- *describe the properties of acids and bases;*
- *differentiate between strong and weak acids and bases;*
- *explain the role of water in dissociation of acids and bases;*
- *explain the term ionic product constant of water;*
- *define pH;*
- *correlate the concentration of hydrogen ions and pH with neutral, acidic and basic nature of aqueous solutions;*

- *recognize the importance of pH in everyday life,;*
- *define salts and describe their methods of preparation;*
- *correlate the nature of salt and the pH of its aqueous solution;*
- *describe the manufacture and use of baking soda, washing soda, plaster of paris and bleaching powder.*

8.1 ACIDS AND BASES

For thousands of years, people have known that vinegar, lemon juice, Amla, tamarind and many other food items taste sour. However, only a few hundred years ago it was proposed that these things taste sour because they contain ‘acids’. The term **acid** comes from Latin term ‘accre’ which means sour. It was first used in the seventeenth century by Robert Boyle to label substances as acids and bases according to the following characteristics:

Acids	Bases
(i) taste sour	(i) taste bitter
(ii) are corrosive to metals	(ii) feel slippery or soapy
(iii) change blue litmus red	(iii) change red litmus blue
(iv) become less acidic on mixing with bases	(iv) become less basic on mixing with acids

While Robert Boyle was successful in characterising acids and bases he could not explain their behaviour on the basis of their chemical structure. This was accomplished by Swedish scientist Svante Arrhenius in the late nineteenth century. He proposed that on dissolving in water, many compounds dissociate and form ions and their properties are mainly the properties of the ions they form. Governed by this, he identified the ions furnished by acids and bases responsible for their characteristic behaviour and gave their definitions.

8.1.1 Acids

An acid is a substance which furnishes hydrogen ions (H^+) when dissolved in water. For example, in its aqueous solution hydrochloric HCl (aq) dissociates as:

$$HCl\ (aq) \longrightarrow H^+(aq) + Cl^-(aq)$$

Some examples of acids are:

(i) Hydrochloric acid (HCl) in gastric juice

(ii) Carbonic acid (H_2CO_3) in soft drinks

(iii) Ascorbic acid (vitamin C) in lemon and many fruits

H^+
ACIDS

(iv) Citric acid in oranges and lemons

(v) Acetic acid in vinegar

(vi) Tannic acid in tea

(vii) Nitric acid (HNO_3) used in laboratories

(viii) Sulphuric acid (H_2SO_4) used in laboratories

8.1.2 Bases

A base is a substance which furnishes hydroxide ions (OH^-) when dissolved in water.

For example, sodium hydroxide NaOH (aq), in its aqueous solutions, dissociates as:

$$NaOH\ (aq) \longrightarrow Na^+(aq) + OH^-(aq)$$

OH^-
BASE

The term '**alkali**' is often used for water soluble bases.

Some examples of bases are:

(i) Sodium hydroxide (NaOH) or caustic soda used in washing soaps.

(ii) Potassium hydroxide (KOH) or potash used in bathing soaps.

(iii) Calcium hydroxide ($Ca(OH)_2$) or lime water used in white wash.

(iv) Magnesium hydroxide ($Mg(OH)_2$) or milk of magnesia used to control acidity.

(v) Ammonium hydroxide (NH_4OH) used in hair dyes.

8.1.3 Indicators

You might have seen that the spot of turmeric or gravy on cloth becomes red when soap is applied on it. What do you think has happened? Turmeric has acted as an indicator of base present in soap. There are many substances that show one colour in an acidic medium and another colour in a basic medium. Such substances are called acid-base indicators.

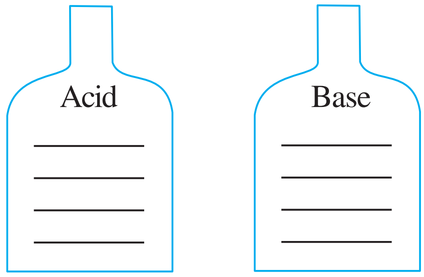
Litmus is a natural dye found in certain lichens. It was the earliest indicator to be used. It shows red colour in acidic solutions and blue colour in basic solutions. Phenolphthalein and methyl orange are some other indicators. The colours of these indicators in acidic, neutral and basic solutions are given below in table 8.1.

Table 8.1 Colours of some indicators in acidic and basic solutions

Indicator	Colour in acidic solutions		Colour in neutral solutions		Colour in basic solutions	
Litmus		red		purple		blue
Phenolphthalein		colourless		colourless		pink
Methyl orange		red		orange		yellow

INTEXT QUESTION 8.1

1. Put the following substances in acid or base bottle.
   (a) Milk of magnesia
   (b) gastric juice in humans
   (c) soft drinks
   (d) lime water
   (e) vinegar
   (f) soap



2. What will happen if you add a drop of the following on a cut unripe apple, curd, causting soda solution and soap soluton.
   (i) phenolphthalein
   (ii) litmus

8.2 PROPERTIES OF ACIDS AND BASES

Each substance shows some typical or characteristics properties. We can categorize a substance as an acid or a base according to the properties displayed. Let us learn the characteristic properties of acids and bases.

8.2.1 Properties of Acids

The following are the characteristic properties of acids:

1. Taste

You must have noticed that some of the food items we eat have sour taste. The sour taste of many unripe fruits, lemon, vinegar and sour milk is caused by the acids present in them. Hence, we can say that acids have a sour taste. This is particularly true of dilute acids (see table 8.2).

Table 8.2 Acids present in some common substances

Substance	Acid present
1. Lemon juice	Citric acid and ascorbic acid (vitamin C)
2. Vinegar	Ethanoic acid (commonly called acetic acid)
3. Tamarind	Tartaric acid
4. Sour milk	Lactic acid

ACTIVITY 8.1

Go to your neighbourhood shop and procure.

1. Packaged Curd
2. Juices in tetra packs

Test these with a litmus paper to find out if these are acidic in nature.

2. Action on Indicators

We have learnt earlier (section 8.1.3) that indicators show different colours in presence of acids and bases. Let us recall the colours of the three commonly used indicators in presence of acids.

Table 8.3 Colours of some indicators in presence of acids.

Indicator	Colour in acidic medium
1. Litmus	Red
2. Phenolphthalein	Colourless
3. Methyl orange	Red

3. Conduction of electricity and dissociation of acids

Do you know that solutions of acids in water (aqueous solutions) conduct electricity? Such solutions are commonly used in car and inverter batteries. When acids are dissolved in water they produce ions which help in conducting the electricity. This process is known as *dissociation*. More specifically, acids produce hydrogen ions (H^+) which are responsible for all their characteristic properties. These ions do not exist as H^+ in the solution but combine with water molecules as shown below:

$$\underset{\text{hydrogen ion}}{H^+} + H_2O \longrightarrow \underset{\text{hydronium ion}}{H_3O^+}$$

The H_3O^+ ions are called **hydronium ions**. These ions are also represented as $H^+(aq)$.

On the basis of the extent of dissociation occurring in their aqueous solutions, acids are classified as strong and weak acids.

A. Strong and Weak acids

Acids are classified as strong and weak acids and their characteristics are as follow :

Points to ponder

All hydrogen containing compounds are not acids

Although Ethyl alcohol (C_2H_5OH) and glucose ($C_6H_{12}O_6$) contain hydrogen but do not produce H^+ ion on dissolving in water. Their solutions do not conduct electricity and are not acidic.

Strong Acids	Weak Acids
The acids which completely dissociate in water are called strong acids Nitric acid completely dissociates in water $HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$ There are only seven strong acids 1. HCl Hydrochloric Acid 2. HBr Hydrobromic Acid 3. HI Hydroiodic Acid 4. $HClO_4$ Perchloric Acid 5. $HClO_3$ Chloric Acid 6. H_2SO_4 Sulphuric Acid 7. HNO_3 Nitric Acid	The acids which dissociate partially in water are called weak acids. All organic acids like acetic acid and some inorganic acids are weak acids. Since their dissociation is only partial, it is depicted by double half arrows. $HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$ The double arrows indicates here that (i) the aqueous solution of hydrofluoric acid not only contains H^+ (aq) and F^-(aq) ions but also the undissociated acid HF(aq). (ii) there is an equilibrium between the undissociated acid HF(aq) and the ions furnished by it, H^+(aq) and F^- (aq) **Examples:** (a) CH_3COOH Ethanoic (acetic) acid, (b) HF Hydrofluoric acid (c) HCN Hydrocynic acid (d) C_6H_5COOH Benzoic acid

4. Reaction of Acids with Metals

The reaction of acids with metals can be studied with the help of the following acitivity.

ACTIVITY 8.2

This activity may be carried out in the chemistry laboratory of your study centre.

Aim: To study the reaction of acids with metals.

What is required?

A test tube, zinc granules, dilute H_2SO_4, match box and a test tube holder.

What to do?

- Add a few zinc granules in a test tube.
- Add dil. sulphuric acid carefully along the sides of the test tube.
- Set the apparatus as shown in the Fig. 8.1.
- Bring a burning match stick near the mouth of the test tube, (Fig. 8.1.

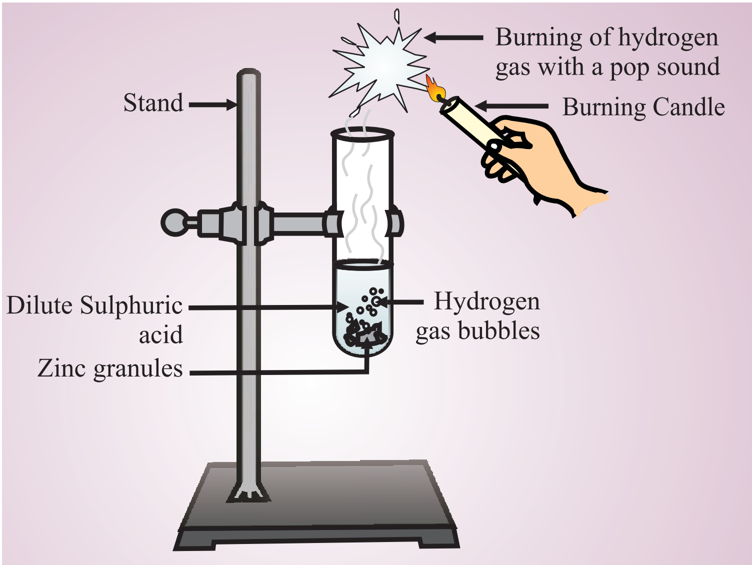


Fig. 8.1: *Experiment to study the reaction of dil. H_2SO_4 with zinc. The gas burns with a 'pop' sound when a burning match stick is brought near the mouth of the test tube.*

What to observe?

- When dilute sulphuric acid is added to zinc granules, hydrogen gas is formed. The gas bubbles rise through the solution.
- When the burning match stick is brought near the mouth of the test tube the gas in the test tube burns with a 'pop' sound. This confirms that the gas evolved is hydrogen gas.

From this experiment it can be said that dilute sulphuric acid reacts with zinc to produce hydrogen gas. A similar reaction is observed when we use other metals like iron. In general, it can be said that in such reactions metal displaces hydrogen from acids and hydrogen gas is released. The metal combines with the remaining part of the acid and forms a compound called a salt, thus,

$$\text{Acid} + \text{Metal} \longrightarrow \text{Salt} + \text{Hydrogen gas}$$

For example, the reaction between zinc and dil. sulphuric acid can be written as:

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2 \uparrow$$

zinc metal	dil sulphuric acid acid	zinc sulphate salt	hydrogen gas

5. Reaction of acids with metal carbonates and hydrogen carbonates

Reaction of acids with metal carbonates and hydrogen carbonates can be studied with the help of activity 8.2.

ACTIVITY 8.3

This experiment may be carried out in the chemistry laboratory of your study centre.

Aim: To study the reaction of acids with metal carbonates and hydrogen carbonates.

What is required?

One test tube, one boiling tube fitted with a cork, thistle funnel and delivery tube, sodium carbonate, sodium hydrogen carbonate, dilute HCl and freshly prepared lime water.

What to do?

- Take the boiling tube and add about 0.5 g sodium carbonate to it.
- Take about 2 mL of freshly prepared lime water in a test tube.

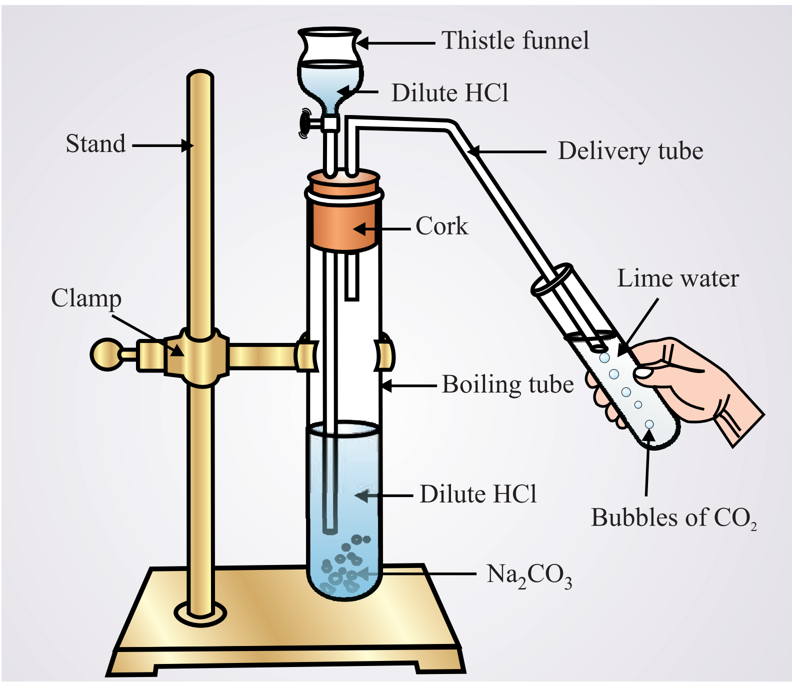


Fig. 8.2: *Experimental set up to study the reaction of acids with metal carbonates and hydrogen carbonates*

- Add about 3 mL dilute HCl to the boiling tube containing sodium carbonate and immediately fix the cork filled with a delivery tube and set the apparatus as shown in the Fig. 8.2.
- Dip the other end of the delivery tube in the lime water as shown in Fig. 8.2.
- Observe the lime water carefully.
- Repeat the activity with sodium hydrogen carbonate.

What to observe?

- When dilute HCl is added to sodium carbonate or sodium hydrogen carbonate, carbon dioxide gas is evolved.
- On passing CO_2 gas, lime water turns milky.
- On passing the excess of CO_2 gas, lime water becomes clear again.

From the above activity it can be concluded that if sodium carbonate or sodium hydrogen carbonate react with dilute hydrochloric acid, carbon dioxide gas is evolved. The respective reactions are:

$Na_2CO_3(s)$	+	$2HCl(aq)$	$\longrightarrow$	$2NaCl(aq)$	+	$H_2O(l)$	+	$CO_2(g)\uparrow$
sodium carbonate		dil. hydrochloric acid		sodium chloride		water		carbon dioxide

$NaHCO_3(s)$	+	$HCl(aq)$	$\longrightarrow$	$NaCl(aq)$	+	$H_2O(l)$	+	$CO_2(g)\uparrow$
sodium hydrogen carbonate		dil. hydrochloric acid		sodium chloride		water		carbon dioxide

On passing the evolved carbon dioxide gas through lime water, $Ca(OH)_2$, the later turns milky due to the formation of white precipitate of calcium carbonate

$Ca(OH)_2(aq)$	+	$CO_2(g)$	$\longrightarrow$	$CaCO_3(s)$	+	$H_2O(l)$
lime water		carbon dioxide		calcium carbonate (white ppt.)		water

If excess of carbon dioxide gas is passed through lime water, the white precipitate of calcium carbonate disappears due to the formation of water soluble calcium hydrogen carbonate.

$CaCO_3(s)$	+	$H_2O(l)$	+	$CO_2(g)$	$\longrightarrow$	$Ca(HCO_3)_2(aq)$
calcium carbonate (white ppt.)		water		Carbon dioxide		calcium hydrogen carbonate (soluble in water)

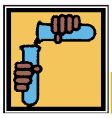
Thus, we can summarize that,

$$\text{Metal carbonate + Acid} \longrightarrow \text{Salt + Water + Carbon dioxide}$$

and $$\text{Metal hydrogen carbonate + Acid} \longrightarrow \text{Salt + Water + Carbon dioxide}$$

6. Reaction of Acids with metal oxides

We can study the reaction of acids with metal oxides with the help of activity 8.4.



ACTIVITY 8.4

This activity may be carried out in the chemistry laboratory of your study centre.

Aim : To study the reaction of acids with metal oxides.

What is required?

A beaker, glass rod, copper oxide and dilute hydrochloric acid.

What to do?

- Take a small amount of black copper oxide in a beaker.
- Add about 10 mL of dilute hydrochloric acid and stir the solution gently with the help of a glass rod. [Fig. 8.3(a)].
- Observe the beaker as the reaction occurs. [Fig. 8.3(b)].

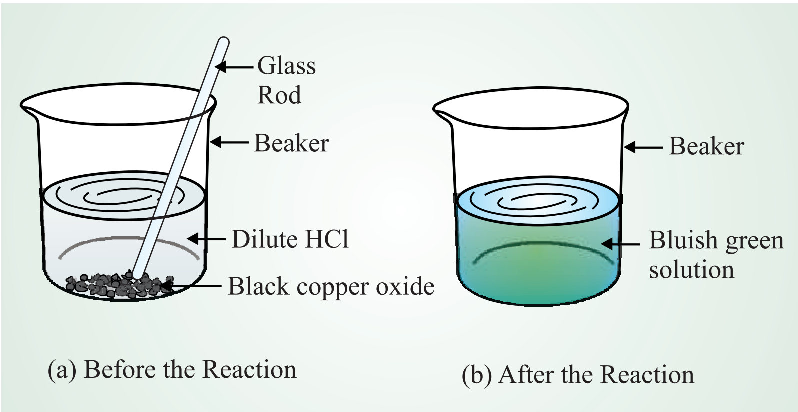


Fig. 8.3 *Reaction between dilute hydrochloric acid and copper oxide (a) before reaction black particles of copper oxide in transparent dilute hydrochloric acid and (b) after reaction bluish green solution.*

What to Observe?

- When a mixture of dilute HCl and copper oxide is mixed, the black particles of copper oxide can be seen suspended in colourless dilute hydrochloric acid.
- As the reaction proceeds, the black particles slowly dissolve and the colour of the solution becomes bluish green due to the formation of copper (II) chloride (cupric chloride) – a salt.

From this activity, we can conclude that the reaction between copper oxide and dilute hydrochloric acid results in the formation of copper (II) chloride (cupric chloride) which is a salt of copper. This salt forms bluish green solution. The reaction is:

$$CuO(s) + 2HCl(aq) \longrightarrow CuCl_2(aq) + H_2O(l)$$

$CuO(s)$	$2HCl(aq)$	$CuCl_2(aq)$	$H_2O(l)$
copper oxide	dil. hydrochloric acid	copper (II) chloride	water

Many other metal oxides like magnesium oxide (MgO) and calcium oxide (CaO) or quick lime also react with acid in a similar way. For example,

$$CaO(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l)$$

$CaO(s)$	$2HCl(aq)$	$CaCl_2(aq)$	$H_2O(l)$
calcium oxide (quick lime)	dil. hydrochloric acid	calcium chloride	water

So, we can summarize with a general reaction between metal oxides and acids as:

$$\text{Metal oxide + Acid} \longrightarrow \text{Salt + Water}$$

7. Reaction of acids with bases

Let us study the reaction of acids with bases with the help of the following activity.

ACTIVITY 8.5

This activity may be carried out in the chemistry laboratory of your study centre.

Aim : To study the reaction between acids and bases.

What is required?

A test tube, dropper, phenolphthalein indicator, solution of sodium hydroxide and dil. hydrochloric acid.

What to do?

- Take about 2 mL solution of sodium hydroxide in a test tube.
- Add a drop of phenolphthalein indicator to it and observe the colour.
- With the help of a dropper add dil. HCl dropwise and stir the solution constantly till the colour disappears.
- Now add a few drops of NaOH solution. The colour of the solution is restored.

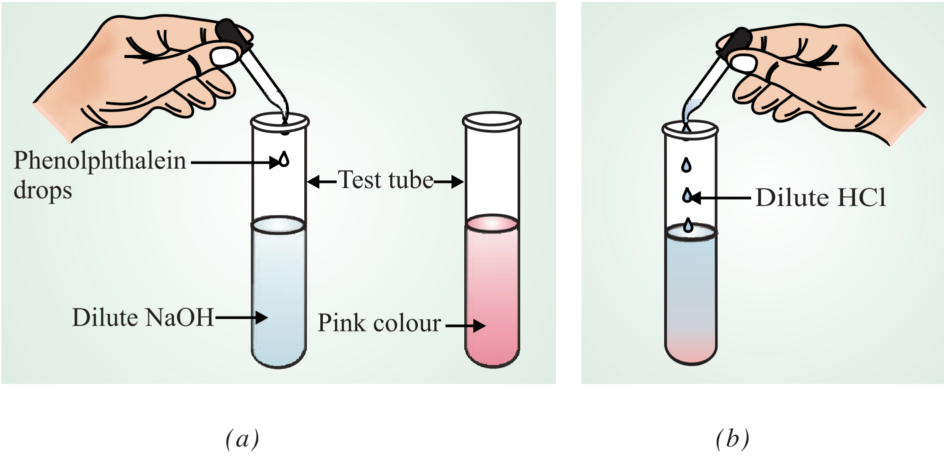


Fig. 8.4: *Reaction between NaOH and HCl (a) Pink colour solution containing NaOH solution and a drop of phenolphthalein (b) The solution becomes colourless on addition of dil HCl*

What to Observe?

- When a drop of phenolphthalein is added to a solution of NaOH the solution becomes pink in colour.
- On adding HCl, the colour of the solution fades due to the reaction between HCl and NaOH.
- When whole of NaOH has reacted with HCl, the solution becomes colourless.
- On adding NaOH, the solution becomes pink again.

From this activity, we can see that when dilute HCl is added to NaOH solution, the two react with each other. When sufficient HCl is added, the basic properties of NaOH and acidic properties of HCl disappear. The process is therefore called **neutralization**. It results in the formation of salt and water. The reaction between hydrochloric acid and sodium hydroxide forms sodium chloride and water.

$$\underset{\text{hydrochloric acid}}{HCl(aq)} + \underset{\text{sodium hydroxide}}{NaOH(aq)} \longrightarrow \underset{\text{sodium chloride}}{NaCl(aq)} + \underset{\text{water}}{H_2O(l)}$$

Similar reactions occur with other acids and bases. For example ,sulphuric acid and potassium hydroxide react to form potassium sulphate and water.

$$\underset{\text{sulphuric acid}}{H_2SO_4(aq)} + \underset{\text{potassium hydroxide}}{2KOH(aq)} \longrightarrow \underset{\text{potassium sulphate}}{K_2SO_4(aq)} + \underset{\text{water}}{2H_2O(l)}$$

In general, the reaction between and acid and a base can be written as:

$$\text{Acid} + \text{Base} \longrightarrow \text{Salt} + \text{Water}$$

8. Corrosive Nature

The ability of acids to attack various substances like metals, metal oxides and hydroxides is referred to as their corrosive nature. (It may be noted here that the term 'corrosion' is used with reference to metals and refers to various deterioration processes (oxidation) they undergo due to their exposure to environment). Acids are corrosive in nature as they can attack variety of substances.

'Strong' is different from 'corrosive'

Corrosive action of acids is not related to their strength. It is related to the negatively charged part of the acid. For example, hydrofluoric acid, (HF)is a weak acid. Yet, it is so corrosive that it attacks and dissolves even glass. The fluoride ion attacks the silicon atom in silica glass while the hydrogen ion attacks the oxygen of silica (SiO_2) in the glass.

$$\underset{\text{silica (in glass)}}{SiO_2} + \underset{\text{hydrofluoric acid}}{4HF} \longrightarrow \underset{\text{silicon tetra fluoride}}{SiF_4} + \underset{\text{water}}{2H_2O}$$

8.2.2 Properties of Bases

The following are the characteristic properties of bases:

1. Taste and touch

Bases have a bitter taste and their solutions are soapy to touch.

Warning

Although we talk of 'taste' of acids and bases, it is not advisable to taste any acid or base. Most of them are harmful. Similarly touching the solutions of strong acids and bases should be avoided. They may harm the skin.

2.Action on Indicators

As seen earlier (section 8.1.3) each indicator shows characteristic colour in presence of bases. The colours shown by three commonly used indicators in presence of bases are listed below for easy recall.

Table 8.3 Colours of some common indicators in basic solution

Indicator	Colour in basic medium
1. Litmus	Blue
2. Phenolphthalein	Pink
3. Methyl orange	Yellow

3. Conduction of electricity and dissociation of bases

Aqueous solutions (solution in water) of bases conduct electricity which is due to the formation of ions. Like acids, bases also dissociate on dissolving in water. Bases produce hydroxyl ions (OH^-) which are responsible for their characteristic properties.

The bases which are soluble in water and give OH^- ions in their aqueous solution are called **alkalies**. *All alkalies are bases but all bases are not alkalies*. On the basis of the extent of dissociation occurring in their solution, bases are classified as strong and weak bases.

A. Strong and Weak Bases

Bases are classified as strong and weak bases and their characteristics are as follow :

Strong Bases	Weak Bases
These bases are completely dissociated in water to form the cation and hydroxide ion (OH^-). For example, potassium hydroxide dissociates as $KOH(aq) \longrightarrow K^+(aq) + OH^-(aq)$ There are only eight strong bases. These are the hydroxides of the elements of the Groups 1 and 2 of the periodic table 1. LiOH Lithium hydroxide 2. NaOH Sodium hydroxide 3. KOH Potassium hydroxide 4. RbOH Rubidium hydroxide 5. CsOH Caesium hydroxide 6. $Ca(OH)_2$ Calcium hydroxide 7. $Sr(OH)_2$ Strontium hydroxide 8. $Ba(OH)_2$ Barium hydroxide	Weak bases do not furnish OH^- ions by dissociation. They react with water to furnish OH^- ions. $NH_3(g) + H_2O(l) \longrightarrow NH_4OH$ $NH_4OH(aq) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ or $NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ The reaction resulting in the formation of OH^- ions does not go to completion and the solution contains relatively low concentration of OH^- ions. The two half arrows are used in the equation to indicate that equilibrium is reached before the reaction is completed. Examples of weak bases (i) NH_4OH, (ii) $Cu(OH)_2$ (iv) $Cr(OH)_3$ (v) $Zn(OH)_2$ etc.

4. Reaction of bases with metals

Like acids, bases also react with active metals liberating hydrogen gas. Such reactions can also be studied with the help of activity 8.2 given earlier. For example, sodium hydroxide reacts with zinc as shown below:

$$\underset{\text{zinc metal}}{Zn(s)} + \underset{\text{sodium hydroxide}}{2NaOH(aq)} \longrightarrow \underset{\text{sodium zincate}}{Na_2ZnO_2(aq)} + \underset{\text{hydrogen}}{H_2(g)\uparrow}$$

5. Reaction of Bases with non-metal oxides

Bases react with oxides of non-metals like CO_2, SO_2, SO_3, P_2O_5 etc. to form salt and water.

For example,

$$\underset{\substack{\text{calcium hydroxide} \\ \text{(lime water)}}}{Ca(OH)_2(aq)} + \underset{\substack{\text{carbon} \\ \text{dioxide}}}{CO_2(g)} \longrightarrow \underset{\substack{\text{calcium} \\ \text{carbonate}}}{CaCO_3(s)} + \underset{\text{water}}{H_2O(l)}$$

The reaction can be written in a general form as:

$$\text{Base + Non-metal oxide} \longrightarrow \text{Salt + Water}$$

6. Reaction of bases with acids

We have learnt the mutual reaction between acids and bases in previous section. Such reactions are called *neutralization* reactions and result in the formation of salt and water. The following are some more examples of neutralization reactions:

$$HCl(aq) + KOH(aq) \longrightarrow KCl(aq) + H_2O(l)$$

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

Caustic nature

Strong bases like sodium hydroxide and potassium hydroxide are corrosive towards organic matter and break down the proteins of the skin and flesh to a pasty mass. This action is called caustic action and it is due to this property that sodium hydroxide is called 'caustic soda' and potassium hydroxide is called 'caustic potash'. The term 'caustic' is not used for corrosive action of acids.

INTEXT QUESTIONS 8.2

1. Name the substances in which the following acids are present:
   (a) Ethanoic acid (b) Tartaric acid
2. Which of these acids would be partially dissociated in their aqueous solution?
   (a) HBr (b) HCN
   (c) HNO_3 (d) C_2H_5COOH
3. An acid reacts with a substance X with liberation of a gas which burns with a 'pop' sound when a burning match stick is brought near it. What is the nature of X?
4. An acid reacts with a substance Z with the liberation of CO_2 gas. What can be the nature of Z?
5. Which of the following oxides will react with a base?
   (a) CaO (b) SO_2

8.3 WATER AND DISSOCIATION OF ACIDS AND BASES

In the previous sections, we have learnt that a substance is an acid if it furnishes H^+ ions in its aqueous solution and a base if it furnishes OH^- ions. Water plays very important role in these processes, we shall learnt about it in this section.

8.3.1 Role of water in dissociation of acids and bases

If a dry strip of blue litmus paper is brought near the mouth of the test tube containing dry HCl gas , its colour does not changes. When it is moistened with a drop of water and again brought near the mouth of the test tube , its colour turns red. It shows that there are no H^+ ion in dry HCl gas. Only when it dissolves in water, H^+ ions are formed and it shows its acidic nature by turning the colour of the blue litmus paper to red.

A similar behavior is exhibited by bases. If we take a pallet of dry NaOH in dry atmosphere and quickly bring a dry strip of red litmus paper in its contact, no colour change is observed. NaOH is a **hygroscopic** compound and soon absorbs moisture from air and becomes wet. When this happens, the colour of the red litmus paper immediately changes to blue. Thus in dry solid NaOH although OH^- ions are present but they are not free and do not show basic nature on coming in contact with water, OH^- ions becomes free and show the basic nature by changing red litmus blue. From the above discussion, it is clear that acidic and basic characters of different substances can be observed only when they are dissolved in water.

Warning

Dissolution of H_2SO_4 in water is highly exothermic process. Therefore, to prepare an aqueous solution, conc. sulphuric acid is added slowly to water with constants stirring. Water is **never** added to con. sulphuric acid as huge amount of heat is liberated. Due to that spattering occurs and the acid can cause serious burns on skins or damage the items on which it falls.

(i) When an acid like sulphuric acid or a base like sodium hydroxide is dissolved in water, the solution that is formed is hotter. It shows that the dissolution process is **exothermic**. A part of the thermal energy which is released during the dissolution process is used up in overcoming the forces holding the hydrogen atom or hydroxyl group in the molecule of the acid or the base in breaking the chemical bond holding them and results in the formation of free H^+(aq) and OH^- (aq) ions.

(ii) Many bases are ionic compounds and consist of ions even in the solid state. For example sodium hydroxide consists of Na^+ and OH^- ion. These ions are held very tightly due to the strong electrostatic forces between the oppositely charged ions. Presence of water as a medium (solvent) weakens these forces greatly and the ions become free to dissolve in water.

8.3.2 Self dissociation of water

Water plays an important role in acid base chemistry. We have seen that it helps in the dissociation of acids and bases resulting in the formation of H^+(aq) and OH^-(aq) ions respectively. Water itself undergoes dissociation process which is called 'self-dissociation of water'.Let us learn about it.

Self-dissociation of water

Water dissociates into H^+(aq) and OH^-(aq) ions as:

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The dissociation of water is extremely small and only about two out of every billion (10^9) water molecules are dissociated at 25°C. As a result, the concentrations of H^+(aq) and OH^-(aq) ions formed is also extremely low. At 25°C (298K),

$$[H^+] = [OH^-] = 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

Here, square brackets denote the molar concentration of the species enclosed within. Thus, $[H^+]$ denotes the concentration of H^+(aq) ions in moles per litre and $[OH^-]$ the concentration of OH^-(aq) ions in moles per litre.

It must be noted here that in pure water and in all aqueous **neutral solutions**,

$$[H^+] = [OH^-]$$

Also, in pure water as well as in all aqueous solutions at a given temperature, product of concentrations of H^+(aq) and OH^-(aq) always remains constant. This product is called 'ionic product of water' and is given the symbol *Kw*. It is also called **ionic product constant of water**. Thus,

$$Kw = [H^+]\,[OH^-]$$

At 25°C (298 K), in pure water, *Kw* can be calculated as:

$$Kw = (1.0 \times 10^{-7}) \times (1.0 \times 10^{-7})$$
$$= 1.0 \times 10^{-14}$$

8.3.3 Neutral, acidic and basic solutions

We have seen that in pure water H^+(aq) and OH^-(aq) ions are produced in equal numbers as a result of dissociation of water and therefore, their concentrations are also equal i.e.

$$[H^+] = [OH^-]$$

(i) Neutral solutions

In all neutral aqueous solutions, the concentrations of H^+(aq) and OH^-(aq) ions remains equal i.e.

$$[H^+] = [OH^-]$$

In other words the neutral solution is the one in which the concentrations of H^+ and OH^- ions are equal.

(ii) Acidic solutions

Acids furnish H^+(aq) ions in their solutions resulting in increase in their concentration. Thus, in acidic solutions

$$[H^+] > [OH^-]$$

and $$[H^+] > 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

In other words the acidic solution is the one in which the concentration of H^+(aq) is greater than that of OH^-(aq) ions.

We have seen earlier that the ionic product of water *Kw* is constant at a given temperature. It can remain so only if the concentration of OH^-(aq) ions decreases.

$$[OH^-] < 10^{-7} \text{ mol L}^{-1}$$

(iii) Basic solutions

Bases furnish OH^-(aq) ions in their solutions. This results in an increase in their concentration. Therefore, in basic solution

$$[OH^-] > [H^+]$$

and $$[OH^-] > 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

In other words, the basic solution is the one in which the concentration of H^+(aq) ions is smaller than that of OH^{-1}(aq) ions.

Here also, because of constancy of ionic product of water Kw, the concentration of H^+(aq) decreases. Thus

and $$[H^+] < 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

We may summarize the nature of aqueous solution in terms of concentration of hydrogen ions H^+(aq) as shown in table 8.3.

Table 8.3 Concentration of H^+(aq) ions in different types of aqueous solutions

Nature of solution	Concentration of H^+ ions at 25°C (298 K)
Neutral	$[H^+] = 1.0 \times 10^{-7}$ mol L^{-1}
Acidic	$[H^+] > 1.0 \times 10^{-7}$ mol L^{-1}
Basic	$[H^+] < 1.0 \times 10^{-7}$ mol L^{-1}

INTEXT QUESTIONS 8.3

1. Why does the colour of dry blue litmus paper remains unchanged even when it is brought in contact with HCl gas?
2. How does water help in dissociation of acids and bases?
3. Identify the nature of the following aqueous solutions (whether acidic, basic or neutral)
   (a) Solution A: $[H^+] < [OH^-]$
   (b) Solution B: $[H^+] > [OH^-]$
   (c) Solution C: $[H^+] = [OH^-]$

8.4 pH AND ITS IMPORTANCE

When dealing with range of concentrations (such as these of $H^+(aq)$ ions) that spans many powers of ten, it is convenient to represent them on a more compressed logarithmic scale. By convention, we use the **pH scale** for denoting the concentration of hydrogen ions. **pH** notation was devised by the Danish biochemist Soren Sorensen in 1909. The term pH means "power of hydrogen".

The pH is the logarithm (see box) of the reciprocal of the hydrogen ion concentration. It is written as:

$$pH = \log \frac{1}{\left[H^+\right]}$$

Alternately, the pH is the negative logarithm of the hydrogen ion concentration i.e

$$pH = -\log [H^+].$$

Because of the negative sign in the expression, if $[H^+]$ increases, pH would decrease and if it decreases, pH would increase.

In pure water at 25° (298 K)

$$[H^+] = 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

$$\log[H^+] = \log(10^{-7}) = -7$$

$$\text{and} \quad pH = -\log[H^+] = -(-7)$$

$$pH = 7$$

Since in pure water at 25°C (298 K)

$$[OH^-] = 1.0 \times 10^{-7} \text{ mol L}^{-1}$$

$$\text{Also,} \quad pOH = 7$$

$$\text{Since,} \quad Kw = 1.0 \times 10^{-14}$$

$$pKw = 14$$

Logarithm

Logarithm is a mathematical function

If $\quad x = 10^y$

then $\quad y = \log_{10}x$

Here $\log_{10}x$ mean log of x to the base 10. Usually, the base 10 is omitted in the notation thus, y = log x.

e.g. $\quad \log 10^3 = 3 \times \log 10$

$\qquad = 3 \times 1 = 3$

$\quad \log 10^{-5} = -5 \times \log 10$

$\qquad = -5 \times 1$

$\qquad = -5$

Note : log 10 = 1

The relationship between pKw, pH and pOH is

$$pKw = pH + pOH$$

at 25°C (298 K)

$$14 = pH + pOH$$

8.4.1 Calculations based on pH concept

In the last section, we learned the concept of pH and its relationship with hydrogen ion or hydroxyl ion concentration. In this section, we shall use these relations to perform some calculations.

The method of calculation of pH used in this unit are valid for (i) solutions of *strong* acids and bases only and (ii) the solutions of acids or bases should not be extremely dilute and the concentrations of acids and bases *should not be less than* 10^{-6} *mol* L^{-1}.

Example 8.1: Calculate the pH of 0.001 molar solution of HCl.

Solution: HCl is a strong acid and is completely dissociated in its solutions according to the process:

$$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$$

From this process it is clear that one mole of HCl would give one mole of H^+ ions. Therefore, the concentration of H^+ ions would be equal to that of HCl i.e. 0.001 molar or 1.0×10^{-3} mol L^{-1}.

Thus, $[H^+] = 1 \times 10^{-3}$ mol L^{-1}

$$pH = -\log[H^+] = -(\log 10^{-3})$$

$$= -(-3 \times \log 10) = -(3 \times 1) = 3$$

Thus, $pH = 3$

Example 8.2: What would be the pH of an aqueous solution of sulphuric acid which is 5×10^{-5} mol L^{-1} in concentration.

Solution: Sulphuric acid dissociates in water as:

$$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$$

Each mole of sulphuric acid gives two mole of H^+ ions in the solution. One litre of 5×10^{-5} mol L^{-1} solution contains 5×10^{-5} moles of H_2SO_4 which would give $2 \times 5 \times 10^{-5} = 10 \times 10^{-5}$ or 1.0×10^{-4} moles of H^+ ion in one litre solution. Therefore,

$$[H^+] = 1.0 \times 10^{-4} \text{ mol } L^{-1}$$

$$pH = -\log[H^+] = -\log 10^{-4} = -(-4 \times \log 10)$$

$$= -(-4 \times 1) = 4$$

Example 8.3: Calculate the pH of 1×10^{-4} molar solution of NaOH.

Solution: NaOH is a strong base and dissociate in its solution as:

$$NaOH(aq) \longrightarrow Na^+(aq) + OH^-(aq)$$

One mole of NaOH would give one mole of OH^- ions. Therefore,

$$[OH^-] = 1 \times 10^{-4} \text{ mol L}^{-1}$$

$$pOH = -\log[OH^-] = -\log \times 10^{-4} = -(-4)$$

$$= 4$$

Since $$pH + pOH = 14$$

$$pH = 14 - pOH = 14 - 4$$

$$= 10$$

Example 8.4: Calculate the pH of a solution in which the concentration of hydrogen ions is 1.0×10^{-8} mol L^{-1}.

Solution: Here, although the solution is extremely dilute, the concentration given is *not of acid or base* but that of H^+ ions. Hence, the pH can be calculated from the relation:

$$pH = -\log[H^+]$$

$$\text{given } [H^+] = 1.0 \times 10^{-8} \text{ mol L}^{-1}$$

$$\therefore \quad pH = -\log 10^{-8} = -(-8 \times \log 10)$$

$$= -(-8 \times 1) = 8$$

8.4.2 pH Scale

The pH scale ranges from 0 to 14 on this scale. pH 7 is considered neutral, below 7 acidic and above 7 basic. Farther from 7, more acidic or basic the solution is. The scale is shown below in Fig. 8.5.

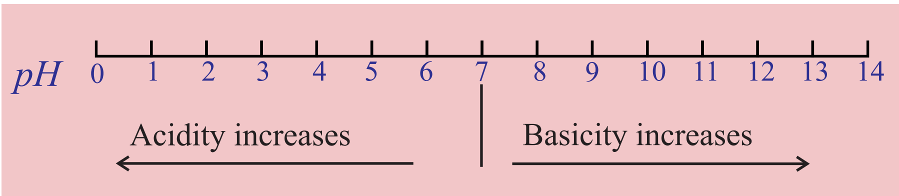


Fig. 8.5: *The pH scale*

We have learnt earlier that the sum of pH and pOH of any aqueous solution remains constant. Therefore, when one increases the other decreases. This relationship is shown in Fig. 8.6

$$pH + pOH = 14$$

Fig. 8.6: *Relationship between pH and pOH at 25°C.*

pH of some common substances is shown in table 8.5.

Table 8.5: pH of some common acids and bases

Common Acids	pH	Common Bases	pH
HCl (4%)	0	Blood plasma	7.4
Stomach acid	1	Egg white	8
Lemon juice	2	Sea water	8
Vinegar	3	Baking soda	9
Oranges	3.5	Antacids	10
Soda, grapes	4	Ammonia water	11
Sour milk	4.5	Lime water	12
Fresh milk	5	Drain cleaner	13
Human saliva	6-8	Caustic soda 4% (NaOH)	14
Pure water	7		

8.4.3 Determination of pH

pH of a solution can be determined by using proper indicator or with the help of a pH meter. The latter is a device which gives accurate value of pH. You will study more about it in higher classes. We shall discuss here the use of indicators for finding out the pH of a solution.

Universal Indicator/pH paper.

It is a mixture of a number of indicators. It shows a specific colour at a given pH. A colour guides is provided with the bottle of the indicator or the strips of paper impregnated with it which are called pH paper strips. The test solution is tested with a drop of the universal indicator, or a drop of the test solution is put on pH paper. The colour of the solution on the pH paper is compared with the colour chart/guard and pH is read from it. The pH values thus obtained are only approximate values.

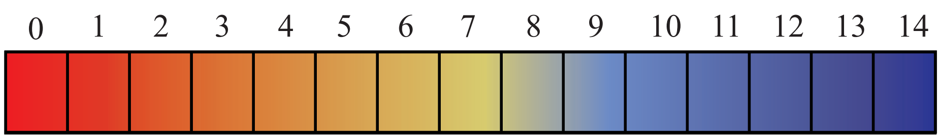


Fig. 8.7: *Colour chart/guide of universal indicator/pH paper.*

8.4.2 Importance of pH in everyday life

pH plays a very important role in our everyday life. Some such examples are described here.

(a) pH in humans and animals

Most of the biochemical reactions taking place in our body are in a narrow pH range of 7.0 to 7.8. Even a small change in pH disturbs these processes.

(b) Acid Rain

When the pH of rain water falls below 5.6, it is called **acid rain**. When acid rain flows into rivers, the pH of the river water also falls and it become acidic. As a result, the survival of aquatic life become difficult.

(c) pH in plants

Plants have a healthy growth only when the soil has a specific pH range which should be neither highly alkaline nor highly acidic.

(d) In digestive system

Our stomach produce hydrochloric acid which helps in digestion of food. When we eat spicy food, stomach produces too much of acid which causes 'acidity' i.e. irritation and sometimes pain too. To get rid of this we use 'antacids' which are bases like 'milk of magnesia' (suspension of magnesium hydroxide in water).

(e) Self defence of animals and plants

Bee sting causes severe pain and burning sensation. It is due to the presence of methanoic acid in it. Use of a mild base like baking soda can provides relief from pain.

Some plants like 'nettle plant' have fine stinging hair which inject methanoic acid into the body of any animal or human being that comes in its contact. This causes severe pain and buring sensation. The leaves of dock plant that grows near the nettle plant when rubbed on the affected area provides relief.

Fig. 8.8 *Nettle plant*

(f) Tooth decay

Tooth enamel is made of calcium phosphate which is the hardest substance in our body and can withstand the effect of various food articles that we eat. If mouth is not washed properly after every meal, the food particles and sugar remaining in the mouth undergoes degradation due to the bacterial present in the mouth. This process produces acids and the pH goes below 5.5. The acidic condition thus created corrode the tooth enamel and in the long run can result in tooth decay.

INTEXT QUESTIONS 8.4

1. pOH of a solution is 5.2. What is its pH. Comment on the nature (acidic, basic or neutral) of this solution.
2. pH of a solution is 9. What is the concentration of H^+ ions in it.

3. What is the nature (whether acidic, basic or neutral) of the following solutions?
   (a) Solution A: pH = pOH
   (b) Solution B: pH > pOH
   (c) Solution C: pH < pOH

8.5 SALTS

Salts are ionic compounds made of a cation other than H^+ ion and an anion other than OH^- ion.

8.5.1 Formation of salts

Salts are formed in many reactions involving acids and bases.

1. By Neutralization of acids and bases

Salts are the product (besides water) of a neutralization reaction.

For example,

	Base		Acid		Salt		Water
	$NaOH$	+	HCl	$\longrightarrow$	$NaCl$	+	H_2O
	KOH	+	HNO_3	$\longrightarrow$	KNO_3	+	H_2O
In general,	MOH	+	HX	$\longrightarrow$	MX	+	H_2O

In all the above cases we can see that the positively charged cation of the salt comes from the base. Therefore, it is called the 'basic radical'. The negatively charged anion of the salt comes from the acid. It is therefore, called the 'acid radical' of the salt. For example, in the salt NaCl, the cation Na^+ comes from the base NaOH and is its basic radical and the anion Cl^- comes from the acid HCl and is its 'acid radical'.

2. By action of acids on metals

In a reaction between an acid and a metal, salt is produced along with hydrogen,

Metal		Acid		Salt		Hydrogen
Zn	+	H_2SO_4	$\longrightarrow$	$ZnSO_4$	+	H_2

3. By action of acids on metal carbonates and hydrogen carbonates

Salts are produced in reactions between acids and metal carbonates and hydrogen carbonates (bicarbonates) along with water and carbon dioxide.

Metal carbonate or hydrogen carbonate		Acid		Salt		Water		Carbon dioxide
$CaCO_3$	+	$2HCl$	$\longrightarrow$	$CaCl_2$	+	H_2O	+	CO_2
$NaHCO_3$	+	HCl	$\longrightarrow$	$NaCl$	+	H_2O	+	CO_2

Type of salt and the nature of its aqueous solution:

	Salt of		Nature of Salt Solution	pH (at 25°C)
	Acid	Base		
1.	Strong	Strong	Neutral	pH = 7
2.	Weak	Strong	Basic	pH > 7
3.	Strong	Weak	Acidic	pH < 7
4.	Weak	Weak	More information required	–

8.6 SOME COMMONLY USED SALTS

A large number of salts are used in our homes and industry for various purposes. In this section we would learn about some such salts.

8.6.1 Baking soda

You must have seen your mother using baking soda while cooking some 'dals'. If you ask her why does she use it, she would tell that it helps in cooking some items fasters which otherwise would take must longer time. Chemically baking soda is sodium hydrogen carbonate, $NaHCO_3$.

(a) Manufacture

Baking soda is manufactured by Solvey's process. It is mainly used for manufacturing washing soda but baking soda is obtained as an intermediate.

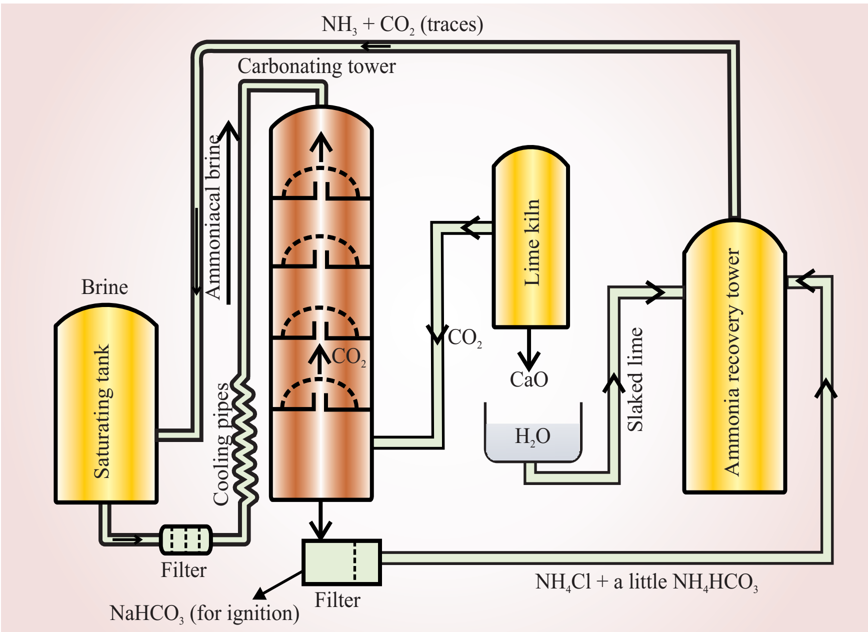


Fig. 8.9 Solvey's process for manufacturing of Baking soda

Raw materials required

The raw materials required to manufacture washing soda are:

- Lime stone which is calcium carbonate, $CaCO_3$
- Sodium chloride (NaCl) in the form of brine(Conc. NaCl Solution)
- Ammonia (NH_3)

Process

In Solvey's process, carbon dioxide is obtained by heating limestone strongly,

$$\underset{\text{lime stone}}{CaCO_3(s)} \longrightarrow \underset{\text{quick lime}}{CaO(s)} + \underset{\text{carbon dioxide}}{CO_2(g)\uparrow}$$

It is then passed through cold brine (a concentrated solution of NaCl in water) which has previously been saturated with ammonia,

$$\underset{\substack{\text{sodium chloride}\\ \text{in brine}}}{NaCl(aq)} + CO_2(g) + \underset{\text{ammonia}}{NH_3(g)} + H_2O(l) \longrightarrow \underset{\substack{\text{sodium hydrogen}\\ \text{carbonate}}}{NaHCO_3(s)\downarrow} + \underset{\substack{\text{ammonium}\\ \text{chloride}}}{NH_4Cl(aq)}$$

$NaHCO_3$ is sparingly soluble in water and crystallises out as white crystals. Its solution in water is basic in nature. It is a mild and non-corrosive base.

Action of heat: On heating, sodium hydrogen carbonate is converted into sodium carbonate and carbon dioxide is given off,

$$\underset{\text{sodium carbonate}}{2NaHCO_3} \xrightarrow{\text{heat}} Na_2CO_3 + H_2O + CO_2\uparrow$$

(b) Use

1. Used for cooking of certain foods.
2. For making **baking power** (a mixture of sodium hydrogen carbonate and tartaric acid). On heating during baking, baking soda gives off carbon dioxide. It is this carbon dioxide which raises the dough. The sodium carbonate produced on heating the baking soda gives a bitter taste. Therefore, instead of using the baking soda alone, baking powder is used. The tartaric acid present in it neutralises the sodium carbonate to avoid its bitter taste. Cakes and pastries are made flufly and soft by using baking powder.
3. In medicines

   Being a mild and non-corrosive base, baking soda is used in medicines to neutralise the excessive acid in the stomach and provide relief. Mixed with solid edible acids such as citric or tartaric acid, it is used in effervescent drinks to cure indigestion.
4. In soda acid fire extinguishers

8.6.2 Washing soda

Washing soda is used for washing of clothes. It is mainly because of this chemical that the clothes washed by a washerman appear so white. Chemically, washing soda is sodium carbonate decahydrate, $Na_2CO_3.10H_2O$.

(a) Manufacture

Washing soda is manufacturing by Solvey's process. We have already learnt about the raw materials required and part of the process in the manufacture of baking soda. Sodium carbonate is obtained by calcination (strong heating in a furnace) of sodium hydrogen carbonate and then recrystallising from water:

$$2NaHCO_3 \xrightarrow{\text{heat}} Na_2CO_3 + H_2O + CO_2$$

$$\underset{\text{sodium carbonate}}{Na_2CO_3 + 10H_2O} \longrightarrow \underset{\text{washing soda}}{Na_2CO_3.10H_2O}$$

(b) Uses

1. It is used in the manufacture of caustic soda, glass, soap powders, borex and in paper industry.
2. For removing permanent hardness of water.
3. As a cleansing agent for domestic purpose.

8.6.3 Plaster of Paris

You must have seen some beautiful designs made on the ceiling and walls of rooms in many houses. These are made of plaster of paris, also called POP. Chemically, it is $2CaSO_4.H_2O$ or $CaSO_4.\frac{1}{2}H_2O$ (calcium sulphate hemi hydrate)

(a) Manufacture

Raw material

Gypsum, ($CaSO_4.2H_2O$) is used as the raw material.

Process

The only difference between gypsum ($CaSO_4.2H_2O$) and plaster of paris ($CaSO_4.1/2H_2O$) is in the less amount of water of crystallization.

When gypsum is heated at about 100° (373 K) temperature, it loses a part of its water of crystallization to form:

$$\underset{\text{gypsum}}{CaSO_4.2H_2O} \xrightarrow[100°C(373\ K)]{\text{heat}} \underset{\text{plaster of paris}}{CaSO_4.1/2H_2O} + 3/2H_2O$$

The temperature is not allowed to rise beyond 100°C otherwise whole of water of crystallization is lost and anhydrous calcium sulphate is produced which is called 'dead burnt' as it does not have the property to set after mixing with water.

(b) Uses

1. In making casts for manufacture of toys and statues.
2. In medicine for making plaster casts to hold fractured bones in place while they set. It is also used for making casts in dentistry.
3. For making the surface of walls and ceiling smooth.
4. For making decorative designs on ceilings, walls and pillars.
5. For making' chalk' for writing on blackboard.
6. For making fire proof materials.

8.6.4 Bleaching Powder

Have you ever wondered at the whiteness of a new white cloth? How is it made so white? It is done by bleaching of the cloth at the time of its manufacture. **Bleaching** is a process of removing colour from a cloth to make it whiter. Bleaching powder has been used for this purpose since long. Chemically, it is calcium oxychloride, $CaOCl_2$.

(a) Manufacture

1. **Raw material required**: The raw material required for the manufacture of bleaching powder are:
   - Slaked lime, $Ca(OH)_2$
   - Chlorine gas, Cl_2

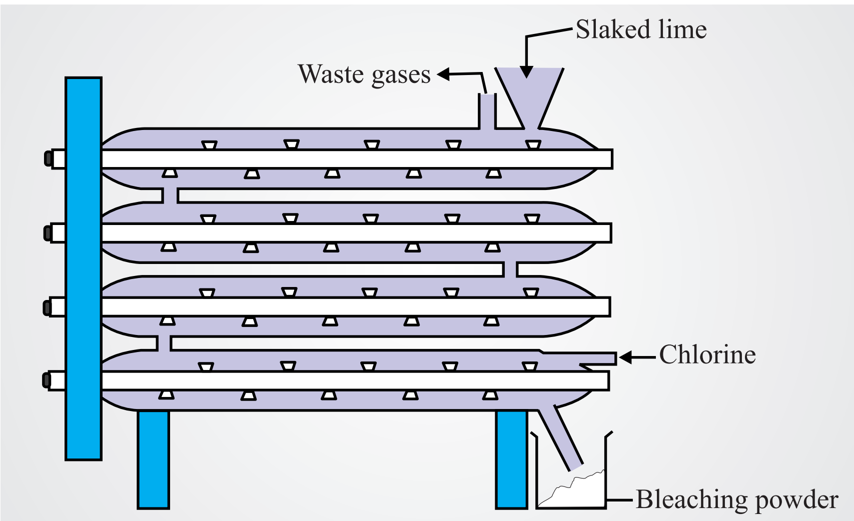


Fig. 8.10 Hasen-Clever plant for manufacturing of bleaching powder

2. **Process**: It is manufactured by Hasen-Clever Method. The plant consists of four cylinders made of cast iron with inlet for chlorine near the base. The dry slaked lime, calcium hydroxide is fed into the chlorinating cylinders from the top. It moves down slowly and meets the upcoming current of chlorine. As a result of the reaction between them, it is converted into bleaching power which collects at the bottom.

$$\begin{array}{ccccccc} Ca(OH)_2 & + & Cl_2 & \longrightarrow & CaOCl_2 & + & H_2O \\ \text{slaked lime} & & \text{chlorine} & & \text{bleaching powder} & & \end{array}$$

(b) Uses

1. In textile industry for bleaching of cotton and linen.
2. In paper industry for bleaching of wood pulp.
3. In making wool unshrinkable.
4. Used as disinfactant and germicide for sterilization of water.
5. For the manufacture of chloroform.
6. Used as an oxidizing agent in chemical industry.

INTEX QUESTIONS 8.5

1. Identify acid radical and basic radical in $CaSO_4$.
2. $CuSO_4$ was prepared by reacting an acid and a base. Identify the acid and the base that must have been used in this reaction.
3. Which one of the following is the correct formula of plaster of paris?

   $CaSO_4.H_2O$ or $2CaSO_4.H_2O$

WHAT YOU HAVE LEARNT

- Acids are the substances which taste sour, change blue litmus red, are corrosive to metals and furnish H^+ ions in their aqueous solutions.
- Bases are the substances which taste bitter, change red litmus blue, feel slippery and furnish OH^- ions in their aqueous solutions.
- Indicators are the substances that show one colour in an acidic medium and another colour in a basic medium. Litmus, phenolphthalein and methyl orange are commonly used indicators.

- Acids are presents in many unripe fruits, vinegar, lemon, sour milk etc., while bases are present in lime water, window pane cleaners, many drain cleaners etc.
- Aqueous solutions of acids and bases both conduct electricity as they dissociate on dissolving in water and liberate cations and anions which help in conducting electricity.
- Strong acids and bases dissociate completely in water. HCl, HBr, HI, H_2SO_4, HNO_3, $HClO_4$ and $HClO_3$ are strong acids and LiOH, NaOH, KOH, RbOH, CsOH, $Ca(OH)_2$, $Sr(OH)_2$ and $Ba(OH)_2$ are strong bases.
- Weak acids and bases dissociate partially in water. For example, HF, HCN, CH_3COOH etc. are some weak acid and NH_4OH, $Cu(OH)_2$, $Al(OH)_3$ etc. are some weak bases.
- Acids and bases react with metals to produce salt and hydrogen gas.
- Acids react with metal carbonates and metal hydrogen carbonates to produce salt, water and CO_2.
- Acids react with metal oxides to produce salt and water.
- Bases react with non-metal oxides to produce salt and water.
- Acids and bases react with each other to produce salt and water. Such reactions are called neutralization reactions.
- Acids and bases dissociate only on dissolving in water.
- Water itself undergoes dissociation and furnishes H^+ and OH^- ions in equal numbers. This is called self dissociation of water. The extent of dissociation is very small.
- Concentrations of H^+ and OH^- ion formed by the self dissociation of water are 1.0×10^{-7} molar each at 25°C.
- Product of concentrations of hydrogen and hydroxyl ions is called the 'ionic product' or ionic product constant' of water, Kw. It remains unchanged even when some substance (acid, base or salt etc.) is dissolved in it.
- pH is defined as $\log \frac{1}{\left[H^+\right]}$ or $-\log[H^+]$, likewise pOH = $-\log[OH^-]$ and pKw = $-\log$ Kw
- In pure water or in any aqueous solution pH + pOH = pKw = 14 at 25°C.
- In pure water $[H^+] = [OH^-]$. It is also true in any neutral aqueous solution. In terms of pH, pH = pOH = 7 in water and any neutral solution.
- In acidic solution $[H^+] > [OH^-]$ and pH < pOH. Also pH < 7 at 25°C.
- In basic solutions $[H^+] < [OH^-]$ and pH > pOH. Also pH > 7 at 25°C.
- Universal indicator is prepared by mixing a number of indicators. It shows a different but characteristic colour at each pH.

- Maintenance of correct pH is very important for biochemical process occuring in humans and animals.
- If pH of rain water falls below 5.6, it is called acid rain and is quite harmful.
- pH plays an important role in proper growth of plants and also for proper digestion in our bodies.
- Salts are ionic compounds made of a cation other than H^+ ion and an anion other than OH^- ion. They are formed in neutralization reaction.
- Salts are also formed in reaction of acids and bases with metals, of acid with metal carbonates, hydrogen carbonates and oxides and in reaction of bases with non-metal oxides.

TERMINAL EXERCISE

A. Objective Type Questions

I. Mark the correct choice

1. Lemon juice contains
   (a) tartaric acid (b) ascorbic acid
   (c) acetic acid (d) lactic acid
2. Aqueous solutions of acids conduct electricity. This shows that
   (a) They contain H^+ ions
   (b) They contain OH^- ion
   (c) They contain cations and anions
   (d) They contain both H^+ and OH^- ions
3. Which of the following is not a strong acid?
   (a) HCl (b) HBr
   (c) HI (d) HF
4. Self dissociation of water produces
   (a) a large number of H^+ ions
   (b) a large number of OH^- ions
   (c) H^+ and OH^- ions in equal numbers
   (d) H^+ and OH^- ions in unequal numbers
5. In any aqueous basic solution
   (a) $[H^+] > [OH^-]$ (b) $[H^+] < [OH^-]$
   (c) $[H^+] = [OH^-]$ (d) $[H^+] = 0$

6. In an aqueous solution of HCl which of the following species is not present?
   (a) H^+ (b) OH^-
   (c) HCl (d) Cl^-
7. Which of the following is not a raw material for manufacturing washing soda?
   (a) Lime stone (b) Ammonia
   (c) Slaked lime (d) Sodium chloride

II. Mark the following statements as true (T) or false (F):

1. Acids furnish H^+ ions only in the presence of water.
2. Lime water turns blue litmus red.
3. HF is a strong acid.
4. H_2 gas is produced when acids react with metal oxides.
5. Corrosive action of acids is due to H^+ ions present in them.
6. When the pH of the rain water become more than 5.6 it is called acid rain.
7. Aqueous solutions of all the salts are neutral in nature i.e. neither acidic nor basic in nature.

III. Fill in the blanks

1. Acids taste .... while bases taste ....
2. Milk of magnesia turns .... litmus ....
3. One mole of sulphuric acid would furnish .... mole/s of H^+ ions and .... moles of SO_4^{2-} ions.
4. .... gas is produced when acids react with metal hydrogen carbonates.
5. Lime water turns milky on passing CO_2 gas due to the formation of ....
6. The reaction between an acid and a base is known as ....
7. Bee sting injects .... acid which causes severe pain and burning sensation.
8. In NH_4NO_3 the acid radical is .... and the basic radical is ....
9. Chemically baking soda is ....

B. Descriptive Questions

1. What is an acid?
2. Give two examples of acids found in food articles.
3. What is a base?
4. Give two examples of bases.

5. What are indicators?
6. What is the colour of methyl orange indicator in (i) acidic medium and (ii) basic medium.
7. Why do solutions of acids and bases conduct electricity?
8. Differentiate between strong and weak acids and give one example of each.
9. Write down the reaction between zinc and sulphuric acid.
10. Which gas is evolved when an acid reacts with metal carbonates? Which other category of compounds would produce the same gas on reacting with acids?
11. What type of oxides react with acids? Give one examples of this type of oxide and write down the balanced equation for the reaction.
12. What is the name given to the reaction between an acid and a base? What are the products formed in such reactions?
13. "Corrosive action of acids is not related to their strength". Justify this statement.
14. Give one example each of the following (i) a strong base (ii) a weak base
15. List three categories of substances that can react with a base. Give one example of each and write the chemical reaction involved in each case.
16. What happens when a dry strip of each of red litmus paper and blue litmus paper is brought in contact with HCl gas? In which case a change would be observed if the strips are moistened and then brought in contact with HCl gas and what would be the change?
17. A small palette of NaOH is kept on dry red litmus paper. Initially, no change is observed but after some time its colour starts changing to blue around the place where the palette of NaOH is kept. Explain these observations.
18. How does water help in dissociation of acids and bases? Explain.
19. What is 'self dissociation of water'? Name the resulting species and give their concentrations at 25°C.
20. What is ionic product constant of water? Give its value at 25°C. Will the value change if an acid, base or a salt is dissolved in water?
21. Give the relationships between the concentrations of hydrogen ions and hydroxyl ions in (i) pure water (ii) a neutral solution (iii) an acidic solution and (iv) a basic solution.
22. What is pH? What happens to the pH if the hydroxyl ion concentration in the solution increases?
23. Predict whether a given aqueous solution is acidic, basic or neutral if its pH is (a) 7.0, (b) 11.9 and (c) 3.2.
24. Calculate the pH of 1.0×10^{-4} molar solution of HNO_3.

25. What is the pH of 1.0×10^{-5} molar solution of KOH?
26. What is the pH of 1.0×10^{-2} mol L^{-1} solution of NaCl?
27. What do you understand by the term 'universal indicator'?
28. What is acid rain?
29. What is the importance of pH for humans and animals, and our digestive system?
30. Which chemical causes pain and burning sensation when somebody accidentally touches 'nettle plant'?
31. What is a salt? Give two examples.
32. How are salts obtained from an acid? Mention four types of substances that can be used for it.
33. Give chemical formula of (i) baking soda and (ii) washing soda.
34. List the raw materials required for the manufacture of baking soda and describe the process with the help of suitable chemical equations.
35. Distinguish between baking powder and baking soda. Why is baking powder preferred for making cakes?
36. Give any two uses of baking soda.
37. What is washing soda? Give its chemical formula. How is it manufactured by Solvey's method?
38. Give two uses of washing soda.
39. What is the chemical formula of 'plaster of paris'? How is it manufactured? What precaution is taken during its manufacture?
40. List any four uses of 'plaster of paris'.
41. What is bleaching? Chemically, what is bleaching powder? Give its any four uses.
42. List the raw materials required and the method of manufacture of bleaching powder. Write the equation for the reaction involved.

ANSWERSTO INTEXT QUESTIONS

8.1

1. Acidic : (b), (c) and (e)

   Basic : (a), (d) and (f)

2. Phenolphthalein: Colourless on unripe apple and pink in solutions of caustic soda and soap.

   Litmus: Red on unripe apple and curd, and blue in solutions of caustic soda and soap solution.

8.2

1. (a) Vinegar (b) tamarind
2. (b) and (d)
3. It must be a metal.
4. It may be either a metal carbonate or hydrogen carbonate.
5. SO_2

8.3

1. It is because HCl gas does not contain $H^+(aq)$ ions and is non acidic
2. (i) The heat released in dissolution process help in the dissociation process by overcoming the forces that hold the hydrogen atom or the hydroxyl group in the molecules of the acid or the base, or in breaking the chemical bond holding them.

   (ii) Presence of water weaken the electrostatic forces between anion and cations.
3. (a) Solution A – basic

   (b) Solution B – acidic

   (c) Solution C – neutral

8.4

1. Since $pH + pOH = 14$

   $pH = 14 - pOH = 14 - 5.2$

   $= 8.8$

   Since $pH > 7.0$, it is basic in nature
2. $pH = -\log[H^+] = 9$

   $\therefore$ $\log[H^+] = -9$

   or $[H^+] = 10^{-9}$ mol L^{-1}
3. (a) Solution A — neutral

   (b) Solution B — basic (since $[H^+] < [OH^-]$ in it)

   (c) Solution C — acidic (since $[H^+] > [OH^-]$ in it)

8.5

1. Acid radical SO_4^{2-}

   Basic radical Ca^{2+}
2. Acid: H_2SO_4 (corresponding to the acid radical SO_4^{2-})

   Base: $Cu(OH)_2$ (corresponding to the basic radical Cu^{2+})
3. (a) Carbonates (b) potassium salts
4. $2CaSO_4.H_2O$

MODULE - 3

MOVING THINGS

Notes

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9

MOTION AND ITS DESCRIPTION

You must have seen number of things in motion. For example car, bicycle, bus moving on a road, train moving on rails, aeroplane flying in the sky, blades of an electric fan and a child on a swing. What makes things move? Are all the motions similar?

You might have seen that some move along straight line, some along curved path and some to and fro from a fixed position. How and why these motions are different? You will find answers to all such questions in this lesson. Besides studying about various types of motions, you will learn how to describe a motion. For this we will try to understand the concepts of distance, displacement, velocity and acceleration. We will also learn how these concepts are related with each other as well as with time. How a body moving with constant speed can acquire acceleration will also be discussed in this lesson.

OBJECTIVES

After completing this lesson you will be able to:

- *explain the concept of motion and distinguish between rest and motion;*
- *describe various types of motion – rectilinear, circular, rotational and oscillatory;*
- *define distance, displacement, speed, average speed, velocity and acceleration;*
- *describe uniform and uniformly accelerated motion in one dimension;*
- *draw and interpret the distance time graphs and velocity time graphs;*
- *establish relationship among displacement, speed, average speed, velocity and acceleration;*
- *apply these equations to make daily life situation convenient and*
- *explain the circular motion.*

9.1 MOTION AND REST

If you observe a moving bus you will notice that the position of bus is changing with time. What does this mean? This means that the bus is in motion. Now suppose you are sitting in a bus moving parallel to another bus moving in the same direction with same speed. You will observe that the position of the other bus with respect to your bus is not changing with time. In this case the other bus seems to be at rest with respect to your bus. However, both the buses are moving with respect to surroundings. Thus, an object in motion can be at rest with respect to one observer whereas for another observer, the same object may be in motion. Thus we can say that the motion is relative.

Let us understand the concept of relative motion. Suppose you are sitting in a vehicle waiting for traffic signal and the vehicle beside you just starts moving, you will feel that your vehicle is moving backward.

Suppose Chintu and Golu are going to the market. Golu is running and Chintu is walking behind him. The distance between the two will go on increasing, though both are moving in the same direction. To Golu it will appear that Chintu is moving away from him. To Chintu also, it will appear that Golu is moving ahead and away from him. This is also an example of relative motion. See Fig. 9.1.

Chintu Golu

Fig. 9.1 *An example of relative motion*

Think and Do

One day, Nimish while standing on the bank of a river in the evening observed boats were approaching the bank, vehicles passing on the bridge, cattle going away from the bank of the river towards the village, moon rising in the sky, birds flying and going back to their nests, etc. Can you list some thoughts that could be emerging in the mind of the Nimish. What type of world Nimish has around him?

We can conclude that motion is a continuous change in the position of the object with respect to the observer. Suppose you are moving towards your friend standing in a field. In what way are you in motion? Are you in motion if you are observing yourself? Is your friend in motion with respect to you? Are you in motion with respect to your friend? Now you may have understood that observer with respect to itself can not be in motion. Thus, you are moving towards the object with respect to your friend and your friend is moving towards you with respect to you in opposite direction. In other words the change in position of the object with respect to observer decides whether object is in motion. This change should also be continuous. Let us take an interesting example to understand the concept of motion. There are five players participating in 200 metre race event. They are running in their lanes as shown in the Fig. 9.2. The players A, B, C, D and E runs 2, 3, 4, 3, 2 metre respectively in one second. Can you help the player to understand that which player is in motion with respect to which player and which player is at rest with respect to which player? Fill your responses in the table given below.

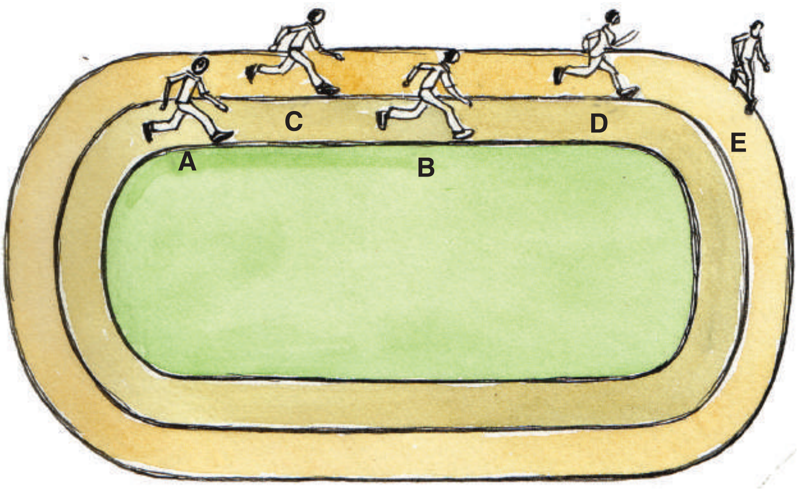


Fig. 9.2

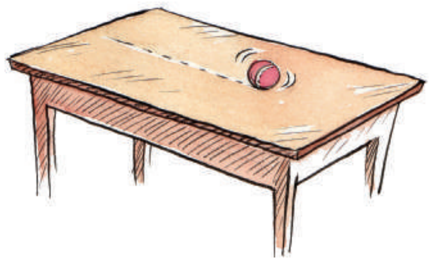
Table 9.1

Observer player	Player in motion	Player at rest	Remark
A	B, C, D	E	E is in rest with respect to A because change in position of A and E in 1second is zero while in other cases is not.
B			
C			
D			

Now you will be able to help Nimish to answer some of his questions.

9.1.1 Types of Motion

In our daily life we see many objects moving. Some objects moving in straight line and some are not. For example, a ball rolls on a horizontal surface, a stone falling from a building, and a runner on 100 m race track. In all these examples, you may notice that the position of moving objects is changing with respect to time along a straight line. This type of motion is called motion in a straight line or **rectilinear motion**.



(a) Ball rolling on horizontal surface

(b) Stone falling by hand

(c) A runner on a 100 m race track

Fig. 9.3 *Example of rectilinear motion*

Can you think at least two more other example of such motions. You might have observed the motion of time hands of a clock, motion of child sitting on a merry-go-round, motion of the blades of an electric fan. In such a motion, an object follows a circular path during motion. This type of motion is called **circular motion**.

ACTIVITY 9.1

(A) Suspend a small stone with a string (of length less than your height) with the help of your hand. Displace the stone aside from the position of rest and release.

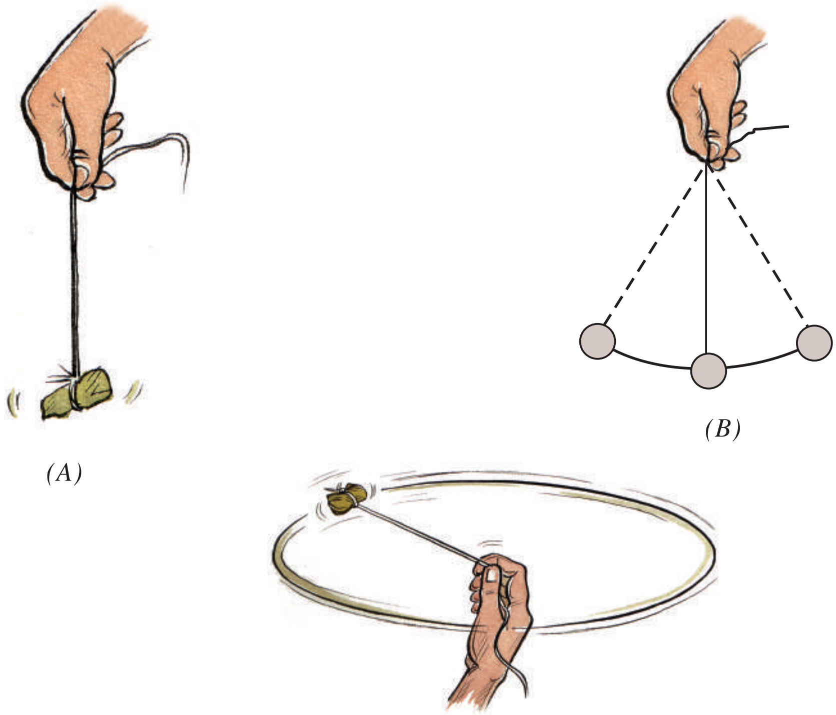
(B) Let the stone comes to rest and bring it to the point of suspension with the help of your hand and release it.

(C) Now hold the stone firmly in your hand and whirl it over your head.

Write in table given below, what type of motion of stone you have observed in all the above three cases with justification.

Table 9.2

Case	Type of motion	Justification
A		
B		
C		



(A)

(B)

(C)

(A) A person suspend the stone attached to a string, (B) A person oscillate the stone attached to a string, (C) A person whirling the stone attached to a string

Fig. 9.4 (A), (B) (C)

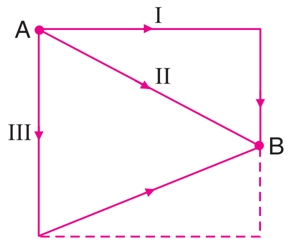
Have you ever noticed that the motion of the branches of a tree? They move to and fro from their central positions (position of rest). Such type of motion is called **oscillatory motion**. In such a motion, an object oscillates about a point often called position of rest or equilibrium position. The motion of swing and pendulum of wall clock are also oscillating motions. Can you think about the motion of the needle of a sewing machine? What type of motion is it? Now you can distinguish some of the motions viewed by Nimish.

9.2 DISTANCE AND DISPLACEMENT

For a moving object two points are significant. One is the point of start or origin where from the object starts its motion and the other is the point where it reaches after certain interval of time. Points of start and destination are connected by a path taken by the object during its motion. The length of the path followed by object is called distance. There may be a number of paths between the point of start and the point of destination. Hence the object may cover different distances between same point of start and destination. The unit of distance is metre (m) or kilometre (km).

ACTIVITY 9.2

An object moves from point A to B along three different paths. Measure the distance travelled by object along these three paths.



Take a scale 1 cm = 10 m

Fig. 9.5

In any motion, you will notice that object gets displaced while it changes its position continuously. **The change in position of the object is called displacement.** Basically, it is the shortest distance between initial and final position of the object. The path followed by the object between initial and final positions may or may not be straight line. Hence, the length of the path does not always represent the displacement.

ACTIVITY 9.3

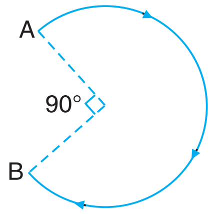
In the following cases measure the distance and displacement and write their values in the table given below:

(a) A body moves from A to B

(b) A body moves from A to B then comes to C

(c) A body goes from position A to B and comes back to position A

(d) A body goes from posion A to B and then C



(e) A body moves from position A to B along a circular arc

Fig. 9.6

Table 9.3

Case	Distance	Displacement
(i)		
(ii)		
(iii)		
(iv)		
(v)		

Now you can conclude that:

(a) displacement is smaller or equal to the distance.

(b) displacement is equal to distance, if body moves along a straight line path and does not change its direction.

(c) if a body does not move along a straight line path its displacement is less than the distance.

(d) displacement can be zero but distance can not be zero.

(e) magnitude of displacement is the minimum distance between final position and initial position.

(f) distance is the length of the path followed by the body.

(g) distance is path dependent while displacement is position dependent.

Can you now, suggest a situation in which the distance is twice the displacement?

9.2.1 Graphical Representation of Distance and Displacement

Distance and displacement can also be shown by graphical representation. To draw a graph, follow the following steps:

(i) Analyse the range of variables (maximum and minimum values).

(ii) Select the suitable scale to represent the data on the graph line adequately.

(iii) Take independent quantity on x-axis and dependent quantity on y-axis.

Take distance on x-axis and displacement on y-axis. You know that for a motion along a straight line without changing its direction the distance is always equal to the displacement. If you draw the graph, you will find that the graph line is a straight line passing through origin making an angle of 45° with distance axis as shown in Fig 9.7.

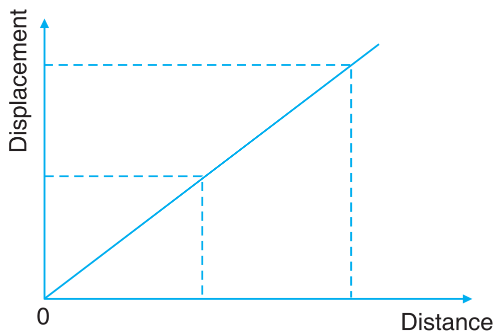


Fig. 9.7

Let us take another situation where an object moving from one position to another and coming back to the same position. In this case the graph line will be a straight line making an angle of 45° with distance axis upto its maximum value and then comes to zero as shown in Fig. 9.8.

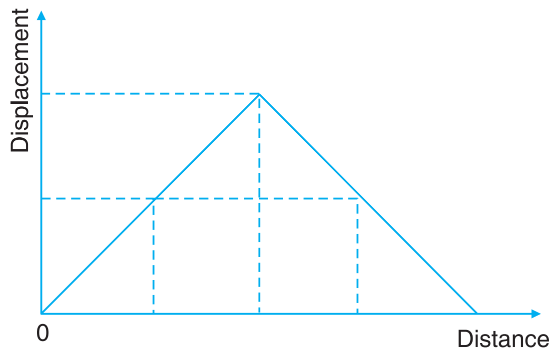


Fig. 9.8

Now you can infer that:

- If graph line is a straight line making an angle of 45° with x-axis or y-axis, the motion is straight line motion and distance is equal to the displacement.
- For same value of displacement, the distance travelled can be different.
- If graph line does not make an angle of 45° with x-axis or y-axis, the motion will not be straight line motion.

When an object moves along a circular path, the maximum displacement is equal to the diameter of the circular path and the distance travelled by object keeps on increasing with time as shown in Fig. 9.9.

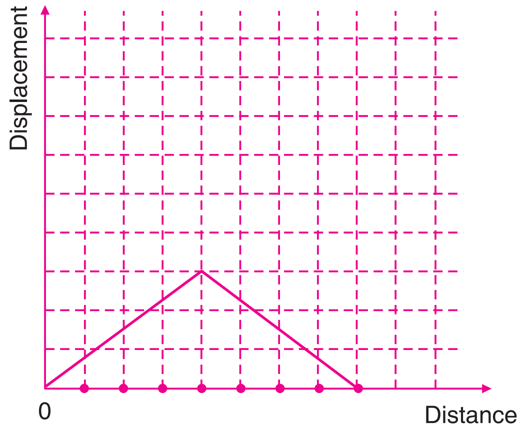


Fig. 9.9

INTEXT QUESTIONS 9.1

Choose the correct answer in the followings:

1. For an object moving along a straight line without changing its direction the
   (a) distance travelled > displacement
   (b) distance travelled < displacement
   (c) distance travelled = displacement
   (d) distance is not zero but displacement is zero
2. In a circular motion the distance travelled is
   (a) always > displacement
   (b) always < displacements
   (c) always = displacement
   (d) zero when displacement is zero

3. Two persons start from position A and reach to position B by two different paths ACB and AB respectively as shown in Fig. 9.10.

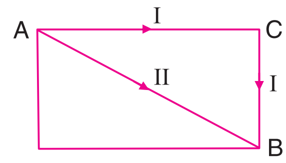


Fig. 9.10

   (a) Their distances travelled are same
   (b) Their displacement are same
   (c) The displacement of $I >$ the displacement of II
   (d) The distance travelled by $I <$ distance travelled by II

4. In respect of the top point of the bicycle wheel of radius R moving along a straight road, which of the following holds good during half of the wheel rotation.
   (a) distance = displacement
   (b) distance < displacement
   (c) displacement = $2R$
   (d) displacement = πR

5. An object thrown vertically upward to the height of 20 m comes to the hands of the thrower in 10 second. The displacement of the object is
   (a) 20 m (b) 40 m (c) Zero (d) 60 m

6. Draw a distance-displacement graph for an object in uniform circular motion on a track of radius 14 m.

9.3 UNIFORM AND NON-UNIFORM MOTION

Let us analyze the data of the motion of two objects A and B given in the table 9.4.

Table 9.4

Time in seconds (t)	0	10	20	30	40	50
Position of A (x_1 in metre)	0	4	8	12	16	20
Position of object B (x_2 in metre)	0	4	12	12	12	20

Do you find any difference between the motion of object A and B? Obviously objects A and B start moving at the same time from rest and both objects travel equal distance in equal time. However, the object A has same rate of change in its position and object B has different rate of change in position. The motion in which an object covers equal distance in equal interval of time is called uniform motion whereas the motion in which distance covered by object is not equal in equal interval of time is called non-uniform motion. Thus, the motion of object A is uniform and of object B is non-uniform. You can draw the position-time graph for the motion of object A and B and observe the nature of the graph for both types of motion.

For the uniform motion of object A the graph is a straight line graph and for non-uniform motion of object B the graph is not a straight line as shown in the Fig. 9.11.

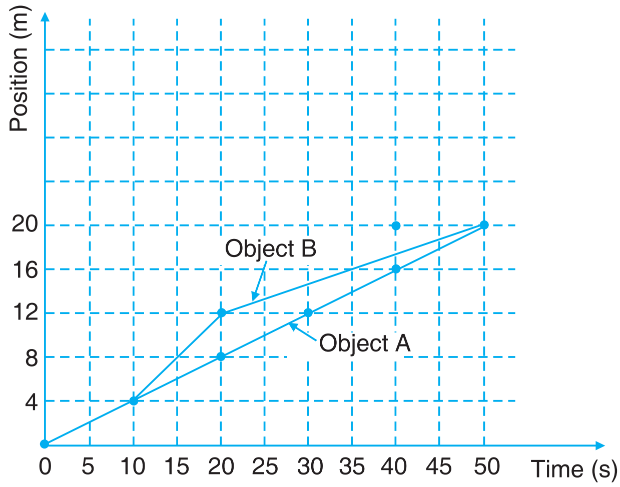


Fig. 9.11 *Graph representing uniform and non-uniform motion*

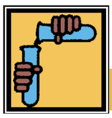
9.3.1 Speed

While you plan your journey to visit a place of your interest you intend to think about time of journey so that you can arrange needful things like eatables etc. for that period of time. How will you do it? For this you would like to know how far you have to reach and how fast you can cover the destination. The measure of how fast motion can take place is the speed. **Speed can be defined as the distance travelled by a body in unit time.**

Thus $$\text{speed} = \frac{\text{Distance travelled}}{\text{time taken}}$$

Its SI unit is metre per second which is written as ms^{-1}. The other commonly used unit is km h^{-1}.

i.e., $$1\ \text{kmh}^{-1} = \frac{1000\ \text{m}}{60 \times 60\ \text{s}} = \frac{5}{18}\text{ms}^{-1}$$



ACTIVITY 9.4

Here position of four bodies *A*, *B*, *C* and *D* are given after equal interval of time i.e. 2 s. Identify the nature of the motion of the bodies as uniform and non-uniform motion.

Table 9.5

Time (s) →	Bodies ↓	0	2	4	6	8
positions (m) →	A	0	4	8	12	16
	B	0	8	8	10	12
	C	4	8	12	16	20
	D	0	6	12	16	20

To identify the nature of the motion you can make a table as given below

Table 9.6

Time taken by body (s) → Distance covered by body (m) ↓	2 – 0 = 2	4 – 2 = 2	6 – 4 = 2	8 – 6 = 2
A	4 – 0 = 4	8 – 4 = 4	12 – 8 = 4	16 – 12 = 4
B	8 – 0 = 8	8 – 8 = 0	10 – 8 = 2	12 – 10 = 2
C	8 – 4 = 4	12 – 8 = 4	16 – 12 = 4	20 – 16 = 4
D	8 – 4 = 4	12 – 6 = 6	16 – 12 = 4	20 – 16 = 4

From the above table you can conclude that body *A* and *C* travel equal distances in equal interval of time so their motion is uniform. But the distances travelled by body *B* and *D* for equal intervals of time are not equal, hence their motion is non-uniform motion.

To analyze the motion as uniform motion or non-uniform motion, the motion can be represented by graph. The position-time graph of all the four bodies *A*, *B*, *C* and *D* is shown in Fig. 9.12.

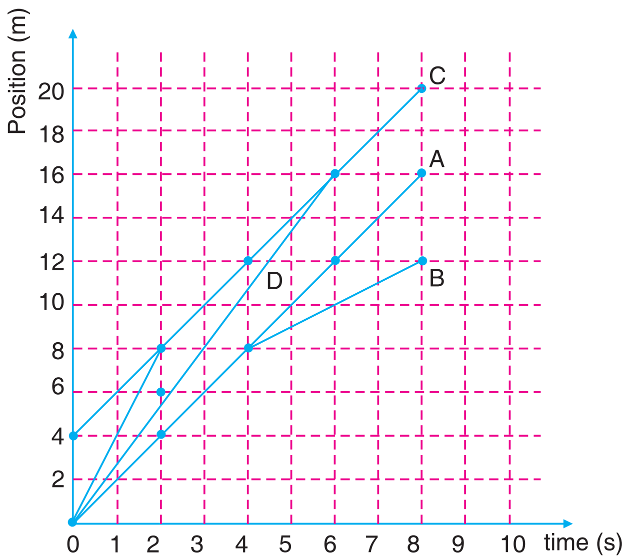


Fig. 9.12

Now you can see that the bodies having uniform motion e.g. *A* and *C* have their graph line straight and the bodies having non-uniform motion do not have their position time graph line straight. In this graphical representation on axis 1 div = 1s and on y-axis 1 div = 2m.

A graph drawn for different distances travelled by object with respect to time is called distance-time graph as shown in Fig. 9.13.

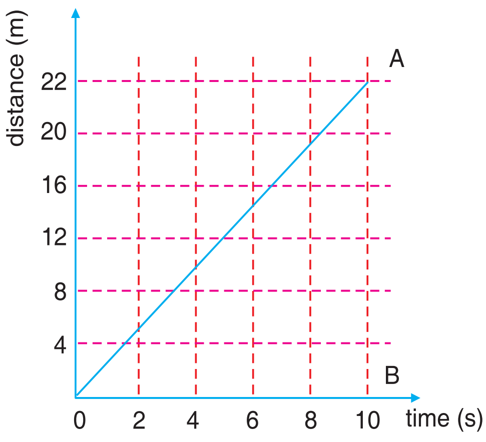


Fig. 9.13

In Fig. 9.13 distance travelled in 10 s is 22 m. Therefore, the speed of the object

$$= \frac{22(\text{m})}{10\ (\text{s})} = 2.2\ \text{ms}^{-1}$$

This motion can be represented by another way i.e., speed $= \frac{AB}{OB}$. This ratio is also known as slope of the graph line. Thus the speed is the slope of position-time graph.

Example 9.1 An object moves along a rectangular path of sides 20 m and 40 m respectively. It takes 30 minutes to complete two rounds. What is the speed of the object?

Solution: $$\frac{\text{Distance travelled}}{\text{time taken}} = \frac{2 \times 2(20+40)\ \text{m}}{30 \times 60\ \text{s}}$$

$$= \frac{4}{30}\text{ms}^{-1}$$

9.3.2 Velocity

If you are asked to reach a destination and you are provided three, four paths of different lengths, which of the path would you prefer? Obviously, the path of shortest length but not always. This is also called displacement. In the previous section you have learnt about distance. When motion is along the shortest path, it is directed from the point of start to the point of finish. How fast this motion is determines the velocity. The velocity is the ratio of length of the shortest path i.e. displacement to the time taken

$$\text{velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

Velocity has same unit as the unit of speed i.e., ms^{-1} (S.I. unit) or kmh^{-1}.

The shortest path or the displacement is directed from initial position of the object to the final position of the object. Hence, the velocity is also directed from initial position of the object to the final position of the object. Thus we can say that the velocity has direction. Speed does not have direction because it depends upon the total distance travelled by the object irrespective of the direction. The quantities which have direction are called vector and which do not have direction are called scalar quantity. Thus, velocity can also be expressed as

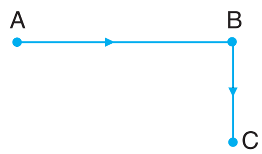
$$\text{velocity} = \frac{\text{Change in position}}{\text{Time taken}}$$

ACTIVITY 9.5

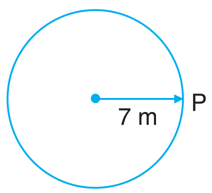
Observe the motion of an object in the following situations. Find speed and velocity in each situation and comment over the situation which you find different from other.

Object moves from A to B in time 10 s on the scale 1 cm = 10 m

Object moves from A to B than to C in 10 s on the scale 1 cm = 10 m



Object moves from A to B than to C in 20 s on the scale 1 cm = 10 m



Object completes a round of radius 7 m in 10 s

Fig. 9.14

Now you will be able to distinguish the speed and velocity. Magnitude of instantaneous velocity is the speed. Now you can understand the importance of preplanning your journey to save time, effort and fuel etc.

Example 9.2 In a rectangular field of sides 60 m and 80 m respectively two formers start moving from the same point and takes same time i.e. 30 minutes to reach diagonally opposite point along two different paths as shown in Fig. 9.15. Find the velocity and speed of both the formers.

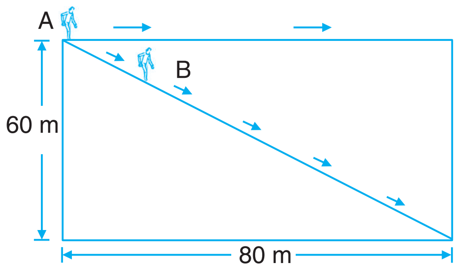


Fig. 9.15

Solution: The displacement of both the former in same i.e.,

$$\sqrt{60^2+80^2} = \sqrt{3600+6400} = \sqrt{10000} = 100 \text{ m}$$

$$\therefore \quad \text{Velocity } A \text{ and } B, \quad v = \frac{\text{displacement}}{\text{time taken}} = \frac{100 \text{ m}}{30 \times 60\text{s}} = \frac{1}{18} \text{ ms}^{-1}$$

$$\text{speed of } A = \frac{\text{Distance travelled}}{\text{time taken}} = \frac{(80+60)\text{m}}{30{\times}60\text{s}}$$

$$= \frac{140}{3800} \text{ ms–1} = \frac{14}{18} \text{ ms}^{-1}$$

and

$$\text{speed of } B = \frac{\text{Distance travelled}}{\text{time taken}} = \frac{100\text{s}}{30{\times}60\text{s}} = \frac{1}{18} \text{ ms}^{-1}$$

Note: In this example you can appreciate that the velocity of both the formers is same but not the speed.

9.3.3 Average speed and average velocity

Speed during a certain interval of time can not be used to determine total distance covered in given time of the journey and also the time taken to cover the total distance of journey. It is because a body does not always travel equal distance in equal interval of time. In most of the cases the body travels non-uniformly. Thus, in case of non-uniform motion to determine average speed is quite useful. The average speed can be determined by the ratio of total distance covered to the total time taken.

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

Similarly in case of average velocity in place of total distance covered you can take total displacement.

$$\therefore \qquad \text{Average speed} = \frac{\text{total displacement}}{\text{total time taken}}$$

Let us take few examples to understand the average speed and average velocity.

Example 9.3 If a body covers 50 m distance in 30 s and next 100 m in 45 s then total distance covered

$$= 50 + 100 = 150 \text{ m}$$

and $\qquad \text{total time taken} = 30 + 45 = 75 \text{ s}$

$$\therefore \qquad \text{Average speed} = \frac{150 \text{ m}}{75 \text{ s}} = 2\text{ms}^{-1}$$

Example 9.4 If an object moves with the speed of 10 ms^{-1} for 10 s and with 8 ms^{-1} for 20 s, then total distance covered will be the sum of distance covered in 10 s and the distance covered in 20 s = $10 \times 10 + 8 \times 20 = 260$ m

$$\therefore \qquad \text{The average speed} = \frac{\text{total distance covered}}{\text{total time taken}}$$

$$= \frac{260 \text{ m}}{(10+20)\text{s}} = \frac{260 \text{ m}}{30 \text{ s}}$$

$$= 8.66 \text{ ms}^{-1}$$

Example 9.5 If a body moves 50 m with the speed of 5 ms^{-1} and then 60 m with speed of 6 ms^{-1}, then total distance covered

$$= 50 + 60 = 110 \text{ m}$$

and total time taken will be the sum of time taken for 50 m and 60 m = 20 s

$$\text{Thus,} \qquad \text{average speed} = \frac{\text{total distance covered}}{\text{total time taken}}$$

$$= \frac{110 \text{ m}}{20 \text{ s}} = 5.5 \text{ ms}^{-1}$$

Example 9.6 If an object moves 30 m toward north in 10 s and then 40 m eastward in next 10s, The displacement of the object will be OB

$$= \sqrt{30^2 + 40^2} = \sqrt{900 + 1600} = \sqrt{2500}$$

$$= 50 \text{ m}$$

$$\therefore \quad \text{The average velocity} = \frac{\text{total displacement covered}}{\text{total time taken}}$$

$$= \frac{50 \text{ m}}{(10+10)\text{ s}} = \frac{50 \text{ m}}{20 \text{ s}} = 2.5 \text{ ms}^{-1}$$

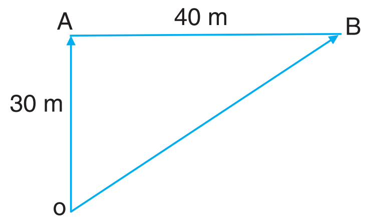


Fig 9.16

Example 9.7 If an object moves along a circular track of radius 14 m and complete one round in 20 s then for one complete round total displacement is zero and the average velocity will also be zero.

From these examples you can conclude that:

(i) Instantaneous speed is the magnitude of instantaneous velocity but average speed is not the magnitude of average velocity.

(ii) Average velocity is less than or equal to the average speed.

(iii) Average velocity can be zero but not average speed.

INTEXT QUESTIONS 9.2

1. Some of the quantities are given in column I. Their corresponding values are written in column II but not in same order. You have to match these values corresponding to the values given in column I:

Column I	Column II
(a) 1 kmh^{-1}	(i) 20 ms^{-1}
(b) 18 kmh^{-1}	(ii) 10 ms^{-1}
(c) 72 kmh^{-1}	(iii) 5/18 ms^{-1}
(d) 36 kmh^{-1}	(iv) 5 ms^{-1}

2. A cyclist moves along the path shown in the diagram and takes 20 minutes from point *A* to point *B*. Find the distance, displacement and speed of the cyclist.

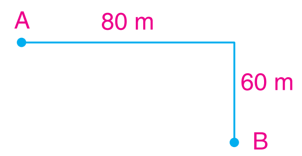


Fig. 9.17

3. Identify the situation for which speed and average speed of the objects are equal.
   (i) Freely falling ball
   (ii) Second or minute needle of a clock
   (iii) Motion of a ball on inclined plane
   (iv) Train going from Delhi to Mumbai
   (v) When object moves with uniform speed

4. The distance-time graph of the motion of an object is given. Find the average speed and maximum speed of the object during the motion.

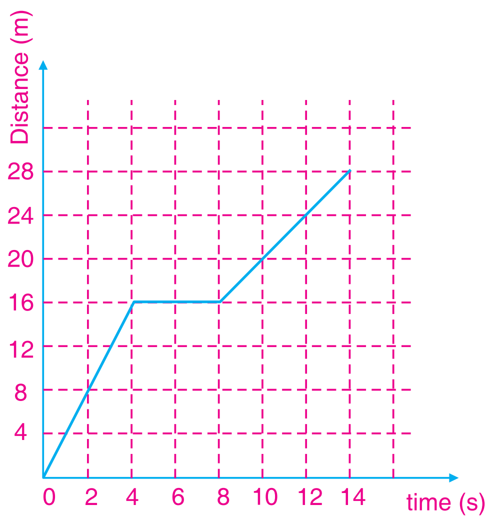


Fig. 9.18

5. The distance travelled by an object at different times is given in the table below. Draw a distance-time graph and calculate the average speed of the object. State whether the motion of the object is uniform or non-uniform.

Table 9.7

Time (s) →	0	10	20	30	40	50
Distance (m) →	0	2	4	6	8	10

6. A player completes his half of the race in 60 minutes and next half of the race in 40 minutes. If he covers a total distance of 1200 m, find his average speed.
7. A train has to cover a distance of 1200 km in 16 h. The first 800 km are covered by the train in 10 h. What should be the speed of the train to cover the rest of the distance? Also find the average speed of the train.
8. A bird flies from a tree *A* to the tree *B* with the speed of 40 km h^{-1} and returns to tree *A* from tree *B* with the speed of 60 km h^{-1}. What is the average speed of the bird during this journey?
9. Three players *P*, *Q* and *R* reach from point *A* to *B* in same time by following three paths shown in the Fig. 9.19. Which of the player has more speed, which has covered more distance?

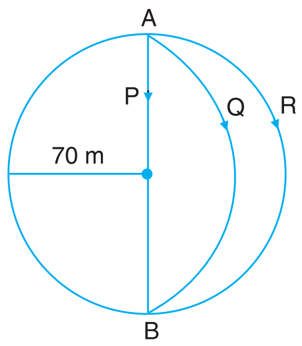


Fig. 9.19

9.4. GRAPHICAL REPRESENTATION OF MOTION

It shows the change in one quantity corresponding to another quantity in the graphical representation.

9.4.1 Position-time Graph

It is easy to analyze and understand motion of an object if it is represented graphically. To draw graph of the motion of an object, its position at different times are shown on y-axis and time on x-axis. For example, positions of an object at different times are given in Table 9.8.

Table 9.8 Position of different objects at different time

Time (s)	0	1	2	3	4	5	6	7	8	9	10
Position (m)	0	10	20	30	40	50	60	70	80	90	100

In order to plot position-time graph for data given in Table 9.8, we represent time on horizontal axis and position on vertical axis drawn on a graph paper. Next, we choose a suitable scale for this.

For example, in Fig. 9.20 one division on horizontal axis represents 1 s of time interval and one division on vertical axis represents in 10 m, respectively. If we join different points representing corresponding position time data, we get straight line as shown in Fig. 9.20. This line represents the position-time graph of the motion corresponding to data given in Table 9.8.

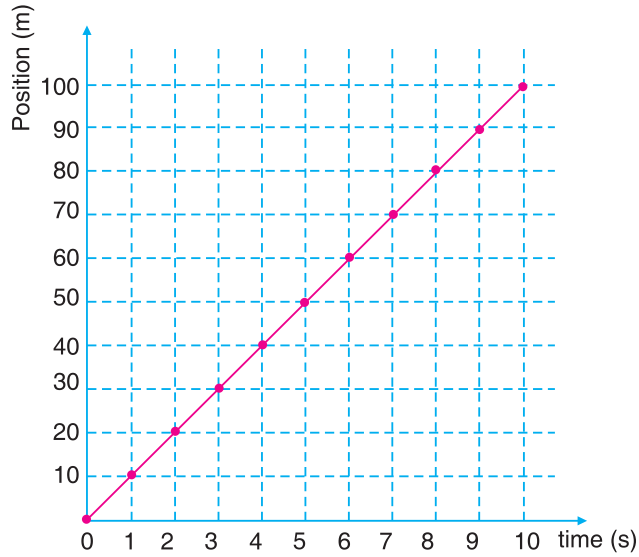


Fig. 9.20 *Position-time graph for the motion of a particle on the basis of data given in table*

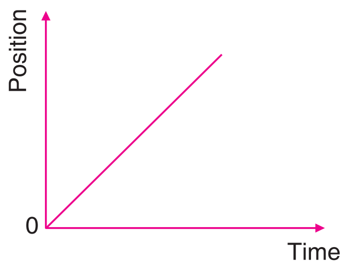
We note from the data that displacement of the object in 1st second, 2nd second,....., 10th second is the same i.e., 10 m. In 10 second, the displacement is 100 m. Therefore, velocity is $\dfrac{100\text{ m}}{10\text{ s}} = 10\text{ ms}^{-1}$ for the whole course of motion. Velocity during 1st second = 10 ms^{-1} and so on.

Thus, velocity is constant i.e., equal to 10 ms^{-1} throughout the motion. The motion of an object in which velocity is constant, is called **uniform motion.**

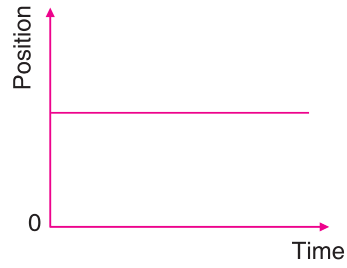
As you see Fig. 9.20, for uniform motion position-time graph is a straight line.

Like position-time graph, you can also plot displacement-time graph. Displacement is represented on the vertical axis and time interval on the horizontal axis. Since displacement in each second is 10 m for data in table, the same graph (Fig. 9.20) also represents the displacement-time graph if vertical axis is labeled as displacement.

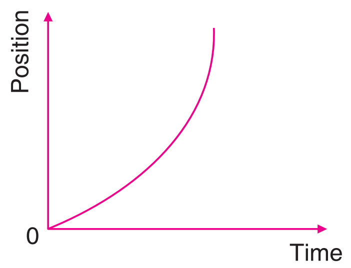
For good understanding you can observe the following graphs.



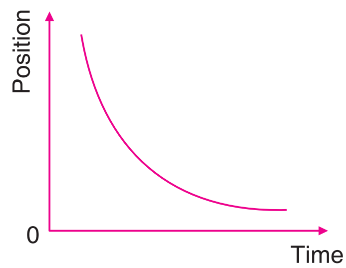
(A) Uniform motion



(B) Object is at rest



(C) Non-uniform motion, rate of change in position is increasing



(D) Non-uniform motion, rate of change in position is decreasing

Fig. 9.21 *Graph (A), (B), (C), (D)*

9.4.2 Velocity-Time Graph

Take time on the horizontal axis and velocity on the vertical axis on a graph paper. Let one division on horizontal axis represent 1 s and one division on vertical axis represent 10 ms^{-1}. Plotting the data in Table 9.9 gives us the graph as shown in Fig. 9.22.

Table 9.9 Velocity-time data of objects *A* and *B*

Time (s)	0	1	2	3	4	5	6	7	8
Velocity of *A* (ms^{-1})	0	10	20	30	40	50	60	70	80
Velocity of *B* (ms^{-1})	0	10	10	10	10	10	10	10	10

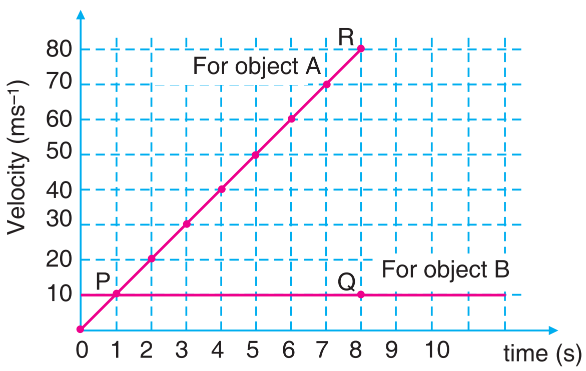


Fig. 9.22 *Velocity-time graph for the motion of object A and B on the basis of data given in table*

Lines *OR* and *PQ* represent the motion of object *A* and *B* respectively. Thus, we see that the velocity-time graph of motion represented in Table 9.9 is a straight line and parallel to time axis for object *B*. This is so because the velocity is constant throughout the motion. The motion is uniform. Consider the area under the graph in Fig. 9.22 for object *B*.

Area = (8s) × (10 ms^{-1}) = 80 m. This is equal to the displacement of the object B in 8 s.

Area under velocity-time graph = Displacement of the object during that time interval

Similarly for object *A* area under the graph in Fig. 9.22.

$$=\frac{1}{2}(8\ \text{s})\times(80-0)\ \text{ms}^{-1}$$

$$=\frac{1}{2}(8)\times(80)\ \text{m}\ = 320\ \text{m}$$

This is equal to the displacement of object *A* in 8 s.

Though, we obtained this result for object *B* for a simple case of uniform motion, it is general result.

Let x be displacement of an object in time t, moving with uniform velocity v, then

$$x = vt \text{ (for uniform motion)}$$

You may have seen the motion of objects moving differently. Can you think what make this difference? Observe the motion of a ball on a floor. The ball slows down and finally comes to rest. This means that the velocity during different time intervals of motion is different. In other words velocity is not constant. Such a motion is called accelerated motion.

9.5 ACCELERATION

In the previous section we have learnt about the non-uniform motion in which the change in velocity in different intervals of motion is different. This change in velocity with time is called **acceleration.** Thus, the acceleration of an object is defined as the change in velocity divided by the time interval during which this occurs.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time interval}}$$

Its unit is ms^{-2}. It is specified by direction. Its direction is along the direction of change in velocity. Suppose the velocity of an object changes from 10 ms^{-1} to 30 ms^{-1} in a time interval of 2 s.

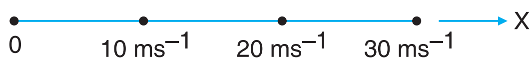


Fig. 9.23 *Changing velocity*

The acceleration, $a = \dfrac{30\ \text{ms}^{-1} - 10\ \text{ms}^{-1}}{2.0\text{s}} = 10\ \text{ms}^{-2}$

This means that the object accelerates in +x direction and its velocity increases at a rate of 10 ms^{-1} in every second.

If the acceleration of an object during its motion is constant, we say that object is moving with **uniform acceleration**. The velocity-time graph of such a motion is straight line inclined to the time axis as shown in Fig. 9.24.

For a given time interval, if the final velocity is more than the initial velocity, then according to Fig. 9.24, the acceleration will be positive. However, if the final velocity is less than the initial velocity, the acceleration will be negative.

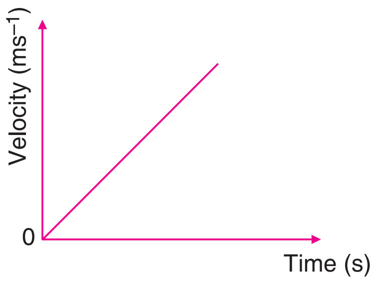


Fig. 9.24 *velocity-time graph of an object moving with uniform acceleration*

When velocity of the object is constant, acceleration will be zero. Thus, for uniform motion, the acceleration is zero and for **non-uniform** motion, the acceleration is non-zero.

Example 9.8 Find the distance and displacement from the given velocity-time graph in Fig. 9.25.

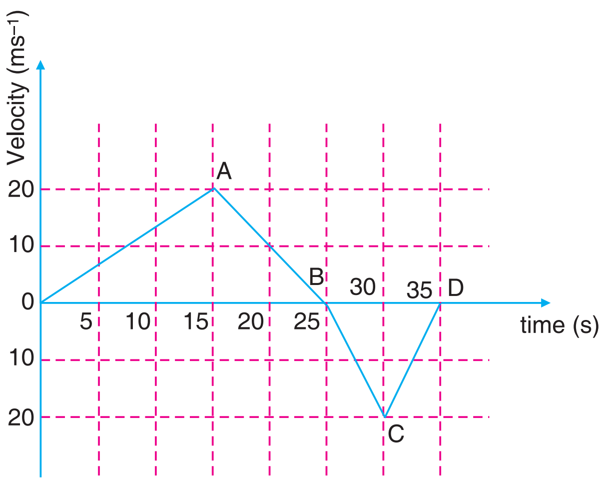


Fig. 9.25

Solution:

$$\text{Distance travelled} = \text{Area of } \Delta OAB + \text{Area of } \Delta BCD$$

$$= \frac{1}{2}(25) \times (20) + \frac{1}{2}(10) \times (20)$$

$$= 250 + 100 = 350 \text{ m}$$

$$\text{Displacement} = \text{Area of } \Delta OAB - \text{Area of } \Delta BCD$$

$$= \frac{1}{2}(25) \times (20) - \frac{1}{2}(10) \times (20)$$

$$= 250 - 100 = 150 \text{ m}$$

Example 9.9 From the given velocity-time graph obtain the acceleration-time graph.

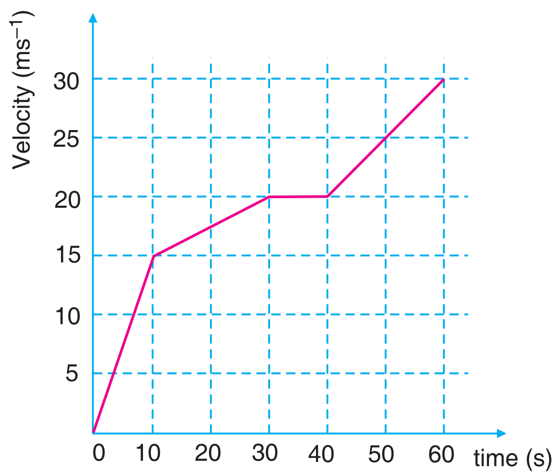


Fig. 9.26

Solution: From the given graph acceleration for 0 – 10 s time interval

$$= \frac{15-0}{10-0} = 1.5 \text{ ms}^{-2}$$

acceleration for 10 – 20s time interval in same as for 20 – 30s time interval

$$= \frac{20-15}{30-10} = \frac{5}{20} = 0.25 \text{ ms}^{-2}$$

acceleration for 30 – 40s time interval $= \dfrac{20-20}{40-30} = 0$

acceleration for 40 – 50 and 50 – 60s interval $= \dfrac{30-20}{60-40} = \dfrac{10}{20} = 0.5\ ms^{-2}$

For all the above time intervals the acceleration-time graph can be drawn as shown in Fig. 9.27.

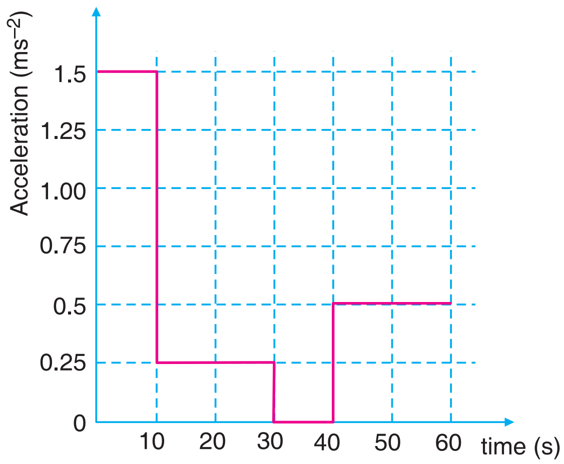


Fig. 9.27

INTEXT QUESTIONS 9.3

1. Describe the motion of an object shown in Fig. 9.28.

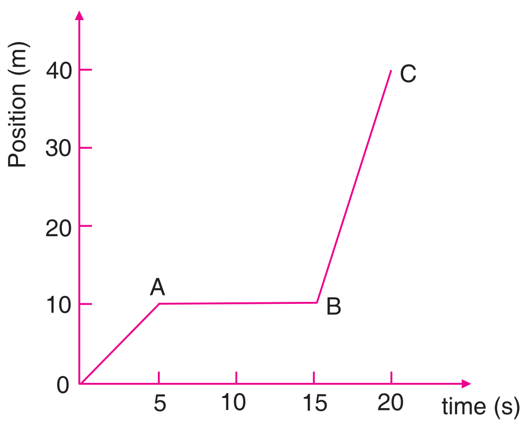


Fig. 9.28 *Position-time graph of an object*

2. Compare the velocity of two objects where motion is shown in Fig. 9.29.

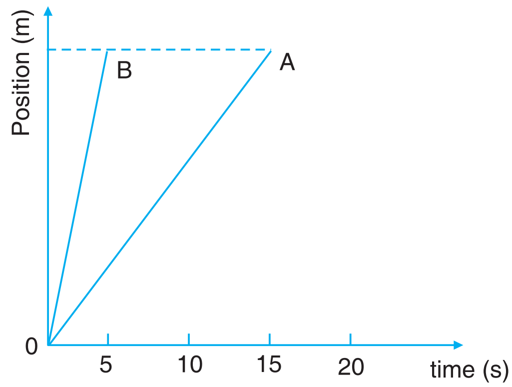


Fig. 9.29 *Position-time graph for object A and B.*

3. Draw the graph for the motion of object *A* and *B* on the basis of data given in Table 9.10.

Table 9.10

Time (s)	0	10	20	30	40	50
Position (m) for *A*	0	5	5	5	5	5
Position (m) for *B*	0	2	4	6	8	10

4. A car accelerates from rest uniformly and attains a maximum velocity of 2 ms^{-1} in 5 seconds. In next 10 seconds it slows down uniformly and comes to rest at the end of 10^{th} second. Draw a velocity-time graph for the motion. Calculate from the graph (i) acceleration, (ii) retardation, and (iii) distance travelled.

5. A body moving with a constant speed of 10 ms^{-1} suddenly reverses its direction of motion at the 5^{th} second and comes to rest in next 5 second. Draw a position-time graph of the motion to represent this situation.

9.6 EQUATIONS OF MOTION

Consider an object moving with uniform acceleration, a. Let u be the initial velocity (at time $t = 0$), v, velocity after time t and S, displacement during this time interval. There are certain relationships between these quantities. Let us find out.

We know that

$$\text{Acceleration} = \frac{\text{Chnage in velocity}}{\text{Time interval}}$$

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

or $$v = u + at \qquad ...(9.1)$$

This is called as the first equation of motion.

Also, we know that

$$\text{Displacement} = (\text{average velocity}) \times (\text{time interval})$$

or $$s = \left(\frac{v+u}{2}\right)t = \left(\frac{u+at+u}{2}\right)t \qquad (\because\ v = u + at)$$

or $$s = ut + \frac{1}{2}at^2 \qquad ...(9.2)$$

This is called the second equation of motion.

If object starts from rest, $u = 0$ and

$$s = 0 \times t + \frac{1}{2}at^2$$

or $$s = \frac{1}{2}at^2$$

Thus, we see that the displacement of an object undergoing a constant acceleration is proportional to t^2, while the displacement of an object with constant velocity (zero acceleration) is proportional to t.

Now, if we take $a = \frac{v-u}{t}$ and $s = \left(\frac{v+u}{2}\right).t$ and multiply them, we find that

$$a.s = \frac{(v-u)}{t}\left(\frac{v+u}{2}\right)t = \frac{v^2-u^2}{2}$$

or $$2a.s = v^2 - u^2$$

or $$v^2 = u^2 + 2as \qquad ...(9.3)$$

This is called as third equation of motion. In case of motion under gravity 'a' can be replaced by 'g'.

INTEXT QUESTIONS 9.4

1. A ball is thrown straight upwards with an initial velocity 19.6 ms^{-1}. It was caught at the same distance above the ground from which it was thrown:

   (i) How high does the ball rise?

   (ii) How long does the ball remain in air? (g = 9.8 ms^{-2})

2. A brick is thrown vertically upwards with the velocity of 192.08 ms^{-1} to the labourer at the height of 9.8 m. What are its velocity and acceleration when it reaches the labourer?
3. A body starts its motion with a speed of 10 ms^{-1} and accelerates for 10 s with 10 ms^{-2}. What will be the distance covered by the body in 10 s?
4. A car starts from rest and covers a distance of 50 m in 10 s and 100 m in next 10 s. What is the average speed of the car?

9.7 UNIFORM CIRCULAR MOTION

You may have seen the motion of the bicycle on a straight level road. Do all movable parts of the bicycle move alike? If not, then how are they moving differently? Does the peddling make a difference in these motions? Like Nimish, number of questions you may have in your mind. Let us try to answer these questions. Bicycle is moving on a straight road so its motion is rectilinear motion.

Fig. 9.30 *Bicycle moving on a road*

Now look at the wheels of the bicycle. Any point on the wheel of the bicycle always remains at a constant distance from the axis of the wheel and moves around the fixed point i.e., axis of the wheel. On the basis of this description of motion of the wheel you can decide very obviously that this motion is circular motion.

Similarly, can you think about the motion of the flywheel of the bicycle? During non-peddling, there is no circular motion of flywheel and it moves in a straight line thus, its motion is rectilinear motion. But during the peddling its motion is circular motion can you think about the motion of any part of the bicycle which has two types of motion at the same time? Yes, during the circular motion of the wheel or flywheel, they are also advancing in forward direction on a straight road. Thus, there motion is circular motion as well as rectilinear motion at the same time.

Now consider the motion of an object along a circular track of radius R through four points *A*, *B*, *C* and *D* on the track as shown in Fig. 9.31. If object completes each round of motion in same time, than it covers equal distance in equal interval of time and its motion will be uniform motion. Since during this uniform motion equal distance is being covered in equal interval of time, therefore, the ratio of distance covered to the time taken i.e., speed will remain constant. It means **in uniform circular motion speed remains constant.**

Now think about velocity, velocity remains along the direction of motion. In Fig. 9.31 you can see the direction of motion changes at every point as shown at point *A*, *B*, *C* and *D*. Since there is a change in direction of motion, therefore, the direction of velocity also changes. We can say that in uniform circular motion, velocity changes due to change in direction of motion and the motion of the object is accelerated motion. This acceleration is due to change in the direction of motion. But in this motion speed remains constant. How interested this motion is because a body moving with constant speed acquires acceleration.

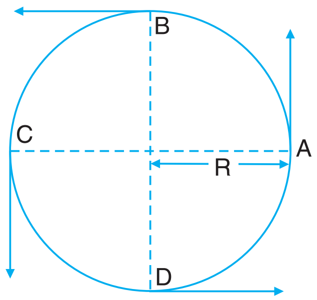


Fig. 9.31 *Circular motion*

Think and Do

K	I	L	O	M	E	T	R	E	T	O
S	P	E	E	D	T	O	N	C	N	E
O	N	D	I	S	T	A	A	N	O	E
P	D	I	S	P	L	A	C	D	I	A
A	N	S	V	E	L	O	C	I	T	Y
T	A	P	P	E	E	R	C	S	A	N
K	A	L	U	D	I	N	E	T	R	A
T	E	A	M	Y	O	Y	L	A	E	D
M	A	C	H	I	N	E	E	N	L	L
E	P	E	P	T	A	D	R	C	E	K
T	O	M	F	T	R	E	A	E	C	D
R	N	E	N	G	I	N	T	G	C	Q
E	E	N	K	L	O	M	E	T	A	R

In the above word grid identify the meaningful words, related to description of motion, in horizontal or vertical columns in sequence and define them (at least three).

INTEXT QUESTIONS 9.5

1. In circular motion the point around which body moves
   - (a) always remain in rest
   - (b) always remain in motion
   - (c) may or may not be in motion
   - (d) remain in oscillatory motion
2. In uniform circular motion
   - (a) speed remain constant
   - (b) velocity remain constant
   - (c) speed and velocity both remain constant
   - (d) neither speed nor velocity remain constant
3. A point on a blade of a ceiling fan has
   - (a) always uniform circular motion
   - (b) always uniformly accelerated circular motion
   - (c) may be uniform or non-uniform circular motion
   - (d) variable accelerated circular motion

WHAT YOU HAVE LEARNT

- If a body stays at the same position with time, it is at rest.
- If the body changes its position with time, it is in motion.
- Motion is said to be rectilinear if the body moves in the same straight line all the time. e.g., a car moving in straight line on a level road.
- The motion is said to be circular if the body moves on a circular path; e.g. the motion of the tip of the second needle of a watch.
- The total path length covered by a moving body is the distance travelled by it.
- The distance between the final and initial position of a body is called its displacement.
- Distance travelled in unit time is called speed, whereas, displacement per unit time is called velocity.

- Position-time graph of a body moving in a straight line with constant speed is a straight line sloping with time axis. The slope of the line gives the velocity of the object in motion.
- Velocity-time graph of a body in straight line with constant speed is a straight line parallel to time axis. Area under the graph gives distance travelled.
- Velocity-time graph of a body in straight line with constant acceleration is a straight line sloping with the time axis. The slop of the line gives acceleration.
- For uniformly accelerated motion

$$v = u + at$$

$$\mathbf{s} = ut + \frac{1}{2}at^2$$

and $$v^2 = u^2 + 2as$$

where u = initial velocity, v = final velocity, and s = distance travelled in t seconds

TERMINAL EXERCISE

1. An object initially at rest moves for t seconds with a constant acceleration a. The average speed of the object during this time interval is

   (a) $\frac{a \cdot t}{2}$; (b) $2a \cdot t$; (c) $\frac{1}{2}a \cdot t^2$; (d) $\frac{1}{2}a^2 \cdot t$

2. A car starts from rest with a uniform acceleration of 4 ms^{-2}. The distance travelled in metres at the ends of 1s, 2s, 3s and 4s are respectively,

   (a) 4, 8, 16, 32 (b) 2, 8, 18, 32

   (c) 2, 6, 10, 14 (d) 4, 16, 32, 64

3. Does the direction of velocity decide the direction of acceleration?
4. Establish the relation between acceleration and distance travelled by the body
5. Explain whether or not the following particles have acceleration:

   (i) a particle moving in a straight line with constant speed, and

   (ii) a particle moving on a curve with constant speed.

6. Consider the following combination of signs for velocity and acceleration of an object with respect to a one dimensional motion along x-axis and give example from real life situation for each case:

Table 9.11

Velocity	Acceleration	Example
(a) Positive	Positive	Ball rolling down on a slope like slide or ramp
(b) Positive	Negative	
(c) Positive	Zero	
(d) Negative	Positive	
(e) Negative	Negative	
(f) Negative	Zero	
(g) zero	Positive	
(h) Zero	Negative	

7. A car travelling initially at 7 ms^{-1} accelerates at the rate of 8.0 ms^{-2} for an interval of 2.0 s. What is its velocity at the end of the 2 s?
8. A car travelling in a straight line has a velocity of 5.0 ms^{-1} at some instant. After 4.0 s, its velocity is 8.0 ms^{-1}. What is its average acceleration in this time interval?
9. The velocity-time graph for an object moving along a straight line has shown in Fig. 3.32. Find the average acceleration of this object during the time interval 0 to 5.0 s, 5.0 s to 15.0 s and 0 to 20.0 s.

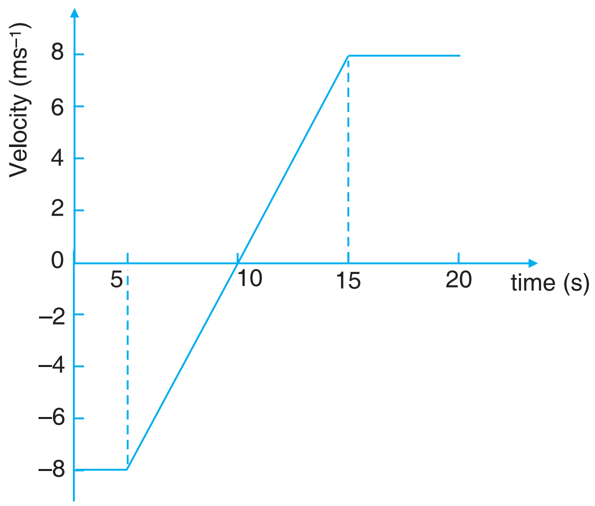


Fig. 9.32

10. The velocity of an automobile changes over a period of 8 s as shown in the table given below:

Table 9.12

Time (s)	Velocity (ms^{-1})	Time (s)	Velocity (ms^{-1})
0.0	0.0	5.0	20.0
1.0	4.0	6.0	20.0
2.0	8.0	7.0	20.0
3.0	12.0	8.0	20.0
4.0	16.0		

(i) Plot the velocity-time graph of motion.

(ii) Determine the distance the car travels during the first 2 s.

(iii) What distance does the car travel during the first 4 s?

(iv) What distance does the car travel during the entire 8 s?

(v) Find the slope of the line between t = 5.0 s and t = 7.0 s. What does the slope indicate?

(vi) Find the slope of the line between t = 0 s to t = 4 s. What does this slope represent?

11. The position-time data of a car is given in the table given below:

Table 9.13

Time (s)	Position (m)	Time (s)	Position (m)
0	0	25	150
5	100	30	112.5
10	200	35	75
15	200	40	37.5
20	200	45	0

(i) Plot the position-time graph of the car.

(ii) Calculate average velocity of the car during first 10 seconds.

(iii) Calculate the average velocity between t = 10 s to t = 20 s.

(iv) Calculate the average velocity between t = 20 s and t = 25 s. What can you say about the direction of the motion of car?

12. An object is dropped from the height of 19.6 m. Draw the displacement-time graph for time when object reach the ground. Also find velocity of the object when it touches the ground.

Notes

13. An object is dropped from the height of 19.6 m. Find the distance travelled by object in last second of its journey.

14. Show that for a uniformly accelerated motion starting from velocity u and acquiring velocity v has average velocity equal to arithmetic mean of the initial (u) and final velocity (v).

15. Find the distance, average speed, displacement, average velocity and acceleration of the object whose motion is shown in the graph (Fig. 9.33).

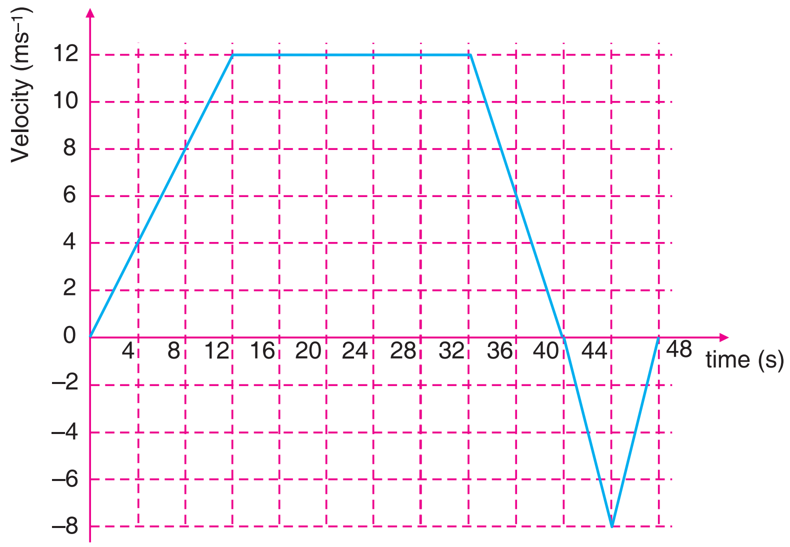


Fig. 9.33

16. A body accelerates from rest and attains a velocity of 10 ms^{-1} in 5 s. What is its acceleration?

ANSWERS TO INTEXT QUESTIONS

9.1

1. (c) 2. (a) 3. (b) 4. (a) 5. (c)

6.

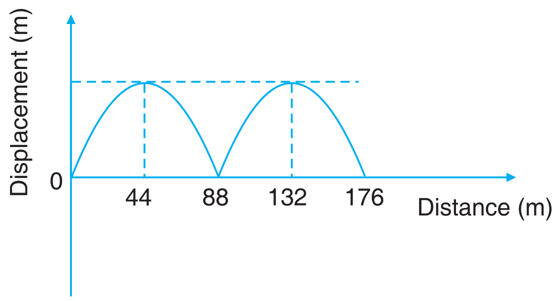


Fig. 9.34

9.2

1. (a) (iii) (b) (iv) (c) (i) (d) (ii)
2. Distance = 140 m, Displacement = 100 m, Speed = 7 ms^{-1}
3. When object moves with uniform speed
4. 2ms^{-1}, 5 ms^{-1}
5. Average speed = 0.2 ms^{-1}, motion is uniform motion

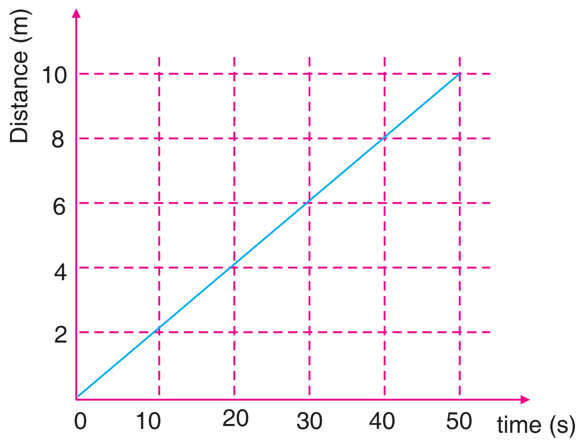


Fig. 9.35

6. 0.2 ms^{-1} 7. 63 km h^{-1} 8. 48 km h^{-1} 9. R, R

9.3

1. For first five seconds object moves with constant speed i.e. 2ms^{-1}. From 5 to 15 second it remains at rest and then from 15 to 20 seconds it moves with constant speed 2 ms^{-1}.

   The motion of the object is not uniform.
2. Velocity of object *A* is 4 times the velocity of *B*.
3.

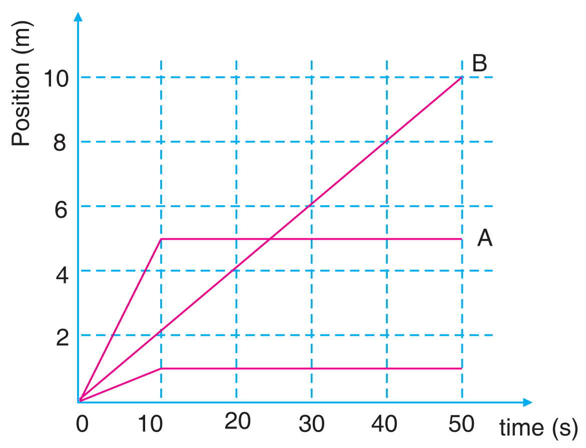


Fig. 9.36

4.

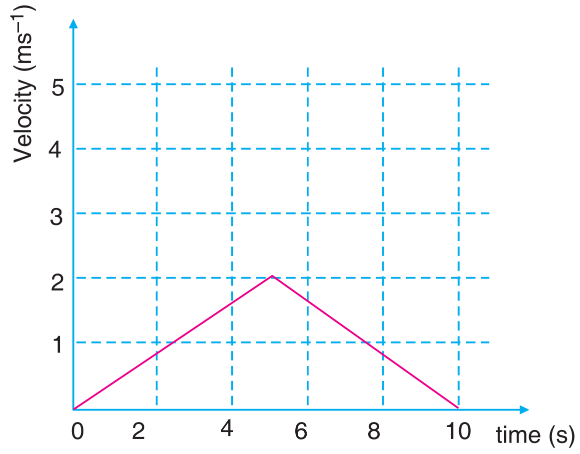


Fig. 9.37

(i) $a = 0.4\ \text{ms}^{-2}$, (ii) $-a = 0.4\ \text{ms}^{-2}$, (iii) 10 m

5.

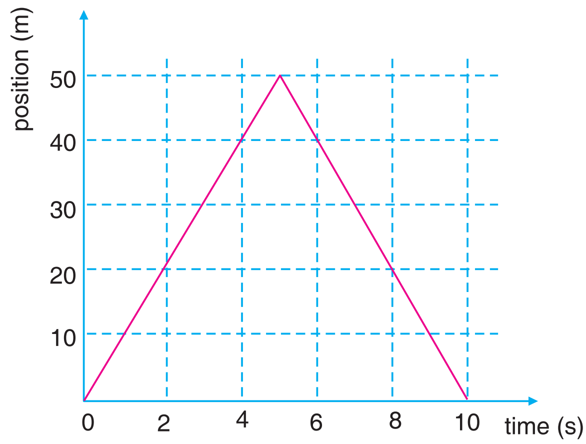


Fig. 9.38

9.4

1. (i) 19.6 m, (ii) 4 s
2. Zero and $9.8\ \text{ms}^{-2}$
3. 600 m
4. $7.5\ \text{ms}^{-1}$

9.5

1. (a)
2. (a)
3. (b)

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10

FORCE AND MOTION

In the previous lesson you have learnt about the motion of a body along a straight line. You also know that motion can be uniform or non-uniform. You might have seen that a body at rest can be brought to motion and a moving body can be brought to rest. Do you know what makes bodies at rest to move or stop if they are in motion? What changes the speed or direction of a moving object? Why do the dust particles get detached from a carpet when it is beaten with a stick? Why does a ball rolling along the ground stops after moving through some distance? Why cutting tools always have sharp edges?

In this lesson we shall try to find the answer of all such questions.

OBJECTIVES

After completing this lesson, you will be able to:

- *explain the cause of motion - concept of force;*
- *distinguish between balanced and unbalanced forces;*
- *define the terms inertia, mass and momentum;*
- *state and explain the three laws of motion and explain their significance in daily life and nature;*
- *derive a relationship between force, mass and acceleration;*
- *explain the force of friction and analyze the factors on which it depends;*
- *illustrate and appreciate that rolling friction is less than sliding friction;*
- *cite examples from everyday life where importance of friction can be appreciated and*
- *explain the terms thrust and pressure, citing example from daily life situations.*

10.1 FORCE AND MOTION

If we place a ball on a flat surface, it will remain there until unless we disturb it. It will move only when either we push it or pull it. This push or pull acting on an object is known as a **force**. What else happens when we apply force on an object? Think! Let us do an activity to understand it.

ACTIVITY 10.1

Hold an inflated balloon between your palms. Now, apply a force on it by pressing your palms (Fig. 10.1). What do you observe?

You will observe that on pressing the balloon, its shape changes. Thus, we can say that on applying force, the shape of a body can be changed. Can you now think of some other effect of force?

Fig. 10.1 *Shape of balloon changes on applying force on it*

While playing football if you want to change the direction of the moving ball you will have to kick the ball in a particular direction. When you kick the ball, you apply certain force to change the direction of the moving ball. Similarly, you can also change the speed of a moving object by applying force on it. For example the speed of a moving bicycle can be changed by applying brakes on it.

Thus, on the basis of above examples and activities we can say that the force applied on an object can

- make the object move from rest.
- change the speed of a moving object.
- change the direction of motion of the object
- change the shape of the object.

Now, it is time to assess how much have you learnt?

INTEXT QUESTIONS 10.1

1. Is there any force applied when a cricket player changes the direction of ball by using his/her bat?

Notes

2. Give an example from your daily life in which the shape of an object changes by applying a force.

10.2 BALANCED AND UNBALANCED FORCES

Have you even seen a game of tug-of-war (Fig. 10.2)? In this game when the two teams pull with equal force they apply balanced forces on the rope. The rope thus remains stationary. When one of the teams applies greater force, it is able to pull the other team and the rope towards their side. In this case forces are unbalanced.

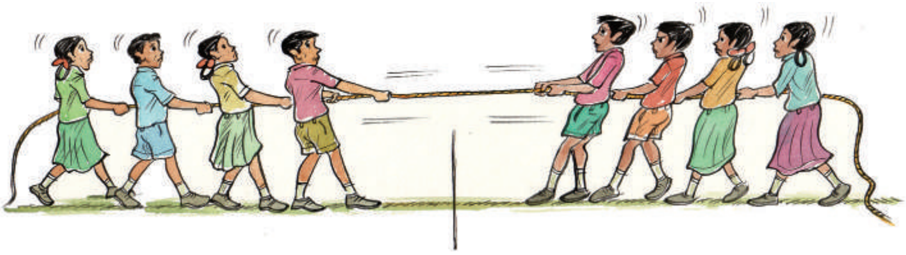
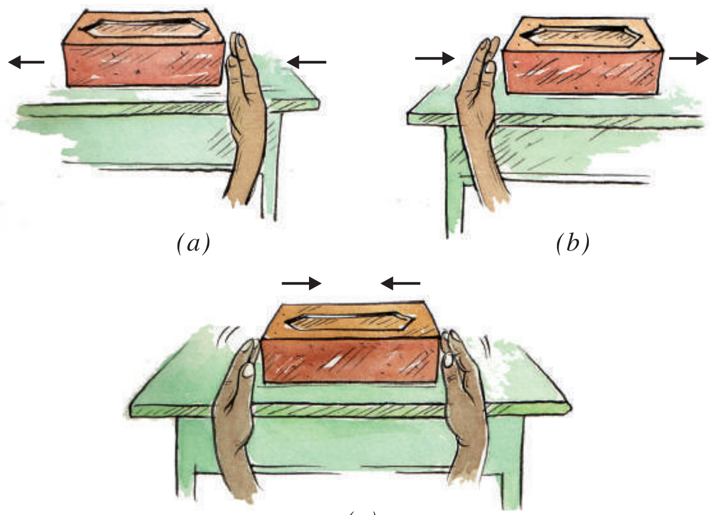


Fig. 10.2 *Tug of war*

For understanding the concepts of balanced and unbalanced forces, let us perform the following activity.

ACTIVITY 10.2

Place a brick on a table. Push the brick towards left with your right hand. What do you observe? The brick begins to move to the left direction [Fig. 10.3 (a)]. Now push the brick towards right with your left hand. In which direction the brick moves this time [Fig. 10.3 (b)]?



(a) (b)

(c)

Fig. 10.3 *Unbalanced and balanced forces*

Now push the brick from both the sides with equal forces [Fig. 10.2 (c)]. What do you observe? In this case you will observe that the brick does not move in any direction. Can you think why the brick does not move this time? In fact, in this case the two forces balance each other. Such forces are called **balanced forces**.

What type of changes can be produced by balanced forces? As seen above, balanced forces do not change the state of rest or motion of the object on which they are applied. Now recall the activity 10.1 and think whether it was balanced or unbalanced force on the balloon? Yes, you are right, it was the balanced force applied by your palms that changed the shape of balloon.

What happen when the two opposite forces acting on the brick are of different magnitudes? In this case the brick would begin to move in the direction of greater force. Such forces are called **unbalanced forces**. Unbalanced forces acting on an object may change its state of rest or motion.

Try to find out some more examples of balanced and unbalanced forces.

INTEXT QUESTIONS 10.2

1. What are balanced forces?
2. Can a balanced force produces any acceleration in a body?
3. What type of change can be produced by an unbalanced force in a body?

10.3 NEWTON'S LAWS OF MOTION

10.3.1 Inertia

You would have seen that whenever we shake the branches of a tree vigorously, the leaves and fruits get detached. Similarly, when you beat a carpet with a stick, you will see that the dust particles get detached from the carpet. Do you know why?

The answer to all such questions is inertia. What is inertia? We can understand the property of inertia by doing a simple activity.

ACTIVITY 10.3

Take a smooth sheet of paper (30 cm × 8 cm) and place it on a table with some part of it coming out of the edge of the table. Now place a glass half filled with water on the paper. Remove the paper with a jerk (Fig. 10.4). What do you observe? You will find that the glass remains in its position. The inertia of the glass prevents it from moving with the paper.

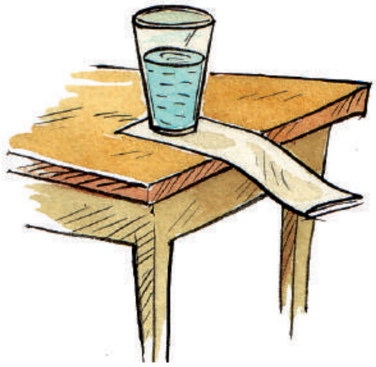


Fig. 10.4 *Glass remains in its position due to inertia*

Thus we can say that the inertia is the tendency of objects to stay at rest or to keep moving with the same velocity. You can find out some more examples of inertia from your daily life. In fact it is the inertia due to which a sprinter keeps running for some time even after crossing the finish line. Similarly, you would have noticed that it is difficult to take out the tomato sauce from a bottle by just inverting it. However, it is easy to take out the sauce from the bottle by giving a sudden jerk to it. By moving the bottle in the downward direction the sauce comes in motion. When the bottle stops suddenly, the sauce remains in motion due to inertia of motion and comes out of the bottle.

10.3.2 Inertia and Mass

By now you have learnt that due to inertia an object offer resistance to change its state of motion. Do all objects have the same inertia? Let us find out.

Push an empty box on a smooth surface. Now try to push a similar box full of books on the same surface. What do you find? Why is it easier to push an empty box than a box full of books?

Now suppose you are asked to stop a table tennis ball and a cricket ball moving with the same velocity. On which ball you are supposed to apply more force to stop it. You will find that cricket ball require more force to stop as compared to table tennis ball.

Thus all objects do not resist a change in their state of rest or motion equally. Massive objects resist more than lighter ones. What do you conclude from these observations? We can say that mass is a measure of inertia.

10.3.3 Newton's First Law of Motion

You have learnt that an object offer resistance to change in its state of motion. This was studied by Newton in detail and he presented his findings in the form of three fundamental laws that govern the motion of objects. Newton's first law of motion is stated as follows:

"Every body continues in its state of rest or of uniform motion in a straight line until unless it is compelled by some unbalanced force to change that state."

Newton's first law of motion tells us that all bodies resist a change in their state of motion. We know that this property of bodies is called inertia. That is why, Newton's first law of motion is also known as the law of inertia.

First law of motion has many applications in our daily life. Why do the passengers standing in a bus fall in the backward direction when the stationary bus begins to move suddenly (Fig. 10.5)?

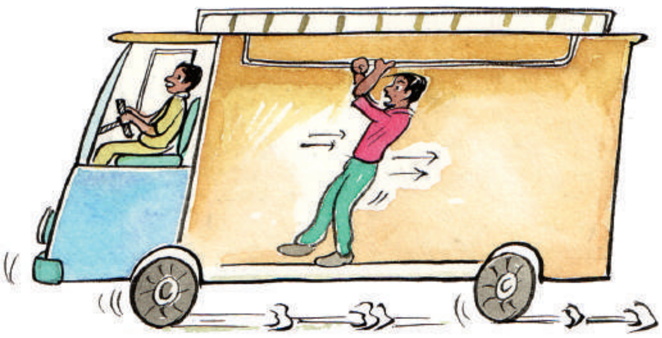


Fig. 10.5 *Passengers falling in the backward direction when the bus starts suddenly*

This observation can be explained on the basis of first law of motion. The feet of passengers are in contact with the bus. When the bus starts suddenly, the feet start moving with the bus. But the upper part of the passengers tries to remain at rest due to inertia and tends to fall in the backward direction.

What happen when the moving bus stops suddenly? In this case the passengers standing in the bus fall in the forward direction. Can you think the reason of it on the basis of the explanation of the above example?

Fig. 10.6 *Passengers falling forward as the moving bus stops suddenly*

Now you should be able to explain why do the dust particles get detached from a carpet when it is beaten with a stick? Try to explain it on the basis of first law of motion.

10.3.4 Momentum

You have learnt in the earlier section that the force required to stop a moving body depends upon its mass. Now suppose two balls of same mass are moving with different velocities. Which ball will need more force to stop? You will find that the faster moving ball require more force to stop it. Thus, the force required to stop a body also depends upon its velocity.

You must have noticed that a small bullet when fired from a gun can kill a person. But the same bullet if thrown with hand can hardly do any harm. Similarly a truck parked along a road side does not require any attention. But a moving truck may kill a person standing in its path. Is it only the velocity of the truck which makes us frightened? If it is so, then a toy car moving with the same velocity as the truck would have equally frightened to us.

From these observations it appears that the impact produced by the objects depends on their mass and velocity. These two quantities help us to define a new quantity called **momentum**.

The momentum, p of a moving body is defined as the product of its mass, m and velocity, v. That is

$$p = mv \tag{10.1}$$

SI unit of momentum is kilogram-metre per second (kg m s^{-1}). Momentum has both magnitude and direction. Its direction is same as that of velocity.

10.3.5 Newton's second law of motion

According to Newton's first law of motion the application of an unbalanced force brings a change in the velocity of an object. Thus, the force can produce a change of momentum. Newton's second law of motion establishes a relationship between force and change in momentum.

Second law of motion states that the **rate of change of momentum of a body is directly proportional to the force acting on it and takes place in the same direction as the force.**

Sir Isaac Newton
(1642-1727)

Newton's second law of motion also gives a relation between force and acceleration. Let us derive this relationship.

Suppose the velocity of an object of mass m changes from u to v in time t by the application of a constant force F.

The magnitude of initial and final momentum of the object will be p_1 = mu and $p_2 = mv$ respectively. The change in momentum in time $t = p_2 - p_1$.

The rate of change of momentum = $\dfrac{(p_2 - p_1)}{t}$

According to second law of motion, the magnitude of the force F, is

$$F \propto \frac{p_2 - p_1}{t}$$

or $$F = \frac{k(p_2 - p_1)}{t} \qquad ...(10.2)$$

where k is constant of proportionality.

Substituting the value of p_1 = mu and p_2 = mv, we get

$$F = \frac{k(mv - mu)}{t}$$

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

Now, $\dfrac{v-u}{t}$ is the rate of change of velocity, which is the acceleration 'a'. Therefore, we have

$$F = \text{kma} \qquad (10.3)$$

We choose the unit of force in such a manner that the value of k becomes one. For this we can define one unit of force as that amount which produces an acceleration of 1 m/s^2 in an object of 1kg mass. So that:

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

Thus, the value of constant k becomes 1. Therefore, from equation (10.3)

$$F = ma \qquad (10.4)$$

The unit of force is called newton and its symbol is N.

So a force of 1 newton will produce an acceleration of 1 m/s^2 on an object of mass 1 kg.

Can you estimate, how much is 1 N force?

For this, let us experience it. Keep a mass of 100 g on your palm. How much force you feel on your palm? Calculate this force.

From equation 10.4,

$$F = ma$$

Here, $m = \dfrac{1}{10}$ kg and $a = 10$ ms^{-2} (approximately)

Therefore, $$F = \frac{1}{10}\text{kg} \times 10 \text{ ms}^{-2} = 1 \text{ N}$$

Thus the force exerted by a mass of 100 g on your palm is approximately equal to 1 newton.

10.3.6 Some Example of Second Law of Motion from Daily Life

In our everyday life we see many applications of second law of motion. In many situations we try to decrease or increase the rate of change of momentum by changing the time in which the change of momentum takes place. Let us consider some examples.

(a) While catching a fast moving cricket ball, why does a fielder moves his hands backward?

By doing so the fielder increases the time duration in which the momentum of the ball becomes zero (Fig. 10.7). As the rate of change of momentum decreases, a small force is required for holding the catch. So the hands of the fielder do not get hurt.

Fig. 10.7 *A fielder moves his hands backward while holding a catch*

(b) Why does a person get hurt when he falls on a cemented floor?

Just before touching the floor, the person has some initial velocity, say u, which becomes zero when he comes to rest. Thus the momentum of the person becomes zero within a very short time. As the rate of change of momentum is very high, so very large force is exerted on the person, thereby hurting him. On the other hand,

Notes

if he falls on sand or husk or on a foam mattresses, he does not get hurt due to longer period of time in making momentum zero and hence reduction of force.

(c) How does a karate player breaks a pile of tiles or a slab of ice with a single blow?

The karate player hits the pile of tiles or a slab of ice as fast as possible with her hand. In doing so the entire momentum of the hand is reduced to zero in a very short time. As a result, the force delivered on the tiles or slab of ice is large enough to break it.

(d) You would have noticed that when a bundle tied with a string is lifted quickly by holding it, the string breaks (Fig. 10.8). Can you now explain why the string breaks in this case?

Fig. 10.8 *The string breaks when the bundle is lifted quickly.*

Example 10.1: What is the acceleration produced by a force of 15 N exerted on an object of mass 3 kg?

Solution: According to second law of motion

$$F = ma$$

Here $m = 3$ kg and $F = 15$ N

Therefore, $15 \text{ N} = 3 \text{ kg} \times a$

or $a = \dfrac{15 \text{ N}}{3 \text{ kg}} = 5 \text{ ms}^{-2}$

Example 10.2: What force accelerates a 50 kg mass at 5 ms^{-2}?

Solution: Newton's second law gives

$$F = ma$$

Here, $m = 50$ kg and $a = 5$ ms^{-2}

Therefore, $F = 50 \text{ kg} \times 5 \text{ ms}^{-2}$

$$= 250 \text{ N}$$

10.3.7 Newton's Third Law of Motion

You must have noticed that when a rubber balloon filled with air is released, the balloon moves opposite to the direction of the air coming out of it (Fig. 10.9). Why does the balloon move in a direction opposite to the direction in which the air escapes? Let us find out.

You must have also noticed that when you jump from a boat to the river bank, the boat moves in the backward direction (Fig. 10.10). Why does this happen?

While jumping out of the boat, your foot exerts a backward force on the boat. This force is called **action**. At the same time a force is exerted by the boat on your foot, which makes you move forward. This force is known as **reaction**. Remember that two bodies and two forces are involved in this problem. You pushed the boat backward and the boat pushes you forward. These two forces are equal in magnitude but opposite in direction.

Fig. 10.9 *A balloon moves opposite to the direction in which air escapes*

Fig. 10.10 *A girl jumping out of a boat*

Let us consider the balloon problem again. In this case the air coming out of the balloon (action) exerts a force of reaction on the balloon and this force pushes the balloon backwards (reaction).

Newton in his third law of motion stated a relation between action and reaction. According to this law, **to every action there is an equal and opposite reaction.** The action and reaction act on two different bodies if action and reaction are on same body they will constitute a balanced force and body will not move.

Look at the Fig. 10.11 and find out the action and reaction forces and try to analyse wheather the truck will move or not.

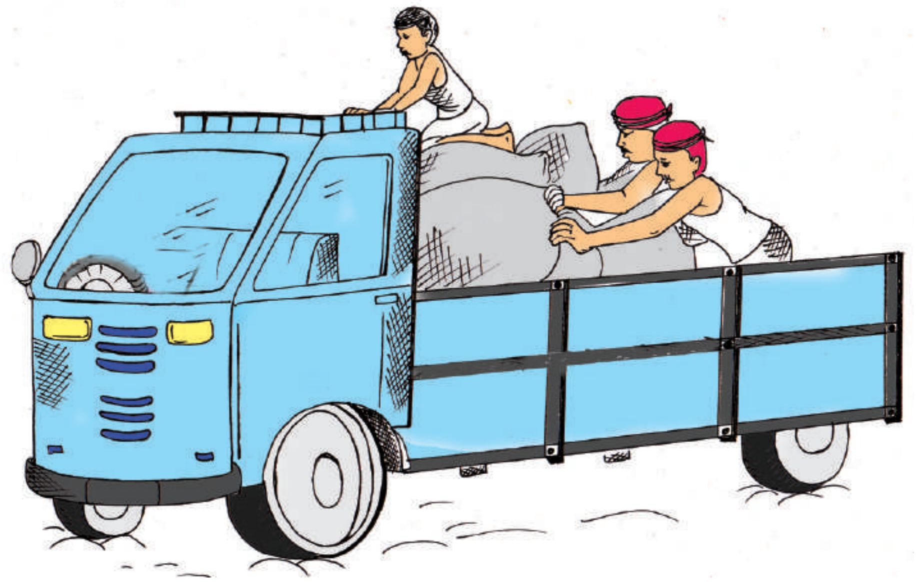


Fig. 10.11

There are three significant features of third law of motion:

(i) We cannot say which force out of the two forces is the force of action and which one is the force of reaction. They are interchangeable.

(ii) Action and reaction always act on two different bodies.

(iii) The force of reaction appears so long as the force of action acts. Therefore, these two forces are simultaneous.

Remember, it is not necessary that the two bodies, amongst which the forces of action and reaction act are in contact. They may be quite far from each other. For example, attraction or repulsion between two magnets can take place even without being in contact (Fig. 10.12).

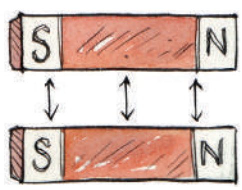


Fig. 10.12 *Repulsion between two magnets*

Do you know that action and reaction forces enable us to walk on the surface of the earth? Let us see how? While walking on the ground we push the ground with our foot in the backward direction. This is the force of action.

In return the ground exerts an equal force of reaction on our foot in the forward direction. The force that actually makes us walk in the forward direction is this reaction force.

Similarly, during swimming we push the water in the backward direction, with our hands and feet, to move in forward direction. It is the reaction to this force that pushes us forward (Fig. 10.13).

Fig. 10.13 *A swimmer pushes the water backwards with hands to move in forward direction.*

It may be interesting for you to know that rockets and jet-planes also work on the principle of action and reaction. In each of these, when the fuel burns, hot burning gases are ejected from the tail. The hot gases come out in the backward direction and the rocket or the jet plane moves in the forward direction (Fig. 10.14).

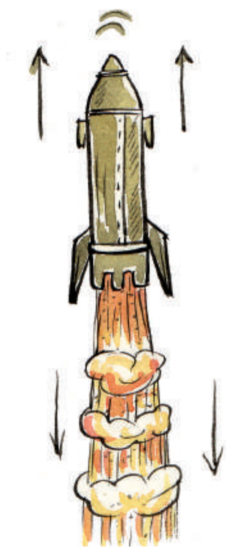


Fig. 10.14 *Working of jet planes and rockets*

Now think, why a rifle kicks backward when we fire a bullet?

10.3.8 Conservation of Momentum

Law of conservation of momentum is a very important law of science. According to this law, if two or more objects collide with each other, their total momentum remains conserved before and after the collision provided there is no external force acting on them.

From the Newton's laws of motion, we know that the rate of change of momentum is equal to the force.

If p_1 = initial momentum and p_2 = final momentum after time t, then

$$F = \frac{p_2 - p_1}{t}$$

Now, if $F = 0$, then we have $p_1 = p_2$. Which shows that the momentum of a system remains unchanged (or conserved) if no force is acting on it?

You can verify the law of conservation of momentum with the help of a simple activity.

ACTIVITY 10.4

Take a plastic channel of about 40 cm length and seven marbles of same size. Place the channel on a horizontal table and put the marbles on the channel touching each other as shown in figure 10.15. Remove one marble and keep it at a distance of about 15 cm from the rest. Hit this marble with your fore finger gently so that it collides with other marbles. What do you observed?

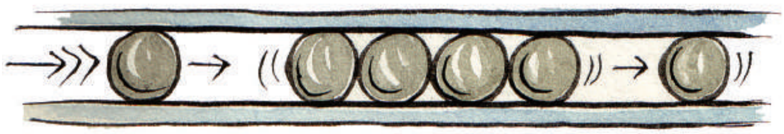


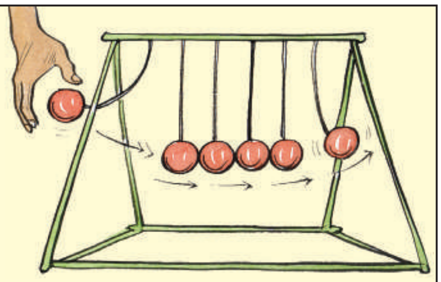
Fig. 10.15 *Arrangement to show the law of conservation of momentum*

You will find that after the collision, the moving marble comes to rest and the last marble out of the rest moves ahead. Try to guess the speed of this marble after the collision and compare it with the speed of marble you had thrown before the collision. Do the two speeds appear to be equal? What does it indicate? If the speeds are equal then the total momentum of the marble is same before and after the collision.

Repeat this activity by removing two marbles and striking them with the five marbles at rest. What do you observe this time? What conclusion do you derive from this activity? You will find that in each case, total momentum of marbles before collision is same as after collision.

Do you know

Have you ever seen a toy as shown here? If not, try to find this toy in a toy shop or a science museum. Can you tell the principle on which this toy works?



Example 10.3: A bullet of mass 0.03 kg is fired with a velocity of 100 ms^{-1} from a rifle of mass 3 kg. Calculate the recoil velocity of the rifle.

Solution:

Here, mass of the rifle m_1 = 3 kg

mass of the bullet m_2 = 0.03 kg

Initial velocity of the riffle $u_1 = 0$

Initial velocity of the bullet $u_2 = 0$

Final velocity of the rifle = v_1 (say)

Final velocity of the bullet v_2 = 100 ms^{-1}

According to the law of conservation of momentum,

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

On substituting the given values,

$$0 + 0 = 3 \times v_1 + (0.03) \times 100$$

$$v_1 = \frac{-100 \times 0.03}{3} = -1.0 \text{ ms}^{-1}$$

∴ Recoil velocity of the rifle = –1.0 ms^{-1}

Negative sign indicates that the rifle would move in the direction opposite to that bullet.

Example 10.4: A rifle having a mass of 5 kg fires a bullet at a speed of 250 ms^{-1}. If the rifle recoil with a velocity of 1 ms^{-1} then find the mass of the bullet.

Solution:

Here, $M = 5$ kg; $m = ?$

$V = -1 \text{ ms}^{-1}$; $v = 250 \text{ ms}^{-1}$

$U = 0$ $u = 0$

According to the law of conservation of momentum

$$MU + mu = MV + mv$$

$$0 = MV + mv$$

$$m = \frac{-MV}{v} = \frac{-5\times(-1)}{250} = \frac{1}{50} = 0.02 \text{ kg}$$

So, Mass of the bullet = 0.02 kg or 20 g

Negative sign indicates that the rifle would move in the direction opposite to that obullet.

INTEXT QUESTIONS 10.3

1. Why does water comes out from a wet piece of cloth when you shake it?
2. Why do we fall forward, when a moving bus stops suddenly?
3. Two similar trucks are moving on a road with the same velocity. One of them is empty while the other one is loaded. Which of the two has more momentum?
4. If a body of mass 5 kg moves with a velocity of 10 ms^{-1}, then what is the momentum of the body?
5. Why does a boxer move his head backward while taking an oncoming punch?

10.4 FRICTION

You might have noticed that a ball rolling along the ground stops after moving through some distance. Similarly a moving car begins to slow down the instant its engine is switched off and finally it stops. Why does it happen? Let us find out.

10.4.1 Force of Friction

According to Newton's first law of motion, a moving body continues to move along a straight line until unless an external force is applied on it. Is this external force slows down the motion of the ball or the car? Think! Infact the ball or car is slowed down by a force called **friction**. Friction exists between the surfaces of all materials which are in contact with each other. The direction of the frictional force is always in a direction opposite to the motion.

Now, try to analyze the forces acting on an object moving with a constant velocity. If an object is to move with a constant velocity, a force equal to the opposing force of friction must be applied. In that condition the two forces are balanced forces. They exactly cancel one another and the net force on the body is zero. Hence the acceleration produced in the body is zero and the body maintains its velocity. It neither speeds up nor slows down.

The resistive force, before the body starts moving on a surface is called **static friction**. Once a body starts moving on a surface the friction between them is called **sliding or kinetic friction**. You should remember that the sliding friction is slightly less than the static friction.

10.4.2 Factors affecting friction

You must have seen that it is easier to move a bicycle on a concrete road than on a rough road. Why is it so? Does friction depend upon the smoothen or the roughness of the surfaces? Let us find out.

ACTIVITY 10.5

Set up an inclined plane on a table as shown in Fig. 10.16. Mark a line near the top edge of the inclined plane. Now hold a pencil cell on this line. Release the pencil cell. What do you observe? The cell moves down the inclined plane and continues to move for some distance on the table. Note down the distance upto which the cell move on the table.

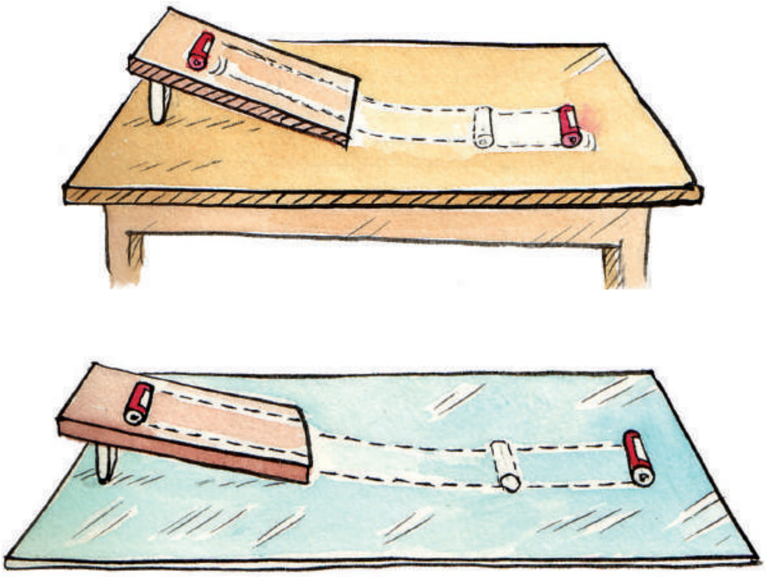


Fig. 10.16 *Pencil cell covers different distances on different type of surfaces*

Now place a glass sheet on the table. Again release the pencil cell from the line on the inclined plane and note the distance up to which the cell moves on the glass plate. Repeat this activity by spreading a uniform layer of sand on the table.

In which case the distance covered by the pencil cell is maximum? In which case it is minimum? What do you conclude from this activity?

You will find that the distance moved by the cell is maximum on the glass surface and minimum over the sand. This difference is due to the friction offered by different type of surfaces. Smooth glass surface offers less friction compared to a rough sand bed. Thus **smoothness of the surfaces is one of the factor on which friction depends**.

You might have observed that more force is needed to move a heavy box than to move a lighter box on the same surface. It is so because the heavy box has grater normal reaction (reaction of the surface on the box against the action of its weight) and hence greater frictional force. Thus **friction also depends upon the normal reaction**.

10.4.3 Advantages and disadvantages of friction

The friction plays a very important role in our day to day life. It has several advantages as well as disadvantages.

(a) Advantages of friction

Have you ever walked on ice or a wet marble floor? You might have found that it difficult to balance your body. The force of friction developed between the soles of your shoes and the ground helps us to move. Had there been no friction, walking or running would have been impossible.

You can write with a pen on page or with a chalk on the blackboard due to friction. Buildings may be constructed only due to force of friction between different building materials. Without friction, you could not fix a nail on the wall.

Tyres of automobiles are treaded to increase the friction between tyres and surface of the road. Thus the tyres get better grip with the ground. The breaks applied in automobiles also work only due to friction.

Can you think of some more examples from your daily life where friction is useful?

(b) Disadvantages of friction

Due to friction, a lot of energy is wasted in the form of heat that causes wear and tear of the moving parts of a machine. Friction also reduces efficiency of the machines as considerable amount of energy is wasted in overcoming friction. However, the efficiency of a machine can be increased by putting a suitable lubricant between its moving parts.

In most of the machines, to reduce friction ball bearings are used between the moving parts. By using the ball bearing the sliding friction is replaced by **rolling friction**. As the rolling friction is less than the sliding friction, therefore, the friction between the moving parts is reduced.

Friction also wears out the soles of shoes. You would have seen that the steps of foot over-bridge at railway stations also wear out due to friction.

Vandana and Navneet are racing on rock ice with the specially designed shoes shown in the Fig. *A* and *B* respectively. Who will win?

(A) Shoes for Vandana

(B) Shoes for Navneet

Cite some more example from you daily life where friction is undesirable.

INTEXT QUESTIONS 10.4

1. Why does a fast moving car slow down when its engine is switched off?
2. Why do we slip when we step on a banana peel?
3. Why are tyres of automobiles treaded?

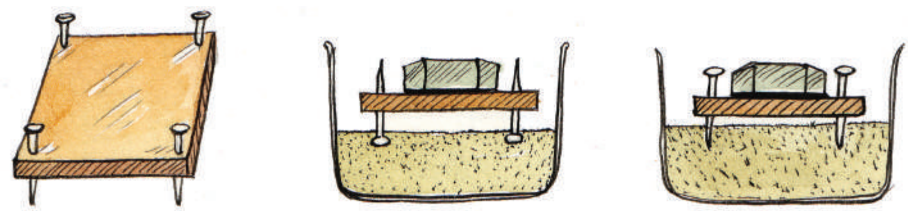
10.5 THRUST AND PRESSURE

Observe some bodies around you like table, desk, bucket full of water, etc. They press the floor with a force equal to their own weight. You know that weight is the force acting vertically downwards. As the surface of the floor can be taken as horizontal, therefore, the force with which each of the above mentioned bodies presses the floor is directed perpendicular to the surface of the floor. The force acting upon the surface of a body perpendicular to it is called **thrust**.

Let us find out the effect of thrust acting on a surface.

ACTIVITY 10.6

Take a small wooden board (10 cm × 10 cm × 1.0 cm) with four nail fixed at each corner as shown in Fig. 10.17 (a). Fill a tray with sand to a depth of about 6 cm. Place the wooden board on sand with the nail-heads downwards [Fig. 10.17 (b)] Also put about 500 g weight on the board. Observe the depth of the nails upto which they penetrate into the sand.



(a) (b) (c)

Fig. 10.17 (a), (b), (c) *Arrangement to show that pressure depends upon the area on which force is exerted*

Now place the wooden board on the sand with pointed side of the nails facing downwards and put the same weight on the board as in the previous case [Fig. 10.17 (c)]. Again observe the depth of the nails upto which they penetrate upto the sand.

In which of the above two cases the penetration is more? You will find that the penetration is more in the second case.

Thus the action of the given thrust depends on the area of the surface it acts upon. The smaller the area on which the thrust acts, the more evident is the result of its action. The thrust on unit area is called pressure. Thus

$$\text{Pressure} = \frac{\text{thrust}}{\text{area}} \qquad ...(10.5)$$

The SI unit of pressure is Nm^{-2}. This unit has also been given a specific name pascal (Pa) in honour of the scientist named Blaise Pascal.

Do you know

Pascal was a French philosopher and mathematician. He formulated the famous Pascal's law of hydraulics regarding transmission of pressure through fluids. He also invented one of the earliest calculating machines. The unit of pressure pascal (Pa) was named in his honour.


Blaise Pascal (1623-1662)

Equation (10.5) shows that 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 cutting tools like knives and axes always have sharp edges.

In many cases it is desirable to decrease pressure. In such cases the area on which the thrust is acting should be increased. For example, foundation of buildings and dams are made on larger area. Similarly trucks and vehicles used to carry heavy loads have much wider tyres. Also army tank weighing more than a thousand tonne rests upon a continuous chain.

INTEXT QUESTIONS 10.5

1. Why does a porter carrying a heavy load place a round piece of cloth on his head?
2. Why a nail has a pointed tip?
3. Why shoulder bags are provided with broad straps?
4. State the SI unit of pressure.

WHAT YOU HAVE LEARNT

- Unbalanced forces acting on an object may change its state of rest or motion.
- Balanced forces do not change the state of rest or motion of an object. Balanced forces can change the shape of the object on which they are applied.
- Inertia is the tendency of objects to stay at rest or to resist a change in their state of motion.

- The mass of an object is a measure of its inertia.
- Newton's first law of motion states that, everybody continues in its state of rest or of uniform motion in a straight line until unless it is compelled by some unbalanced force to change that state.
- The momentum of a body is the product of its mass and velocity. The SI unit of momentum is kg ms^{-1}.
- Second law of motion states that the rate of change of momentum of a body is directly proportional to the force acting on it and takes place in the same direction as the force.
- The unit of force is newton and its symbol is N. A force of 1 newton will proceed on acceleration of 1 ms^{-2} on an object of mass 1 kg.
- Newton's third law of motion states that, to every action there is always an equal and opposite reaction. Action and reaction always act on two different bodies.
- According to the law of conservation of momentum, in an isolated system the total momentum remains conserved.
- Force of friction always opposes motion of bodies. Friction depends on the smoothness of surfaces in contact. It also depends upon the normal reaction.
- Rolling friction is less than the sliding friction.
- Force acting perpendicular to the surface of a body is called thrust.
- Thrust per unit area is called pressure. The SI unit of pressure is Nm^{-2}. This unit is known as pascal (Pa).

TERMINAL EXERCISE

1. Why does a sprinter keep running for sometime even after crossing the finish line?
2. Why is it advised to tie the luggage with a rope on the roof of busses?
3. Why do the dust particles from the hanging blanket fall off when it is beaten with a stick?
4. State Newton's first law of motion. Why do the passengers standing in a stationary bus fall in the backward direction when the bus begins to move suddenly.
5. Define momentum. How the rate of change of momentum is related to force?
6. If a body of mass 10 kg moves with a velocity of 7 ms^{-1}, then what is the momentum of the body?
7. If a force of 50 N acts on a body of mass 10 kg then what is the acceleration produced in the body?

8. State Newton's third law of motion. Why it is difficult for a fireman to hold a hose pipe which ejects larger amount of water at a high speed?
9. "Action and reaction forces are equal in magnitude and opposite in direction". Then, why do they not balance each other?
10. A motorcycle is moving with a velocity of 72 km/h and it takes 6 s to stop after the breaks are applied. Calculate the force exerted by the breaks on the motorcycle, if its mass along with the rider is 175 kg.
11. An object of mass 2 kg travelling in a straight line with a velocity of 10 ms^{-1} collides with and sticks to a stationary object of mass 6 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.
12. What is the force of friction? State two methods to reduce friction.
13. What is the relation between thrust and pressure? State the SI units of thrust and pressure. Why a camel can run in a desert easily?
14. A block of wood kept on a table applies a thrust of 49 N on the table top. The dimensions of the wooden block are 40 cm × 20 cm × 10 cm. Calculate the pressure exerted by the wooden block 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.

ANSWER TO INTEXT QUESTIONS

10.1

1. Yes
2. Pressing a lump of dough with your hands.

10.2

1. When two or more forces acting on an object in opposite direction balances each other then the forces are known as balanced forces.
2. No. Balanced forces do not change the state of motion of an object.
3. Unbalanced forces acting on an object may change its state of rest or motion.

10.3

1. Due to inertia of rest. When we shake the cloth, the water remains in its position and comes out.
2. Lower part of our body come to rest but due to inertia of motion our upper part tends to move in the forward direction and we fall in the forward direction.

3. As momentum is equal to mass × velocity. So the momentum of loaded truck (more mass) has more momentum.
4. Momentum = $m \times v = 5\ \text{kg} \times 10\ \text{ms}^{-1} = 50\ \text{kg ms}^{-1}$.
5. To decrease the rate of change of momentum boxer moves his head backward so that the impact of punch is reduced.

10.4

1. Due to force of friction acting between wheel of car and ground.
2. Because the friction between banana peel and ground is very small.
3. Treaded tyres provide better grip with the ground because in such tyres the friction between the tyres and ground is very large.

10.5

1. Round piece of cloth increases the area of contact between load and head of porter, thereby decreasing the pressure on his head.
2. To increase the pressure.
3. To decrease the pressure.
4. Nm^{-2} or pascal (Pa)

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11

GRAVITATION

In previous chapter you have learnt that a force is required to change the state of rest or of motion of a body. You are also aware that all objects when dropped from a height fall towards the earth. Why do objects fall towards the earth? You might think that this must be due to some force known as force due to gravity or gravitational force. In this lesson we will learn about gravitation, force of gravity and motion of bodies under the influence of gravity.

We shall also discuss about buoyancy and Archimedes' principle.

OBJECTIVES

After completing this lesson you will be able to:

- *illustrate the existence of force of gravitation;*
- *state Newton's law of gravitation;*
- *explain the term acceleration due to gravity;*
- *modify equations of motion of an object falling under gravity;*
- *solve problems relating to one dimensional motion under gravity;*
- *distinguish between mass and weight and find the relation between them;*
- *define free fall motion and explain weightlessness;*
- *illustrate the force of buoyancy experienced by a body immersed wholly or partly in a fluid and*
- *state the principle of Archimedes and apply it to solve problems.*

11.1 FORCE OF GRAVITATION

It is our everyday experience that bodies thrown vertically upward come back to the earth. Even if an object is dropped from some height, it falls towards the earth. Similarly tree leaves and fruits fall toward the earth when they are separated from the branches. Why does it happen so? This must be due to some force acting on the bodies like leaves or fruits. What type of force is acting on them? It was Issac Newton who answered this question.

There is an interesting story about Newton. It is said that while Newton was sitting under an apple tree, an apple fell on him. The fall of the apple set Newton thinking, why did the apple fall down? If some force is acting on the apple then it must be in accelerated motion. Let us try to understand this with the help of an activity.

ACTIVITY 11.1

Release a small stone from your hand from a height of about 1 metre. Observe its speed just before it hits the ground. Now, release the same stone from a height of about 5 metres (say from first floor of the house) (Fig. 11.1). Again observe its speed just before it hits the ground. Ensure that in each case the stone is released without pushing. Did the stone possess the same speed just before it hits the ground in both the cases? In which case the stone strike the ground faster? Can you identify the force which accelerated the stone?

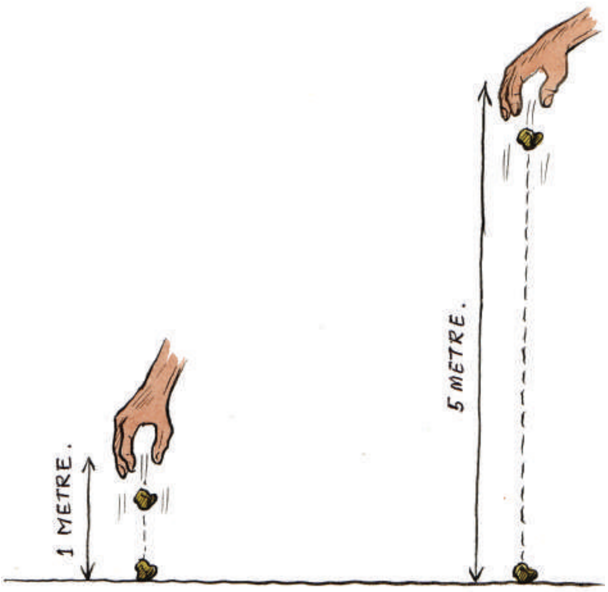


Fig. 11.1 *A stone falling from different heights*

In above activity you have observed that the force of attraction due to earth accelerated the stone. Newton knew that bodies fall towards the earth due to force of gravity. He further thought, if the earth can attract an apple or a stone, can it also attract the moon? He was also curious to know whether the same force was responsible for keeping the planets go around the sun in their orbits.

Newton concluded that in order to move in a circular orbit the moon must be attracted by the earth continuously. Arguing in the same lines he said that there exists a force between the sun and the planets. The force is known as the gravitational force. He stated that gravitational force exists everywhere in the universe. All objects in the universe attract each other. The interesting aspect of the gravitational force is that it is always attractive whatever may be the size of bodies.

11.2 NEWTON'S LAW OF GRAVITATION

On the basis of his observations, Newton expressed the law of gravitation in the language of mathematics. He stated the law as follows:

Every particle in the universe attracts every other particle with a force. This force 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 two particles. Mathematically,

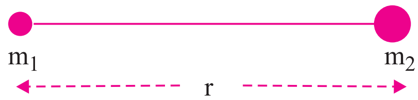


Fig. 11.2 *Newton's law of gravitation*

$$F \propto \frac{m_1 m_2}{r^2}$$

where m_1 and m_2 are the masses of the two particles separated by a distance r.

or $$F = G\frac{m_1 m_2}{r^2} \qquad ...(11.1)$$

where G is a constant of proportionality. It is called the universal gravitational constant. Its value is same everywhere on the earth or in the universe.

In SI units, where m is measured in kilogram, F in newton, r in metre, the accepted value of G is 6.67×10^{-11} Nm^2kg^{-2}. As the value of G is very small, you can realize that the force of gravitation between objects of ordinary mass is very weak.

Let us find out how much the force of attraction between you and your friend sitting on the next bench at a distance of 1 metre apart is. If you are of say 50 kg and your friend is of 40 kg then the force of attraction would be,

$$F = \frac{6.67 \times 10^{-11} \times 40 \times 40}{1 \times 1}$$

$$= 13340 \times 10^{-11}\ N$$

$$= 113.34 \times 10^{-8}\ N$$

You will appreciate that this force is very weak. It is at least a hundred times weaker than the force exerted by a small piece of paper on the pan of a balance. You can also realize how weak the force of gravitation is, when you lift a small stone or when a charged comb picks up small pieces of paper. However, the force of gravitation becomes appreciably stronger if masses of the objects are increased.

Example 11.1: A boy of 40 kg mass is standing on the surface of earth. If the mass of the earth is 6×10^{24} kg and its radius is 6.37×10^6 m, then find the force of attraction between the boy and the earth. Take the value of G as 6.67×10^{-11} $\text{Nm}^2\ \text{kg}^{-2}$.

Solution: Mass of the earth = 6×10^{24} kg

Mass of the boy = 40 kg

Radius of the earth = 6.37×10^6 m

(This is the distance separating the boy from the centre of the earth)

Value of $G = 6.67 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$

The force of attraction (F) between the boy and the earth

$$= \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 40}{6.37 \times 10^6 \times 6.37 \times 10^6} = 394.5 \text{ N}$$

Now you can appreciate that the force with which the earth and the boy attract each other is more than a thousand million times stronger than the force of attraction between you and your friend sitting at a distance of about 1 metre from you.

The gravitational force due to earth is also known as **gravity**. Thus, when we are dealing with very large masses like the earth, the moon or the sun, the gravitational force between such objects is quite large.

INTEXT QUESTIONS 11.1

1. Why do two students sitting close to each other not feel force of gravitational attraction between them?
2. Distance between two bodies is increased by a factor of four. How much will be the change in the force of gravitation?
3. Why is G known as universal gravitational constant?

11.3 ACCELERATION DUE TO GRAVITY

In activity 11.1 we have seen that the speed of a falling stone increases continuously. From this activity we concluded that the stone was accelerated due to force of attraction between the stone and the earth. Can we give some special name to this

Notes

acceleration? This acceleration is called the acceleration due to gravity. Is this acceleration large if the stone has a large mass? Do heavier objects fall faster than lighter one? Let us find out.

ACTIVITY 11.2

Caution: while performing this activity, be careful not to hurt anyone.

Ask one of your friends to stand at the roof top of a two storied building with stones of different masses in his two hands (Fig. 11.3). Ask him to drop these stones together. Carefully observe falling of the stones. What do you find? Why both the stones reach the ground at the same time?

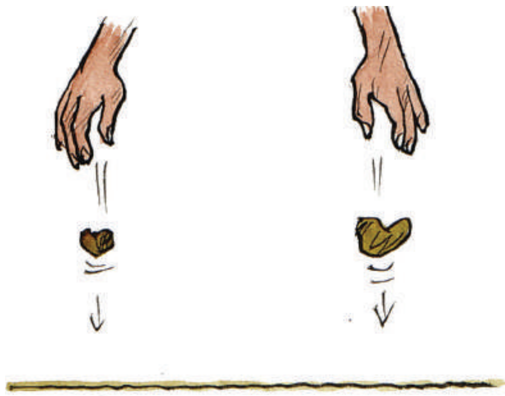
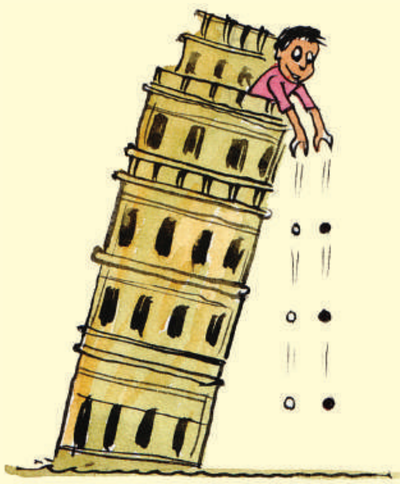


Fig. 11.3 *Dropping two stones of different masses together.*

Do you know

According to a story, Galileo dropped different objects from the leaning tower of Pisa in Italy to prove that objects of different masses fall at the same rate.



You can perform the above activity in an interesting manner.

ACTIVITY 11.3

Drop a five rupee coin and a paper (15 cm × 15 cm) simultaneously from the same height. What do you observe? You will find that the coin falls to the ground much before the paper does. What do you conclude from this observation? You may be tempted to conclude that the heavier objects fall faster than the higher ones.

Now crumple the paper into a small ball. Again drop the coin and the crumpled paper ball simultaneously from the same height. What do you observe now? You will find that both the coin and the paper ball hit the ground at the same time. In the first case the slowing down of paper was due to friction offered by air. Large surface encounters more resistance by air. What conclusion can be drawn from this activity?

This activity shows that two objects of different masses would reach the ground together when dropped from the same height. Think why?

Do you know

A British scientist Robert Boyle placed a coin and feather in a glass tube. He used a vacuum pump to remove air from the glass tube. When the tube was inverted both the coin and the feather hit the bottom at the same time.

The earth's gravity accelerates the coin and paper ball in the downward direction. Since both the coin and paper ball reach the ground together, this acceleration called acceleration due to gravity (g), is same for both of them. Infact, acceleration due to gravity is same for any mass at a given place. The SI unit of g is same as that of acceleration, i.e., ms^{-2}.

Let us try to find out an expression for the acceleration due to gravity. Let the mass of the stone falling from a height (in activity 11.1) be m. The acceleration involved in falling stone due to earth's gravity is denoted by 'g'.

We know that force is product of mass and acceleration. Therefore, the magnitude of force of gravity 'F' will be equal to product of mass and acceleration due to gravity.

$$F = mg \qquad (11.2)$$

From equations (11.1) and (11.2), we have

$$mg = G\frac{Mm}{r^2}$$

or

$$g = \frac{GM}{r^2} \qquad ...(11.3)$$

where M is the mass of the earth and r is the distance between the object and the centre of the earth. If the object is on or near the surface of the earth, the distance r in equation (11.3) will be equal to the radius of the earth R. Thus,

$$g = G\frac{M}{R^2} \qquad ...(11.4)$$

Thus we see that the value of 'g' is independent of the mass of the freely falling body. The radius of the earth is not same at all the places on the surface of the earth. So the value of 'g' changes from place to place on the earth. Its value is greater at the poles than at the equator. The average value of 'g' on and near the surface of the earth is taken as 9.8 ms^{-2}.

11.4 MOTION OF AN OBJECT UNDER GRAVITY

We know that g is constant near the surface of earth. Therefore, all the equations for uniformly accelerated motion of bodies (discussed in Chapter 9) become valid when acceleration a is replaced by g. Can you write now the modified equations of motion? These are:

$$v = u + gt \qquad ...(11.5)$$

$$s = ut + \frac{1}{2}gt^2 \qquad ...(11.6)$$

$$v^2 = u^2 + 2gs \qquad ...(11.7)$$

where u and v are the initial and final velocities and s is the distance covered in time t.

Example 11.2: Take the mass of the earth to be 6×10^{24} kg and its radius as 6.4×10^{6} m. Calculate the value of g. ($G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}).

Solution: From equation 11.4,

$$g = G\frac{M}{R^2}$$

$$= \frac{6.7 \times 10^{-11}\,\text{Nm}^2\text{kg}^{-2} \times 6 \times 10^{24}\,\text{kg}}{\left(6.4 \times 10^{6}\,\text{m}\right)^2}$$

$$= 9.8 \text{ ms}^{-2}$$

Example 11.3: 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^{8} m, calculate the force exerted by the earth on the moon. $G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}.

Solution. The mass of the earth, $m_1 = 6 \times 10^{24}$ kg

The mass of the moon, $m_2 = 7.4 \times 10^{22}$ kg

The distance between the earth and the moon, $r = 3.84 \times 10^{8}$ m

$$G = 6.7 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

From equation (11.1) the force exerted by the earth on the moon is

$$F = G\frac{m_1 m_2}{r^2}$$

$$= \frac{6.7 \times 10^{-11}\,\text{Nm}^2\text{kg}^{-2} \times 6 \times 10^{24}\,\text{kg} \times 7.4 \times 10^{22}\,\text{kg}}{\left(3.84 \times 10^{8}\,\text{m}\right)^2}$$

$$= 2.01 \times 10^{20} \text{ N}$$

Example 11.4: A ball is thrown vertically upwards and rises to a height of 122.5 m. Calculate

(i) the velocity with which the ball was thrown upwards and

(ii) the time taken by the ball to reach the highest point.

(Take $g = 9.8$ ms^{-2})

Solution: Distance travelled, $s = 122.5$ m

Final velocity, $v = 0$ ms^{-1}

Acceleration due to gravity, $g = 9.8$ ms^{-2}

(i) From equation (11.7) $\quad v^2 = u^2 = 2gs$

$$0 = u^2 + 2(-9.8 \text{ ms}^{-2}) \times 122.5 \text{ m}$$

For upward motion g is taken as negative.

$$\therefore \quad -u^2 = -2 \times 9.8 \times 122.5 \text{ m}^2\text{s}^{-2}$$

$$u^2 = 2401 \text{ m}^2\text{s}^{-2}$$

$$u = 49 \text{ ms}^{-1}$$

Thus the velocity with which the ball was thrown upwards is 49 ms^{-1}.

(ii) From equation (11.5), $\quad v = u + gt$

$$0 = 49 \text{ ms}^{-1} + (9.8 \text{ ms}^{-2}) \times t$$

Therefore, $\quad t = \frac{49}{9.8}\text{s} = 5\text{s}$

Thus,

(i) Initial velocity = 49 ms^{-1}; and

(ii) Time taken = 5s

INTEXT QUESTIONS 11.2

1. What do you mean by acceleration due to gravity?
2. Why do a heavier and a lighter object when dropped from a same height fall at the same rate?
3. State SI unit of acceleration due to gravity.
4. Write equations of motion of an object moving under gravity.

11.5 MASS AND WEIGHT

11.5.1 Mass

Mass of a body is the quantity of matter contained in the body. Mass of an object is constant and does not change from place to place. It remains the same whether the object is on earth, on moon or anywhere in outer space. The mass of an object is measured with the help of a pan balance.

We have also learnt in previous chapter that mass of an object is the measure of its inertia. It means that greater the mass, the greater is the inertia of the object.

11.5.2 Weight

The weight of an object is the force with which it is attracted towards the earth. Can you recall the relation between force and acceleration?

$$\text{Force} = \text{Mass} \times \text{Acceleration}$$

Therefore, $$F = mg \qquad (11.8)$$

If weight of an object is denoted by W, then

$$W = mg \qquad (11.9)$$

As weight is a force, therefore, its SI unit is the same as that of the force. Try to recall this unit. It is newton. Its symbol is N. This force (weight) acts vertically downwards. It has both magnitude and direction. The weight of an object is generally measured by a spring balance.

From equation (11.9) we see that weight of an object depends on its mass and value of g. As the value of g is constant at a given place, therefore, the weight of the object at a given place is directly proportional to its mass. However, the weight of an object will be different on different parts of the earth as the value of g is different on different parts of the earth.

11.5.3 Weightlessness

You may have noticed increase in weight while in moving in Lift/Elevator upward and decrease in weight when moving downward. Similar case you can experience in merry-go-round. Also you have heard that an astronaut experiences weightlessness in space. What does the term weightlessness mean?

ACTIVITY 11.4

Hold a heavy book in your hand as shown in Fig. 11.4. Can you feel the weight of the book on your hand? Now move your hand quickly in the downward direction with some acceleration. What do you feel? Do you feel some decrease in the weight of the book? Can you explain the reason for this decrease in the weight?

Book in the hand *Hand moving downward*

Fig. 11.4

We usually measure the weight by a spring balance or a weighing machine which rests on a rigid floor. How does a weighing machine record the weight of an object?

Suppose a child is standing on a weighing machine which rests on the floor. The child exerts a downward force equal to his weight W on the machine (Fig. 11.5).

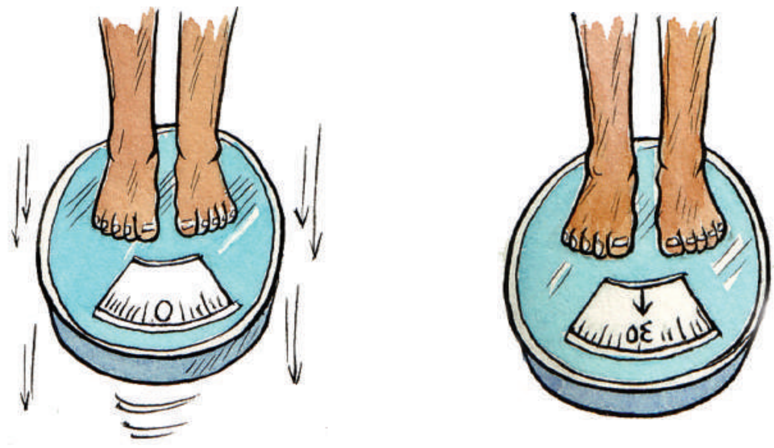


Fig. 11.5 *A child on a weighing machine*

According to the third law of motion the machine exerts an upward reaction 'R' on the boy which is equal to W. The weighing machine measures the reaction R, which is the weight of the boy.

Now imagine that the floor below the weighing machine is suddenly removed. What would happen? The boy and the scale would fall towards the earth with the same acceleration. In this case the boy cannot exert a force on the weighing machine. The weighing machine in this case would show a zero weight. Thus we can conclude that a body falling freely under gravity is weightless.

Now you can understand why an astronaut experiences weightlessness in a spaceship. The spaceship with the astronaut falls freely towards the earth. The astronaut therefore, appears to be floating weightlessly (Fig. 11.6).

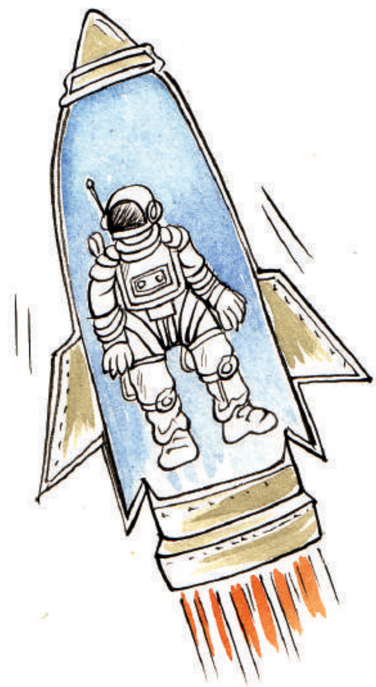


Fig. 11.6 *An astronaut in a spaceship*

INTEXT QUESTIONS 11.3

1. Write two differences between mass of an object and its weight.
2. State two factors on which weight of an object depends.
3. What will be the weight of an apple while it is falling from a tree?

11.6 BUOYANCY AND ARCHIMEDES' PRINCIPLE

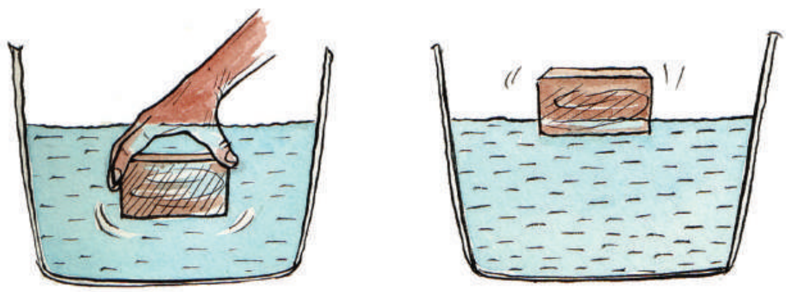
11.6.1 Buoyancy

Have you ever experienced that a mug filled with water appears to be heavier when it is lifted from bottom of the bucket to above the surface of water than the mug within the water in the bucket. Why is it so? Let us understand it with the help of an activity.

ACTIVITY 11.5

Take a large wooden block and put it in a bucket filled with water. What do you observe? You will see that the wooden block floats when placed on the surface of water.

Now push the block into the water. What do you feel? Why do you feel an upward push on your hand? What does it indicate? This indicates that water exerts an upward force on the wooden block. Now, push the wooden block further down till it is completely immersed in water [Fig. 11.7(a)]. Release the wooden block. What do you observe? The block bounces back to the surface of water [Fig. 11.7(b)].



(a) (b)

Fig. 11.7 *(a) Wooden block immersed in water (b) The block becomes back when released*

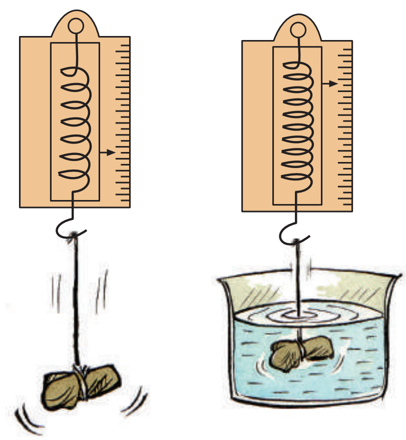
The upward force exerted by the water on the wooden block is known as the **force of buoyancy** or **buoyant force**. This force is also known as **upthrust**. In fact, all bodies experience a buoyant force when they are immersed in a fluid that is a liquid or a gas. Can you cite some more examples of buoyant force?

What is the magnitude of the buoyant force experienced by an object? Do all objects in a given fluid experience the same buoyant force? Is not same for all fluids for a given object? You can answer all such questions after studying Archimedes' principle.

11.6.2 Archimedes' Principle

ACTIVITY 11.6

Take a piece of stone and suspend it from a spring balance with the help of a thread [Fig. 11.8(a)]. Note the reading of the spring balance. This is the weight of the stone in air. Now, dip the stone slowly in to water kept in a container [Fig. 11.8(b)]. Observe carefully. What happens to the reading on the balance?



(a) *(b)*

Fig. 11.8 *Reading of the spring balance decreases when the stone is immersed in water*

You will find that the reading of the spring balance decreases as the stone is gradually lowered in water. However, when the stone gets fully immersed in water, no further change is observed in the reading of the spring balance. What do you infer from this observation? Decrease in the reading of the spring balance shows that an upward force acts on the stone when it is dipped in water. As discussed earlier this upward force is known as the force of buoyancy. Archimedes discovered a principle to determine the magnitude of the force of buoyancy.

Archimedes' principle is 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.

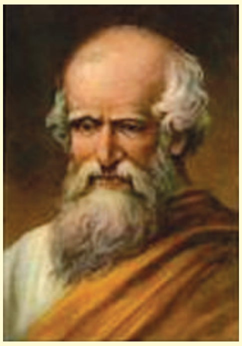
From Archimedes' principle it is clear that the magnitude of the buoyant force acting on a body at a given place depends on

- density of the fluid and
- volume of the body immersed in the fluid.

Archimedes' principle has many applications. It is used in designing ships and submarines. Hydrometers which are used to determine the density of liquids are based on Archimedes's principle. Lactometers, which are used for determining the purity of milk, are also based on this principle.

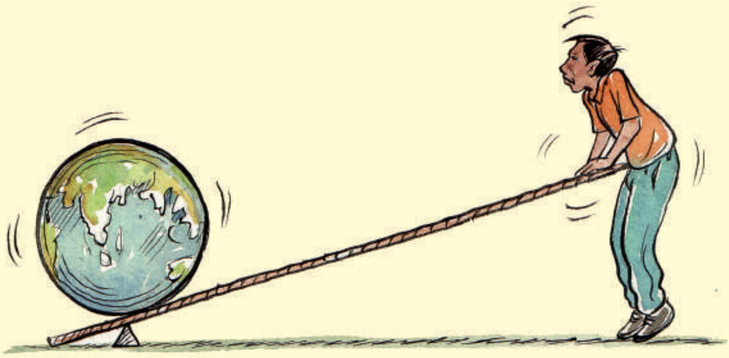
Do you know

Archimedes was a great Greek mathematician and scientist. He is best known for his famous Archimedes' principle. It is said that Archimedes discovered this principle when he stepped in a bathtub full of water and noticed that water overflowed from it. He ran through the streets shouting "Eureka", "Eureka", ..., which means, "I found it".



Archimedes
(287 BC-212 BC)

He invented the famous Archimedes's screw which was used for raising water from a lower to a higher level. His work in the field of mechanics and geometry made him famous. About levers once he said that, "give me a bar, long and strong enough, and a place to stand and I will lift the Earth."



INTEXT QUESTIONS 11.4

1. Hold a mug full of water inside a bucket filled with water. Now lift it above the surface of water. Why do you feel it is heavier now?
2. Why does a piece of cork released under water bounce back?
3. What do you mean by buoyant force?
4. Does the buoyant force act on a body when it is kept in vacuum?
5. State two applications of Archimedes' principle.

WHAT YOU HAVE LEARNT

- Newton's law of gravitation states that every particle in the universe attracts every other particle with a force, which is proportional to the product of their masses and inversely proportional to the square of the distance between them.
- Force of gravitation between objects of ordinary mass is very weak. However, when large masses are involved this force becomes appreciably stronger.
- The gravitational force due to earth is known as gravity.
- The value of acceleration due to gravity is independent of the mass of the body.
- The weight of an object is the force with which it is attracted towards the earth. It is equal to the product of mass and acceleration due to gravity.
- The mass of an object is constant and does not vary from place to place. However the weight of an object may vary from place to place.
- A body falling freely under gravity is weightless.
- All objects experience a buoyant force when they are immersed in a fluid.
- The magnitude of the buoyant force acting on a body at a given place depends on density of the fluid and volume of the body immersed in the fluid.
- Archimedes' principle states that 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.

TERMINAL EXERCISE

1. State Newton's law of gravitation.
2. How does the force of gravitation between two objects change when the distance between them is doubled?
3. How does the gravitational force between two objects change if the masses of both objects are doubled?
4. Derive an expression for the acceleration due to gravity on the surface of the earth in terms of earth's mass, gravitational constant and radius of earth.
5. Write the equations of motion of an object moving or falling only under gravity.
6. What are the differences between the mass of an object and its weight? On what factors does the weight of an object depend?
7. Why does a capped empty plastic bottle released under water bounces back to the surface of water?

8. What is force of buoyancy? What are the factors on which the magnitude of the buoyant force acting on a body at a given place depends?
9. State Archimedes' principle. Give two applications of Archimedes' principle.
10. If the average distance between the earth and the sun is 1.5×10^{11} m, calculate the force of gravitation between the two. Given:

$$\text{mass of the earth} = 6 \times 10^{24} \text{ kg}$$
$$\text{mass of the sun} = 2 \times 10^{30} \text{ kg}$$
$$\text{value of } G = 6.7 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2}$$

11. What is the mass of an object whose weight is 49N? (Given $g = 9.8$ ms^{-2}).
12. A stone is dropped from the top of a tower 45 m high. What is its velocity when it hits the ground? (Given g = 10 ms^{-2}).
13. A body weighs 3.5 N in air and 2 N in water. How much buoyant force acts on the body?
14. A body is immersed in a liquid. If the liquid displaced by the body weighs 1 N then what is the buoyant force acting on the body?

ANSWERS TO INTEXT QUESTIONS

11.1

1. Gravitational force is extremely weak. Therefore, small masses do not attract each other due to this force.
2. As the force of gravitation is inversely proportional to the square of the distance between two bodies, the force will decrease by a factor of 1/16.
3. The value of G is same everywhere on the earth or in the universe. Therefore, G is known as universal gravitational constant.

11.2

1. The acceleration produced due to force of attraction by the earth is known as acceleration due to gravity.
2. Because the acceleration due to gravity is same for both heavy and light objects.
3. SI unit for acceleration due to gravity is ms^{-2}.
4. Equations of motion

$$v = u + gt \quad \text{...(1)}$$

$$s = ut + \frac{1}{2}gt^2 \quad \text{...(2)}$$

$$v^2 = u^2 + 2gs \quad \text{...(3)}$$

11.3

1. Mass is the quantity of matter contained in a body.

   Man of a body remains the same at all places.

   Weight of an object on earth is the force with which it is attracted towards the earth. Weight of an object changes from place to place.

2. Weight of an object depends upon
   - (i) mass of the body
   - (ii) acceleration due to gravity.

3. Zero

11.4

1. When immersed in water a buoyant force acts on the mug. Therefore, it feels lighter inside water. When lifted above the surface of water it feels heavier.
2. Due to buoyant force (or upthrust)
3. When an object is immersed in a fluid it experiences an upward force which is known as buoyant force.
4. No
5. Applications of Archimedes's principle:
   - (i) In designing ships and submarines
   - (ii) Hydrometers or lactometers

MODULE - 4

ENERGY

12. Sources of Energy
13. Work and Energy
14. Thermal Energy
15. Light Energy
16. Electrical Energy
17. Magnetic Effect of Electric Current
18. Sound and Communication

12

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SOURCES OF ENERGY

All of us take food for survival and growth of our body. Vehicles like motorcycles, tractors, buses, trucks, ships and aeroplanes require fuel for their running. Even for cooking food we require fuel. Do you know What is important which we get from the food or from the fuel? Yes, you are right. It is the energy. From the time you wake up to the time you go to sleep at night, energy plays an important role in your life. Energy is important in everyone's life, whether you notice it or not. Without sufficient energy people face difficulties doing their day to day work. All forms of energy including solar energy, light energy, mechanical energy, nuclear energy, and the energy of our body are important to us. The energy of your body enables you to talk, to move and to walk. Is it possible to do any task without energy?

The basic question is: from where do we get all the energy we need? In this lesson we will learn about different sources of energy, their importance and limitations. We will also learn about the energy crisis and how and why it came about? The ways and means of saving and conserving energy in our daily life will also be discussed in this lesson.

OBJECTIVES

After studying this lesson, you will be able to:

- *define energy and list various forms of energy;*
- *identify conventional and non-conventional sources of energy used in India;*
- *distinguish between renewable and non-renewable sources of energy;*
- *describe various types of sources of energy e.g. fossil fuels, water, wind, biomass, sea, geothermal, nuclear energy;*
- *recognise that the sun is the ultimate source of energy;*
- *explain the advantages and disadvantages of different sources of energy;*

- *explain what is energy crisis and how did it develop;*
- *recognise the need of conservation of energy sources and*
- *explain the methods of mitigation of energy crisis – energy efficiency and conservation in your daily life.*

12.1 ENERGY – AN INTRODUCTION

Energy is a very common word frequently used in our day-to-day life. Energy is defined as the ability to do work. We require energy for all types of activities including the activities within our body, with our body or with other bodies. When we say a body has energy, it means that it is capable of doing work. Look around you will find countless examples where energy is used to do work. An engine uses energy of its fuel to move a car along. A battery stores the energy needed to switch on the radio or tape recorder. The heavy flow of water can break the banks of rivers as it also has energy in it. Similarly the wind also carries enough energy to shake trees.

12.1.1 Importance of Energy in our Life

Energy plays a very important role in our lives, providing comfort, increasing productivity and allowing us to live the way we want to. Since the beginning of mankind, we have made use of wood, water, and fossil fuels as a means of heating and making machines work. Almost for all types of activities, we rely on one or another form of energy.

Amount of energy used by a society is an indicator of its economic growth and development. Without energy even our body would be unable to perform basic functions like respiratory, circulatory, or digestive functions to name a few. Plants would also be unable to complete the process of converting Carbon dioxide, water and minerals into food without the light from the Sun. Almost all the machines used for the production and manufacture of different types of items would be unable to operate without the use of a source of electrical energy. Almost everything we see around us, the clothes we wear, the food we eat, the houses we live in, the paper we write on, the vehicles we drive, all need energy to be created or transformed from some natural resource to the final product. Nowadays, the electrical energy has become so important that almost in all walks of life electricity is required. For example all electrical appliances in our homes and at our workplace require electricity. All the industries and factories run on electricity.

12.1.2 Various forms of Energy

In our daily life we use different forms of energy such as heat energy, light energy, mechanical energy, electrical energy, chemical energy, and sound energy. The most common forms of energy are heat, light and electricity. We use all these forms of energies for different types of work.

As per requirement, one form of energy can be converted into another form of energy by using specific types of devices or processes. We get energy for our daily use from different sources. We will learn about details of different forms of energy in other lessons.

12.1.3 Different Sources of Energy

In simple terms we can say that anything out of which usable energy can be extracted is a source of energy. There is a variety of sources that provide us energy for different purposes. You must be familiar with coal, petrol, diesel kerosene and natural gas. Similarly you must have also heard about hydroelectric power, wind mills, solar panels, biomass etc.

It can be easily seen that some of the energy sources can be replenished in a short period of time. Such energy sources are referred to as "renewable" energy sources, whereas the energy sources that we are using up and cannot be generated in a short period of time are called non-renewable energy sources. Thus, all the sources of energy can be divided into two categories: renewable sources and non-renewable sources of energy.

INTEXT QUESTIONS 12.1

1. List out any five activities from your daily life in which different forms of energy are involved.
2. What are the three most common forms of energy that we use frequently?
3. Differentiate between renewable and non-renewable sources of energy.

12.2 NON-RENEWABLE ENERGY SOURCES

You know that petrol and diesel extracted from crude oil are commonly used to run different kinds of vehicles, such as cars, buses, tractors, trucks, train, aeroplanes etc. Similarly, kerosene and natural gas are used as fuels in lamps and stoves. You should also know that crude oil coal and natural gas occur in limited and exhaustible quantities. They cannot be regenerated in a short period of time or used again and again. Hence, they are called non-renewable sources of energy.

It is a fact that at present we get most of our energy from non-renewable energy sources which include fossil fuels such as coal, crude oil and natural gas. Looking at the present and future energy requirements, it is expected that our oil and natural gas reserves may last for another 30-35 years (assuming no major new fields are discovered). Similarly the coal reserves may last no longer than another 100 years. So we must use these non-renewable energy sources judicially and avoid all wastages.

Radioactive elements like natural uranium are also non-renewable. When the atoms of uranium are split into two or more parts, a very large amount of energy is released which can be used to generate electrical energy.

Let us now, look into details of the fossil fuels as sources of energy.

12.2.1 Fossil Fuels – Conventional Source of Energy

Fossil fuels, such as coal, oil and natural gas, are important non-renewable sources of energy. Since the beginning of mankind, we have been using fossil fuels to generate heat, light and electricity for various purposes. These are the primary sources for generating electrical energy in the world today. Over 85% of our energy demands are met by the combustion of fossil fuels. Carbon is the main constituent of these fossil fuels. Fossil fuels are excellent sources of energy for our transportation needs. You may be surprised to know that approximately 1.9 billion tons of coal is burnt in a year to generate electricity in the world. A large amount of chemical energy is stored in the fossil fuels. This stored chemical energy is converted into various other forms of energy such as heat, light and mechanical energy.

You may be interested in knowing how the fossil fuels are formed? Millions of years ago the remains of dead plants and animals were buried under the ground. Over the years by the action of heat from the Earth's core and pressure from rock and soil, these buried and decomposed organic materials have been converted into fossil fuels.

(a) Coal

Coal is formed in a way similar to the other fossil fuels, though it goes through a different process called "coalification". Coal is made of decomposed plant matter in conditions of high temperature and pressure, though it takes a relatively shorter amount of time to form. Coal is not a uniform substance either; its composition varies from deposit to deposit. Factors that cause this deviation are the types of original plant matter, and the extent to which the plant matter decomposed.

There are different types of coal such as peat, lignite, sub-bituminous and bituminous. The first kind of coal is **peat** which is merely a mass of dead and decomposing plant matter. Peat has been used as fuel in the past, as an alternative to wood. Next, the peat becomes **lignite**, a brownish rock that contains recognizable plant matter and has a relatively low calorific value. Lignite is basically the halfway point from peat to coal. The next phase is **sub-bituminous** which is a shade of dull black with very little visible plant matter. This type of coal has a less than ideal calorific value. **Bituminous** coal is the best quality of coal. It. is jet black, very dense and brittle. This type of coal has high calorific value.

Generation of Electrical Energy from Coal

You may be curious to know that how do we get electrical energy from coal? It is basically by means of *coal power plants*. These power plants first burn the coal in large furnaces creating tremendous amounts of heat. This heat is used to boil water in boilers so as to convert it into steam. The steam expands, causing pressure to increase in the boiler. A steam turbine is placed at the exit of the boiler so that the moving steam rotates the turbine. In this process the energy from the moving steam gets converted into mechanical energy. The rotating turbine is used to spin a magnet inside a power generator. This generator is a large electromagnet that encases the spinning magnet. In this way the electricity is generated and so generated electricity is then sent to the national power grid from where it is distributed in different areas.

(b) Natural Gas

Natural gas is another major source of the energy in our country. Oil and gas fields have been found everywhere on the planet except on the continent of Antarctica. These fields always contain some gas, but this natural gas (methane) does not take nearly as long to form. Natural gas is also found in independent deposits within the ground as well as from others sources too. Methane is a common gas found in swamps and is also the byproduct of animals' digestive system.

Although Natural Gas is a fossil fuel, it is cleaner burning than gasoline, but does produce Carbon Dioxide, the main greenhouse gas. Like petrol and diesel, natural gas is also a finite source, though available in larger quantities than the former.

12.2.2 Advantages and Disadvantages of Energy from Fossil Fuels

Use of fossil fuels as sources of energy has both advantages and disadvantages. Let us first take advantages:

- Generation of energy from the fossil fuels technology-wise is easy and relatively cost effective,
- Fossil fuels have a very high calorific value
- Fossil fuels can generate huge amounts of electricity in just a single location.
- Transportation of fossil fuels like oil and gas to the power stations can be made through the use of pipe-lines, making it an easy task.
- Power plants that utilize gas are very efficient.

- Construction of power plants that work on fossil fuels is relatively easy technology-wise and they can be constructed in almost any location.

If we look into the disadvantages of using fossil fuels, we find that:

- Pollution is a major disadvantage of using fossil fuels as source of energy. During the process of combustion of fossil fuels a lot of toxic gases (and fly-ash in case of coal) are generated which cause pollution of the atmosphere. These gases include carbon dioxide, which traps the Sun's heat and may be causing global warming. Besides carbon dioxide, coal also gives off sulphur dioxide which may cause acid rain.
- The supply of fossil fuels is limited and cannot be replenished. The rate at which they are being consumed, their reservoirs are sure to run out soon.
- Extraction of fossil fuels including coal has resulted in the destruction of wide areas of land and has endangered the environmental balance in some areas
- Mining of fossil fuels including coal is difficult and rated as one of the most dangerous jobs. Many a times, it endangers the lives of miners
- Use of natural gas can cause unpleasant smell in the area.

Do you know

The particles formed on burning of fossil fuels are very dangerous. These small particles can exist in the air for indefinite periods of time, up to several weeks and can travel for miles. The particles, sometimes smaller than 10 microns in diameter, can reach deep within the lungs. Particles that are smaller than this can enter the blood stream, irritating the lungs and carry with them toxic substances such as heavy metals and pollutants. Those affected by these particulates could become afflicted with fatal asthma attacks and other serious pulmonary diseases.

Industrial societies need huge amounts of energy to run their homes, vehicles and factories. More than 80% of this energy comes from burning coal, oil and natural gas. These are called fossil fuels, because they formed from the remains of plants and tiny sea creatures that lived on Earth many millions of years ago. They include fuels made from oil, such as petrol, diesel and fuel for jet planes.

12.2.3 Energy from the Atom – Nuclear Energy

The atoms of a few elements such as radium and uranium act as natural source of energy. In fact atoms of these elements spontaneously undergo changes in which the nucleus of the atom disintegrates.

Let us see how we get energy from the atom. You should know that a large amount of energy is stored in the nucleus of every atom. The energy stored in the nuclei of atoms can be released by breaking a heavy nucleus such as uranium into two lighter nuclei. The splitting of the nucleus of an atom into fragments that are roughly equal in mass with the release of energy is called **nuclear fission**. (A small amount of each fission mass vanishes, in releasing huge amounts of energy as per $E = mc^2$, where m is the missing mass and *c* is the velocity of light). When a free neutron strikes a Uranium (235) nucleus at a correct speed, it gets absorbed. A Uranium (235) nucleus on absorbing a neutron becomes highly unstable and splits into nuclei of smaller atoms releasing huge amount of energy in the process. During this process, a few neutrons are also released. These neutrons split other nuclei of the Uranium (235). The reaction continues rapidly and is known as the **chain reaction**. In this process a large amount of energy is released. This energy is used for boiling water till it becomes steam. Steam so generated is used to drive a turbine which helps in generating electrical energy.

Nuclear Fusion

Energy is also produced when two light nuclei such as deuterium (heavy hydrogen) combine together to form a heavy nucleus. A process in which the nuclei of light atoms are combined to form a nucleus of a heavier atom with the release of energy is called **nuclear fusion.**

Nuclear fusion requires very high temperature, say of the order of 4 million degree Celsius (4000000 °C). This is the mechanism through which energy is produced in stars, including our sun. This reaction has been used to make hydrogen bombs.

The fission reaction is carried out in a controlled and regulated manner in nuclear reactors. (Else, they would explode like bombs with an uncontrolled chain reaction.) In order to control the fission reaction, some of the neutrons released by the reaction are absorbed by the control rods made of boron / cadmium. In our country nuclear reactors are functioning at Tarapur, Kalpakkam, Kota and Narora for generating electricity.

? Do you know

If the nuclear chain reaction is uncontrolled, all the nuclei in the piece of uranium split in a fraction of a second and this may cause a devastating explosion – such as those of the atom bombs dropped on Hiroshima and Nagasaki in Japan by America.

(a) Uses of Nuclear Energy

Nuclear energy is non-renewable as the uranium fuels used are consumed in the fission reaction and hence are non replenishable. Nevertheless, nuclear energy has many uses:

(i) Energy produced in a nuclear reactor can be harnessed to produce electricity.

(ii) Nuclear energy is also being used to power submarines and ship. Vessels driven by nuclear energy can sail for long periods without having to refuel.

(iii) Radioisotopes obtained as by-products in nuclear reactions are used in medicine, agriculture and research.

(b) Hazards of Nuclear Energy

On one side nuclear energy seems to be an alternative to fossil fuels, on the other, it can also be hazardous. Nuclear radiations and the radioactive wastes are two major hazards that accompany production of nuclear energy. Let us know little more about them.

1. In the process of producing nuclear energy, harmful nuclear radiations may get accidentally leaked/released which can penetrate human bodies and cause irreparable damage to cells. For preventing this from happening, nuclear reactors are covered with a thick shell of radiation absorbent material such as lead. However, accidental releases of these extremely harmful radiations into the environment pose a constant threat to those inhabiting the surrounding areas. Perhaps you may be aware of the two major accidents in nuclear power plants – one at the Three Mile Island (U.S.A.) and the other at Chernobyl (the then Soviet Union). The immediate devastation caused in these two accidents through the release of harmful nuclear radiations was huge and its full extent is yet to be assessed.
2. Another hazard relate to the problems involving disposal of harmful radiant wastes mainly spent fuels produced in the fission process. During nuclear reactions, a number of harmful substances capable of emitting nuclear radiations are generated. These substances are called nuclear wastes. Presently, most of the nuclear waste generated in nuclear power plants is simply being stored underground in strong lead containers. We have not yet been able to discover safer and more satisfactory methods of disposing the nuclear wastes.

There are major advantages of using nuclear energy over fossil fuels.

- Unlike fossil fuels, the nuclear fuel used in nuclear power stations, do not burn. Hence no waste gases are produced.
- Small amounts fuel materials, yield huge amount of energy.

INTEXT QUESTIONS 12.2

1. Name any four non-renewable sources of energy and give at least one advantage of each.
2. Nuclear energy is considered to be a very powerful alternative of fossil fuels. Even then why is it not being used on a much larger scale?
3. What are the limitations of using natural gas for meeting our energy requirements?

Notes

12.3 RENEWABLE ENERGY SOURCES

You have learnt in the previous section that the fossil fuels such as coal, oil and natural gas meet most of the energy needs of the world today. But what will happen when the reserves of these non-renewable sources of energy get completely exhausted?, We also need to pay attention to the damaging effects of fossil fuels on the environment.

The solution, surely, must lie in switching to alternative sources of energy and environment-friendly natural fuels. There are several alternative and renewable sources of energy which are not only environment friendly but can also be available in abundance. Water, wind, sunlight, geothermal, sea waves, hydrogen and biomass are some such possible sources of energy. In addition to the renewability, there are other reasons why we should look to switching over to such sources. Such as:

- To reduce pollutants, greenhouse gases and toxins that are by-products of non-renewable sources of energy;
- The use of alternative energy sources can help preserve the delicate ecological balance of the earth, and help conserve the non-renewable energy sources like fossil fuels; and
- Renewable sources are inexhaustible.

Fortunately there are many means of harnessing renewable sources of energy which have less damaging effects on our environment. Here are some possible alternatives in the next sub sections.

12.3.1 Sun - The Ultimate Source of Energy

The sun has been providing us heat and light for billions of years and it is expected that it will continue to do so for billions of years to come. All plants get their energy from the sun and all animals get their energy mainly from the plants. Therefore, it may be concluded that sun is a source of energy for animals. Even the energy stored in butter, milk and eggs comes form the sun. Why do we say so? The sun in fact is the ultimate source of energy for all living beings. Apart from nuclear energy, all other forms of energy result from solar energy. It is said that the fossil fuels, bio-fuels and natural gas are in effect "bottled" solar energy. The wind and rivers which provide renewable energy are also the result of solar energy. Can you think how?

Fig. 12.1

Sun is one of the most powerful renewable sources of energy for the future. As long as the sun exists, we will continue to get its energy. About 30% of the incoming solar radiation is absorbed by the upper atmospheres, the rest is absorbed by the land, sea and clouds.

Fig. 12.2 *Photovoltaic Water Pumping*

Solar energy is used commonly for heating, cooking, production of electricity, and even in the desalination of seawater. With the help of solar cells, solar energy is converted into electricity. One of the most common uses of the sun's energy has been for water heating systems. It is also used to provide power to the vehicles, generate electricity, lighting streets, cooking etc. On a small scale, solar energy is being used to heat up water for daily use in our homes and also the swimming pools. On a larger scale, solar energy could be used to run cars, power plants, and space ships etc.

Fig. 12.3 *Solar flat plate collector*

Fig. 12.4 *Box type solar cookers*

(a) Advantages of Using Solar Energy

We have been using the light and heat of the sun's rays since ancient times for different purposes. Some of the advantages of using solar energy are:

- Use of solar energy causes no environmental pollution, because no chemical waste or toxic gases get released while using solar energy,

- Solar energy can be used for practical purposes such as heating and lighting,
- The sun is an ever lasting source of energy which is freely available, and
- Can be converted into electrical energy and put to many uses.

(b) Limitations of Using Solar Energy

No doubt, the sun is the source of all the energies in one way or another, but using the sun as a source of energy also has certain limitations. Firstly, solar power plants can not produce energy if the sun is not shining. For example during night time and cloudy days it is not possible to produce energy from the sun. Secondly, establishment of solar power stations can be very expensive. Thirdly the solar panels need to be regularly maintained and cleaned to continue generating electricity.

12.3.2 Wind Energy

Wind power is another alternative energy source that could be used without producing by-products that are harmful to nature. Like solar power, harnessing the wind is highly dependent on weather and location. However, it is one of the oldest and cleanest forms of energy and the most developed of the renewable energy sources. There is the potential for a large amount of energy to be produced from windmill.

Fig. 12.5 *Windmill*

You must have seen a **phirki**. It is also called a wind-vane. What happens when you blow air on the blades of **phirki**? It starts rotating. Using **phirki**, you can easily experience that wind provides energy.

Fig. 12.6 *Phirki*

(a) Advantages of Wind Energy

- Wind energy is free of cost and reliable,
- Wind power is clean and produces no environmental pollution,
- In wind power generation no harmful by-products are left over as in case of burning of fossil fuels,
- Since wind is a renewable source of energy, we never run out of it,
- Farming and grazing can still take place on land occupied by wind turbines which can help in the production of bio fuels. When used inland, the land beneath the windmill can still be used for farming purposes.
- Wind farms can be built off-shore.
- In some cases wind farms can even be tourist attractions.

(b) Limitations of Wind Energy

- Wind power is not available all the time, at all the places and has to be used while being produced, as it cannot be stored.
- Persistent wind and consistent wind speeds are needed for continuous power generation. If wind speed decreases, the turbine lingers and less electricity is generated.
- The wind farms, whether onshore or off shores are unsightly, noisy and generate a lot of opposition.
- Large wind farms can have a negative effect on the scenery.
- They are hazards for wildlife, especially birds who commonly fly into their blades.

Different parts of our country, which are windy most of the time, have windmills to pump water and generate electricity. These wind mills are big wind-wanes in which wind energy is used. Let us look into the working of a windmill.

(c) Working of Windmill

A windmill is basically a mechanical arrangement to convert wind energy into another form of energy. It has blades. The blades of the windmill rotate in a vertical plane which is kept perpendicular to the wind. As wind flow crosses the blades of the windmill, the blades start rotating. The rotation of blades makes the turbine rotate. The turbine is attached with an electrical generator which converts mechanical energy of the turbine into electrical energy. The blades are angled into the wind, so as to rotate in a way which maximize the generation of electricity.

In older windmills, wind energy was used to run machinery to do physical work, like crushing grain or pumping water. Wind towers are usually built together on wind farms. Now, electrical currents are harnessed via large scale wind farms that are used by national electrical grids, as well as small individual turbines used for providing electricity to isolated locations or individual homes.

The wind speed is vital in the production of electricity, and the optimum speed is approximately 25 km/h and this causes the blades to rotate.

12.3.3 Hydroelectric Energy

Like wind energy, the flowing water and water stored in huge dams is also a very important source of energy which is known as hydroelectric energy. But, over-development and unrestricted harnessing of water power can have a devastating effect on the local environment and habitation areas.

(a) Generation of Hydroelectricity

Hydroelectric is produced by the natural flow or fall of water. By channelling water that is flowing downhill, the force of the water can be used to turn turbines and via a generator, produce electricity.

Hydroelectricity comes from the damming of rivers and utilizing the potential energy stored in water. As shown in the Fig. 12.7, when the water stored behind a dam is released its potential/kinetic energy is transferred onto turbine blades and used to generate electricity. Though the initial cost of setting up of hydroelectric power system is high, it has relatively low maintenance costs and provides relatively inexpensive power.

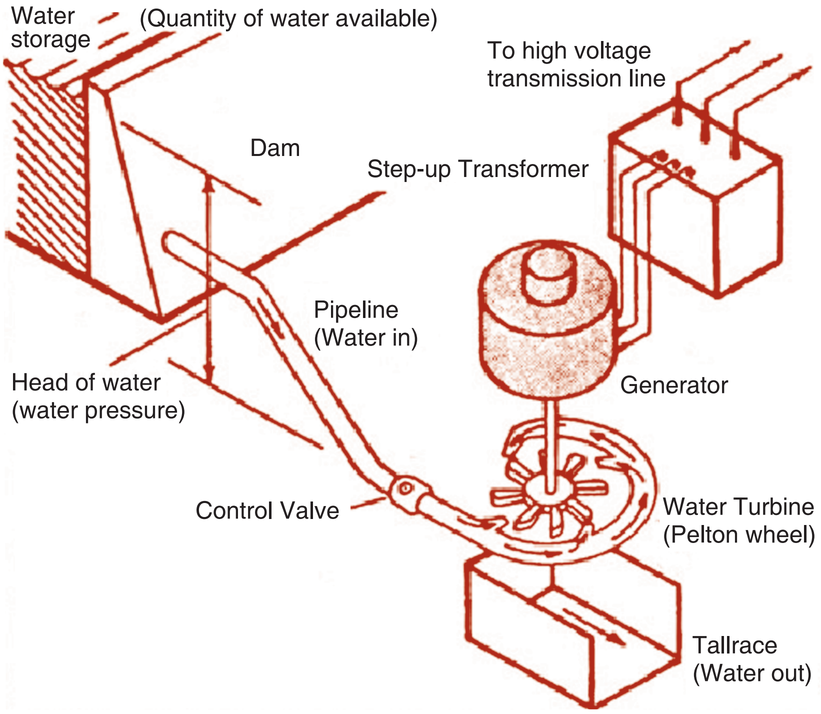

Fig. 12.7 *Generation of Hydroelectricity*

The power output of the hydroelectric source is determined by the difference in height between the source and the outflow. This height difference is known as the head and the greater the head, the larger the output. For this purpose, very big dams are made on the rivers and other water flows.

(b) Advantages of Hydroelectric Power

- It is a source of renewable energy in the form of hydroelectric power.
- It is cost effective and is competitively productive against non renewable sources.
- Electricity can be generated constantly, because there are no external factors, which affect the availability of water.
- Hydroelectric power produces no waste or pollution since no chemicals are involved.
- Water used for hydro power can be reused for other purposes/like irrigation etc.

(c) Limitations in Using Hydroelectric Power

Though water is an excellent source of generating electricity, it also has certain limitations:

- The hydroelectric power plants cannot be sited at a place of our choice. There must be a strong current or considerable height to make the production worthwhile, as the capital cost of setting up production is relatively quite high.
- Dams can be very expensive to build.
- There needs to be a sufficient, and continuously strong water current, or water head, to produce energy.

12.3.4 Geothermal Energy

Geothermal energy is another alternative source of energy. Geothermal energy is obtained from the internal heat of the earth. In fact it is one of the oldest types of natural sources of heat. It dates back to Roman times, when the heat from the earth was used instead of fire, to heat rooms and/or warm water for baths. Presently it is being used as a source for producing electricity, mainly in regions of tectonic plate movement.

Now the basic question is how do we get geothermal energy? You must have heard about the volcanoes found around the world. These volcanic features are called geothermal hotspots. Basically a hotspot is an area of reduced thickness in the mantle which expects excess internal heat from the interior of the earth to the outer crust. These hotspots are well known for their unique effects seen on the earth's surface, such as the volcanic islands, the mineral deposits and geysers (or hot springs). The heat from these geothermal hotspots is altered in the form of steam which is used to run a steam turbine that can generate electricity.

(a) Advantages of Geothermal Energy

Geothermal energy is used for heating homes and for generating electricity without producing any harmful emissions. Some of the advantages of using geothermal energy are:

- Unlike most power stations, a geothermal power plant does not create any pollution. Harnessed correctly, it leads to no harmful by-products.
- Geothermal Power plants have very low running costs. Because they require energy to run a water pump (which is provided by the power plant itself). Moreover, there are no costs for purchasing, transporting, or cleaning up of fuels.
- Geothermal power plants are an excellent source of clean, and inexpensive renewable energy.

- Geothermal energy can be used to produce electricity 24 hours a day.
- Geothermal power plants are generally small and have little effect on the natural landscape, or the near environment.

(b) Limitations of Using Geothermal Energy

Though geothermal energy has several advantages, it also has limitations:

- If harnessed incorrectly, geothermal energy can produce pollutants.
- Improper drilling into the earth can release hazardous minerals and gases.
- Geothermal power plant sites are prone to running out of steam in the long run.

Do you know

The Earth can be divided into three large sections: the mantle, the inner core, and the outer core. The inner core is at the center of the earth. The pressure and temperature increase as one move closer to the center of the earth. As one moves outwards from the inner core, one encounters the outer core and then mantle followed by the crust. The mantle is a layer that is below the crust of the earth. This is said to go down 2,900 kms; its temperature is about 870 degrees Celsius. The outer core has a very high temperature which ranges from about 4,400 degrees Celsius to about 6,100 degrees Celsius. The outer core begins where the mantle ends and it extends further down to the center 2,250 kms. The inner core is about 6,400 km below the earth's surface. The temperature at the inner core of the earth is at the high of about 7,000 degrees Celsius. The high temperature of the earth's core is the basic reason behind geothermal energy.

12.3.5 Ocean – A Source of Energy

You may be surprised to know that the ocean is also a powerful source of renewable energy. The energy of the ocean can be harnessed in three basic ways: using wave power, using tidal power, and using ocean water temperature variations. Let us study each of these, one by one.

(a) Using Ocean Wave Power to Generate Energy

You may know that different types of waves are continuously generated in the ocean. The back-and-forth or up-and-down movement of waves can be captured to harness the wave power by using it to force air in and out of a chamber to drive a piston or spin a turbine that can power a generator. In fact, kinetic energy exists in the moving waves of the ocean. That energy can be used to power a turbine as shown in Fig.12.8. In this figure you can see that when the wave rises into a chamber, it forces the air out of the chamber. The moving air spins a turbine which can turn a generator. When the wave goes down, air flows through the turbine and back into the chamber through doors that are normally closed.

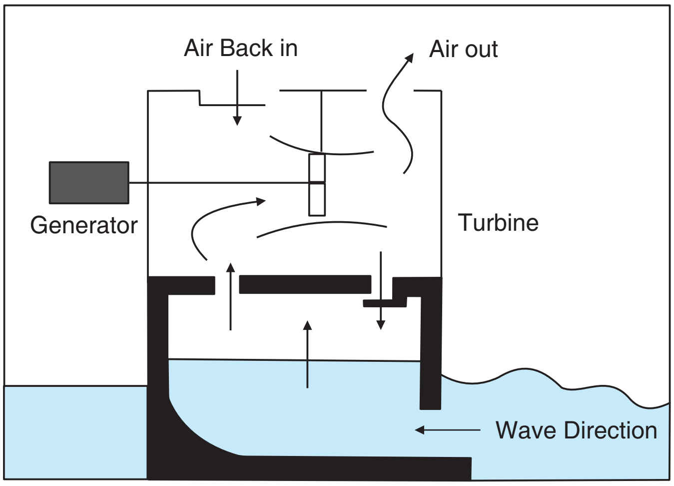

Fig. 12.8 *Generation of Ocean Energy*

This is only one type of wave-energy system. Others actually use the up and down motion of the wave to power a piston that moves up and down inside a cylinder. That piston can also turn a generator. Presently in some cases the wave power is being used in small lighthouses and warning buoys.

(b) Using Tidal Power of Ocean to Generate Energy

The tidal energy of ocean can also be harnessed by trapping water at high tide and then capturing its energy as it rushes out and drops to low tide. When tides come into the shore, they can be trapped in reservoirs behind dams. And when the tide drops, the water behind the dam can be let out just like in a regular hydroelectric power plant. Presently, the power of the tides is being harnessed to produce electricity in Canada and France.

(c) Using Ocean Water Temperature Variations to Generate Energy

If you go swimming in the ocean and dive deep below the surface, you will notice that the water gets colder the deeper you go. It is warmer on the surface because sunlight warms the water. But below the surface, the ocean gets very cold. That is why scuba divers wear wet suits when they dive down deep. Their wet suits trap their body heat to keep them warm.

This temperature difference between deep and surface waters in the ocean is also used to extract energy from the flow of heat between the two. The process is called "ocean thermal energy conversion" (OTEC). Power plants can be built that use this difference in temperature to generate energy. Presently, it is being used in Japan and in Hawaii in demonstration projects.

(d) Advantages and Disadvantages of Using Ocean Energy

The energy potential of an ocean, particularly tidal basins, is large. The ocean energy is preferable to that of wind because tides are constant and predictable and that water's natural density requires fewer turbines than are needed to produce the same amount of wind power. However, tidal energy systems can have environmental impacts on tidal basins because of reduced tidal flow and silt build up.

12.3.6 Energy from Biomass

You may know that the biomass is organic material made from plants and animals. It includes garbage, industrial waste, crop residue, manure, wood, sewage and dead parts of living objects. Like all other sources of energy, it also contains stored energy from the sun. Therefore, biomass is also a very good source of energy.

Do you know how biomass contains sun's energy? You know that the plants absorb sun's energy in a process called photosynthesis. The chemical energy in plants gets passed on to animals and people who eat them. On burning the biomass, the chemical energy stored in it is converted into heat energy. The thermal energy released from biomass can be used to provide heat to industries and homes, and also to produce steam for generating electricity. But you have learnt by now that on burning any type of fuel, harmful emissions are released. So how biomass can be a good source of energy? Can we get energy from biomass without burning?

Yes. Burning biomass is not the only way to release its energy. Biomass can be converted to other useable forms of energy, such as biogas or methane, ethanol and biodiesel. You have learnt earlier that methane is the main ingredient of natural gas as well. The smelly stuff like rotting garbage, and agricultural and human wastes release methane gas - also called "landfill gas" or "biogas". Like liquid petroleum gas (LPG), the biogas is also used for cooking and lighting.

Biofuel including biogas and bio-diesel is another important fuel produced from left-over food products like vegetable oils and animal fats. Biofuel is made mainly in two ways. The first is when large amounts of crops high in sugar or starch content are grown, and then fermented with yeast to produce ethyl alcohol or ethanol. Plants like corn, soybeans, rapeseed, wheat, sugar cane and sugar beet are used to produce ethanol. Ethanol can be used as an alternative fuel in petrol engines, but it is very corrosive and so can be harmful to engine parts and components. The other option is that it can be mixed with petrol to produce a more bio-friendly fuel which can be used in engines. In the second method, plants high in vegetable oils are grown and then the vegetable oil is processed to produce bio-diesel.

Thus we can say that biomass can be used as a source of energy in the following three ways:

- by burning dry biomass directly to produce heat, or generate steam.
- by decomposition of biomass in the absence of oxygen to produce methane gas.
- by producing bio-diesel from the plants high in vegetable oils.

(a) Advantages of Using Biomass as Source of Energy

Biomass is an inexhaustible energy source because we can always grow more trees and crops, and waste will always exist. Using biomass as a source of energy has following advantages:

- When direct combustion of biomass is not used to generate energy, there is hardly any environmental impact.
- Biodiesel and other fuels produced by biomass are viable and a clean source of energy.
- Biomass is easily available throughout the world.
- The residue from biomass plants can be used as manure.

(b) Limitations of Using Biomass as Source of Energy

Though biomass is a clean and renewable source of energy, it has certain limitations. Some of them are:

- The bio-fuel or ethanol produced from biomass is not as energy efficient as petrol.
- If the biomass is directly burnt, it may contribute to global warming and increase emissions causing environmental pollution.
- The main ingredient of biofuel i.e. methane is harmful to the environment.
- Biomass is a relatively expensive source for generating energy, both in terms of producing the biomass and converting it to ethanol.

12.3.7 Hydrogen – A Future Source of Energy

Hydrogen could be a very environmentally friendly source of energy in the future. In the long-term, hydrogen is likely to reduce dependence on conventional sources of energy such as petrol, diesel and coal etc. In addition to it, the use of hydrogen as source of energy will help in reducing the emission of greenhouse gases and other pollutants.

When hydrogen is burned, the only emission it makes is water vapour, so a key advantage of hydrogen is that when burned, carbon dioxide (CO_2) is not produced. Thus, we can say that hydrogen does not pollute the air. Hydrogen has the potential to run a fuel-cell engine with greater efficiency over an internal combustion engine. The same amount of hydrogen will take a fuel-cell car at least twice as far as a car running on gasoline.

Though, the hydrogen fuel cell has proved to be a viable source of energy for vehicles, but there are serious questions on its production, storage and distribution. There are also questions on its efficiency, in so far as it takes more energy to manufacture it than what it produces. Besides, it costs a considerable amount of money to run a hydrogen vehicle because it takes a large amount of energy to liquefy the fuel.

Do you know

Hydrogen is one of the most abundant elements in the universe. It is the lightest element, and it is a gas at normal temperature and pressure. Hydrogen as a gas is not found naturally on Earth, because hydrogen gas is lighter than air and rises into the atmosphere. Natural hydrogen is always associated with other elements in compound form such as water, coal and petroleum.

INTEXT QUESTIONS 12.3

1. Name any one alternative source of energy which you would like to use in your home. Justify your answer.
2. Biofuel is considered to be a good fuel. Why is it not being used on a mass scale to replace the fossil fuels in our country?
3. List any five traditional uses of solar energy.

12.4 TRANSFORMATION OF ENERGY

As you have learnt earlier, energy can exist in many different forms. It is also true that energy can be changed from one form to another. But it cannot be created or destroyed. Normally, we talk about 'using energy', but do you know, it never gets 'used up'. It just gets transformed into another form. Eventually, most of it ends up as heat, but it is so spread out that it cannot be detected or used.

Let us see how transformation of energy takes place in our day-to-day life. Some examples are:

- The food has chemical energy stored in it. When our body uses this stored energy to do some work, it gets converted in to kinetic energy. Similarly, when you kick a ball, your muscles change chemical energy from your food into kinetic energy. As the ball moves through the air and across the ground, friction slows it down and its kinetic energy is changed into thermal energy (heat).
- A car uses stored chemical energy in petrol or diesel to move. The engine changes the chemical energy into heat and kinetic energy to power the car. Things that are moving, such as vehicles, flowing water, and winds etc. have kinetic energy.

- In a thermal power station, the chemical energy of coal is transformed into heat energy of the hot steam, and then into mechanical energy of turbine. This mechanical energy is transformed by a generator into electrical energy, which passes through the power lines to various places – cities, towns, houses, factories etc., where it is transformed back to heat, light, sound or mechanical energy.
- Spring or other stretched or compressed materials have potential energy.
- The water stored in dams and reservoirs also has potential energy which gets converted in other forms of energy.
- When hot materials cool down, they give off heat, or thermal energy. The fuels and batteries have chemical energy stored in them. When they are used their energy is released by chemical reactions.
- When you talk on the phone, your voice i.e. sound energy is transformed into electrical energy, which is transmitted through wire or the air. The phone on the other end changes the electrical energy into sound energy through the speaker. Similarly, a television changes electrical energy into light and sound energy.

As per the "Law of Conservation of Energy", energy can neither be created nor destroyed, it can only be transformed from one form of energy into another. Details about the transformation of energy will be discussed in another lesson.

12.5 ENERGY CRISIS AND ITS MITIGATION

All activities, small or big, need one or another form of energy. We can say that the energy is the lifeline for our survival and development. Because of paucity of electrical energy, some Indian households, particularly in rural areas, go without electricity for days. Even in urban areas the situation is not very good. There are frequent electricity cuts for several hours during a day. This becomes a severe problem during the summer. Energy demand in the future will continue to increase as India's population and its needs continues to grow.

The situation in which a country suffers from frequent disruptions in energy supplies because of large and increasing gaps between availability and demand of electricity accompanied by rapidly increasing energy prices that threaten economic and social development of the nation may be termed as the **energy crisis.** Energy crisis is being faced by all developing nations including India. What are the reasons behind such as energy crisis?

12.5.1 Reasons behind Energy Crisis

It is a fact that presently around 85 percent of the world's energy supply is met from oil, coal and natural gas. Clearly, we live in the age of coal and oil, but the availability, of both of these resources of energy are very limited and will not last beyond a few decades. If we think about the Indian situation only, coal accounts for over 70%

of India's energy production. However, it is a limited resource and also creates environmental problems. Even if more coal is mined, the increasing gap between the demand and supply of energy in India can not be easily bridged. Indian villagers are forced to spend from two to six hours per day gathering fuel for their household cooking needs. Moreover, India's reliance on firewood has led to deforestation and pollution. Thus, the basic reasons behind over energy crisis seem to be the following:

- Our over-dependence on limited and exhaustible sources of energy such as our coal and oil deposits.
- Increasing gap in the demand and supply of the energy.
- Ever increasing prices of the energy and fuel from other countries.
- Reluctance in using alternative and renewable sources of energy, such as solar, wind, bio-energy, etc..
- Overuse and misuse of the available sources of energy.

12.5.2 Methods of Mitigating Energy Crisis

In order to mitigate the problem of energy crisis, the Government as well as the people of the country should take collective and serious steps.

(a) It is believed that one possible solution to India's energy problems is Nuclear Power. Accordingly, we signed a Nuclear Deal to import fuel and technology. The model of nuclear powered energy has been successful in countries like France where they meet more than 75% of their electricity requirements from nuclear energy.

(b) The use of renewable sources of energy like solar power, wind power, hydroelectric power, biogas and biofuel etc should be promoted. As automobiles are major consumers of petroleum fuels/oils, an effort should be made to increase the mileage standards of the automobiles. Even the generation of energy from renewable sources is not very simple and cost effective. Therefore, all of us should make a sincere effort to save and conserve the energy.

(c) Being an agricultural nation we could have come up with a more ingenious solution to produce ethanol and biofuel from sugarcane and vegetable oils.

In addition to the above initiatives to solve the problem of energy crisis, we should follow an 'energy conservation approach' in our daily life. Some useful tips, on how we can save energy in our daily life, are given in the following section.

12.5.3 Conservation of Energy

The key for resolving the country's energy crisis lies with us citizens. Among things we can do is the conservation of our non-renewable sources of energy. It is said that energy saved is as good as energy generated. Therefore, we should not only judiciously use energy sources but save energy as much as we can. You can start conservation of energy in your home. Some of the important tips for saving energy are:

- Switch off lights, fans and other appliances when not in use. Water taps should not be left open.
- While cooking rice, dal etc. the vessel should remain covered and, for cooking, only the required quantity of water should be used. If you soak pulses in water for some time before cooking, it will save energy in cooking.
- Another way of saving energy is by use of more efficient appliances. For example, a LED or CF light is much more efficient that a tube light or bulb; and a tube-light gives much more light than a bulb of same power rating. In fact, bulbs are being totally phased out in some countries. Better stoves burn fuel efficiently and give more heat per unit of fuel burned. The fuel efficient vehicles should be used and their engines should be maintained properly. Similarly, more energy efficient electrical appliances having energy saving stars should be used,

These are only some of the habits which can save a lot of energy. We should find ways for not wasting energy where it can be saved. For example, if you are required to go to a nearby place you may walk or go by a bicycle and avoid the use of an automobile. You may use public transport in place of your own vehicle to save fuel. Share automobiles rides to office, instead of driving alone to office.

INTEXT QUESTIONS 12.4

1. What are the steps that you can and should take for saving energy at home or in the office?
2. List at least three reasons behind the energy crisis in our country.
3. What do you mean by the statement that 'energy can neither be created nor destroyed?

WHAT YOU HAVE LEARNT

- All processes taking place on the earth require energy. Energy is the ability to do work.
- The sun is considered to be ultimate source of energy for life on earth. We all directly or indirectly use sun's energy which is also called solar energy.
- Coal and petroleum are fossil fuels. Presently, they are the main source of energy in our country.

- Energy sources are either renewable or non-renewable. Non-renewable sources are getting depleted.
- We should try to utilize renewable sources of energy in order to conserve fossil fuels and also to protect our environment.
- Energy exists in various forms. Energy can be transformed from one form to another. Energy can neither be created nor destroyed. In any energy transformation, the sum total of energy remains contant.
- Fission is a process of splitting up of the nucleus of a heavy atom into fragments of roughly of equal masses. Huge amount of energy is released in the process of nuclear fission, where the missing mass gets converted into energy (vide $E = mc^2$).
- In order to conserve energy we should not only judiciously use energy sources, we should also save energy as much and as far as we can.

TERMINAL EXERCISE

1. What are different forms of energy?
2. Distinguish between conventional and non-conventional sources of energy.
3. What are conventional sources of energy? Give two examples.
4. Why non-conventional sources of energy are preferred over the conventional sources?
5. "Sun is the ultimate source of energy". Justify this statement.
6. List some uses of nuclear energy.
7. What are the hazards of producing nuclear energy?
8. What do you mean by the energy crisis? List out the possible reasons.
9. What measures should be taken to mitigate the problem of energy crisis in our country?
10. Why should we save energy?

ANSWERS TO INTEXT QUESTIONS

12.1

1. (i) Cooking of food – heat energy and chemical energy of fuel
   (ii) Lightning of bulbs – electrical energy and light energy
   (iii) Talking to each other – sound energy

(iv) Cycling – mechanical energy

(v) Torch – chemical energy of cells

2. (i) Heat, (ii) Light and (iii) Electricity

3. The energy sources that can be replenished in a short period of time are called renewable energy sources, whereas the energy sources that we are using up and cannot be generated in a short period of time are called non-renewable energy sources.

12.2

1. (i) Coal, Advantage: It is cheaper and easily accessible.

   (ii) Oil, Advantage: It is excellent sources of energy for our transportation.

   (iii) Natural Gas, Advantage: It is cleaner burning than gasoline, but does produce Carbon Dioxide, the main greenhouse gas and it has high calorific value.

   (iv) Nuclear Fuel, Advantage: Nuclear fuel used in nuclear power stations does not burn and hence no waste gases are produced.

2. Because of the following reasons:

   It is difficult to set up nuclear power plants and also a lot of money has to be spent on safety of the nuclear power plants. Moreover the nuclear waste produced from plants can be hazardous.

3. Limitations of using natural gas for meeting our energy requirements:

   Stock of natural gas is limited and it cannot be replenished.

   Use of natural gas can cause unpleasant smell in the area.

12.3

1. Solar energy. Because it is free and easily available in the area in which we live. It can be used for cooking, water heating and also for keeping our home warm in winter.

2. (i) The bio-fuel is not as energy efficient as petrol.

   (ii) The main ingredient of bio-fuel i.e. methane is harmful to the environment.

   (iii) Bio-fuel is a relatively expensive source for generating energy, both in terms of producing the biomass and converting it to ethanol.

3. Traditional uses of solar energy.

   (i) drying of clothes (ii) heating of water (iii) drying crops,

   (iv) breeding and raising chicks and (v) drying manure

12.4

1. Steps for saving energy
   - Switch off lights, fans and other appliances when not in use.
   - Water taps should not be left open.
   - While cooking vegetables the vessel should remain covered.
   - For cooking, only the required quantity of water should be used.
   - Soak pulses in water for some time before cooking,
   - use of more efficient appliances.
   - use public transport in place of your own vehicle to save fuel.
   - Share automobiles rides to office, instead of driving alone to office.
2. Reasons behind the energy crisis in our country.
   - Our over-dependence on limited and exhaustible sources of energy such as our coal and oil deposits.
   - Increasing gap in the demand and supply of the energy.
   - Ever increasing prices of the energy and fuel from other countries.
   - Reluctance in using alternative and renewable sources of energy, such as solar, wind, bio-energy, etc..
   - Overuse and misuse of the available sources of energy.
3. The statement 'energy can neither be created nor be destroyed' means that energy the total energy remains constant. It can only be transformed from one form of energy into another.

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13

WORK AND ENERGY

In previous lesson we have learnt that force changes the motion (i.e. momentum). But during the change in motion the body on which the force is applied also moves through some distance. This leads us to some more basic concepts of science - **work**, **power** and **energy**, which we will discuss in this lesson.

We commonly use the word like work and energy in our daily life. Let us study the lesson and found out how science define these terms.

We will also come to know in this chapter about the various forms of energy, examples of their interconversion and the most basic law of nature which governs these energy transformations – **the law of conservation of energy**.

Sometimes we want the work to be done more quickly. The quantity which measures the rate at which work is done is called **power**. Performance of a machine is usually rated by power.

OBJECTIVES

After studying this lesson you will be able to:

- *define the terms work and energy and their SI units;*
- *compute work done by a constant force;*
- *list various forms of energy-like mechanical, thermal, light, sound, electrical, chemical, and nuclear energy with examples;*
- *define and explain potential and kinetic energy with suitable examples;*
- *cite examples of transformation of energy;*
- *state and explain the law of Conservation of Energy' with the help of suitable examples and*
- *explain the term power and define its SI unit.*

13.1 WORK

Work is a common term we use in our day to day conversation. Ordinarily we include standing, reading, lying etc. in the category of work. But in sciences physical work has a very specific meaning, that is, work is said to be done when force is applied on a body and the body moves through some distance in the direction of force. To elaborate, it implies that:

- If a force is applied on a body and the body does not move then no work is done at all.

Example: When you try to push a wall you do not do any work as distance moved by the wall is zero (Fig. 13.1).

- If no force is applied on a body and the body is either at rest or moving with a constant velocity then again no work is done.

Example: A car moving with a constant velocity on a level road does not do any net work. Because the fuel it consumes is used in doing work against fraction, so that, its velocity may be maintained.

- If the force and displacement are perpendicular to each other, the work done by the force is zero as shown in Fig 13.3.

Fig. 13.1 *No displacement, no work is done in case of pushing a wall*

13.2 RELATION BETWEEN WORK, FORCE AND DISPLACEMENT

Work is measured as the product of force and the displacement in the direction of the force.

i.e., work = force × displacement in the direction of the force.

If force and displacement are in the same direction you can easily find work done by finding their product. But if force and displacement are in different directions the work done is obtained by finding the product of force and the projection of displacement in the direction of the force. For the situation shown in Fig. 13.2.

$$\text{work done } W = F \times PR \text{ and not } F \times PQ$$

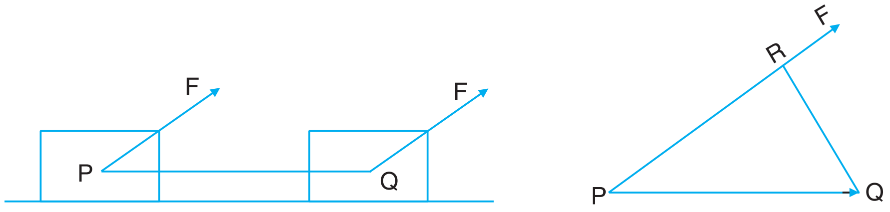


Fig. 13.2 *Work done when force and displacement are in different directions*

Example: A person carrying a heavy load on his head and moving on a level road does no work against gravity, because, there is no component of displacement in the direction of force of gravity as shown in Fig 13.3.

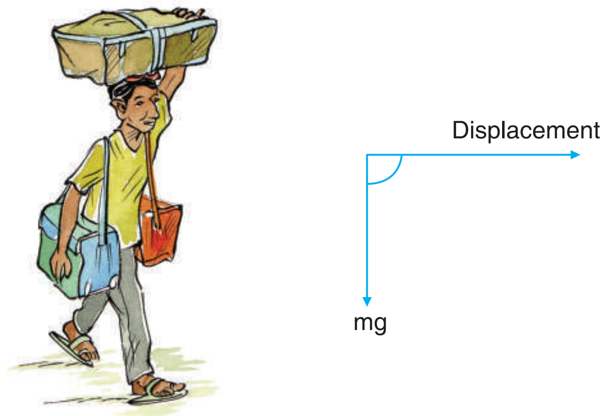


Fig. 13.3 *No work done against gravity when a person moves on a level road carrying a heavy load on his head*

The SI Unit of work is newton-metre (Nm) or joule (J). 1 J work is done when a body moves through a distance of 1m under a force of 1 N, in the direction of force.

INTEXT QUESTIONS 13.1

Choose the correct option

1. (i) Work done is zero:

   (a) When force and displacement are in the same direction.

   (b) When force and displacement of the body are in opposite directions

(c) When force acting on the body is perpendicular to the direction of the displacement of the body.

(d) When force makes an angle with displacement

(ii) 1 J of work is done when a force of 0.01 N moves a body through a distance of :

(a) 0.01 m (b) 0.1 m (c) 1 m (d) 10 m (e) 100 m

(iii) In which of the following situations work is done?

(a) A person is climbing up a stair case.

(b) A satellite revolving around the earth in closed circular orbit

(c) Two teams play a tug of war and both pull with equal force

(d) A person is standing with heavy load on his head

2. A car of mass 500 kg is moving with a constant speed of 10 ms^{-1} on a rough horizontal road. Force expended by the engine of the car is 1000 N. Calculate work done in 10 s by:

(a) net force on the car (b) gravitational force
(c) the engine (d) frictional force

13.3 ENERGY AND ITS RELATION WITH WORK

When you play for a long time or do a lot of physical work at your home or outside you get tired, i.e., your body shows unwillingness or reluctance towards further play or work. At this time you may also feel hungry. After taking rest for some time or/ and eating some thing you may again be ready for work. How does one explain these experiences? In fact, when you do work, you spend energy and more energy is required to do more work. The capacity of a body to do work is determined by the energy possessed by it.

i.e., Energy possessed by a body = Total work that the body can do

Energy has the same unit as work, i.e., joule denoted by J.

However, conversion of 100% of energy may not always be practicable, because, in the process of conversion of energy into work some energy may remain unused or may be wasted. To understand this point perform the following activity.

ACTIVITY 13.1

Alok and Kapil are inflating long (at least 5 cm) balloons in different ways as shown in Fig. 13.4. Alok blows in his balloon with part of its opening ushering in air, while Kapil blows in air in the whole area of the opening.

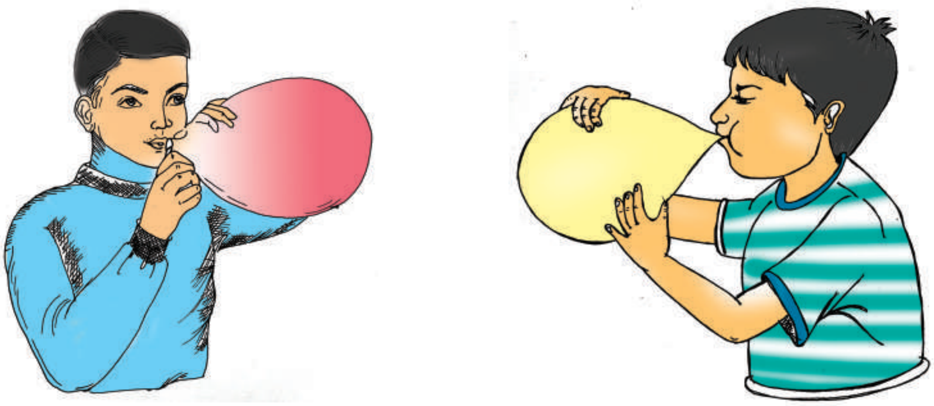


Fig. 13.4 *Alok and Kapil are inflating identical long balloons in different ways*

- Which of them is making more effort?
- Which of them is doing more work?

Do this activity, find out which technique resulted in a bigger baloon can you explain the reason.

On the basis of your conclusion now you can understand why air is blown from a distance in Phukini (metal pipe) to light the fire in Chulhas.

Fig. 13.5 *Use of Phukini (metal pipe) to light the fire*

Note: This cooking practice is unhealthy as it can lead to several health related problem.

13.4 DIFFERENT FORMS OF ENERGY

You do work by spending muscular energy which you gain from the chemical energy of the food you eat. Your fan runs on electrical energy. While playing with magnets you might have seen that a magnet can move a piece of iron so it has magnetic energy. Thus energy is available to us in many different forms like mechanical, thermal, light, electrical, magnetic, sound and nuclear. Let us acquaint ourselves with different forms of energy.

1. Mechanical Energy

This is the capacity of doing work that a body possesses by virtue of its position (potential energy) or by virtue of its motion (kinetic energy).

(a) Potential Energy

A body (say hammer) raised to a certain height above the ground when left to itself, falls down. If it is allowed to fall on a piece of dried clay it may break it into pieces. A body raised above the ground has thus ability to do work i.e. it has energy. This energy possessed by a body raised above the ground is called its potential energy.

When two bodies one lighter and another heavier are dropped from the same height on a pit of sand it will be found that the heavier body penetrates more in sand than the lighter body. Hence a heavier body possesses more potential energy.

If same body is dropped from different heights, we find that the body dropped from a greater height penetrates more, hence it has more potential energy. Potential energy of a body, thus depends on

- Weight of the body ($W = mg$)
- Height of the body (h) above the ground

It is found that the relation between Potential energy PE (E_p), weight (W), and height (h) is $E_p = W \times h = mgh$

(b) Kinetic Energy

Kinetic energy is the capacity of doing work that a body has by virtue of its motion. To understand the factors on which the kinetic energy of a moving body depends perform the following activity.

ACTIVITY 13.2

Make a stack of two thick hard bound books (about 10 cm) as shown in Fig.13.4. Let a hard bound register be placed on it to form a sloping plane. Place a match box near the plane with its length parallel to the horizontal edge of the incline. Let a pencil cell roll down the incline and hit the match box. Does the match box move?

Yes. The rolling cell had some kinetic energy due to which it made the match box move through a distance. Thus a moving object has ability to do work.

Now placing the match box at the same position let a torch cell roll from the same height and strike the match box. Does it move again? Does it move through a longer distance? Why does it do so? The torch cell has more mass than pencil cell so it has more kinetic energy and does more work.

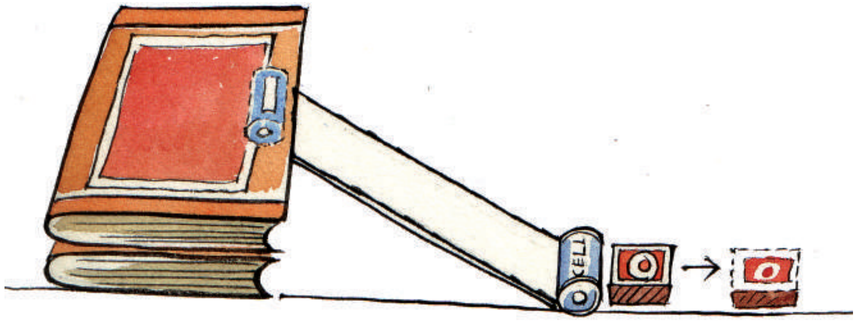


Fig. 13.6 *Experimental setup to demonstrate conversion of potential energy into kinetic energy*

Now repeat the experiment by making the cell roll from a greater height. Does it move the match box through still more distance? From these observations we may conclude:

- When a body comes down from a height its potential energy decreases where as its kinetic energy increases.
- The kinetic energy (KE) of a moving body depends on :
  - (i) its mass (m) – more the mass (for same velocity) more is its kinetic energy.
  - (ii) its velocity (v) – more the velocity (for same mass) more is its kinetic energy.

It is found that the kinetic energy of a moving body, K.E.= $\frac{1}{2}mv^2$

2. Thermal Energy

This is a form of energy which flows into our body to give us sensation of hotness and out of our body to give us sensation of coldness. You shall learn some more details about thermal energy in lesson 14.

3. Light Energy

The form of energy which enables us to see things is called light energy. You will study more about light energy in lesson 15.

4. Electrical Energy

You may be familiar with the energy that lights our bulbs, runs our fans, operates our pumps, heats our rooms, turns on our TV and radio and runs the refrigerator in our homes. The electrical energy is generated due to movement of charged particles. You will learn more about this form of energy in lesson 16.

5. Magnetic Energy

You know that a magnet can attract a piece of iron. Thus magnets have an ability to do work. The energy involved in the functioning of a magnet is called magnetic energy. You will study more about this form of energy in lesson 17.

6. Sound Energy

The form of energy which enables us to hear is called sound. Sound originates when a body vibrates giving out waves which travel to our ear through a material medium. You will study more about sound in lesson 18.

7. Nuclear Energy

The nuclear energy is a non-conventional form of energy which is released in nuclear reactions by conversion of mass into energy. You must have read in lesson 12 that India is trying to generate electrical power through nuclear energy.

INTEXT QUESTIONS 13.2

1. Explain the terms work and energy with one example each.
2. The ability to do work is called ....
3. The SI unit of all forms of energy is ....
4. Energy possessed by a spring is .... energy.
5. The energy possessed by a body due to its position is called .... energy.
6. The energy possessed by a body due to its motion is called .... energy.
7. At height h the potential energy is E_p at height $\frac{h}{2}$ the potential energy would be ....
8. At height h the potential energy of a body of mass m is E_p. At the same height the potential energy of a body of mass $\frac{m}{2}$ would be ....
9. A body of mass m moving with a speed v has kinetic energy, E_k. The body if moves with speed $2v$, will have kinetic energy equal to ....
10. A body of mass m moving with a speed v has kinetic energy E_k. A body of mass $2m$ moving with the same speed will have a kinetic energy..............

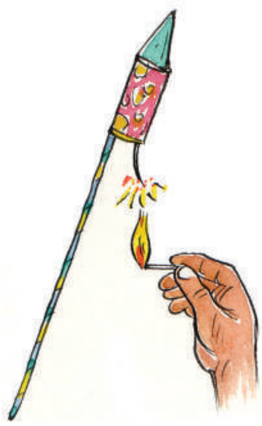
13.5 ENERGY TRANSFORMATIONS AND CONSERVATION

The various forms of energy mentioned in section 13.4 get converted from one form to another in different situations. This phenomenon of converting one form of energy to another form is called energy transformation. The following examples will make the point clear.

- Potential energy of water stored in a dam changes into kinetic energy as water falls from a height. The kinetic energy of flowing water changes into kinetic energy of rotation of a turbine. The coil attached with the shaft of the turbine rotates in a magnetic field to convert kinetic energy of rotation of the turbine into electrical energy.
- In our homes an electric bulb (or tube light) converts electrical energy into light energy, electric oven (or heater or iron or soldering iron) convert electrical energy into heat energy and electric pump (or motor) converts electrical energy into mechanical energy.
- An electric cell converts chemical energy into electrical energy; solar cell converts light energy into electrical energy and a thermocouple changes heat energy into electric energy.
- A microphone converts sound energy into electrical energy and a loudspeaker changes electrical energy into sound energy.
- Heat engine converts heat energy into work (mechanical energy) and work done against friction is converted into heat.

During transformation of energy from one form to another it remains constant. This is known as **Law of Conservation of Energy**.

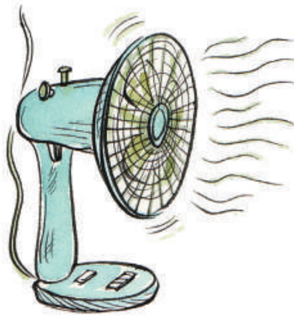
(a) Photosynthesis (Solar energy $\rightarrow$ chemical energy of food)



(b) Bursting of fireworks (chemical energy $\rightarrow$ heat, light and sound energy)

(c) Electric bulb (electrical energy → light energy)

(d) Loudspeaker (electrical energy → sound energy)



(e) Table fan (electrical energy → kinetic energy)

(f) Physical exercise (chemical energy of food → muscular energy)

Fig. 13.7 *Some examples of energy transformation*

INTEXT QUESTIONS 13.3

Give one example each of the following energy transformations.

1. (i) Light energy into chemical energy.
   (ii) Chemical energy into heat.
   (iii) Chemical energy into electrical energy.
   (iv) Mechanical energy into electrical energy.
   (v) Thermal energy into electrical energy.
   (vi) Light energy into electrical energy.
2. (i) A motor converts electrical energy into ....
   (ii) An electric heater converts electrical energy into ....
   (iii) A microphone converts sound energy into ....
   (iv) A loudspeaker converts sound energy into ....
   (v) A heat engine converts heat energy into ....
   (vi) When we rub our hands together we change work into ....

13.6 POWER AND ITS UNIT

Have you ever heard statements such as : Quarter horse power motor is enough for the pump of a room cooler, one horse power motor will fill the tank in half the time a half horse power motor does. Horse power is a unit of power. And what is power? Power is a quantity which tells us how fast the work is done. **Power is defined as the time rate of doing work** i.e., the amount of work done in unit time.

or $$\text{Power} = \frac{\text{work done}}{\text{time taken}}$$

SI Unit of power is watt. One watt is the power spent when 1 J work is done in 1 s. It is also measured in horse power. 1 horse power (H.P.) = 746 watts.

ACTIVITY 13.3

Move up a staircase slowly and then run up on it to the same height. In which case do you get tired more? Why?

Your answer would be that it has to be more in the second case. Why so, because, in the second case you took lesser time and hence spent more power.

Do you know

- About 1J of work is done when you take a glass of water (200 mL) from your dinning table to your lips – a distance of about half metre.
- A football player spends about 150 J of energy when he/she kicks a ball of about 1/2kg to a height of 3 m.
- A normal adult weighing about 50 kg does about 5000 J of work in ascending up the staircase of a single storey building.
- In pulling out a 20 litre bucket of water from a 20 m deep well approximately 4000 J of work is done.

INTEXT QUESTIONS 13.4

1. Kamya climbs up a staircase in 5 minutes, Suraiya takes only 3 minutes in going up the same staircase. The weight of Kamya is equal to the weight of Suraiya.
   (i) Which of the two does more work?
   (ii) Which of the two spends more power?

2. Express 1.5 H.P. in SI Unit of power.
3. One cricket ball and One plastic ball are dropped from the same height. Which will reach the ground with
   (a) more energy, (b) less power?

WHAT YOU HAVE LEARNT

- Work is done when a force is applied on a body and the body has some displacement in the direction of the force.
- Work is defined as the product of force and the displacement in the direction of force.
- Ability to do work is called energy. The capacity of a body to do work is determined by the energy possessed by it.
- There are various forms of energy: mechanical, thermal, light, electrical, sound, magnetic and nuclear.
- Mechanical energy may be of two types: kinetic and potential.
- Energy can be changed from one form to another. The process is called energy transformation.
- During energy transformation energy is neither created nor destroyed. This fact is due to the Law of Conservation of Energy.
- The rate of doing work is called **power**. SI unit of power is watt.

TERMINAL EXERCISE

1. Define the following terms and give their SI units. (a) Work (b) Power (c) Energy
2. List different forms of energy.
3. State Law of Conservation of Energy. Explain with the help of examples.
4. List the energy transformation taking place in a thermal power plant.
5. A ball of mass 0.5 kg has100 J of kinetic energy. What is the velocity of the ball?
6. A body of mass 100 kg is lifted up by 10 m. Find
   (a) The amount of work done.
   (b) Potential energy of the body at that height (g =10 ms^{-2})

7. Why road accidents at high speeds are much worse than the accidents at low speeds?
8. Two bodies of equal mass move with uniform velocities u and 4 u respectively. Find the ratio of their kinetic energies.
9. What would you like to prefer a ramp or a staircase to reach at the third floor of your hospital? Justify.

ANSWER TO INTEXT QUESTIONS

13.1

1. (i) c (ii) e (iii) a
2. (i) Zero (ii) Zero (iii) 10^5J (iv) -10^{+5} J

13.2

1. **Work:** Work is said to be done when force is applied on a body and the body moves through some distance in the direction of force. Example: A person climbing up a staircase.

   Energy: The ability to do work is called energy. Example: A weightlifter lifts the weight.

2. energy	3. joule	4. potential
5. potential	6. kinetic	7. $E_p/2$
8. $E_p/2$	9. $4E_k$	10. $2E_k$

13.3

1. (i) In photosynthesis green plants transform light energy into chemical energy of carbohydrates.

   (ii) In digestion of food chemical energy of food is converted into heat.

   (iii) Electrical cells convert chemical energy into electrical energy.

   (iv) In electric generators mechanical energy is converted into electrical energy.

   (v) In thermal power plants heat energy is converted into electrical energy.

   (Note: a still better example would be a thermocouple which directly converts heat energy into electrical energy)

   (vi) In Solar Cells Light energy is converted into electrical energy.

2. (i) mechanical energy
   (ii) heat energy
   (iii) electrical energy
   (iv) electrical energy
   (v) mechanical energy
   (vi) heat energy

13.4

1. (i) They both do work against gravity. Because both of them have equal weight and climb equal height they do equal work.

   (ii) Because Suraiya takes lesser time in climbing up the staircase and power is inversely proportional to time so, Suraiya spends more power.

2. SI unit of power is watt

   and $1 \text{ H.P.} = 746 \text{ watt}$

   $1.5 \text{ H.P.} = 746 \times 1.5 = 1119.0 \text{ watt} = 1.12 \text{ kW}$

3 (a) Cricket ball (b) Plastic ball

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14

THERMAL ENERGY

In previous lesson, we have studied that one of the most common forms of energy is thermal energy. It is the energy due to which we feel hot or cold. If the energy flows into our body we feel hot and if it flows out of our body we feel cold. To prevent heat from flowing out of our body we wear woolen clothes during winter.

Thermal energy is also called heat. We receive heat directly from the sun along with light. The heat from the sun dries our clothes, ripens our crops and evaporates water from water bodies to cause rain. We need heat to cook our food, to light the fire, to run a thermal power station. Generally, we produce heat for all such purposes by burning a fuel or by passing electric current through a conductor.

In antiquity, fire was produced by striking two stones together. We have now refined that method in the form of a match box. Heat is thus an important form of energy, connected intimately with our life and comfort.

In this lesson you will study about heat, its various effects and its role in our lives.

OBJECTIVES

After completing this lesson you will be able to:

- *distinguish between heat and temperature;*
- *describe experiments to show the expansion in solids, liquids, and gases;*
- *describe the construction and working of a laboratory thermometer and a clinical thermometer;*
- *state different scales of temperature, viz .fahrenheit, celsius and kelvin;*
- *relate readings on fahrenheit, celsius, and kelvin scales of temperature and solve numerical problems based on these relationships;*
- *give examples of latent heat and its applications in daily life and*
- *define specific heat and give its SI unit.*

14.1 HEAT AND TEMPERATURE

We know that thermal energy is provided to water in a kettle when it is placed on fire. If we touch water in the kettle before we start heating it and then after some time of heating we find that the water becomes warmer. This degree of hotness or coldness of a body due to which we call it warmer is called Temperature. Heat and temperature are intimately related. Normally, more the heat given to a body higher will become its temperature.

14.1.1 Heat

When water is boiled in a kettle the steam built up in the kettle raises its lid up and when the steam escapes out the lid falls down. Heat thus can do work, so, it is a form of energy. This property of steam was used to build **steam engines** – the devices which convert heat of steam into mechanical work.

You may ask, is the converse operation also possible? Can we convert mechanical work into heat? Why not? Why don't you recall that when you rub your hands together they become warm? In fact work done against friction is always converted into heat.

The equivalence of work and heat was noticed and experimentally established by J. P. Joule. While boring the barrel of a gun with a blunt borer Joule found that so huge amount of heat was produced in the process that even water in which the process of boring was being carried out started boiling.

Through further experiments he found that **one Calorie** (Unit of heat prevalent at that time) **of heat is equivalent to 4.2 Joule of work.**

14.1.2 Temperature

As discussed above temperature is a quantity which tells us how hot a body is? If a hot body is kept in contact with a colder body for some time, we will find that the hotter body does not remain that hot and the colder body becomes some what hotter. Thus heat is transferred from a hotter body (a body at higher temperature) to a Colder body (i.e. a body at lower temperature). Hence **temperature is the degree of hotness of a body which determines the direction of flow of heat.** Heat always flows from a body at higher temperature to a body at lower temperature.

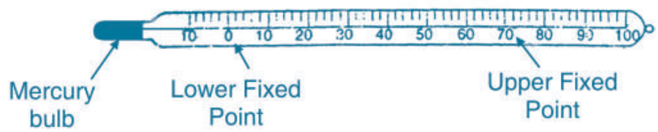
14.2 MEASUREMENT OF TEMPERATURE

You might have noticed that whenever a patient is brought to a doctor, the doctor normally measures his body temperature. Do you know the device the doctor uses to measure his body temperature? What do they call it? They call it **thermometer**.

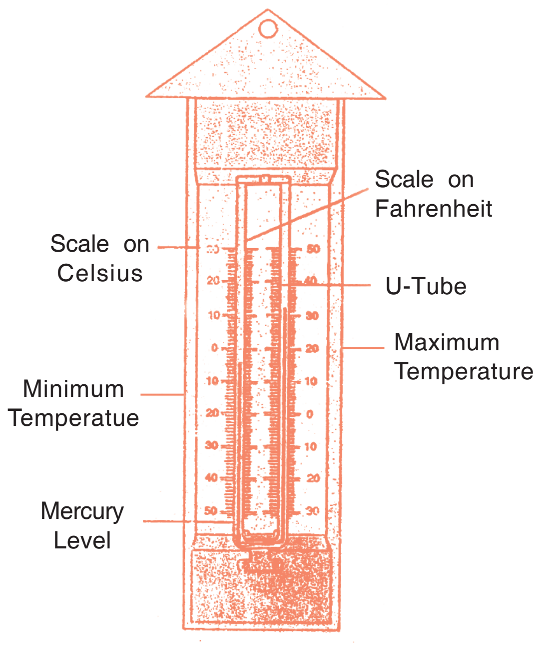
There are different types of thermometers that they use for different purposes. The thermometer that a doctor uses to measure the temperature of human body is called

Clinical thermometer Fig. 14.1(a). The thermometer that we use for measuring temperature in science experiments is called **laboratory thermometer** Fig. 14.1(b) and the thermometer that the **meteorologists** use for determining the maximum and minimum temperature during a day is called as **maximum – minimum thermometer** Fig. 14.1(c). These days they are using **digital thermometers** Fig. 14.1(d) for different purposes.

(a) Clinical thermometer



(b) Laboratory thermometer



(c) Maximum – minimum thermometer

(d) Digital thermometer

Fig 14.1 *Different types of Thermometers*

14.3. CONSTRUCTION OF A THERMOMETER

Normally mercury-in-glass thermometer is conveniently used in day to day applications. In this type of thermometer there is a thin walled bulb attached to a thick walled capillary. The bulb and to a certain height the capillary are filled with mercury by repeated heating and cooling. The capillary above mercury level is evacuated and its upper end is sealed. Then the thermometer is calibrated (marked) to measure temperature. For calibration lower and upper fixed points are marked respectively by burying the bulb first in melting ice and then in steam for sufficient time, so that mercury level in the stem remains fixed with time in each case (Fig.14.2).

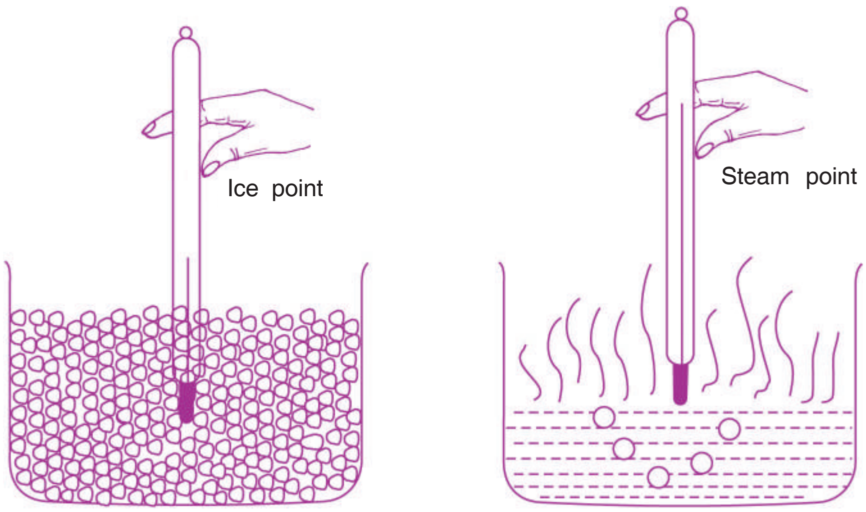


Fig. 14.2 *Calibration of a thermometer*

You may ask why use of mercury is preferred as thermometric liquid. The reasons are many. Mercury acquires the temperature of the body, it is kept in contact with very quickly; it absorbs very little heat from the body in contact and has large uniform expansion over a wide range. It is opaque and does not stick to the walls of the container. These properties make mercury the most appropriate liquid for accurate temperature measurements over a wide range.

Giving different values to the lower fixed point and upper fixed point and dividing the space between these two marks in equal number of divisions different scales are developed for measuring temperature. Three such scales are shown in Fig. 14.3. These are: celsius scale, fahrenheit scale and kelvin scale. In celsius scale the lower fixed point (ice point) is marked as 0, the upper fixed point(steam point) is marks as 100 and the intervening space is divided into 100 equal parts .In fahrenheit scale the lower fixed point is marked as 32, upper fixed point as 212 and the intervening space is divided into 180 equal pats. In case of a kelvin's scale the lower fixed point is marked as 273, steam point as 373 and the space between them is divided into 100 equal parts. SI Unit of temperature is kelvin (K).

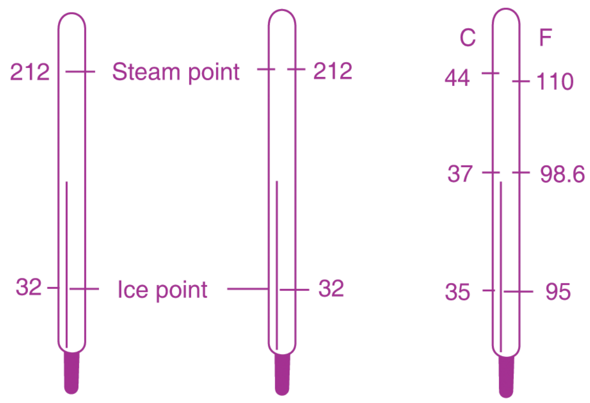


Fig. 14.3 *Different scales of temperature*

This is clear from Fig. 14.3 that the three scales are related by the formula

$$\frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100} \qquad (14.1)$$

INTEXT QUESTIONS 14.1

State whether the following statements are true or false:

(i) Heat can be measured in kelvin.

(ii) –30° F is a lower temperature than –30° C.

(iii) The numerical value of temperature of any hot body measured on kelvin's scale is always higher than the value on Fahrenheit scale.

(iv) Thermal energy can be measured either in calories or in joules.

(v) Pure alcohol can also be used as thermometric liquid.

(vi) A body is felt cold when heat flows from our body to that body.

14.4 EFFECTS OF HEAT

When a body is heated changes may occur in some of its properties .These changes are the effects of heat. Some of the effects of heat, as you might have observed are:

14.1 Rise in temperature

When a body is heated its temperature increases, that is why, it appears warmer when touched.

14.2 Change of state

When heat is supplied to a substance in solid state its temperature rises till at a particular temperature it may change into its liquid state without any further change in its temperature. This characteristic constant temperature at which a solid changes into its liquid state is called **melting point** of the solid. The melting point of a substance is a characteristic, constant value and different substances may have different values of melting points (Table 14.1).

Conversion of a solid into its liquid state at its melting point is called **change of state** from solid to liquid (fusion) and the heat that is transferred to the substance during melting is called **Latent Heat of Fusion**. Because, it does not becomes apparent in the form of rise in temperature. Latent heat of fusion of a solid substance is defined as the amount of heat (in joules) required to convert 1kg of the substance from solid to liquid state at its melting point (Table 14.1).

Similarly, when heat is supplied to a substance in liquid state its temperature rises but there is a possibility that it changes into its vapour state at a constant temperature. The heat supplied in this case is called **Latent Heat of Vaporization.** Latent heat of vaporization of a liquid is defined as the amount of heat (in joules) required to convert 1kg of the substance from its liquid to gaseous state at a constant temperature. Latent heats of vaporization of different substances are also different (Table 14.1).

It may be noted that vaporization may take place in two different ways: (i) Evaporation from the surface of a liquid at any temperature (ii) Boiling of the whole mass of the liquid at a constant temperature called boiling point of the liquid. Boiling points of different liquids may also be different (Table 14.1).

Table 14.1 Melting, boiling points, latent heat of fusion and latent heat of vaporization of some materials

S. No.	Name of Material	Melting Point (°C)	Latent heat of fusion ($\times 10^3$ J/kg)	Boiling Point (°C)	Latent heat of vaporization ($\times 10^3$ J/kg)
1.	Helium	–271	–	-268	25.1
2.	Hydrogen	–259	58.6	–252	452
3.	Air	–212	23.0	–191	213
4.	Mercury	–39	11.7	357	272
5.	Pure Water	0	335	100	2260
6.	Aluminum	658	322	1800	–
7.	Gold	1063	67	2500	–

This may again be noted that on cooling change of state may take place in reverse order. The chart given below illustrates the various events of change of state.

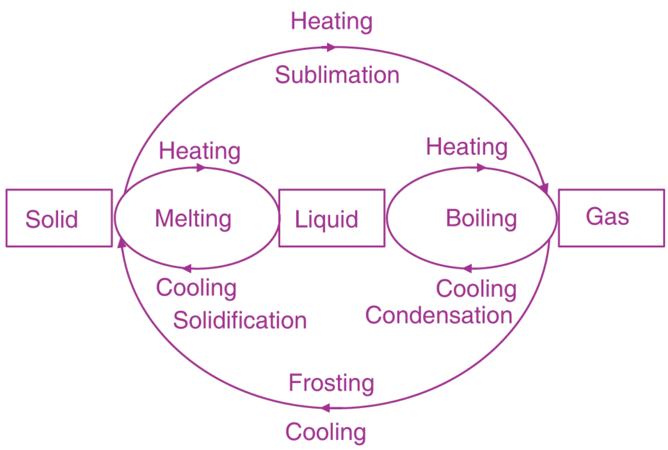


Fig. 14.4 *Change of state*

14.5 THERMAL EXPANSION

Take a metallic ring fitted with a handle and a sphere of the same metal fitted with a chain such that the sphere just passes through the ring (Fig. 14.5). Now heat the sphere in steam for some time and place it over the ring. Does it pass through the ring now? It doesn't. Obviously, the size of the sphere has increased on heating. In fact every material (except water which contracts on heating from 0°C to 4°C) expands on heating. The increase in the size of a body on heating is called **thermal expansion.**

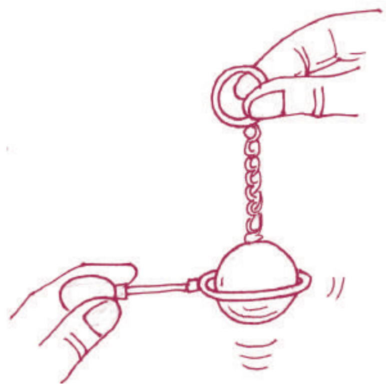


Fig. 14.5 *Ball and ring experiment to demonstrate thermal expansion*

The expansivity of different materials is normally different. The fact can be easily noticed with the help of a bimetallic strip. A bimetallic strip is a strip having two layers of two different metals one over the other. Consider the bimetallic strip made of steel and aluminium (Fig. 14.6). When we clamp one end of the strip and heat it uniformly with the help of a Bunsen burner, it bends with aluminium layer outward. This clearly shows that aluminium has increased in length more than steel and caused bending.

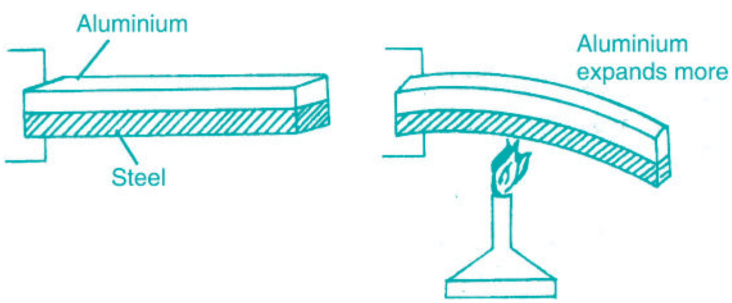


Fig. 14.6 *The bimetallic strip bends on heating*

It can be seen that increase in length of a metallic bar will be more for a longer bar and also for a greater rise in temperature of the same bar. Let us consider a metallic bar of length L_0 at temperature 0° C. Increase in its length ΔL at a temperature Δt is given by:

$$\Delta L \propto L_0 \Delta t$$

$$\Delta L = \alpha L_0 \Delta t$$

$$\alpha = \frac{\Delta L}{L_0 \Delta t}$$

Here α is a constant for the material of the bar and is called as the **Linear expansivity** of the bar.

The **Linear expansivity** (or **Coefficient of Linear expansion**) of a material is defined as the change in length per unit original length per degree celsius rise in temperature. The SI Unit of coefficient of expansion is per kelvin (which is same as per degree celsius in magnitude).

A piece of solid may expand along length, breadth and height simultaneously hence there will be an increase in its volume with temperature.

The **Volume expansivity** of a material may be defined as change in volume per unit original volume per degree celsius rise in temperature.

i. e. $$\gamma = \frac{\Delta V}{V \Delta t}$$

The value of coefficient linear expansion (α) and the coefficient of volume expansion (γ) of some materials are given in Table 14.2.

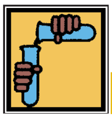
Table14.2 Values of Coefficient of Linear expansion and Coefficients of volume expansion of some common substances

S. No.	Name of Material	Coefficient of Linear Expansion (°C^{-1})	Coefficient of Volume Expansion (°C^{-1})
1	Quartz	0.4×10^{-6}	1.2×10^{-6}
2	Steel	8×10^{-6}	24×10^{-6}
3	Iron	11×10^{-6}	33×10^{-6}
4	Brass	18×10^{-6}	54×10^{-6}
5	Silver	18×10^{-6}	54×10^{-6}
6	Aluminium	25×10^{-6}	75×10^{-6}
7	Lead	2.9×10^{-6}	8.7×10^{-6}

The table clearly shows that expansivity of solids is very small therefore we cannot see and measure expansion of solids easily. But liquids expand much more than solids

Notes

and gases many times more than liquids and so we can see expansion of liquids and gases easily. However, since liquids and gases do not have a definite shape, it will be volume expansivity only relevant for fluids.

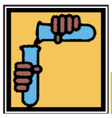


ACTIVITY 14.1

Demonstration of expansion in liquids

Take a small transparent bottle (say an injection bottle) fill it with water up to the brim. Make a small hole in its cork and insert a thin transparent plastic pipe in it (say a used up empty ball-pan refill) so that the lower end of the pipe dips in water and water rises in the pipe up to a certain height. Mark the level of water in the pipe indicated as (A). Now heat the bottle. What do you find? Does the level of water in the pipe come down? Why so? Keep on heating the bottle. Does the level of water start increasing after reaching a certain minimum level (B)? Does it shoot off the initial position (A) and rises further up to the height (C)? Why so? Can you infer from this experiment that water expands more than glass for the same temperature rise?

Fig. 14.7 *Expansion of Liquid*



ACTIVITY 14.2

Demonstration of expansion in gases

Take a thin walled narrow bored glass tube and entrap a drop of mercury in it. Then heat one end of the tube and pressing it on a hard surface seal this end. Let the tube cool to normal temperature. Hold the tube vertically and mark the position of mercury in the tube. This way we have entrapped a column of air between mercury drop and sealed end of the pipe. Now even if we warm the air column by holding it in our hand we can see the drop of mercury shifting its position. Does it move up or down? What do you conclude from this experiment? Does this show that gases have high expansion even for a small rise in temperature?

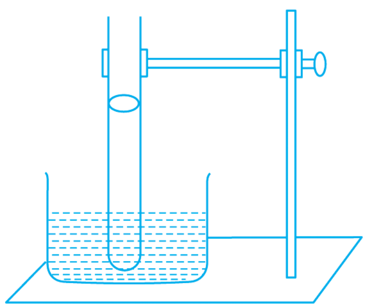


Fig. 14.8 *Expansion of gas*

14.5.1 Uses of thermal expansion in day to day life

1. The property of thermal expansion is used in the construction of thermometers.
2. A tightly closed metallic cap of a bottle may be opened by using thermal expansion. The cap on heating expands, becomes loose and may be opened easily.

Fig. 14.9 *Loosening a metal cap by heating it*

3. Have you seen a horse-cart (Tanga)? It has wooden wheels on the rims of which iron rings are mounted. Do you know how the iron ring is mounted on a wooden wheel? The iron ring is, in fact, made of a radius slightly less than the radius of wheel. Then the ring is heated so that its radius becomes slightly more than the radius of the wheel. The ring is than slipped on the rim of the wheel while hot. Subsequently on cooling, it contracts and firmly holds the rim of the wheel.

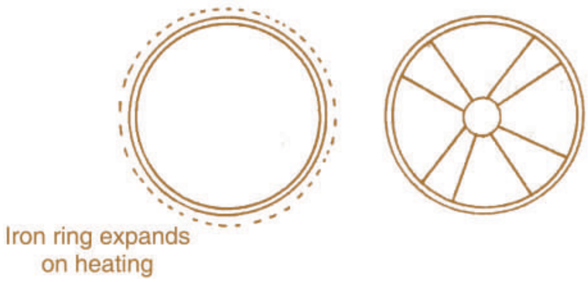


Fig. 14.10 *Fitting iron tyre on wooden wheel*

4. Thermostats used in heating/cooling devices make use of a bimetallic strip to automatically switch off the heating cooling circuit when the temperature rises/falls beyond a certain value. After some time when the temperature returns below/above a certain value the bimetallic strip resumes its original position and the circuit again becomes on. A simple bimetallic thermostat is shown in Fig. 14.11.

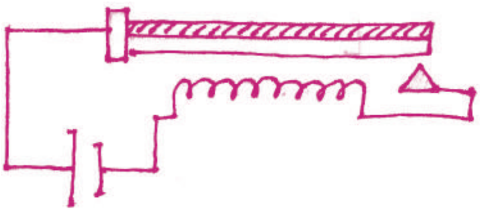


Fig. 14.11 *Principle of a thermostat*

5. We have to take care of thermal expansion while making big structures or otherwise these structures may collapse, for example:
   (a) Gaps are left at the joints of a railway tracks [Fig. 14.12(a)] or else during summer due to thermal expansion the rails will bend and derail the train.
   (b) The iron bridges are not made of continuous structures. At one end the girders are left open and placed over rollers [Fig. 14.12(b)].

(a) *(b)*

Fig. 14.12 *(a) Gap in railway tracks (b) Girders in iron bridges placed on rollers*

6. While pouring hot tea in a glass tumbler it is suggested that a metallic spoon be first placed in the tumbler and the tea be poured over it. In case the tea is directly poured in the tumbler it may get cracked due to uneven expansion of its different parts.

INTEXT QUESTIONS 14.2

Fill in the blanks with the correct choice

1. A bimetallic strip is used as a thermostat in the electrical device named …………….. (electric bulb, T.V., refrigerator).
2. Melting point of 1 kg wax will be …………….. the melting point of 2 kg wax (double, half, same as).
3. Latent heat of evaporation is measured in …………….. (J, J/K, J/kg).
4. 1 kg steam at 100 °C has 2260 J …………….. heat than water at 100 °C (more, less).
5. The cubical expansivity of a substance is …………….. its linear expansivity (equal to, two times, three times)
6. The expansivity of …………….. is maximum. (solids, liquids, gases).

14.6 SPECIFIC THERMAL CAPACITY OF A MATERIAL

When two bodies at different temperatures are kept in contact, heat is transferred from the hot body to the cold body till both of them acquire the same temperature. The two bodies then are called in **thermal equilibrium.** In acquiring thermal equilibrium the hot body loses heat and the cold body acquires an equal amount of heat, i.e., heat lost by hot body = heat gained by cold body, provided we assure that there is no loss of heat to the surrounding.

It can be seen that if the temperature of hot body is more, the rise in the temperature of cold body will also be more i.e. heat transferred from a hot body to a cold body is directly proportional to their temperature difference,

$$Q \propto \Delta\theta$$

Similarly it can be shown that if the mass of cold body is more it will absorb more heat from the cold body

i. e. $\qquad Q \propto m$

so, $\qquad Q \propto m\Delta\theta$

$$= ms\Delta\theta$$

Where s is a constant of proportionality which depends on the nature of the material of the body. This is also called as the specific heat capacity of the material.

The specific heat capacity of a material is defined as the amount of heat (in Joule) required to raise the temperature of 1kg mass of that material through 1 K.

The SI Unit of specific heat capacity (or simply specific heat) is J kg^{-1} K^{-1}

The specific heat capacities of different materials may have different values. Table 4.3.3 gives the specific heat of some materials.

Table 14.3 Specific heats of some materials at 20°C

S. No.	Substance	Specific Heat		Substance	Specific Heat	
		J kg^{-1} K^{-1}	Cal kg^{-1} K^{-1}		J kg^{-1} K^{-1} × 10^{3}	Cal kg^{-1} K^{-1}
1	Aluminium	875	0.29	Ethyl alcohol	2.436	0.58
2	Copper	380	0.091	Methyl alcohol	2.562	0.61
3	Caste Iron	500	0.119	Benzene	1.680	0.40
4	Wrought Iron	483	0.115	Ethene	2.352	0.56
5	Steel	470	0.112	Glycerin	2.478	0.59
6	Lead	130	0.031	Mercury	0.140	0.033
7	Brass	396	0.092	Turpentine	1.800	0.42
8	Ice	2100	0.502	Water	4.200	1.00

From the table it is clear that of all substances water has highest value of specific heat.

Higher the value of specific heat of a substance lower will be the rate at which it is heated or cooled as compared to the substance of lower specific heat under identical conditions.

INTEXT QUESTIONS 14.3

Choose the correct alternative

1. Two iron balls of radii r and $2r$ are heated to the same temperature. They are dropped in two different ice boxes A and B respectively. The mass of ice melted
   (a) will be same in the two boxes.
   (b) in A will be twice than in B.
   (c) in B will be twice than that in A.
   (d) in B will be four times than that in A.
2. An iron ball A of mass 2 kg at temerature 20°C is kept in contact with another iron ball B of mass 1.0 kg at 20°C. The heat energy will flow
   (a) from A to B only
   (b) from B to A only
   (c) in neither direction
   (d) Initially from A to B and then from B to A.
3. When solid ice at 0°C is heated, its temperature
   (a) rises (b) falls
   (c) does not change until whole of it melts.
   (d) first rises then falls back to 0°C.
4. When steam at 100°C is heated its temperature
   (a) does not change. (b) increases
   (c) decreases (c) none of these
5. Specific heat of aluminium is almost two times the specific heat of copper. Equal amount of heat is given to two pieces of equal masses of copper and iron respectively. Rise in temperature of
   (a) Copper will be equal to that of aluminium.
   (b) Copper will be twice the rise in temperature of aluminium.
   (c) Copper will be half the rise in temperature of aluminium.
   (d) Copper will be four times the rise in temperature of aluminium.

6. Equal heat is given to three pieces of copper A, B, and C having masses in the ratio 1:2:3. The rise in temperature will be in the order

   (a) $A > B > C$ (b) $B > C > A$

   (c) $C > B > A$ (d) $A > C > B$

WHAT YOU HAVE LEARNT

- Thermal energy is a form of energy and like any other form of energy can be used to do work. Therefore, the SI unit of thermal energy is also joule (J)
- Temperature is a measure of degree of hotness of a body and is measured in degree Fahrenheit (°F) or degree celsius (°C) or kelvin (K), with the help of a thermometer.
- The three scales of temperature are related as $\frac{C}{100} = \frac{F-32}{180} = \frac{K-273}{100}$
- When change of state does not take place on heating a body its temperature rises. The heat which does not become apparent in the form of rise in temperature during change of state is called latent heat.
- There are two types of latent heat (i) Latent heat of fusion of a solid. (ii) Latent heat of vaporization of a liquid
- The constant temperature at which a solid melts is called its melting point and the constant temperature at which a liquid boils is called its boiling point. Melting point and boiling point are characteristic properties of the substance.
- All substances expand on heating but different substances expand to different extents when heated for same rise in temperature.
- Expansivity of a substance is a constant. Expansivity of different substances are different.
- Liquids expand more than solids and gases expand very much more than liquids.
- Due to difference in expansivity of two metals a bimetallic strip bends on heating, This property of bimetallic strips is used in thermostats.
- Heat energy flows from a body at higher temperature to a body at lower temperature till both of them acquire a common final temperature.

TERMINAL EXERCISE

1. Distinguish clearly between heat and temperature.
2. During change of state: (i) Is there a rise in temperature of the material on heating it? and (ii)What happens to the heat we supply?

3. Name the factors on which the thermal expansion of a wire depends.
4. Give any two uses of a bimetallic strip.
5. If you have a uncalibrated mercury thermometer how will you calibrate it into a
   (a) celsius thermometer (b) fahrenheit thermometer.
6. Explain the following:
   (i) Why is mercury used as a thermometric liquid?
   (ii) Why does a bimetallic strip bend on heating?
   (iii) Why does steam at 100°C gives more severe burns than water at 100°C?
   (iv) Why do we use ice for cooling our drinks and not water at 0°C.?
7. Why is the heat given at the time of change of state called latent heat?
8. A certain amount of water is heated at a constant rate. The time to bring it to boiling is t_1 and the time required from beginning of boiling to boiling off the whole amount is t_2. Which is greater $t_1$or t_2? Why?
9. At what temperature the numerical value of temperature on fahrenheit scale will be double the value on celsius scale.
10. A 50 cm silver bar shortens by 1.0 mm when cooled. How much was it cooled?
    (Given: Coefficient of linear expansion of silver = 18×10^{-6} per degree celsius)
11. How much heat energy is required to change 200 g of ice at –20°C to water at 70°C?
    (Given: Latent heat of fusion of ice = 335 kJ kg^{-1}, and specific heat of ice = 2100 J kg^{-1} $°C^{-1}$, specific heat of water = 4.2 kJ kg^{-1} $°C^{-1}$)

ANSWER TO INTEXT QUESTIONS

14.1

(i) False (ii) False (iii) True

(iv) True (v) True (vi) True

14. 2

1. refrigerator 2. same as 3. J/kg

4. more 5. three times 6. gases

4.3

1. (d) 2. (c) 3. (c)

4. (b) 5. (b) 6. (a)

15

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LIGHT ENERGY

Light is the common form of energy. It makes the objects visible to us. You might have seen in torches there is curved sheet of metal around the bulb. Can you think why it is so? You may have also seen the stars twinkling in the sky in a clear night. Also on a clear day the sky appears blue at the time of sun rise or sun set while sun near the horizon it appears orange or red.

Have you ever tried to find out the reason for such natural phenomenon? In this lesson you will find the answer to all such questions. You will also study the defects of human eyes and image formation in mirrors and lenses.

OBJECTIVES

After completing this lesson, you will be able to:

- *define reflection of light and state the laws of reflection;*
- *describe the image formation by plane and spherical mirror with suitable ray diagrams in different cases;*
- *write mirror formula and define magnification;*
- *define refraction of light and state the laws of refraction;*
- *define refractive index of a medium and states its significance;*
- *give some examples in nature showing the refraction of light;*
- *describe various types of lenses and explain image formation by convex and concave lens with the help of ray diagrams;*
- *write the lens formula and define magnification;*
- *explain power of lens and define diopter;*
- *explain the correction of defects of vision (near and far) by using lenses;*
- *explain how white light disperse through a prism and*
- *describe the scattering of light and give examples of its application in daily life.*

15.1 REFLECTION OF LIGHT

Can you think how an object becomes visible to you? When we see an object we do so because light from the object enters in our eyes. Some objects such as sun, stars, burning candles, lamp, etc. which emit light by their own are called **luminous objects**. Some other objects may bounce back a part of the light falling on them from any luminous object. This bouncing back of light after falling on any surface is called **reflection of light**.

Thus, when a beam of light comes in contact with an object, a part or all of it gets bounced back. This phenomenon is called reflection of light. Some objects having smooth and shiny surface reflect better than others. A smooth shining surface, which reflects most of the light incident on it, is called a **mirror**. In Fig. 15.1 reflection from a plane mirror is shown.

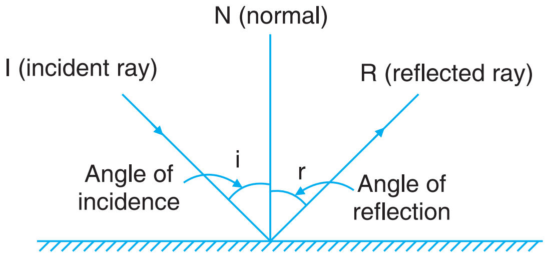


Fig. 15.1

Greek mathematician Euclid explained how light is reflected. The phenomenon of reflection was translated into laws by an Arabian scientist Alhazan in about 1100 A.D.

Alhazen (Ibn al-Haytham)
(965-1040)

To understand the phenomenon of reflection of light ray we define some terms. The direction of propagation of light, a beam of light consists of number of rays. The incident ray is the ray of light falling on the reflecting surface. The normal is the line drawn at 90° to the surface at the point where the incident ray strikes the surface. The light coming back from the reflecting surface is called reflected ray. The angle of incidence is the angle between incident ray and normal and angle of reflection is the angle between reflected ray and normal.

15.1.1 Laws of reflection of light

Suppose a ray of light (*IO*) falls on a reflecting surface *AB* at *O*, after reflection it goes along *OR* as shown in Fig. 15.2. The reflection of light from the surface takes place according to the following two laws.

(i) Incident ray, reflected ray and the normal at the point of incidence, all lie in the same plane.

(ii) The angle of incidence is equal to the angle of reflection i.e.,

$$\angle i = \angle r$$

During reflection, there is no change in speed, frequency and wavelength of light. Reflection of light may be classified as regular reflection and diffused reflection.

15.1.2 Regular reflection

When reflecting surface is very smooth and the rays of light falling on it are reflected straight off it, then it is called **regular reflection**, as shown in Fig. 15.2.

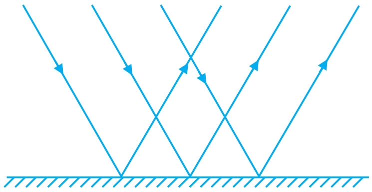


Fig. 15.2 *Regular reflection from a smooth plane surface*

15.1.2 Diffused reflection

When the reflection of light takes place from rough surface the light is reflected off in all directions as shown in Fig. 15.3 is called diffused reflection.

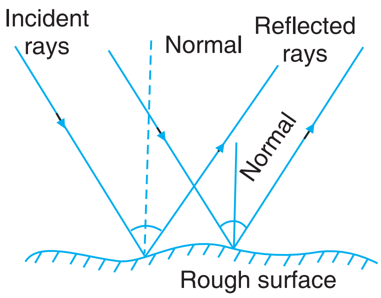


Fig. 15.3 *When surface is rough, parallel incident rays do not reflect parallel*

In diffused reflection due to roughness of the surface normal drawn at the point of incidence of parallel incident rays are not parallel, hence the reflected rays reflect in all direction but obey the laws of reflection.

15.2 FORMATION OF IMAGES DUE TO REFLECTION

You might have learnt that to see an object or image, the light from it should reach to the eyes of the observer. It means light coming from an object or image should fall on retina where from it will be sensed by brain with the help of optical nerves.

When light rays coming from the object meet or appear to meet at retina of eye, the object become visible and we say that the image of object is formed at retina.

When an object is placed infront of a mirror its image is formed by reflection. Every point on the object acts like a point source, from which a number of rays originate. In order to locate the image of the point object, an arbitrarily large number of rays emanating from the point object can be considered. However, for the sake of simplicity, we take any two rays of light (starting from the point object). The paths on reflection from the mirror (reflected rays corresponding to the incident rays) are traced using laws of reflection. The point where these two rays actually meet is the real image of the point object. If these rays appear to come from and not actually coming, the virtual image of the point is formed. Real images obtained by actual intersection of reflected rays, hence they can be projected on screen. Virtual images are obtained when the rays appear to meet each other but actually do not intersect each other, hence they cannot be cast on screen.

ACTIVITY 15.1

Take a plane mirror on paper in vertical position. Use a pipe (straw) as incident beam at certain angle and coincide its image with another pipe (straw). You have to put the second pipe in such a way that the image and this pipe remain in same line. The second pipe (straw) will represent the reflected beam. Can you touch this image? Can you cut some part of this image by cutting the paper on which it is seen? You can not do it because the image formed is a virtual image.

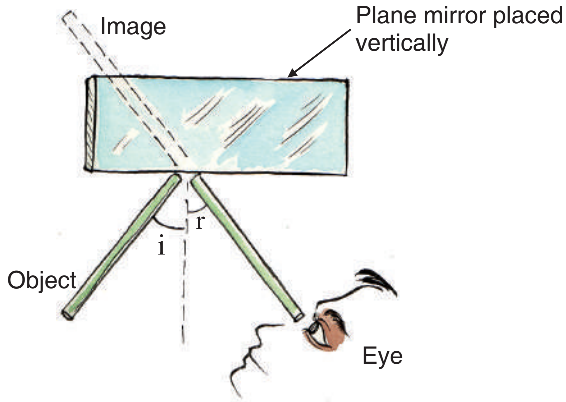


Fig. 15.4

15.3 IMAGE FORMATION IN PLANE MIRROR

To understand the image formation in a plane mirror

(i) Put the mirror M_1M_2 in a vertical position over the sheet as shown in Fig. 15.5.

(ii) Put two pins, one at '*A*' some distance away from the mirror and another one very near to the mirror at '*B*' so that, the line *AB* makes an angle with the line M_1M_2 showing the position of the mirror.

(iii) Look at the images of *A* and *B* of the two pins through the mirror, put two other pins at *C* and *D* so that all four pins *A*, *B*, *C* and *D* are in the same straight line.

(iv) Now, look at the images of all these pins closing one of your eyes and moving your face side ways. If the image of the two earlier pins and the two pins you have put just now appear to be moving together you can say your observation is free from parallax error.

(v) Join the positions of the pins by straight lines.

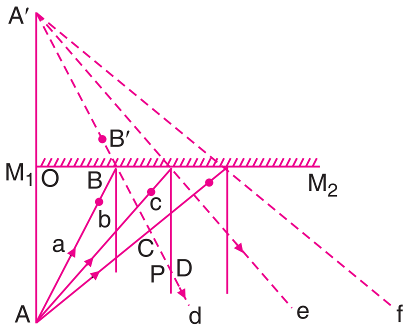


Fig. 15.5 *Image formation by a plane mirror*

(vi) Keeping the first pin as it is, take out other three pins and repeat the experiment described above by putting the pins in new positions. This way takes a few more reading.

To understand the formation of image, you may consider the light rays emerging out of the object A. We have drawn only three rays namely (a), (b), and (c). These rays after striking the mirror M_1M_2 get reflected in the direction (d), (e) and (f), respectively, (as above shown in Fig. 15.5) obeying the laws of reflection.

It is clear that these reflected rays never meet with each other in reality. However, they appear to be coming emerging out from the point A′, inside the mirror i.e., if the reflected rays (d), (e) and (f) are extended in the backward direction, they will appear to meet with each other at A'. Thus at A' we get the image of object *A*.

From the above activity we find that the image formed by a plane mirror has the following **characteristics**.

- This image is virtual (i.e. it is not real), erect and the same in size as the object.
- The object distance and the image distance from the mirror are found to be equal.

i.e., $$OA = OA'$$

Hence, the image of a point in a plane mirror lies behind the mirror along the normal from the object, and is as for behind the mirror as the object is in front. It is an erect and virtual image of equal size.

15.3.1 A few facts about reflection

Put your left hand near a plane mirror. What do you see in the image formed by reflection? The image of your left hand appears as right hand of the image as shown in Fig. 15.6(a). Similarly, the number 2 will appear in an inverted fashion on reflection as shown in Fig. 15.6 (b).

Hence, due to reflection in a plane mirror left handedness is changed into right handedness and vice-versa. This is known as lateral inversion. However, the mirror does not turn up and down. The reason for this is, that the mirror reverses forward and back in three dimensions (and not left and right), i.e., only *z*-direction is reversed resulting in the change of left into right or vice-versa.

For example a left handed screw will appear to be a right handed screw on reflection as shown in Fig. 15.6 (c).

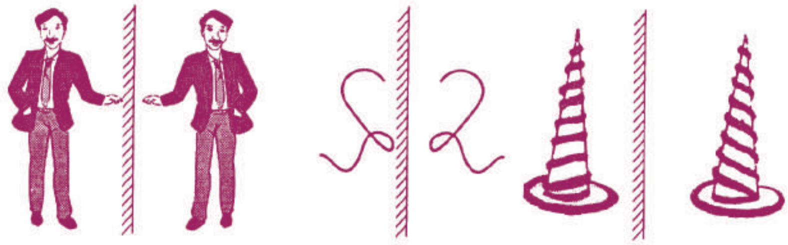


Fig. 15.6 *Lateral inversion in image formed by a plane mirror*

Similarly, if you read the sentence ।ॅनाए डि पाछ लाम्क ाक पाछ in a mirror it will appear as

आप का कमाल आप ही जानें।

In a plane mirror the distance of the image is same as the distance of object from the mirror. If object distance from the mirror changes, the distance of image from the mirror will also change in the same way. It means if an object moves with velocity v towards the mirror, image will also move with same velocity v towards the mirror and at every time the distances of the object and image from the mirror remain equal. However, the velocity of image towards the object will be $2v$.

By drawing a ray diagram you conclude that you can see your full image in a plane mirror whose height is half of your height. See the ray diagram in Fig. 15.7.

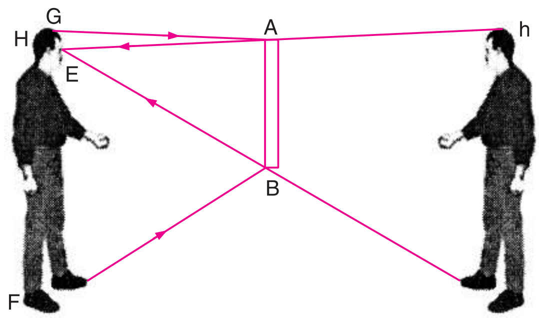


Fig. 15.7 *Size of plane mirror to see the full image*

Think and Do

Take a L-shaped object and try to get the images as given below and describe the position of object in each case

A	└
B	┘
C	┌
D	┐

Do you know

Our eyes can notice the light of wavelength 400 nm (nanometre) to 70 nm. The light in this range of wavelength is called visible light. The light of wavelength more than 700 nm (i.e., of red colour) is called **infrared light** and less than the wavelength of 400 nm (i.e., of violet colour is called **ultra-violet light**. All sources of light emit the combination of these three types of lights. Sun is a source which emits very high percentage of visible light. In sun light 50% visible light, 40% infrared light and 10% ultra-violet light are present. Sun is the ultimate source of all types of energy for us. Sun radiates 3.92×10^{26} joule of energy every second. Out of total energy radiated by sun about 0.0005% of energy reaches to earth. Earth receives 1.388 joule of energy per unit area every second from the sun.

Do you know

The earlier fact about the nature of light was given by Pythagoras, a Greek philosopher, in 6th century B.C. The objects are visible because of light travelling from eyes to the object and then back again. This theory could not stand the test of times and modified. This was due to the contributions of Newton (1642-1727) and Huygen (1670).

ACTIVITY 15.2

Place the following objects infront of a plane mirror and draw their corresponding images in the given table.

Table 15.1

Object	Image
#	....
O	....
काम	....
P	....
OH	....

Try to draw conclusion from this activity regarding image formation in a mirror.

ACTIVITY 15.3

Place a plane mirror at angle of 30°, 45° 60° and 90° with horizontal. Now place an object (linear) in such a way that its image formed by plane mirror is always straight. Note down the angle made by object with horizontal in the given table.

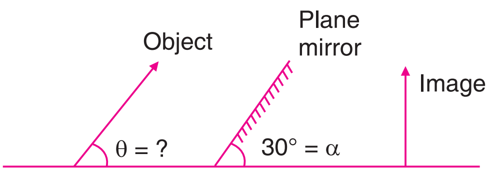


Fig. 15.8

Table 15.2

Angle of mirror α	Angle of object θ
30°	....
45°	....
60°	....
90°	....

INTEXT QUESTIONS 15.1

1. In column A, some sources of light are given. In column B, you have to write whether these are lumineus or non-lumineus.

Source (A)	Nature of source (B)
1. Glowing bulb	1. ....
2. Burning candle	2. ....
3. Moon	3. ....
4. Fire fly	4. ....
5. Shining steel plate	5. ....

2. Write two differences between real and virtual image.
3. When you are standing infront of a plane mirror, a virtual and correct image of you is formed. If some one is taking a photograph of it using camera, what will be the nature of image on photograph?
4. A light ray is falling on a plane mirror at 30° as shown in the diagram. If plane mirror is rotated by 30° without changing the direction of incident ray, by what angle the reflected ray will rotate?

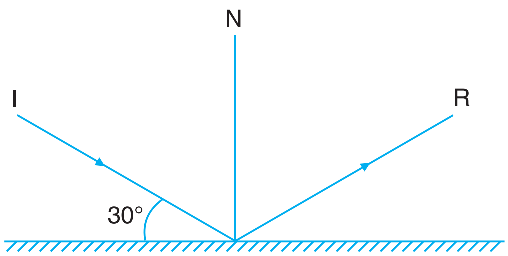


Fig. 15.9

5. An object of height 10 cm is placed infront of a plane mirror of height 8 cm. What will be the height of image formed? Taking the distance of object from the mirror 6 cm, draw the ray diagram.
6. The image of an object placed at 10 cm from the mirror is formed at 10 cm behind the mirror. If the object is displaced by 4 cm towards the mirror, by what distance will the image be displaced with respect to the (i) mirror (ii) object?
7. An object is moving with velocity 6 ms^{-1} towards a plane mirror, what will be the velocity of image towards the (i) mirror (ii) object?
8. Some letters are given in following boxes. Make the meaningful words related to reflection of light choosing the horizontal and vertical sequencing.

N	E	P	R	E	C	T
O	P	X	V	R	T	U
R	L	V	I	R	T	U
M	A	L	R	E	A	L
A	N	I	T	C	A	R
L	E	O	U	T	A	E
A	I	M	A	G	E	J
N	K	N	L	E	N	C

9. The distance and height of an object placed infront of a plane mirror are given in column A and B respectively. In column C and D the distance of image and height of image are given but not in same order. Correct the order.

Distance of object (A)	Height of object (B)	Distance of image (C)	Height of image (D)
10 cm	5 cm	10 cm	10 cm
5 cm	10 cm	5 cm	8 cm
6 cm	8 cm	6 cm	5 cm

15.4 REFLECTION AT SPHERICAL MIRRORS

A spherical mirror is a section of a hollow sphere whose inner or outer surface is polished. Thus, there are mainly two types of spherical mirrors (i) convex mirror and (ii) concave mirror.

(i) **Convex mirror:** It is a mirror in which the reflection takes place from the bulging surface (i.e. inner side is painted and reflected surface is polished to make the surface smooth as shown in Fig. 15.10.

(ii) **Concave mirror:** It is a mirror in which the reflection takes place from the cave side surface (i.e. outer side is painted and the inner or cave side surface is polished to make the reflected surface smooth as shown in Fig. 15.10.

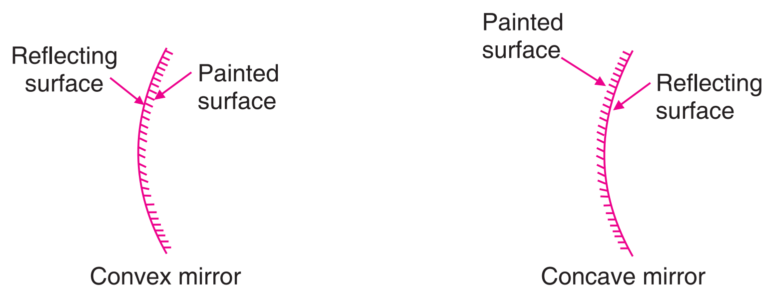


Fig. 15.10

To understand the reflection at spherical surface certain important terms are very useful. They are shown below in Fig. 15.11.

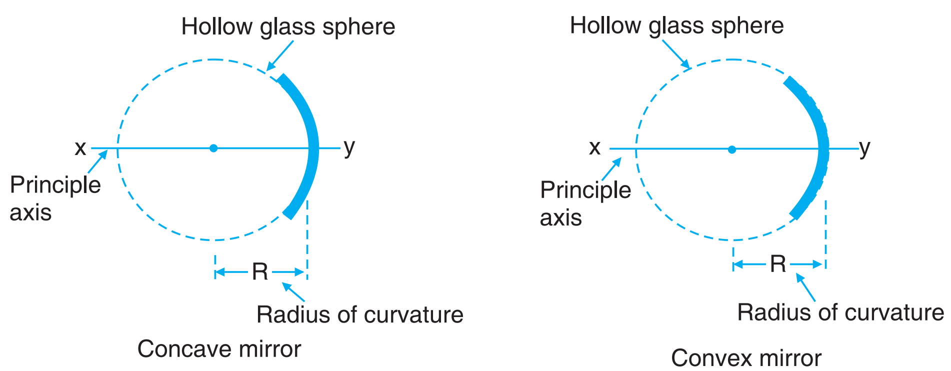


Fig. 15.11 *Some important terms of spherical mirrors*

(i) **Pole (P):** It is the mid point of the spherical mirror. Point *P* is the pole in Fig. 15.11.

(ii) **Centre of curvature (C):** It is the centre of a hollow sphere of which the spherical mirror is a part. It can be determined by finding the point of intersection of two normal drawn at the spherical surface of the mirror. The point *C* is the centre of curvature in Fig. 15.11.

(iii) **Radius of curvature (R):** It is the distance between the pole and centre of curvature of the mirror. *CF* is the radius of curvature in Fig. 15.11.

(iv) **Principal axis:** It is an imaginary line joining the pole to the centre of curvature. Extended line *CP* is the principal axis in Fig. 15.11.

(v) **Principal focus (F):** The rays of light parallel and closed to the principal axis of the mirror after reflection, either pass through a point (in concave mirror) or appear to be coming from a point (in convex mirror) on the principal axis; this point is called principal focus of the mirror. Point *F* is the principal focus in Fig. 15.11.

(vi) **Focal length (f):** It is the distance between the pole and the principal focus of the mirror. *PF* is the focal length in the Fig. 15.11.

15.5 RELATIONSHIP BETWEEN FOCAL LENGTH AND RADIUS OF CURVATURE

Consider the reflection of light of ray *IM* at *M* at a concave mirror. *CM* is the normal drawn at the surface which passes through centre of curvature and *MF* is the reflected ray which passes through the focal point.

$\angle i = \angle r$ (as we know that angle of incidence and reflection are equal)

$\therefore$ in ΔCMF,

$$MF = CF$$

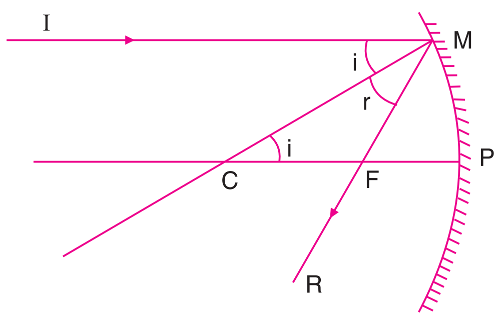


Fig. 15.12

For small aperture of the mirror,

$$MF = PF$$

$$\Rightarrow \quad PC = PF + CF = PF + PF = 2PF$$

$$R = 2f$$

where R = radius of curvature and f is the focal length of the mirror.

15.6 RULES OF IMAGE FORMATION BY SPHERICAL MIRRORS

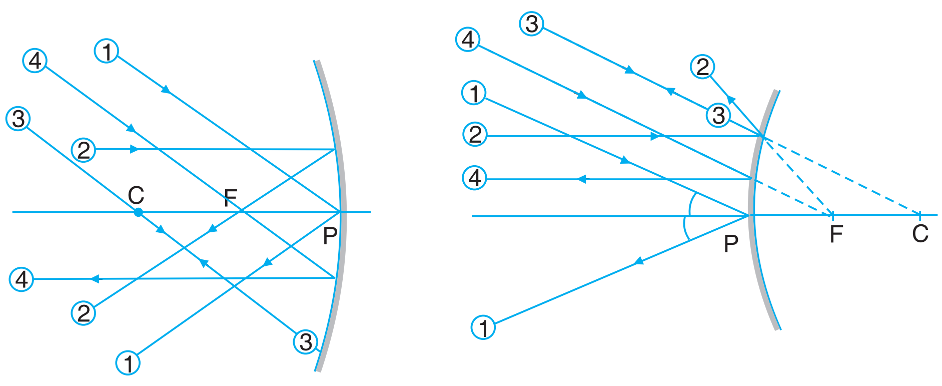
The ray diagram for image formation by mirrors can be drawn by taking any two of the following rays. The point where these two rays meet or appear to be coming from the point will be the image point which determines the position of image.

(i) **Ray striking the pole:** The ray of light striking the pole of the mirror at an angle is reflected back at the same angle on the other side of the principal axis (Ray no 1 in Fig. 15.13).

(ii) **Parallel ray:** For concave mirror the ray parallel to the principal axis is reflected in such a way that after reflection it passes through the principal focus. But for a convex mirror the parallel ray is so reflected that it appears to come from principal focus. (Ray no. 2 in Fig. 15.13)

(iii) **Ray through centre of curvature:** A ray passing through the centre of curvature hits the mirror along the direction of the normal to the mirror at that point and retraces its path after reflection (Ray no. 3 in Fig. 15.13)

(iv) **Ray through focus:** A ray of light heading lowards the focus or incident on the mirror after passing through the focus returns parallel to the principal axis.



(a) (b)

Fig. 15.13 *Image formation by spherical mirror (a) concave mirror (b) convex mirror*

15.6.1 Formation of image by concave mirror

Using the above rules of image formation, the ray diagram for the image formed for different positions of an object are given below.

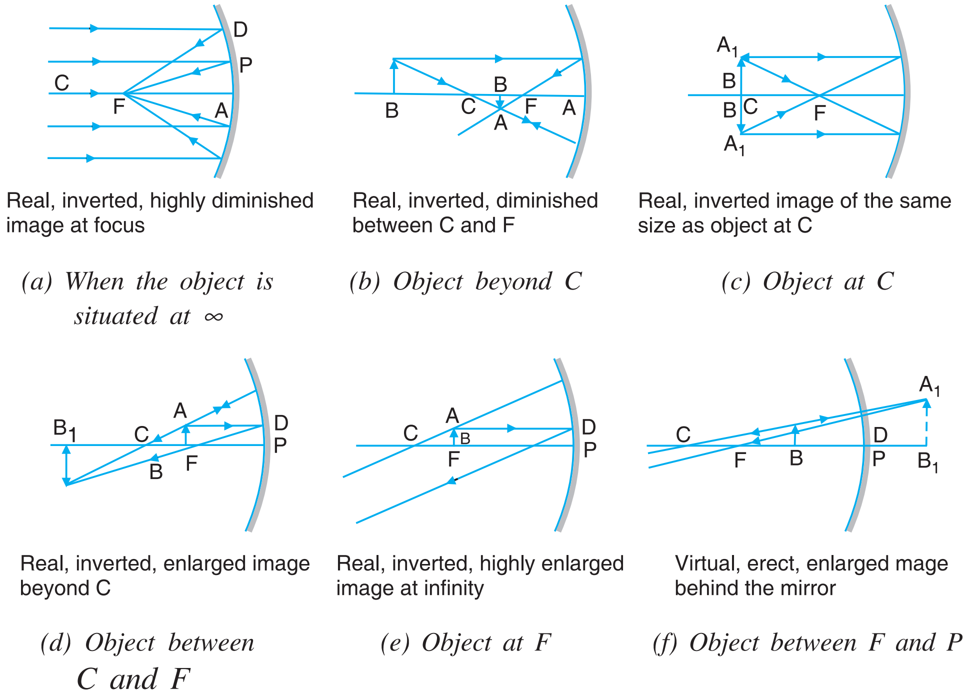


Fig. 15.14 *Image formation by a concave mirror*

15.6.2 Formation of image by convex mirror

Image formation in convex mirror is shown in Fig. 15.15.

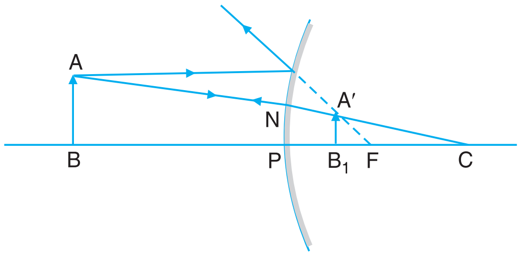


Fig. 15.15 *Image formation by a convex mirror*

The position, nature and size of the image formed in concave mirror and convex mirror can be summarized as given in table below:

Table 15.3

Position of the object	Position of image formed	Nature of image	Size of image
(A) For concave mirror			
(i) between P and F	behind the mirror	virtual	larger
(ii) at F	at infinitely	real	highly enlarged
(iii) between F and $2F$	beyond $2F$	real	larger

(iv) at $2F$	at $2F$	real	same size
(v) beyond $2F$	between F and $2F$	real	smaller in size
(vi) at infinity	at F	real	highly diminished
(B) For convex mirror			
anywhere infront of mirror	between P and F	virtual	always smaller

Do you know

- Every part of a mirror may form a complete image of an extended object from a different angle and due to super-position of these images from different points final image is formed. The brightness of the image will depend on its light reflecting area. Thus a large mirror gives a brighter image than a small one. This phenomenon was used in a popular hindi film's shooting at the Sheeshmahal of 'Amer Fort' in Jaipur (Rajasthan).
- Though every part of a mirror may form a complete image of an object, we usually see only that part of it from which light, after reflection from the mirror reaches our eyes. That is why:

  (i) to see the full image in a plane mirror a person requires a mirror of at least half of his height.

  (ii) to see complete image of the wall behind a person requires a mirror of at least (1/3) of the height of the wall and the should be in the middle of wall and mirror.
- If two plane mirrors are placed inclined to each other at an angle θ, the number of images of a point object formed

$$\approx \left(\frac{360°}{\theta} - 1\right), \text{ if } \left(\frac{360°}{\theta}\right) \text{ is even integer}$$

$$\approx \frac{360°}{\theta} \text{ if } \left(\frac{360°}{\theta}\right) \text{ is odd integer}$$

  For example, there are 5 images formed by two mirrors at 60° angle.
- Two mirrors inclined to each other at different angles may provide same number of images, e.g. for any value of θ between 90° and 120° the number of maximum images formed is $n = 3$. This in turn implies that if θ is given, n is unique but if n is given, θ is not unique.
- The number of images seen may be different from the number of images formed and depends on the position of observer relative to object and mirrors e.g., if $\theta = 120°$ maximum number of images formed will be 3 but number of images seen may be 1, 2 or 3 depending on the position of observer.

15.6.3 Uses of mirrors

(i) Plane mirror is used

- in looking glasses,
- in construction of kaleidoscope, telescope, sextant, and periscope etc.,
- for seeing round the corners,
- as deflector of light etc..

(ii) Concave minor is used

- as a reflector in searchlight, head light of motor cars and projectors etc.,
- for converging solar radiation in solar cookers,
- in flood lights to obtain a divergent beam of light to illuminate buildings,
- in reflecting telescopes etc..

(iii) Convex mirror is used

- as a rear view mirror in motor cars, buses and scooters,
- as safety viewers at dangerous corners and on upper deck of double decker buses etc..

15.7 SIGN CONVENTION AND MIRROR FORMULA

To measure distances with respect to a curved mirror, following convention is followed:

(i) All distances are measured from the pole of the mirror.

(ii) The distances measured in the direction of incident light, are taken as positive.

(iii) The distances measured in opposite direction of incident light, are taken as negative.

(iv) The distances above the principal axis are taken positive, whereas those below it are taken as negative.

You have seen the image formation in concave mirror. When an object is placed at $2f$ (centre of curvature) the image is formed at $2f$. If f be the focal length of the concave mirror, u distance of object and v the distance of image, then

$$u = -2f$$

and $$v = -2f$$

and f can be given as

$$\frac{1}{f} = \frac{1}{-2f} + \frac{1}{-2f}$$

or $$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

This is called mirror formula and it can also be verified for convex mirror. Use this formula and justify the image formation given in image diagrams.

15.8 MAGNIFICATION IN SPHERICAL MIRRORS

Often we find that a spherical mirror can produce magnified image of an object. The ratio of the size of the image to the size of the object is called **linear magnification.**

i.e., linear magnification (M) = $\dfrac{\text{size of the image } (I)}{\text{size of the object } (O)} = \dfrac{v}{u}$

where v = image distance from mirror, u = object distance from mirror.

INTEXT QUESTIONS 15.2

1. An object is placed infront of a concave mirror as shown in the Fig. 15.16. Write the position and nature of the image. What is the focal length of the mirror?

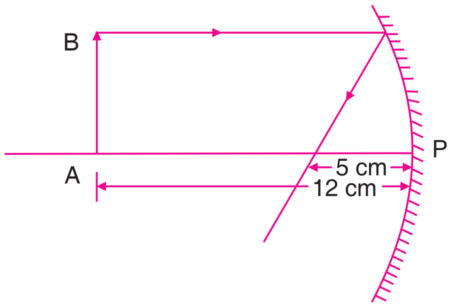


Fig. 15.16

2. In what condition, the image formed by concave mirror is virtual?
3. At what position will the reflected ray shown in Fig. 15.17 intersect the principal axis beyond focus or before focus?

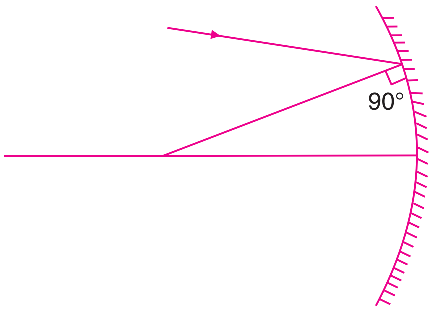


Fig. 15.17

4. What type of image will be formed if an object is placed beyond centre of curvature infront of a concave mirror?
5. Find the position of the object placed infront of a concave mirror of focal length 20 cm if image is formed at the distance of 30 cm from the mirror.
6. Write two uses of concave mirror.
7. Write the nature of image formed in convex mirror.
8. Find the position of the image formed in convex mirror of focal length 12 cm when object is placed at the distance of (i) 8 cm, (ii) 12 cm and (iii) 18 cm from the mirror.
9. Complete the following table with corresponding positions of object and image in case of concave mirror.

Position of object	Position of image
(i) at F	(i) ....
(ii) between F and $2F$	(ii) ....
(iii)	(iii) between F and $2F$
(iv)	(iv) beyond $2F$
(v) beyond $2F$	(v) ....

10. Write two uses of convex mirror.
11. Does concave mirror always converges the light rays?
12. Write the conditions to produce a magnified image in concave mirror.

15.9 REFRACTION OF LIGHT

Have you ever seen a coin placed at the bottom of a tumbler filled with water? The coin appears at smaller depth as its actual depth. Why does it happen so? We see an image where the light rays meet or at the point where light seems to be coming from.

When light comes out from water, it bends due to which the coin appears vertically displaced as shown in Fig. 15.18. Does it always happen? No, it does happen only when light passes from one medium to another obliquely. The bending of light depends upon the density of the medium.

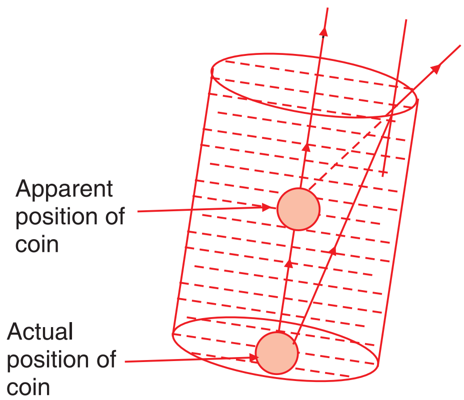


Fig. 15.18 *Coin placed in a tumbler filled with water*

When light passes from denser medium to rarer medium it bends away from the normal. When it passes from rarer medium to denser medium it bends towards the normal. This **phenomenon of bending of light is called refraction of light**. Refraction of light is shown in Fig. 15.19.

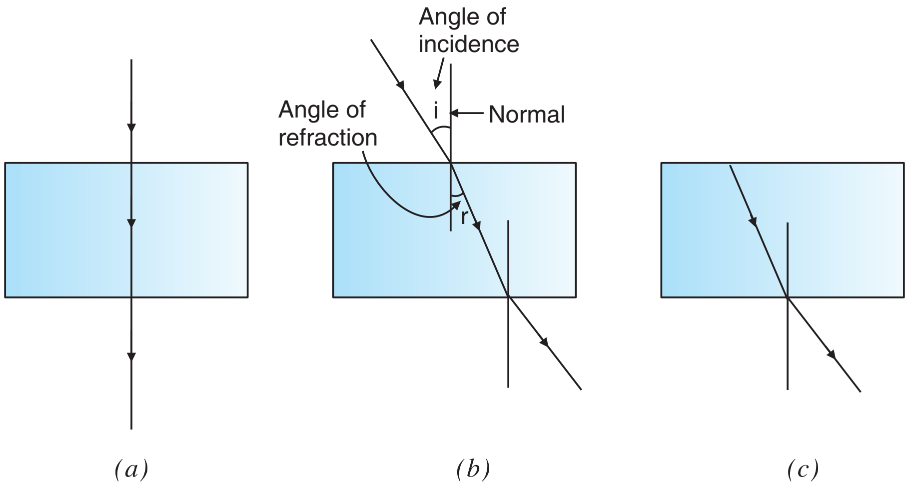
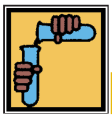


Fig. 15.19 *Refraction of light*

In Fig. 15.19 (b) and (c) light deviate from its path but in Fig. 15.19 (a) it does not deviate from its path. Is it refraction or not? Certainly it is refraction, for normal incidence light rays do not deviate from their paths. During refraction the frequency of the light remains unchanged but its wavelength changes hence the speed of light also changes.



ACTIVITY 15.4

To study the refraction of light place a glass slab on a dressing sheet fixed on a wooden drawing board, sketch a pencil boundary. Draw a line *OC* meeting the boundary line obliquely. Fix the pins *A* and *B* on that line. Now look for these pins from the other side of the glass slab.

Take a pin and fix it on the sheet such that *A*, *B* and *E* are in a straight line. Now fix another pin *F* such that it is in a straight line with pins *A*, *B* and *E*. Remove the slab and the pins.

Draw a line joining the points *F* and *E* to meet the boundary at *D*. The line *ABC* gives the direction of incident ray on the glass slab while the line *DEF* gives the direction of emergent ray. The line *CD* gives the direction of refracted ray within the glass slab. Draw normal N_1CN_2 at *C* and N_3DN_4 at *D* to the boundaries. Now you can conclude that the ray of light, when going from a rarer (air) to a denser (glass) medium, it bends towards the normal. Also, the ray of light when goes from denser to rarer medium it bends away from the normal.

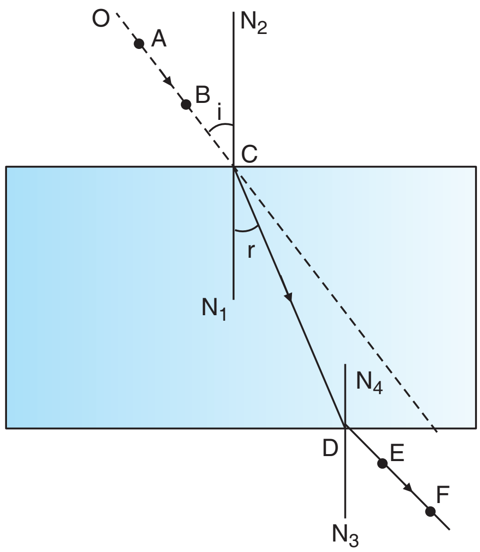


Fig. 15.20 *Refraction through a glass slab*

15.9.1 Refractive Index of the Medium

When light travels from one medium to another its speed changes. A ray of light from a rarer medium to a denser medium slows down and **bends towards the normal.** On the other hand the ray of light going from a denser medium to a rarer medium is speeded up and **bends away from the normal.** It shows that the speed of light in different medium varies. Different s medium have different abilities to bend or refract light. This bending ability of a medium is known as the index of refraction or refractive index. It is defined as the ratio of the speed of light in vacuum to that in the material medium.

Therefore, refractive index of a medium,

$$n \approx \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

15.10 LAWS OF REFRACTION

The extent, to which a ray bends, depends not only on the refractive index of medium, but also on the angle of incidence. The laws of refraction are:

(i) **First law of refraction:** The incident ray, refracted ray and the normal at the point of incidence, all lie in the same plane (Fig. 15.19).

(ii) **Second law of refraction:** How much ray of light refracted depends on that medium. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is constant and equal to the refractive index of that medium. This law is also called **Snell's law**.

$$\text{Refractive index } (n) \approx \frac{\text{sine of angle of incidence}}{\text{sine of angle of refraction}}$$

or
$$n \approx \frac{\sin i}{\sin r}$$

Does the colour of light change during refraction?

The wavelength and frequency of light are related to the velocity as $v = \nu\lambda$, where ν is frequency and λ is wavelength.

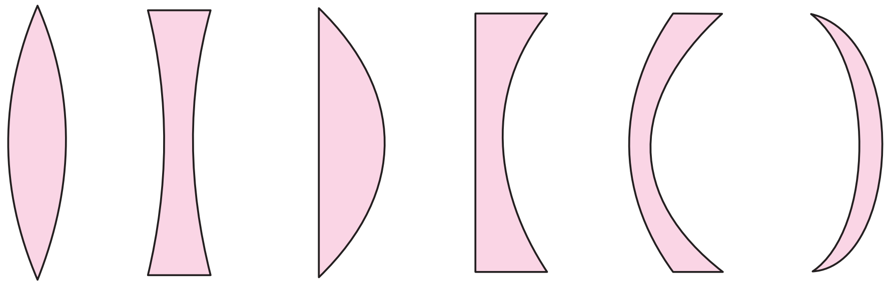
ACTIVITY 15.5

Take a transparent bucket of plastic filled with water. Keep your head inside the water in bucket and hold it above the red colour light bulb as shown in Fig. 15.21. What do you observe? Is there any change in the colour of light seen by you from the water? No, there is no change in the colour of light. It means when light goes from one medium to another, only its speed and wavelength change but the frequency remains constant. It proves that colour is the function of frequency not the wavelength of light.

Fig. 15.21 *The red bulb is seen by a boy keeping his head inside the bucket filled with water*

15.11 REFRACTION THROUGH SPHERICAL SURFACE

In this section we will discuss refraction of light through a lens. A lens is a portion of a transparent refracting medium bounded by two surfaces. Depending upon the nature of surfaces lens may be of following types.



Convex or double convex | Concave or double concave | Plano-convex | plano-concave | Convexo concave | Concavo convex

Fig. 15.22 *Different type of lenses*

(i) **Convex lens:** Convex lens has its two surfaces bulging outward. It makes the parallel rays of light to converge to a point. Hence, it is called **converging lens**. The point of convergence is called **focus** as shown in Fig. 15.23.

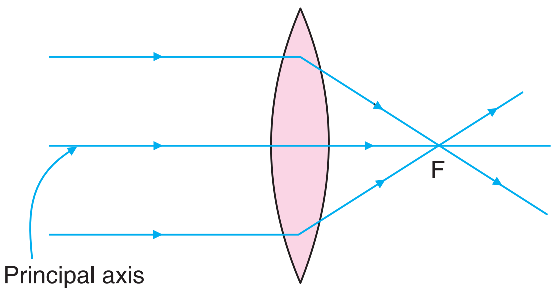


Fig. 15.23 *Converging action of a convex lens*

(ii) **Concave lens:** A concave lens has its two surfaces caving inward as shown in Fig. 15.24. It makes parallel rays of light to spread from a point. Hence it called **diverging lens**. The point where from light rays appear to diverge is called **focus** as shown in Fig. 15.24.

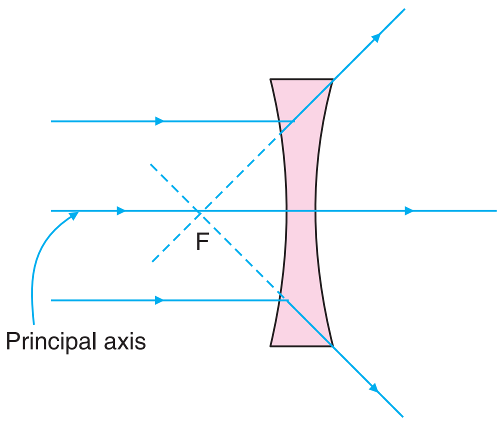


Fig. 15.24 *Diverging action of a concave lens*

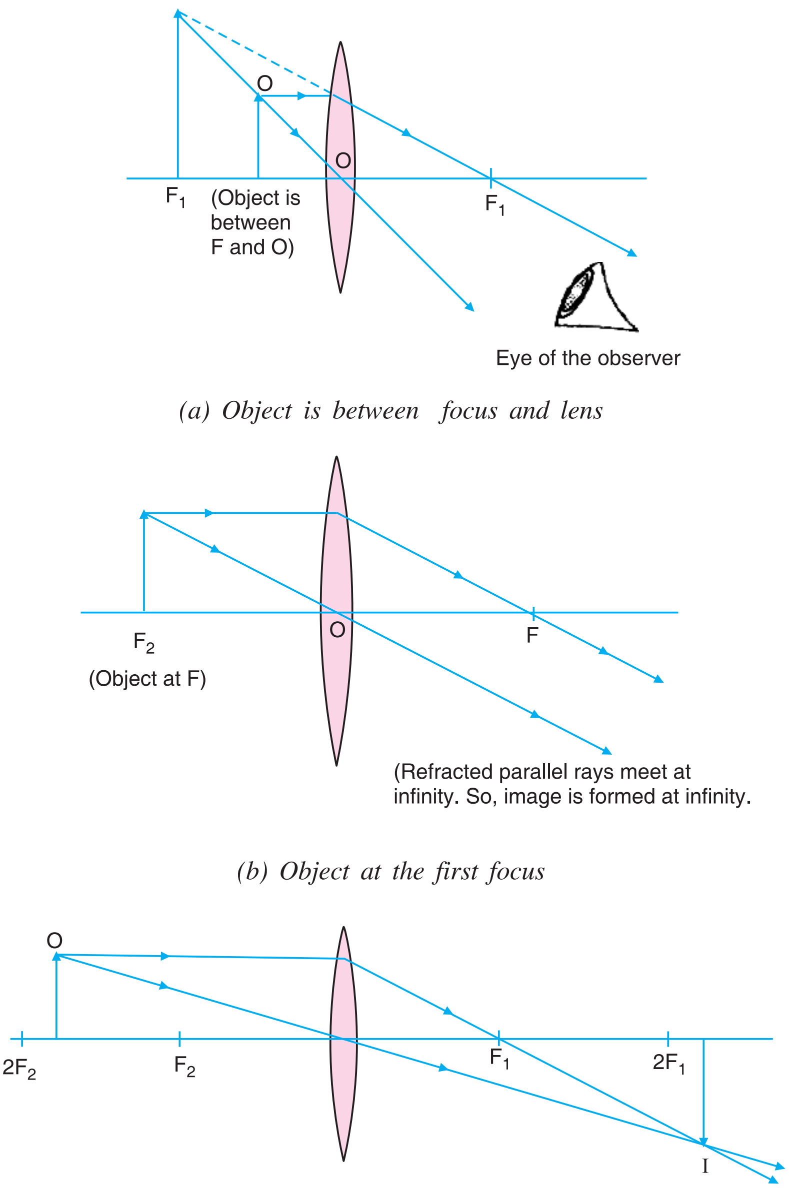
15.12 IMAGE FORMATION IN LENSES

In order to draw the image formed by any lens, only two rays are required. These two rays are:

(i) A ray parallel to the principal axis of the lens converges after refraction at the principal focus of convex lens. It appears to diverge off in the case of concave lens.

(ii) A ray towards the optical centre falls on the lens symmetrically and after refraction passes through it undeviated.

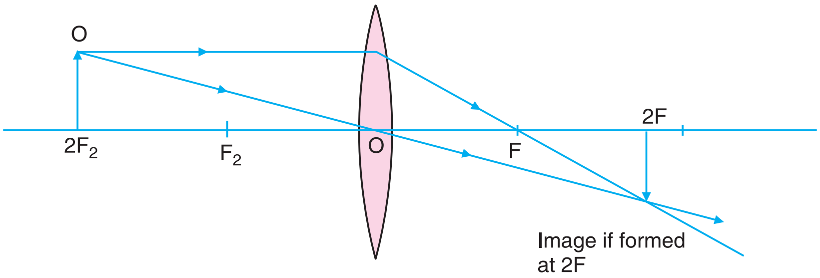
The image formations in convex and concave lenses are shown in Fig. 15.25.



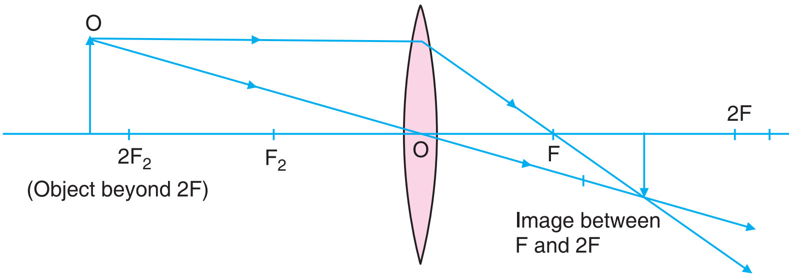
(a) Object is between focus and lens

(b) Object at the first focus

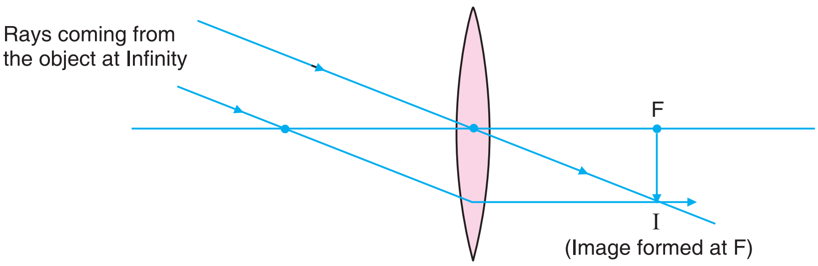
(c) Object is between F_2 and $2F_2$



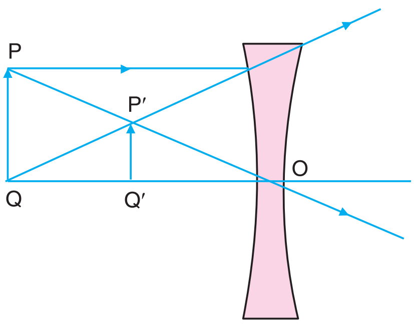
(d) Object is at $2F_2$



(e) Object is beyond $2F_1$



(f) Object placed between optical centre and first focus



(g) Image by concave lens

Fig. 15.25 *Image formation in convex and concave lens*

All these images formed for different positions of object and nature of the image can be summarized as given in the table below:

Table 15.4

Position of the object	Position of image formed	Nature of image	Size of image
(A) For convex lens			
(i) between F and pole	infront of lens	virtual and erect	enlarge
(ii) at F	at infinitely	real and inverted	highly enlarged
(iii) between F and $2F$	beyond $2F$	real and inverted	enlarge
(iv) at $2F$	at $2F$	real and inverted	same size
(v) beyond $2F$	between F and $2F$	real and inverted	smaller in size
(vi) at infinity	at F	real and inverted	highly diminished
(B) For concave lens			
anywhere infront of lens	on the same side between F and pole	virtual and erect	always smaller

15.13 SIGN CONVENTION AND LENS FORMULA

In case of spherical lenses,

(i) all distances in a lens are to be measured from optical centre of the lens

(ii) distances measured in the direction of incident ray are taken to be positive

(iii) distance opposite to the direction of incident ray are taken to be negative

(iv) the height of the object or image measured above the principal are taken positive whereas below it, are taken negative.

Using the above mentioned sign convention and the image formation in Fig. 15.25 let us assume, the distance of object from the optical centre of the lens to be u distance of image from the optical centre to be v and focal length of the lens is f then the relationship between u, v and f for lens can be shown as:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

This is called lens formula. Focal length for convex lens is positive, for concave lens it is taken negative.

15.14 MAGNIFICATION

You would have notice that in case of some lenses, the size of the image of an object is enlarged where as in some other cases it is diminished. If we take the ratio of the size of the image to the size of the object for a particular lens it remains constant for that lens. The ratio of the size of the image to that of the object is called as the magnification of the lens.

$$\text{Magnification} = \frac{\text{size of image } (I)}{\text{size of object } (\theta)}$$

or
$$m = \frac{(I)}{(O)}$$

Also
$$\frac{(I)}{(O)} = \frac{v}{u}$$

or
$$m = \frac{v}{u}$$

INTEXT QUESTIONS 15.3

1. Name the type of lens which always produces virtual image.
2. Draw the ray diagram for the image formation in convex lens where object is placed at (i) F (ii) between F and $2F$ (iii) beyond $2F$.
3. Draw the ray diagram for image formation in concave lens.
4. The sizes of the image and object are equal in a lens of focal length 20 cm. Name the type of lens and distance of object from the lens.
5. An object of size 10 cm is placed infront of convex lens of focal length 20 cm. Find the size of the image formed.

15.15 DISPERSION OF LIGHT THROUGH GLASS PRISM

A prism is a transparent medium bounded by any number of surfaces in such a way that the surface on which light is incident and the surface from which light emerges are plane and non-parallel. Generally equilateral, right angled isosceles or right angled prisms are used.

When white light or sun light passes through a prism it splits up into constituent colours. This phenomenon is called **dispersion** and arises due to the fact that refractive index of prism is different for different colours of light. So, different colours in passing through a prism are deviated through different angles. Rainbow, the most colourful phenomenon in nature, is primarily due to the dispersion of sunlight by rain drops suspended in air. Dispersion of light in glass prism is shown in Fig. 15.26.

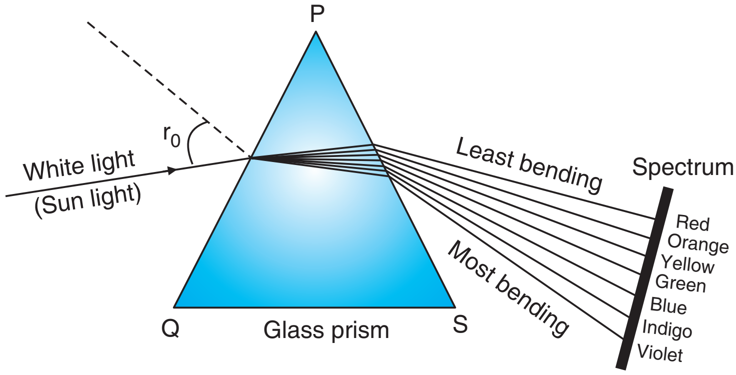


Fig. 15.26 *Dispersion of light*

ACTIVITY 15.6

To produce a spectrum (display of different colour) using a prism and sunlight

(i) Take an empty card board box. Make a rectangular opening on its cover with a knife and close it with transparent while paper to see the spectrum.

(ii) Make a thin slit with knife on the opposite side of card board box.

(iii) Place the prism on a block inside the box.

(iv) Turn the slit-side face of the box towards sun light.

(v) See the coloured strips on the transparent paper.

The frequency of colours in decreasing order is violet, indigo, blue, green, yellow, orange, and red. It can be written as VIBGYOR.

INTEXT QUESTIONS 15.4

1. When light passes from air to a medium its speed reduces to 40%. The velocity of light in air is 3×10^8 ms^{-1}. What is refractive index of the medium?
2. When sunlight is passed through prism, it splits into seven colours as shown in Fig. By numbers write corresponding colours.

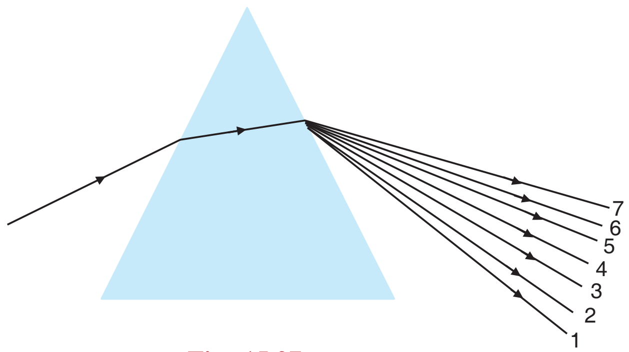


Fig. 15.27

3. How do r and δ change for same angle of incidence i if the prism shown in Fig. is immersed in water

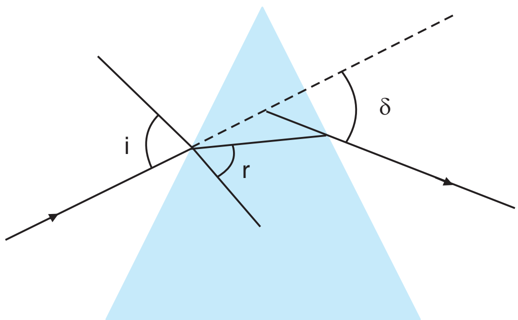


Fig. 15.28

4. Why does white light split into seven colours when it passes through a prism?
5. Write a natural phenomenon of dispersion of light.

15.16 EYE AND ITS DEFECTS

In eye a convex lens forms real, inverted and diminished image at the retina. The lens can changes its convexity to form a suitable image as the distance between eye lens and retina fixed. The human eye is most sensitive to yellow-green light having wavelength 5550 Å, the least to violet 4000 Å and red 7000 Å.

The size of an object as perceived by eye depends on its **visual angle.** When an object is distant, its visual angle θ_1 and image I_1 at retina is small hence it will appear small. If it is brought near the eye, the visual angle $\theta°$ is large and hence size of image I2 will increase as shown in Fig. 15.29.

The far and the near points for normal eye are usually taken to be at infinite and 25 cm respectively. It means a normal eye can see very distant objects clearly but near objects only if they are at a distance greater than 25 cm from the eye. The ability of eye to see objects from infinite distance to 25 cm is called power of **accommodation.**

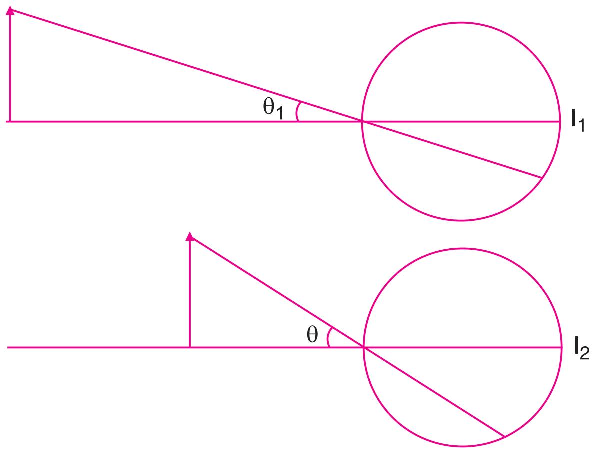
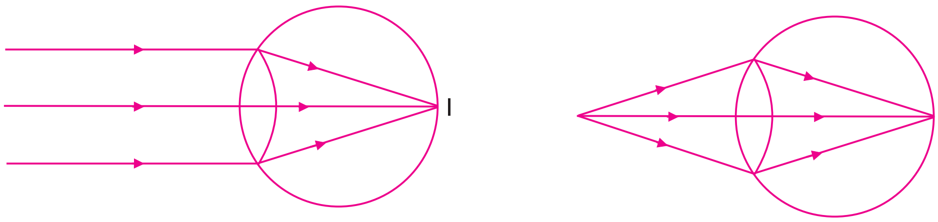


Fig. 15.29 *Image formation in eye*

If an object is at infinity, i.e., parallel beam of light enters the eye, the eye is least strained and said to **relaxed** or **unstrained**. However, if the object is at the least distance of distinct vision (= 25 cm), eye is under the maximum strain and visual angle is maximum. (The angle made by object at eye is called visual angle).

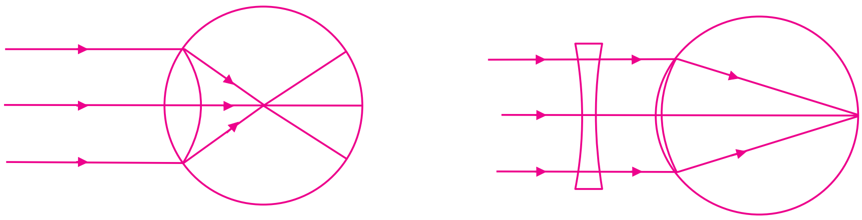


Relaxed eye *Maximum strained eye*

Fig. 15.30

If image of the object does not form at retina the eye has some defects of vision. Following are the common defects of vision.

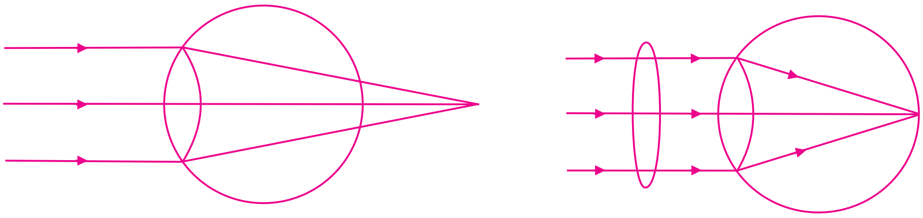
(i) **Myopia:** In this defect the distant objects are not clearly visible i.e., far point is at a distance lesser than infinity and hence image of distant object is formed before the retina as shown in Fig. 15.31. This defect is removed by using diverging (concave) lens. Myopia is also called short sightedness or near sightedness.



Maypic eye *Corrected eye*

Fig. 15.31

(ii) **Hyper metropia:** It is also called long sightedness or far sightedness. In it the near objects are not clearly visible i.e. near point is at a distance greater than 25 cm. So the image of near object is formed behind the retina. This defect is removed by using converging lens as shown in Fig. 15.32.



Hypermetropic eye *Corrected eye*

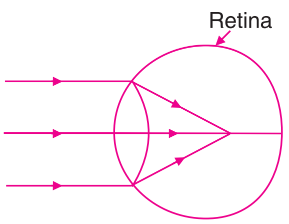
Fig. 15.32

(iii) **Presbypia:** In this defect both near and far object are not clearly visible i.e., far point is lesser than infinity and near point greater than 25 cm. This can be removed either by using two separate spectacles one for myopia and other for hypermetropia or by using bifocal lens. It is an old age disease. At old age ciliary muscles lose their elasticity so they can not change the focal length of eye lens effectively and eye losses its power of accommodation.

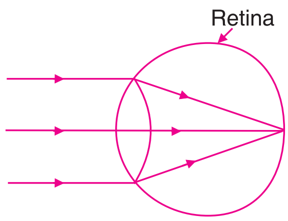
(iv) **Astigmatism:** It is due to imperfect spherical nature of eye lens. The focal length of eye lens is in two orthogonal directions become different so they can not see objects in two orthogonal directions simultaneously. This defect in direction can be removed by using cylindrical lens in a particular direction.

INTEXT QUESTIONS 15.5

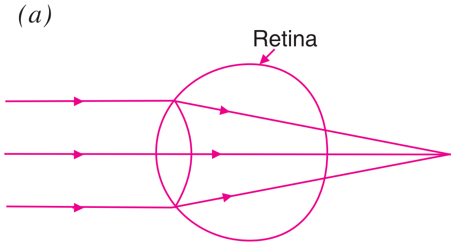
1. Identify the eye having defective vision from the following diagrams. Write the type of defect in vision. How this defect can be removed?



(a)



(b)



(c)

Fig. 15.33

2. Three students Riya, Tiya and Jiya in a class are using sphericals of power $+2D$, $+4D$ and $-2D$. What type of defect in vision they have?
3. How does the focal length of the eye changes when a lens is used to correct the defect of vision in case of (i) short sightedness and (ii) long or for sightedness

WHAT YOU HAVE LEARNT

- Light is a form of energy which makes the objects visible to us.
- When light falls on a smooth and rigid surface and comes back to the same medium, the phenomenon is called reflection.
- In reflection, the angle of incidence is equal to the angle of reflection. Also the incident ray, reflected ray and normal drawn at the point of incidence all lie in the same plane.
- In plane mirror, the virtual image of the size of object and at equal distance from the mirror is formed.
- Spherical mirrors are of two types (i) concave and (ii) convex.
- In spherical mirrors radius of curvature is double of the focal length
- When object is placed infront of a concave mirror at F, between F and $2F$, at $2F$, beyond $2F$, the image will be formed at infinity, beyond $2F$, at $2F$ and between F and $2F$ respectively.
- When an object is placed between F and pole of the concave mirror, the image is formed behind the mirror, virtual and enlarge in size.
- In convex mirror image is always formed between F and pole, smaller in size and virtual nature.
- When light goes from one medium to another its speed changes and the light ray bends. This phenomenon is called refraction of light.
- In refraction, the ratio of sine of angle of incidence to the sine of angle of refraction is constant called refractive index.
- When light goes from rarer to denser medium it bends towards the normal and angle refraction remains less than the angle of incidence.
- When light goes from denser to rarer medium it bends away from the normal and angle of refraction remains greater than the angle of incidence.
- A transparent medium bounded by two well defined surfaces is called lens. There are two types of lens (i) which converges light (convex lens) and (ii) which diverges light (concave lens)

- In convex lens, when object is placed at F, between F and $2F$, at $2F$, beyond $2F$ infront of convex lens the image is formed at infinity, beyond $2F$, at $2F$ and between F and $2F$ respectively.
- When object is placed between F and optical centre of the convex lens, the image formed is virtual and enlarge.
- In concave lens the image is always formed between F and pole, smaller in size and virtual.
- The focal length of a mirror f is given as:

$$\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$$

- The focal length of a lens is given as:

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$$

- The reciprocal of the focal length is called power of the lens $P=\frac{1}{f\left(m\right)}$. Its unit is diopter.
- A person who can see the objects near to him properly but can not see the distant objects has a near sight defect of vision. This defect can be removed by using a concave lens.
- A person who can see the far objects but can not see the near objects has a far sight defect of vision. This defect can be removed by using convex lens.
- When light passes through a prism it splits into its constituent colours and this phenomenon is called dispersion of light.
- Rainbow is the best known example of dispersion in nature.

TERMINAL EXERCISE

1. What happens to the speed of light when it goes from (i) denser medium to rarer medium (ii) rarer medium to denser medium?
2. Can angle of incidence be equal to the angle refraction? Justify.
3. Does a convex lens always converge light? Explain.
4. Write the nature of the image formed by concave lens.
5. In horizontal and vertical boxes of the letter grid some meaningful words regarding the properties of light are placed in different rows and column in the table below. Find at least three and define them?

C	O	A	C	O	N	C	A	V	E	C	Z
C	O	N	V	E	X	E	W	I	M	C	W
V	L	R	E	F	L	R	C	T	I	O	N
I	O	E	I	S	E	R	T	A	R	N	P
R	T	F	M	A	N	E	C	A	R	C	Y
T	A	R	A	T	S	C	T	E	O	A	X
U	M	A	G	N	E	T	O	P	R	V	W
A	C	C	E	P	Q	R	S	T	U	E	V
L	O	T	P	R	I	M	E	T	I	M	E
C	V	I	K	T	U	A	L	M	G	I	N
A	C	O	V	E	R	T	E	X	A	R	P
P	N	U	M	I	R	R	O	R	R	S	Q

6. What will be the nature of the image formed in a convex mirror and in a concave mirror each of focal length 20 cm and object is placed at the distance of 10 cm.
7. Find the position of the image formed in concave mirror of focal length 12 cm when object is placed 20 cm away from the mirror. Also find magnification.
8. In which of the following media, the speed of light is maximum and in which it is minimum.

Medium	Refractive index
A	1.6
B	1.3
C	1.5
D	1.4

9. The image of a candle formed by a convex lens is obtained on a screen. Will full size of the image be obtained if the lower half of the lens is printed black and completely opaque? Illustrate your answer with a ray diagram.
10. Can a single lens ever form a real and errect image?
11. What is dispersion of light? What is the cause of dispersion of light?
12. Why do distant object appear to be smaller and closer to each other?
13. A person looking at a net of crossed wires is able to see the vertical direction more distinctly than the horizontal wires. What is the defect due to? How is such defect of vision corrected?

14. A person can see the objects placed at a distance of 30 cm clearly but cannot see the objects placed 30 m away. What type of defect of vision he has? How is this defect of vision corrected?
15. Distinguish visible, ultraviolet and infrared light.
16. Which of the following quantities remains constant during reflection of light?
    (i) speed of light
    (ii) frequency of light
    (iii) wavelength of light
17. Write the value of angle of reflection at both the reflecting surfaces M_1 and M_2 held perpendicular to each other as shown in Fig. 15.34

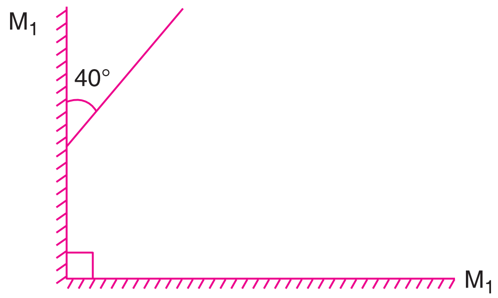


Fig. 15.34

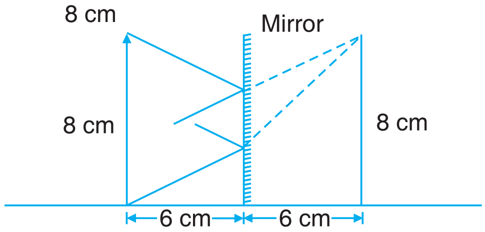
18. An object is placed infront of a plane mirror. The mirror is moved away from the object with the speed of 0.25 ms^{-1}. What is the speed of the image with respect to the mirror and with respect to the object?
19. Size of the image in a plane mirror of height 12 cm is 20 cm. What is the size of the object?

ANSWERS TO INTEXT QUESTIONS

15.1

1. 1. Luminous   2. Luminous   3. Non- luminous
   4. Luminous   5. Non- luminous
2. (i) Real image can be taken on screen while virtual can not.
   (ii) Real image is formed due to light rays meeting at the screen. While virtual image is formed due to light rays appear to meet at the screen.
3. Real
4. 60°

5.



6. (i) 4 cm (ii) 8 cm
7. (i) 6.0 ms^{-1} (ii) 12.0 ms^{-1}
8. Real, Erect, Plane, Virtual, Image
9.

Distance of object (A)	Height of object (B)	Distance of image (C)	Height of image (D)
10 cm	5 cm	10 cm	5 cm
5 cm	10 cm	5 cm	10 cm
6 cm	8 cm	6 cm	8 cm

15.2

1. Position is equal to –8.55 cm, the image is real of focal length 5 cm
2. When object is between focal point and pole of the mirror.
3. before focus
4. Real, smaller in size and inverted
5. 60 cm infront of mirror
6. Saving mirror, magnifying mirror for dentist
7. Always virtual and smaller in size
8. (i) 4.8 cm (ii) 6 cm (iii) 7.2 cm
9.

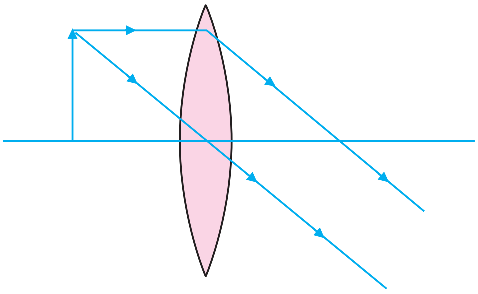
Position of object	Position of image
(i) at F	(i) at infinity
(ii) between F and $2F$	(ii) beyond $2F$
(iii) beyond $2F$	(iii) between F and $2F$
(iv) between F and $2F$	(iv) beyond $2F$
(v) beyond $2F$	(v) between F and $2F$

10. (i) in vehicle for rear view (ii) as safety viewers at dangerous corners
11. No, not always

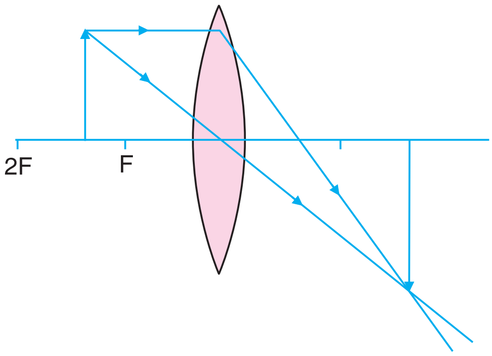
12. Object must be placed either between focal point and pole for virtual image or between F and $2F$ for real image.

15.3

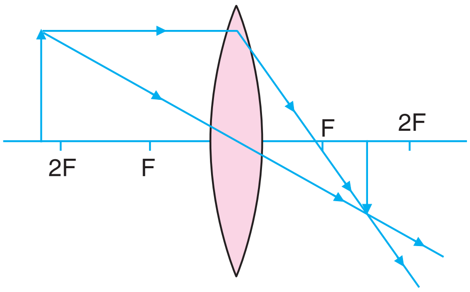
1. Concave lens
2. (i)



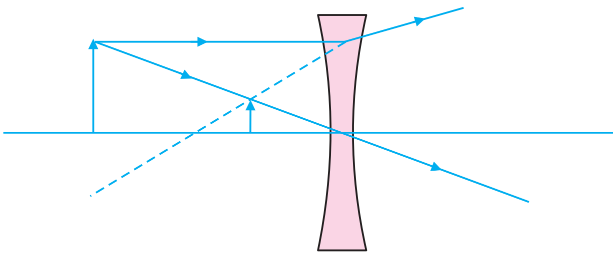
(ii)



(iii)



3.



4. Convex lens, 40 cm
5. –20 cm

15.4

1. 5/3
2. (1) Violet (2) Indigo (3) Blue (4) Green (5) Yellow
   (6) Orange (7) Red
3. r and δ both will decrease
4. Material of the prism has different value of refractive index for different colours of light.
5. Rainbow in the sky

15.5

1. (A) Shortsightedness, it can be removed by using diverging lens.
   (B) No defect
   (C) Longsightedness, it can be removed by using converging lens.
2. Riya and Tiya have longsightedness and Jiya has shortsightedness.
3. (i) increases (ii) decreases

16

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ELECTRICAL ENERGY

All of us have the experience of seeing lightning in the sky during thunderstorm. We also have experience of seeing a spark or hearing a crackle when we take off our synthetic clothes in dry weather. This is Static Electricity. In your toys the source of energy is a battery in which chemical or some other energy is converted into Electrical Energy. This electrical energy also comes from electrical power station to your house through various devices and puts all comforts at our command just with the press of a button. It provides us with heat and light. It powers big machines, appliances and tools at home and in industries e.g. ,radio set, computers, television, vacuum cleaners, washing machines, mixer and grinders, x-ray machines, electric trains etc. Nowadays, it is impossible to think of a world devoid of electrical energy. Life without electricity even for short duration gives a feeling like a fish out of water. Here in this lesson we shall study the nature of electricity and way of its working.

OBJECTIVES

After completing this lesson, you will be able to:

- *cite examples of static electricity from everyday life;*
- *identify two kinds of electric charges and describe the Coulomb's law;*
- *define the terms electrostatic potential, and potential difference;*
- *define electric current;*
- *state ohm's law and define electrical resistance of a conductor;*
- *compute equivalent resistance of a number of series and parallel combination of resistors;*
- *appreciate the heating effect of current by citing examples from everyday life and*
- *define the unit of electric power and electric energy in commercial use and solve problems about these.*

16.1 ELECTROSTATICS

You must have observed that a plastic comb when brought near a piece of paper does not pick up small pieces of a paper. But if you comb your dry hair and bring the comb close to a small piece of paper, you will notice that the bits of paper are attracted towards the comb. Do you know why this happens? This happens because the comb gets charged or electrified when you comb your dry hair . The electricity (or charge) developed on a body on rubbing with another body is called frictional electricity or static electricity. Let us understand more with some simple activities.

Do you know

An understanding of electric charge and their properties and also of magnetism began in 6th century B.C. i.e. 2500 years ago. One of the founders of Greek science, Thales of Miletus knew that if a piece of amber is rubbed with a woolen cloth, it would then attract light feathers, dust, lint, pieces of leaves etc. Amber is a yellow resinous (gum like) substance found on the shores of the Baltic sea. The Greek name for amber was 'electrum' which is the origin of the familiar words electricity, electric charge, electric force and the electron. However, the systematic study of electricity was done by Dr. William Gilbert, the personal physician of Queen Elizabeth–1 of England. Dr. Gilbert had done the experiments i.e. the rubbing of glass rod with silk, rubber shoes against a wooden carpet etc. which produced electrically charged bodies. Dr. Gilbert named amber like substances Electrica, which became electrically charged by rubbing.

ACTIVITY 16.1

One day Dolly and Jolly were studying, suddenly Dolly spread some bits of paper on the table and asked her sister Jolly to lift the bits of paper with the help of a pen or a balloon. Jolly brought pen near the bits of paper but there was no effect on bits of papers. Then she tried with balloon but could not show the magic. Jolly requested Dolly to show the magic. Dolly took the pen and muttered something meanwhile rubbing it on her sweater, she brought the pen near the pieces of paper and they got attracted towards the pen .This activity thrilled Jolly and she ran to tell this to her mother. Similarly she rubbed an inflated balloon on her dry hair brought near the bits of paper, the pieces of paper got attracted towards the balloon. Now Dolly rolled the pen between the palms of her both hands and then brought it near the bits of paper, the pen could not attract the bits of paper. Jolly was wondering that the trick was indeed some magic or some science was involved! Dolly explained that rubbed pen/inflated balloon attract bits of paper whereas before rubbing it does not attract bits of paper. After rolling between the hands, pen loses the property of attraction. Hence, it is concluded that some bodies acquire electric charge on rubbing but if it is touched to a conducting body in contact with ground, the charge leaks away to the earth.

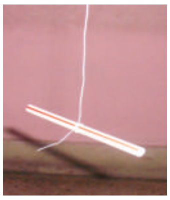
It was realized that metal can be charged by rubbing but only if it is held in a handle of glass or amber. The metals cannot be charged if it is held directly in the hand. This is because electric charges move along the metal and pass through the human body (conductor) to the earth.

ACTIVITY 16.2

Take two straws (a hollow tube through which liquid is sucked), a small piece of paper, a piece of silk cloth, two pieces of threads (~50 cm), one small glass bottle a piece of cello-tape, scissors.

Take one straw and tie one thread at its centre and suspend it from the edge of a table with the help of a piece of cello tape so that it stays horizontally. Let it come to rest. Now bring the other straw nearby the suspended straw and observe the effect. You will notice that there is no effect.

(i)



(ii)

(iii)

(iv)

(v)

(vi)

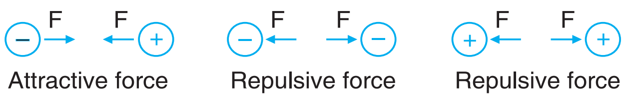
(vii)

(viii)

Now rub the suspended straw with a piece of paper and bring the other straw close to one end of the suspended straw. Observe carefully the position of suspended straw. You will observe that the suspended straw moves towards the straw in your hand.

Rub the second straw (which is in your hand) with the piece of a paper and bring it close to one end of the suspended straw. Observe carefully the interaction between the straws. The suspended straw moves away i.e. repelled away.

Now take the glass bottle and rub it with a piece of silk cloth and bring it close to one end of the suspended straw. Observe carefully the interaction between the straw and the glass bottle, the glass bottle attracts the suspended straw.



What do you infer? It is inferred that two uncharged straws do not affect each other.

We observed that the charged straws repel each other but a charged straw and a glass bottle attract each other. Therefore it is concluded that:

(i) Two different types of charges (positive and negative) are produced.

(ii) Charge developed on glass bottle on rubbing it with silk cloth has a different nature than the charge developed on straw rubbed with paper. From the basic experiment it is established that glass on rubbing with silk cloth gets positive charge which is opposite in nature to the charge acquired by the straw.

(iii) Like charges repel each other while unlike charges attract each other.

16.1.1 Nature of Charges

Have you ever experienced a shock when you touch a metal door knob after walking across a carpet? Let us try to understand this.

When we walk on a carpet made of insulating material such as rubber, nylon, wool or polyester, friction between soles of our footwear and the material of the carpet cause opposite charges to appear on them. When we touch the metal knob, the free charge on our body(generated due to friction) and free charge on the ground cause a discharge at a high voltage (several thousand volts to as much as 15,000 volts).

In early days a French chemist Charles Dufay observed that the charge acquired by a glass rod rubbed with silk is different from the charge acquired by an ebonite rod rubbed with fur/wool. Dufay termed the charge acquired by glass rod in first case as 'vitreous' and the charge acquired by ebonite rod on rubbing it with wool as 'resinous'. Later on American scientist statesman Benjamin Franklin (1706-1790) introduced the terms positive in place of vitreous and negative in place of resinous, which is followed even today.

On rubbing, two materials acquire positive and negative charges equal in magnitude. Infact the process of rubbing does not create electric charges. It results in only transfer of negative charges from one material to the other. The material, from which the negative charges have been transferred, gets an excess of positive charge and the one which receives the negative charge becomes negatively charged. To answer this we have earlier studied that matter is made up of molecules and atoms. An uncharged body contains a large number of atoms each of which contains an equal number of protons and electrons. In some materials some of the electrons are bound rather loosely with their atoms. On rubbing, if some of the electrons are removed, the material which loses the electrons becomes positively charged and the material which has gained electrons becomes negatively charged. In the process of charging, positive charges in atoms are firmly bound and do not participate in the process of charging. Conservation of charge states that the total amount of electric charge in an isolated system (where no charge can get into or out of the system) does not change with time. Within an isolated system interactions between different bodies of the system can cause transfer of charge from one body to another but the total amount of charge of the isolated system always remains constant.

The Coulomb's Law governs the force between the charged particles. It was first studied by a French physicist Charles Augustine de Coulomb. Coulomb presented the inference of his experiments in the form of a law which is called Coulomb's law. According to Coulomb's law, **the magnitude of the force of attraction (or repulsion) between two point charges is directly proportional to the product of the quantity of two charges and inversely proportional to the square of the distance between them**.

Coulomb (1736-1806)

If a charge, q_1 is placed at a distance, r from a similar charge q_2 the two charges will continue to repel each other with a force

$$F = \frac{kq_1q_2}{r^2}$$

Where k is a constant of proportionality depending upon the nature of the medium in which the charges are placed. In SI unit $k = 9 \times 10^9$ N m^2 C^{-2} for vacuum (or air). Charge is a scalar quantity. Coulomb is a SI unit of charge represented by C.

Fig 16.1 *Two charges separated by distance r*

If $q_1 = q_2 = 1\text{C},\ r = 1\text{m}$

$$F = \frac{9\times10^9\,\text{Nm}^2\text{C}^{-2}\times1\text{C}\times1\text{C}}{(1\text{m})^2} = 9 \times 10^{-9}\ \text{N}$$

Thus, 1C is the charge when placed at a distance of 1m from an equal like charge in vacuum, experiences a repulsive force of 1N. Force is directed along the line joining the centres of the two charges. For like charges force is repulsive (positive in sign), while for unlike charges it is attractive (with negative sign).

16.2 ELECTROSTATIC POTENTIAL AND POTENTIAL DIFFERENCE

Consider an uncharged body like a glass rod which is given a certain charge (say a positive charge), the body acquires that charge. Now if you wish to add more charge of the same nature on it, the charge will experience a force of repulsion due to already existing charge on it. Therefore, some work has to be done by any external agent to overcome this force of repulsion. This work will be stored up as electrostatic potential energy in the system of charges. This is analogous to the process of raising a body above the ground against the force of attraction in which work done against gravity is stored in the body as its gravitational potential energy. Let a charge q be moved upto a distance r towards a source charge Q, the electrostatic potential energy possessed by charge q is given by,

$$U = \frac{kQq}{r}$$

The electrostatic potential (or potential) at any point in the vicinity of a charge is defined as the amount of work done in bringing a unit positive charge from infinity to that point. If W is the work done in bringing a positive charge q from infinity to a point in the vicinity of source charge Q, the potential V at the point due to charge Q is

$$V = \frac{W}{q} \quad \text{or} \quad \frac{U}{q} = \frac{kQ}{r}$$

Electrostatic potential is a scalar quantity (It has only magnitude and no direction). Its SI unit is joule/coulomb (JC^{-1}) or volt (V) which is given in the honour of Alessandro Volta (1745-1827) an Italian Physicist.

The potential at a point is 1 V if +1 C charge placed at that point possesses a potential energy of 1 J or the potential at a point is 1 V if 1 J of work is done in bringing 1 C of positive charge from infinity to that point i.e.

$$1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{coulomb}}$$

Consider a charge q is placed at a point as shown in the

Fig. 16.2 *charge q coming from infinity to B or C*

Let B and C be two points where point B is closer to q than C. If a charge q is brought from infinity to C or from infinity to B work done respectively be W_C and W_B. The potential at points B and C respectively be $V_B = \frac{W_B}{q}$ and $V_C = \frac{W_C}{q}$

The potential difference is the difference in potentials V_B and V_C. i.e.

$$V_B - V_C = \frac{W_B - W_C}{q}$$

Where $W_B - W_C$ is the work done in carrying charge from point C to B.

Thus potential difference between two points B and C is equal to the amount of work done in moving a unit charge from point C to point B.

Let us represent $V_B - V_C$ as V; $W_B - W_C$ as W the potential difference

$$V = \frac{\text{Work done}\,(W)}{\text{Amount of charge transferred}\,(q)}$$

The potential difference (pd) between two points of a conductor is said to be 1volt if 1 joule of work is done in moving 1 coulomb of charge from one point to another. Potential difference is a scalar quantity. It is measured using an instrument voltmeter. Voltmeter is always connected in parallel across which we have to measure the potential difference.

Fig. 16.3 *Voltmeter*

Example 16.1: How many electrons make one coulomb?

Solution: Let n electrons make 1C (Since charge is built by the excess or deficiency of electrons only).

Charge on 1 electron is 1.6×10^{-19}C

$$\text{Charge } q = +n|e|$$

$$n = \frac{q}{e} = \frac{1}{1.6\times10^{-19}} = 6.25\times10^{18} \text{ electrons}$$

Example 16.2: Calculate the work done in moving a charge of 3C across two points having a potential difference of 24V.

Solution: Given $q = 3\text{C},\ V = 24\text{V},\quad W = ?$

$$W = qV$$

$$= 3\text{C} \times 24\ \text{V}$$

$$W = 72\ \text{J}$$

INTEXT QUESTIONS 16.1

1. Define the units of (i) charge (ii) electric potential.
2. When a glass rod is rubbed with a piece of silk it acquires +10 micro coulomb of charge. How many electrons have been transferred from glass to silk?
3. How will the force between two small electrified objects vary if the charge on each of the two particles is doubled and separation is halved?
4. How does the force between two small charged spheres change if their separation is doubled?
5. A particle carrying a charge of 1 micro coulomb (μC) is placed at a distance of 50 cm from a fixed charge where it has a potential energy of 10 J. Calculate
   (i) the electric potential at the position of the particle
   (ii) the value of the fixed charge.
6. Two metallic spheres *A* and *B* mounted on two insulated stands as shown in the Fig. 16.4 are given some positive and negative charges respectively. If both the spheres are connected by a metallic wire, what will happen?

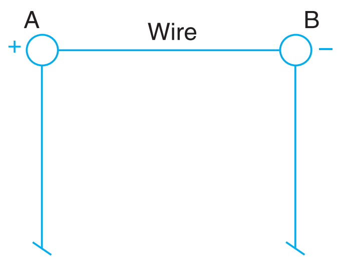


Fig 16.4 *Two metallic spheres mounted on stands*

16.3 ELECTRIC CURRENT

All electrical appliances/gadgets like a bulb or a heater's coil are based on the movement of charges as we know that flowing water constitute water current in rivers, similarly electric charge flowing through a conductor/a metallic wire constitutes electric current i.e., the quantity of charge flowing per unit time. Thus electric current is the charge flowing through any cross section of the conductor in a unit time i.e.,

$$i = \text{charge } (Q)/\text{time}(t)$$

Where Q is the charge in coulomb flowing through the conductor in t seconds. If 1 coulomb (C) of charge flows through any cross section of a conductor in 1 second (s), the current flowing it will be 1 ampere (A) i.e.,

$$1\ \text{A} = 1C/1s$$

Andre-Marie Ampere
(1775-1836)

Here, ampere is the SI unit of current given in the honour of the French scientist Andre Marie Ampere (1775-1836). However, small currents are more conveniently expressed in milliampere symbolically represented by mA, and microampere symbolically represented by μA. Current is a scalar quantity.

$$1\ \text{mA} = 10^{-3}\text{A}$$

$$1\ \mu\text{A} = 10^{-6}\ \text{A}$$

An ammeter is an instrument which on connecting in series in an electrical circuit indicates how many amperes of current is flowing in the electric circuit.

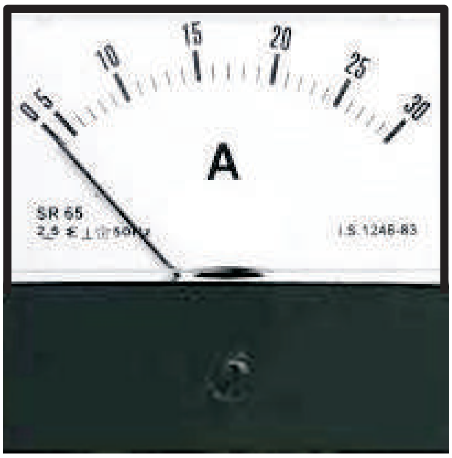
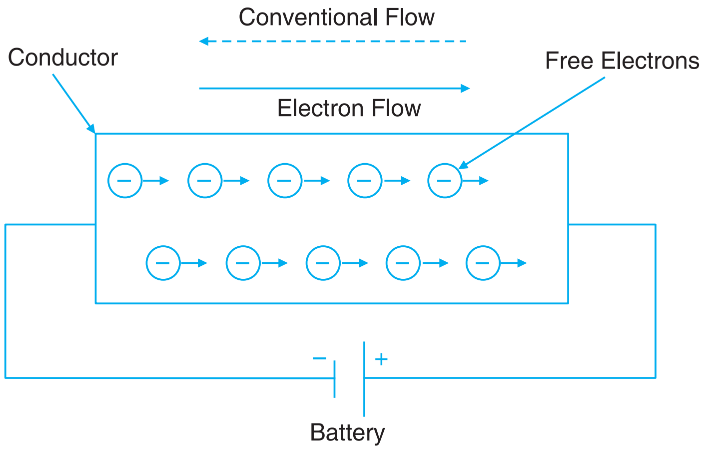


Fig. 16.5 *Ammeter*

Do you know

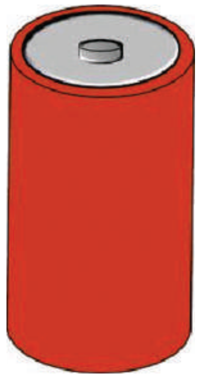
All metals contain large number of free electrons (~10^{-29} m^{-3}) which act as charge carriers. In a metallic conductor/wire these free electrons move with a sufficiently high velocity of the order of 10^5 m s^{-1} in all possible directions between the atoms of the conductor/wire and even then there is no net flow of electrons. But when battery is connected across the ends of the conductor/wire, the electrons drift in one direction i.e., current flows along the wire in one direction from positive terminal of the battery to the negative terminal of the battery along the wire with a very small velocity ~10^{-4}m s^{-1} called drift velocity of the electrons.

We have already read that matter is made up of protons, electrons and neutrons. Protons carry positive charge, electrons carry negative charge and neutrons do not carry any charge. An atom is electrically neutral but if a body carries excess of protons than the electrons, the body gets positively charge. If the body has excess of electrons than the protons, body gets negatively charged. If a charged body is connected to an uncharged body through a metallic wire, the positive charge flows from higher potential to lower potential while negative charge flows from lower potential to higher potential. The charge flows till both the bodies are at the same potential. To pass the charge continuously from one body to another body through a wire a constant potential difference has to be maintained between the two ends of a wire in a circuit. This is done by an external source of energy which forces the charge carriers (electrons) already present in the wire to move in a definite direction i.e. from lower potential region to higher potential region. The external source of energy is called a cell. **A cell is a device in which chemical energy is converted into electrical energy**. In the cell negatively charged plate repels the electrons which causes the electrons to move along the wire. Hence the electrons flow from the negatively charged plate through the wire to positively charged plate of the cell. This is known as the electron current. Conventionally the direction of the current is taken as opposite to the direction of the flow of electrons i.e., from the positive to the negative terminal.



Flow of electron/current

The combination of cells is called a battery. One of the earliest and simplest devices capable of producing steady current was invented by Alessandro Volta (1745-1827) named Voltaic Cell. Batteries are a good source of Direct current. Direct current (DC) means the electric current is flowing in one direction only in a circuit. To measure the current in a circuit, ammeter is used.



Caution: Never connect the two ends of a battery with conducting wire without making the electrons to pass through some load like a light bulb which slows the flow of current. If the electrons flow is increased too much, the conductor may become hot, and the bulb and the battery may be damaged.

16.3.1 Conductors and Insulators

All materials can be divided into two categories on the basis of movement of charges through them viz conductors and insulators.

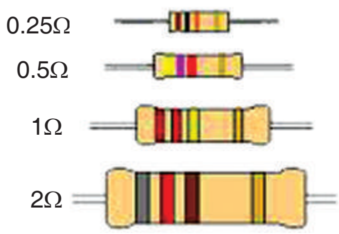
Conductors are the materials which allow the electric current to flow through them quite freely e.g. metals like silver, copper, aluminum.

Insulators are the materials which do not allow electricity to flow through them freely. e. g. rubber, glass, bakelite etc..

16.3.2 Resistors

The electrical resistance is the tendency to resist the flow of electric current. A wire having a desired resistance for use in an electric circuit is called a resistor. It is represented by the symbol -WW-.

Resistance can be both either desirable or undesirable in a conductor/circuit. In a conductor, to transmit electricity from one place to another place, the resistance is undesirable. Resistance in a conductor causes part of electrical energy to turn into heat, so some electrical energy is lost along the path. On the other hand it is the resistance which allows us to use electricity for light and heat e.g., light that we receive from electric bulb and heat generated through electric heaters.



Resistor

ACTIVITY 16.3

During your laboratory classes at your study centre, you can find the relation between the current flowing through a wire and the potential difference applied across it with the help of your tutor and your friends. Take a dry cell, a voltmeter (range 0-1.5V), an ammeter (range 0-1A), a standard fixed resistance coil (1 ohm), rheostat (0-1 ohm), connecting wires and a plug key.

(i) Connect the fixed resistor (R), ammeter (A), dry cell (D), plug key (K) and rheostat (Rh) in series (end to end) and voltmeter (V) in parallel to R. as shown in Fig. 16.6 (a).

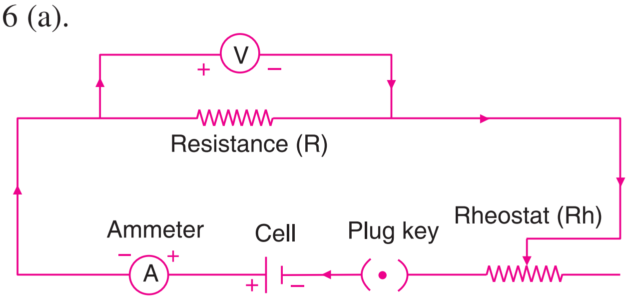


Fig. 16.6 *(a) Circuit diagram to study relationship between voltage and current*

(ii) When the key K is open, (meaning that the circuit is disconnected), check that the readings in ammeter and voltmeter are zero.

(iii) Insert the plug K in the key and move the sliding contact of the rheostate so that there is some small reading in ammeter and voltmeter. Record these readings.

(iv) Increase the value of current with the help of rheostat. Record ammeter and voltmeter readings again.

(v) After changing the readings 4 to 5 times, record the corresponding values of current and voltage from ammeter and voltmeter.

(vi) Plot a graph between ammeter and voltmeter readings.

What do you observe? You will observe that: (i) On increasing ammeter reading, voltmeter reading increases in the same proportion. (ii) The voltage-current graph is a straight line as shown in Fig. 16.6 (b).

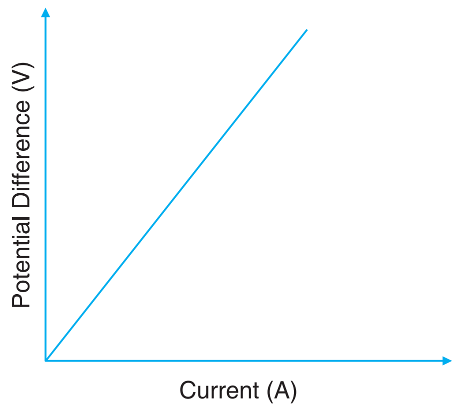


Fig. 16.6 *(b) variation of voltage with current*

What do you conclude? We conclude that the current flowing through a wire is directly proportional to the potential difference applied across its ends.

i. e. $V \propto i$

or $V = Ri$

Here, R is a constant of proportionality and is called the resistance of the given metallic wire. This observation was first made by Georg Simon Ohm and is known as Ohm's Law.

Ohm's Law states that the current flowing through a conductor is directly proportional to the potential difference applied across the ends of the conductor provided temperature of the conductor remains the same.

Now organize a brain storming session with your tutor and other learners on following points. The law can be applied only to conducting wires and that too when its temperature and other physical conditions remain unchanged. If the temperature of the conductor increases its resistance also increases.

'*R*' i.e. resistance of wire, is a constant for a given wire. It can be easily shown that resistance of a wire depends on:

Its length - longer the wire, more the resistance

Its thickness - thicker the wire, lesser the resistance.

Its width – more the width, lesser the resistance.

Therefore, the resistance of the wire is directly proportional to the length and inversely proportional to the cross-sectional area.

The nature of material - copper wire has lesser resistance than iron wire of same length and thickness. The resistance of a wire can never be negative.

Resistance is a scalar quantity and its SI unit is ohm denoted by the symbol Ω (omega). 1 ohm is the resistance of a wire across which when 1V potential difference is applied, 1A current flows through the wire.

i.e. $$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

High resistances are measured in kilo ohm (kΩ) and mega ohm (MΩ)

$$1 \ k\Omega = 10^3 \ \Omega$$

$$1M\Omega = 10^6 \ \Omega$$

16.4 COMBINATION OF RESISTORS

In an electric circuit, resistors can be connected in two different ways viz.

Series Combination: two or more resistors can be combined end to end consecutively.

Parallel Combination: two or more resistors can be connected between the same two points.

16.4.1 Series Combination

In a circuit (Fig. 16.7), three resistors are connected in series with a cell and an ammeter. You will note that due to one path the same current *i* will flow through all of them.

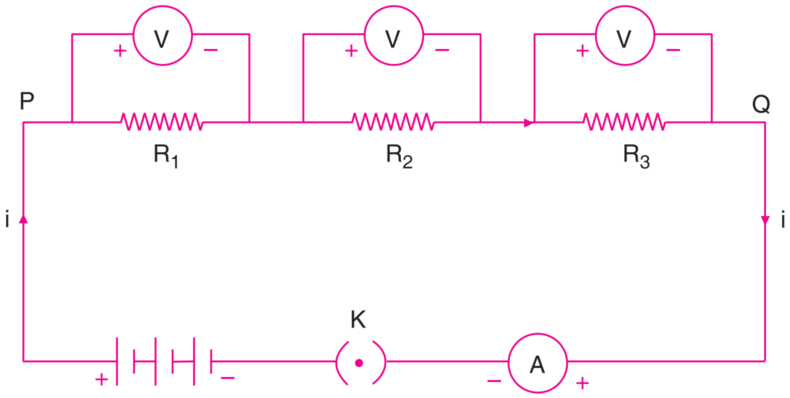


Fig. 16.7 *Resistors in series*

Let the potential difference between the ends of the resistors R_1, R_2 and R_3 are respectively V_1, V_2 and V_3

By ohm's law potential difference across each resistor

$$V_1 = iR_1$$

$$V_2 = iR_2$$

and $$V_3 = iR_3$$

Now if the potential difference between P and Q be V

then $$V = V_1 + V_2 + V_3$$

Substituting the values of the V_1, V_2 and V_3

$$= iR_1 + iR_2 + iR_3$$

$$= i(R_1 + R_2 + R_3) \qquad (16.1)$$

Let total or equivalent resistance between P and Q is R_s

Then total potential difference $V = iR_s$ (16.2)

Comparing equations (16.1) and (16.2), we get

$$iR_s = i(R_1 + R_2 + R_3)$$

or $$R_s = R_1 + R_2 + R_3$$

i.e. The equivalent resistance of three resistors connected in series is equal to the sum of their individual resistances.

16.4.2 Parallel Combination

Figure shows three resistors connected in parallel with a cell and an ammeter. The potential difference between points P and Q will be same across each resistor but the current flows from P to Q will be equal to the sum of the separate currents passing through each branch of a given resistance. If i_1, i_2 and i_3 respectively represent the current passing through the branches having the resistors R_1, R_2, and R_3 then the total current i in the main circuit will be

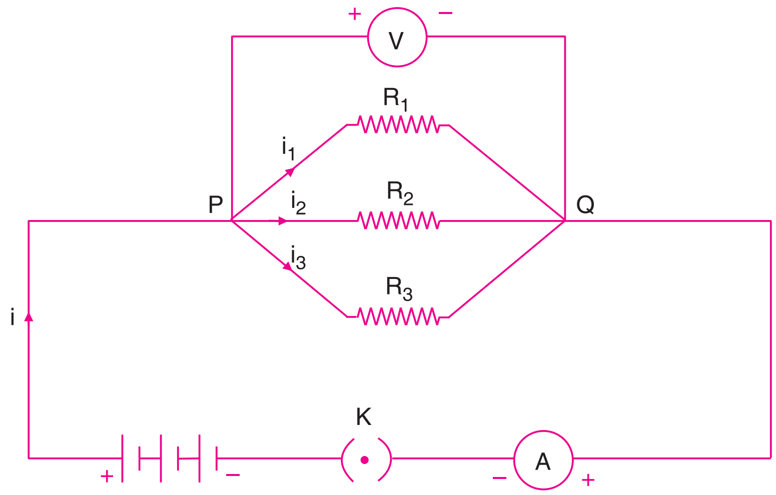


Fig. 16.8 *Resistors in parallel*

$$i = i_1 + i_2 + i_3 \tag{16.3}$$

if V is the potential difference across each of the resistors, then according to Ohm's law

$$i_1 = \frac{V}{R_1},\ i_2 = \frac{V}{R_2} \text{ and } i_3 = \frac{V}{R_3} \tag{16.4}$$

If R_P is the equivalent resistance of the resistors connected in parallel having the same potential difference V then

$$i = \frac{V}{R_p} \tag{16.5}$$

Using equations (16.4) and (16.5) the equation (16.3) will be

$$\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

i.e.

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

i.e. the sum of the reciprocals of the separate resistances is equal to the reciprocal of equivalent or total or resultant resistor R_p.

Remember:

1. Normally all the appliances in our household circuits are connected in parallel. But the chain of small bulbs that we use for decoration on Deepawali has the bulbs connected in series.

2. As we add resistances in series, the circuit resistance increases but when we connect resistances in parallel, the total resistance is smaller than the smallest of the resistances involved.

Do you know

Multimeter is basically an AVO meter i.e., Ammeter, Voltmeter and Ohm meter which is used for measurement of current, voltage and resistance.

Example 16.3: A current of 0.5 A is drawn by a filament of an electric bulb for 5th part of an hour. Find the amount of electric charge that flows through the circuit.

Solution: Given $i = 0.5A$ $\quad t = \frac{1}{5}$ of an hour $= \frac{1}{5} \times 60$ min = 12 min

$$Q = it = 12 \times 60 \text{ s} = 720 \text{ s}$$

$$= (0.5\text{A}) \times 720 \text{ s} = 720 \text{ s}$$

$$= 360 \text{ C}$$

Example 16.4: Find the equivalent resistance of the following combination of resistors.

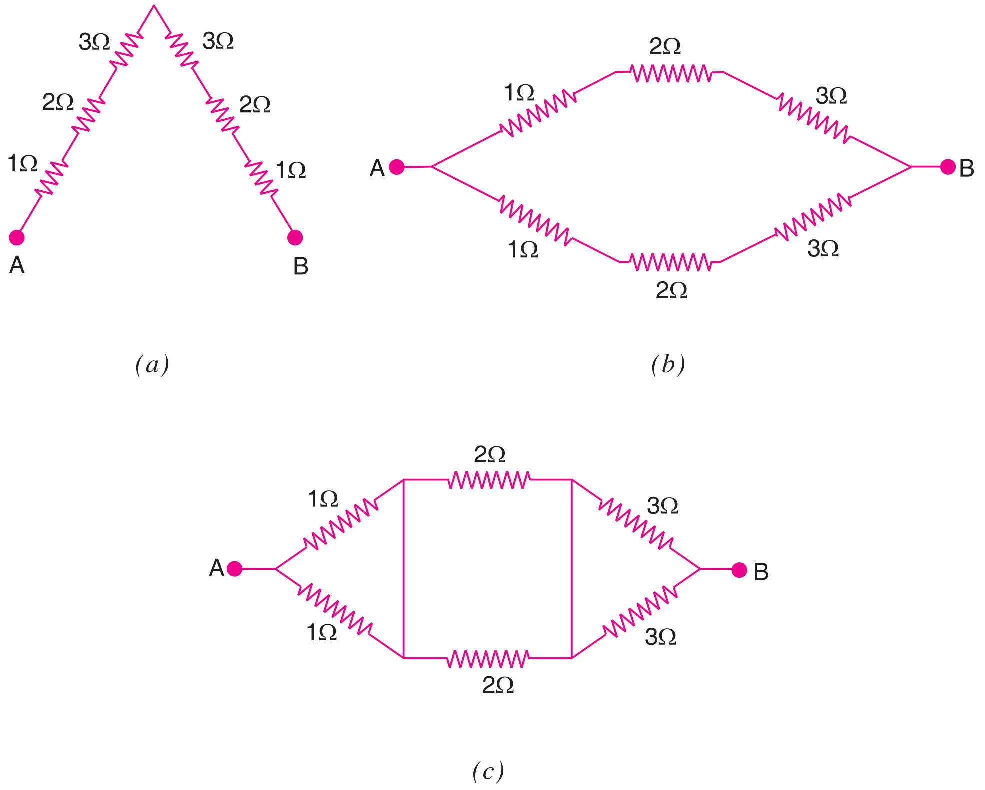


Fig. 16.9

Solution:

(a) Here all resistors are connected in series.

$$R = r_1 + r_2 + r_3 + r_4 + r_5 + r_6 = 1+2+3+3+2+1 = 12\ \Omega$$

(b) Here we have two series combinations of 3 resistors, each connected in parallel.

$$R_1 = 1+2+3 = 6\ \Omega$$

$$R_2 = 1+2+3 = 6\ \Omega$$

$$R = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{6\times 6}{6+6} = \frac{36}{12} = 3\ \Omega$$

(c) Here we have 3 parallel combinations of 2 resistors, each connected in series.

$$R = \frac{r_1 \times r_2}{r_1 + r_2} = \frac{1\times 1}{1+1} = \frac{1}{2}\Omega$$

$$R = \frac{2\times1}{2+2} = 1\Omega$$

$$R = \frac{3\times3}{3+3} = \frac{9}{6} = \frac{3}{2} = 1.5\Omega$$

$$R = R_1 + R_2 + R_3 = \frac{1}{2} + 1 + \frac{3}{2} = 3\Omega$$

INTEXT QUESTIONS 16.2

1. Define the SI units of (i) current (ii) resistance.
2. Name the instruments used to measure (i) current (ii) potential difference.
3. Why is a conductor different from an insulator?
4. How is a volt related to an ohm and an ampere?
5. A number of bulbs are connected in a circuit. Decide whether the bulbs are connected in series or in parallel, when (i) the whole circuit goes off when one bulb is fused (ii) only the bulb that get fused goes off.
6. When the potential difference across a wire is doubled, how will the following quantities be affected (i) resistance of the wire (ii) current flowing through the wire?
7. What is the reading of ammeter in the circuit given below?

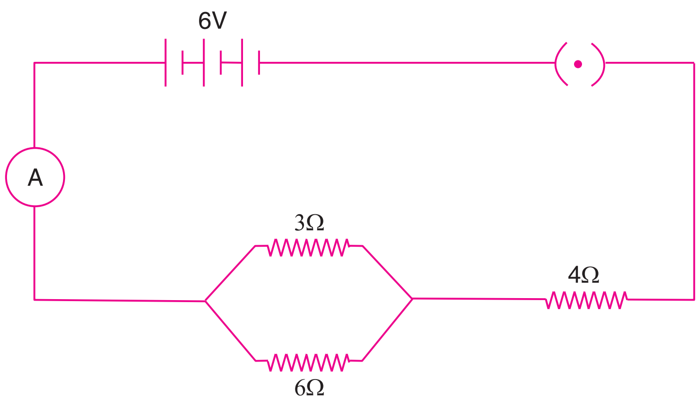


Fig. 16.10

8. How can three resistors of resistance 2Ω, 3Ω and 6Ω be connected to give a total resistance of (i) 11Ω (ii) 4.5Ω and (iii) 4Ω?
9. State two advantages of connecting electrical devices in parallel with the battery instead of connecting them in series.

16.5 HEATING EFFECT OF ELECTRIC CURRENT

It is a matter of common experience that on passing electric current through the filament of an electric bulb, it gets heated and glows brightly. Similarly on passing current through an electric heater, the coil of the heater becomes red hot. Do you know why? It is because in an electric circuit, electrical energy is converted into heat energy. This effect is known as thermal effect of electric current or Joules' heating.

16.5.1 Heat produced in a conductor on passing electric current

Consider a conductor XY of resistance R. Let current 'i' is passed for t seconds through the conductor on applying a potential difference V across the ends X and Y. If the charge Q is to be transferred from point X to Y, the work is done in moving the charge Q across the ends of the conductor. Work done in transferring the charge Q,

$$W = \text{potential difference } (V) \times \text{Charge } (Q)$$

$$= Vit \qquad (\because\ Q = it)$$

According to Ohm's law $V = iR$

$\therefore$ $$W = (iR)it$$

$$W = i^2Rt.$$

Here the work done in moving the electric charge across a resistance appears in the form of heat. Therefore, the heat produced in the conductor is $H = i^2Rt$.

Hence, the amount of heat produced in a conductor on passing the current i is directly proportional to the square of the current (i^2), the resistance of the conductor (R) and the time (t) for which the current flows through the conductor.

This is known as Joule's law of heating. SI unit of heat is joule (J) (4.18 J = 1 cal)

16.5.2 Electric power

The rate at which electric energy is consumed or dissipated is termed as electric power.

$$\text{Electric power } P = \frac{\text{Work done } (W)}{\text{Time taken } (t)} = \frac{Vit}{t} = Vi$$

$\therefore$ $$P = Vi$$

or $= (iR)i \qquad (\because V = iR)$

$= i^2R$

or $= \left(\frac{V}{R}\right)^2 R \qquad \left(\because i = \frac{V}{R}\right)$

$= \frac{V^2}{R}$

SI unit of electric power is joule/second or watt (W) .Thus, from $P = VI$, unit of power is watt i.e 1 watt (W) = 1 volt (V) × 1 ampere (A).

Hence, electric power consumed in a circuit or a device is 1 W if a current of 1A flows through it when a potential difference of one volt is maintained across it.

Since watt is a very small unit of power the bigger units kilowatt (kW) megawatt (MW) are actually used in practice.

1 kilowatt (kW) = 1000 W

1 megawatt (MW) = 10^6 W

1 gigawatt (GW) = 10^9 W

For electric power another bigger unit horse power (hp) is also used.

1 (hp) = 746 W

Since electrical energy consumed by an electrical appliance is equal to the product of power and the time for which it is used. The SI unit for the consumption of electric energy is joule but it is very small from practical point of view. Therefore, the electrical energy spent in the electric circuit is generally expressed in watt hour and kilowatt hour.

1 watt hour is the amount of electric energy which is consumed in 1 hour in an electric circuit when the electric power in the circuit is 1 watt.

1 kilowatt hour is the amount of electric energy consumed when 1 kilowatt power is used for 1 hour in an electric circuit.

1 kilowatt hour (kW h) = 1 kilowatt × 1 hour

= 1000 watt × 3600 second

= 1000 joule/second × 3600 second

= 36×10^5 joule

1 kW h = 3.6×10^6 J

To calculate the cost of electrical energy, special unit kilowatt hour (kW h) is used which is also known as Board of Trade (BOT) unit or simply a unit of electricity. Therefore, the commercial unit of electric energy is kilowatt hour (kW h).

16.5.3 Electrical appliances based on thermal effect of electric current

There is a long list of household appliances based on thermal effect of electric current e.g electric iron, electric kettle, electric immersion rod/heater, electric geyser, cooking range, electric oven, electric toaster, electric stove, room heater, etc.

Beside appliances heating effect of electric current is also used in electric fuse, electric welding and electric arc. In all these appliances potential difference is applied across a conductor, the free electrons inside the conductor get accelerated and during the course of their motion electrons collide with other electrons and atoms/ions of the material of the conductor on their way and transfer their energy to them. The electrons move with constant drift velocity and do not gain kinetic energy. But due to collision with free electrons, the atoms/ions begin to vibrate with increased amplitude .In other words, the average kinetic energy of vibrations of the atoms of conductor increases which results in increase in temperature of the conductor i.e., the heat is produced in the conductor. Thus on applying potential difference, loss in potential energy of the electrons appears in the form of increase of average kinetic energy of the atoms of the conductor which finally appears as heat energy in the conductor

Electric Tester

It is used to indicate presence of electricity (a.c or d.c) in a circuit. It is like a screw driver. This screwdriver has a handle, which can hold easily. It has a neon indicator bulb. The screw end of the tester is just touched with the chassis of the appliance like electric iron and a finger is kept on the clip of the tester to provide earth. If the neon bulb glows up with reddish light it shows that current is passing through the chassis and it would give a shock, therefore, it is essential to switch off the mains immediately. If the light does not glow, it indicates that there is no leakage of current.

If you put a tester in an electric socket and if the neon bulb does not glow , it indicates that there is no power in the electric socket. It is a must tool for electrical automotive, electronic, appliance repairers.

ACTIVITY 16.4

You can do this simple activity with your friends to study thermal effect of electric current. Take two pieces of the element of electric heater (one of which has 10 turns and the other has 20 turns), two dry cells, connecting wires.

(i) Attach connecting wires to the free ends of the 10-turn coil permanently.

(ii) Touch the free ends of the connecting wires to the two terminals of a dry cell, thus passing current through it. Detach the contacts after 10 seconds. Now touch the coil and feel it.

(iii) Repeat the experiment by passing current for 20 seconds.

(iv) Place two dry cells in contact, making series battery and repeat the second step.

(v) Repeat steps 2, 3, 4 with 20-turn heater coil and feel it.

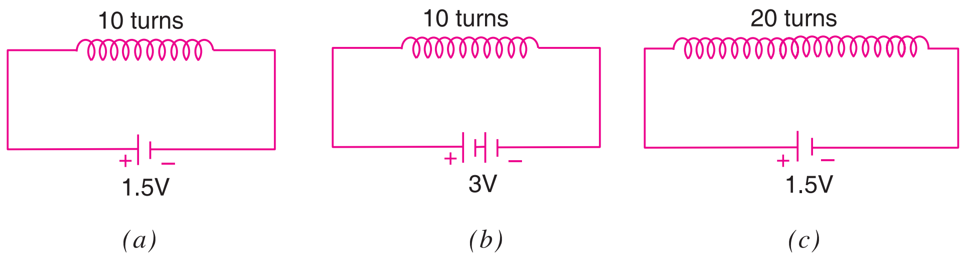


Fig. 16.11 *Study of thermal effect of electric current*

Discuss the observations with your friend, you will observe that on passing current through a conductor it gets heated up. The coil is found to be heated when current is passed for a second. The coil is found to be hotter when greater voltage is applied across it. When same voltage is applied across bigger coil less heat is produced in it. Thus, we conclude that

(i) Current has a heating effect, i.e. when current is passed through a conductor it gets heated up.

(ii) More heat is produced in a conductor

when more potential difference is applied across it.

current is passed through it for more time (t).

more current is passed through the same conductor.

INTEXT QUESTIONS 16.3

1. Which will produce more heat in 1 second – 1 ohm resistance on 10V or a 10 ohm resistance on the same voltage? Give reason for your answer.

2. How will the heat produced in a conductor change in each of the following cases?
   (i) The current flowing through the conductor is doubled.
   (ii) Voltage across the conductor is doubled.
   (iii) Time for which current passed is doubled.
3. 1 A current flows though a conductor of resistance 10 ohms for 1/2 minute. How much heat is produced in the conductor?
4. Two electric bulbs of 40 W and 60 W are given. Which one of the bulbs will glow brighter if they are connected to the mains in (i) series and (ii) parallel?
5. How is 1 kW h related with SI unit of energy?
6. Name two household electric devices based on thermal effect of electric current.

Do you know

There are three types of large scale electric power generating plants

(i) Hydroelectric power plants – when potential energy of water stored in a dam is used for generating electricity. e.g. Bhakra- Nangal hydroelectric power plant, Punjab.

(ii) Thermal power plant – where a fossil fuel is burnt to produce steam which runs a turbine to convert mechanical energy into electrical energy. e.g. Namrup thermal power station, Assam.

(iii) Atomic power plant – where nuclear energy is obtained from a fissionable material like uranium is used to run a turbine. e.g. Narora atomic power station, Uttar Pradesh.

In India all the major plants produce A.C. (alternating current) at 50 hertz, 11000 volts or more. This power can be further stepped up to higher voltages using transformers and hence can be transmitted to long distances without much loss of power.

1. Alternating current (AC) means the electric current is alternating directions in a repetitive pattern.
2. AC is created by generators in power plants, and other sources. This AC current is delivered to our homes and businesses by the power lines we see everywhere.

Example 16.5: Find the resistance of the filament of 100 W, 250 V electric bulb.

Solution:
$$R = \frac{V^2}{P}$$
$$= \frac{250 \times 250}{100} = 625\Omega$$

Example 16.6: Calculate the energy consumed in a 2 kW electric heater in 2 hours. Express the result in joules.

Solution:
$$Q = Pt = 2 \text{ kW} \times 2 \text{ h} = 4 \text{ kW h}$$
$$= 4 \times 3.6 \times 10^6 \text{J} = 14.4 \times 10^6 \text{ J}$$

Example 16.7: How much time will take a 2 kW immersion rod to raise the temperature of 1 litre of water from 30°C to 60°C

Solution:
$$Q = Pt$$
$$Q = mc\theta$$
$$mc\theta = Pt \qquad (1)$$

Mass of 1 litre of water (m) = 1 kg

Specific heat of water $c = 4.18 \times 10^3$ J kg^{-1} °C^{-1}

Rise in temperature of water (θ) = 60 – 30 = 30°C.

$$P = 2 \text{ kW} = 2000\text{W}$$

Substituting in equation (1) we get

$$1 \times 4.18 \times 10^3 \times 30 = 2000 \times \text{t}$$

$$t = \frac{125.4 \times 10^3}{2 \times 10^3} = 62.7\,\text{s}$$

Example 16.8: How many kilowatt hour of energy will be consumed by a 2 hp motor in 10 hours?

Solution:
$$P = 2 \text{ hp} = 2 \times 746 \text{ W}$$
$$= 1.492 \text{ kW}$$
$$Q = Pt = 1.492 \text{ kW} \times 10 \text{ h} = 14.92 \text{ kW h}$$

Notes

Example 16.9: A potential difference of 250V is applied across a resistance of 1000 ohm. Calculate the heat energy produced in the resistance in 10 s.

Solution: Given $V = 250$ V $R = 1000$ W $t = 10$ s

$$Q = \frac{V^2 t}{R} = \frac{250 \times 250 \times 10}{1000} = 625 \text{ J}$$

Example 16.10: Compute the heat generated while transferring 96 kC of charge in one hour through a potential difference of 50V.

Solution: Given: $V = 50\text{V}$ $t = 1$ h $q = 96000$ C

$$W = qV$$
$$= 96000 \text{ C} \times 50 \text{ V}$$
$$W = 4800000 \text{ J}$$
$$= 4.8 \times 10^6 \text{ J}$$
$$= 4.8 \text{ MJ.}$$

Example 16.11: An electric iron of resistance 25 Ω takes a current of 5A. Calculate the heat developed in 1 minute.

Solution: Given: $R = 25\ \Omega$ $i = 5\text{A}$ $t = 1$ min (= 60 s)

Heat developed $H = i^2 Rt$

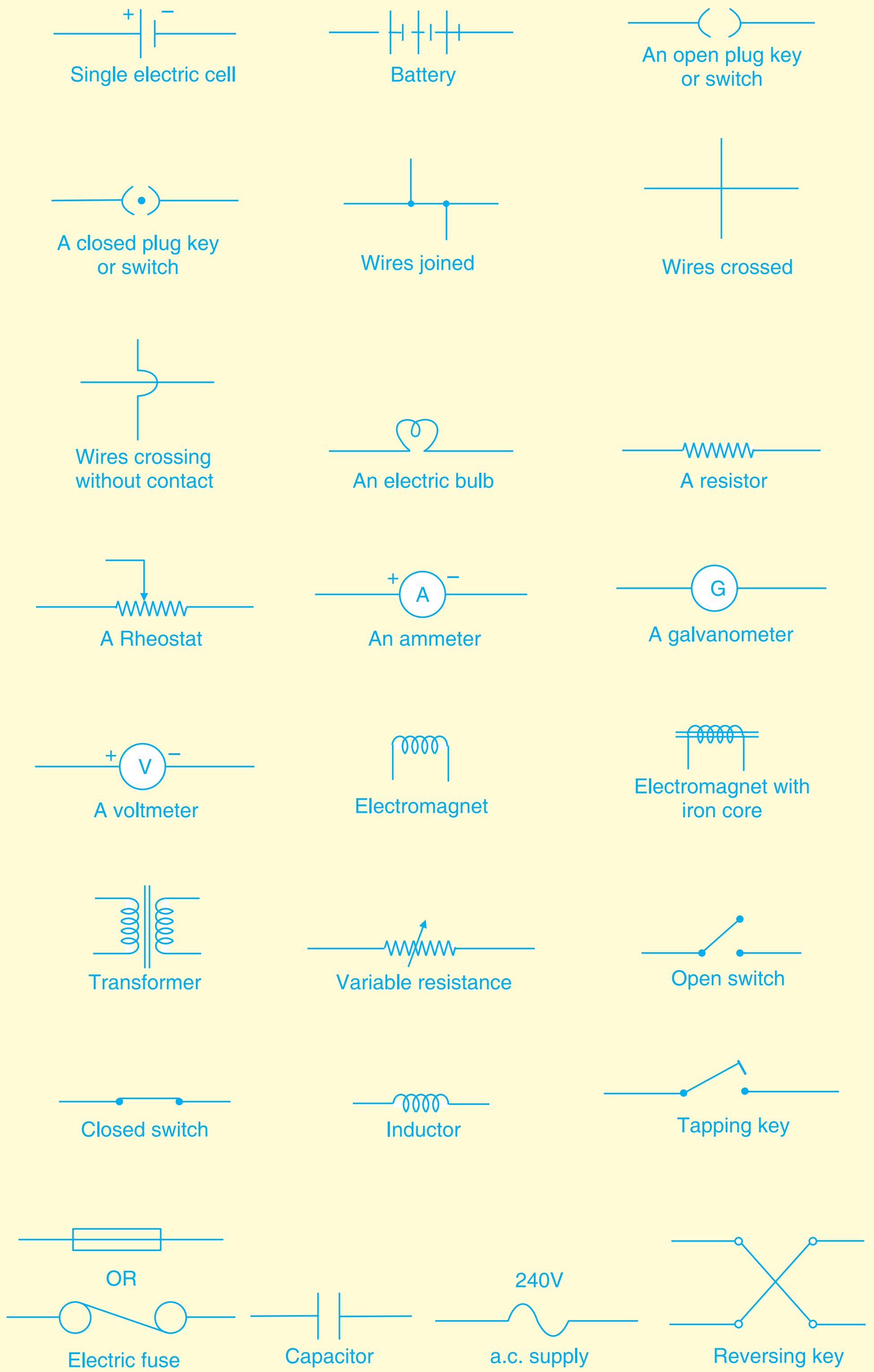
$$= (5\ A)^2 \times 25\ \Omega \times 60 \text{ s}$$
$$= 37500 \text{ J} = 3.75 \times 10^4 \text{ J}$$

INTEXT QUESTIONS 16.4

1. Which has a higher resistance, a 40W-220 V bulb, or a 1 kW-220V electric heater?
2. What is the maximum current that a 100W, 220 V lamp can withstand?
3. How many units of electricity will be consumed by a 60 W lamp in 30 days if the bulb is lighted 4 hours daily?
4. How many joules of electrical energy will a quarter horse power motor consume in one hour?
5. An electric heater is used on 220 V supply and draws a current of 5 A. What is its electric power?
6. Which uses more energy, a television of 250 W in 60 minutes or a toaster of 1.2 kW in $(1/6)^{th}$ of an hour?

Do you know

Symbols used in Electric Circuit Diagram



WHAT YOU HAVE LEARNT

- The force of attraction between the electrons and the protons hold an atom together.
- When two bodies are rubbed together in contact, they acquire a peculiar property of attracting small bits of paper. We say the bodies are electrified or charged by friction.
- Charges are of two types. Charge acquired by a glass rod rubbed with silk is positive and that acquired by an ebonite rod rubbed with fur is negative.
- Like charges repel each other and unlike charges attract each other.
- The force between two charges is given by Coulomb's law according to which $F = \frac{kq_1q_2}{r^2}$. The closer together the charges are, the stronger is the electrostatic force between them.
- Potential is the electrical state of a conductor which determines the direction of flow of charge when the two conductors are either placed in contact or they are connected by a metallic wire.
- Work is done in moving a charge against electric field which is stored up as potential energy of the charge. Hence, when charge is placed at a point in the field it possesses potential energy.
- Potential energy per coulomb of charge at a point is called potential. Positive charge always moves from a higher potential to a lower potential and vice-versa.
- The potential at a point is the amount of work done in bringing a unit positive charge from infinity to that point.
- The potential difference between two points is the amount of work done in moving a unit positive charge from one point to the other.
- Electric current at a place is the charge passing per unit time through that place.
- Electric cell is a device with the help of which we can apply a potential difference between the two ends of a wire due to which current will flow through the wire.
- Circuit diagrams are used to show how all the components connect together to make a circuit.
- Ohm's law states that current flowing through a conductor is directly proportional to the potential difference applied across its ends, provided physical conditions temperature etc.of the conductor remain the same.
- The obstruction offered to the flow of current by the wire is called its resistance. Mathematically ratio of voltage applied across a conductor and the current

flowing through it is called resistance of the conductor. SI unit of resistance is ohm.

- Resistors may be connected in two different independent ways

  (i) In series and (ii) in parallel.

- In series, total resistance of the combination is equal to the sum of the individual resistances.
- In parallel, reciprocal of the combined resistance is equal to the sum of the reciprocals of the individual resistances.
- When current is passed through a conductor, it produces two effects.

  (i) Thermal effect (ii) Magnetic effect.

- Commercial unit of electrical energy is kW h and that of electric power is HP.

For more information:

1. Multimedia CD on Innovative physics experiments developed by Vigyan Prasar, Department of Science & Technology,Govt of India. ***www.vigyanprasar.gov.in***
2. Multimedia CD on Fun with Physics developed by Vigyan Prasar, Department of Science & Technology,Govt of India. ***www.vigyanprasar.gov.in***
3. Flying circus of Physics by Jearl Walker, John Wiley and sons Publication.

TERMINAL EXERCISE

1. Tick mark the most appropriate answer out of four given options at the end of each of the following statements:

   (a) A charged conductor '*A*' having charge Q is touched to an identical uncharged conductor '*B*' and removed. Charge left on A after separation will be:

   (i) Q (ii) $Q/2$ (iii) Zero (iv) $2Q$

   (b) J C^{-1} is the unit of

   (i) Current (ii) Charge (iii) Resistance (iv) Potential

   (c) Which of the following materials is an electrical insulator?

   (i) Mica (ii) Copper (iii) Tungsten (iv) Iron

   (d) The device which converts chemical energy into electrical energy is called

   (i) Electric fan (ii) Electric generator
   (iii) Electric cell (iv) Electric heater

(e) The resistance of a conductor does not depend on its

(i) Temperature (ii) Length (iii) Thickness (iv) Shape

(f) There are four resistors of 12 Ω each. Which of the following values is possible by their combination (series and/or parallel)?

(i) 9 Ω (ii) 16 Ω (iii) 12 Ω (iv) 30 Ω

(g) In case of the circuit shown below in Fig. 16.12, which of the following statements is/are true:

(i) R_1, R_2, and R_3 are in series

(ii) R_2 and R_3 are in series

(iii) R_2 and R_3 are in parallel

(iv) The equivalent resistance of the circuit is $[R_1 + (R_2 R_3/R_2 + R_3)]$

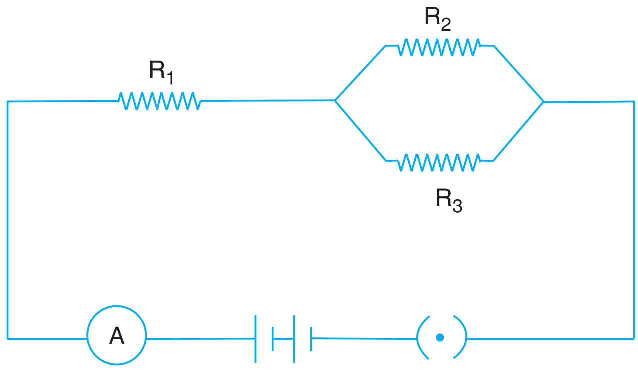


Fig. 16.12

(h) The equivalent resistance of two resistors of equal resistances connected in parallel is —— the value of each resistor.

(i) Half (ii) Twice (iii) Same (iv) One fourth

2. Fill in the blanks.

(a) When current is passed through a conductor, its temperature ....

(b) The amount of .... flowing past a point per unit .... is defined as electric current.

(c) A current carrying conductor carries an .... field around it.

(d) One ampere equals one .... per ....

(e) Unit of electric power is ....

(f) Of the two wires made of the same material and having same thickness, the longer one has .... resistance.

3. How many types of electric charge exist?

4. In a nucleus there are several protons, all of which have positive charge. Why does the electrostatic repulsion fail to push the nucleus apart?

5. What does it mean to say that charge is conserved?
6. A point charge of +3.0 μC is 10 cm apart from a second point charge of –1.5 μC. Find the magnitude and direction of force on each charge.
7. Name the quantity measured by the unit (a) VC (b) Cs^{-1}
8. Give a one word name for the unit (a) JC^{-1} (b) Cs^{-1}
9. What is the potential difference between the terminals of a battery if 250 J of work is required to transfer 20 C of charge from one terminal of the battery to the other?
10. Give the symbols of (a) cell (b) battery (c) resistor (d) voltmeter.
11. What is the conventional direction of flow of electric current? Do the charge carriers in the conductor flow in the same direction? Explain.
12. Out of ammeter and voltmeter which is connected in series and which is connected in parallel in an electric circuit?
13. You are given two resistors of 3 Ω and 6 Ω, respectively. Combining these two resistors what other resistances can you obtain?
14. What is the current in SI unit if+100 coulombs of charge flows past a point every five seconds?
15. Deduce an expression for the electrical energy spent in flow of current through a conductor.
16. Find the value of resistor X as shown in Fig. 16.13.

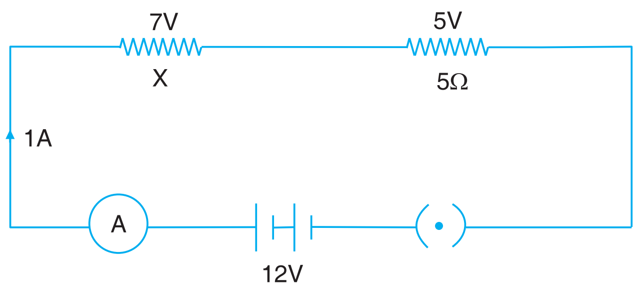


Fig. 16.13

17. In the circuit shown in Fig. 16.14, find (i) Total resistance of the circuit. (ii) Ammeter reading and (iii) Current flowing through 3 Ω resistor.

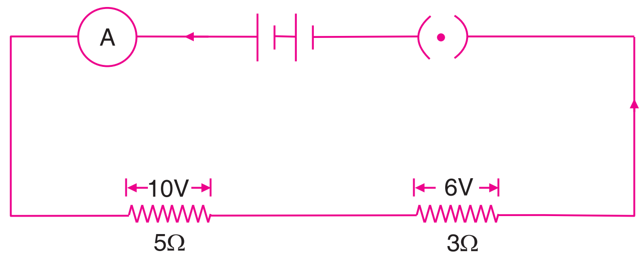


Fig. 16.14

18. For the circuit shown in Fig. 16.15, find the value of:
    (i) Current through 12Ω resistor.
    (ii) Potential difference across 6Ω and 18Ω resistor.

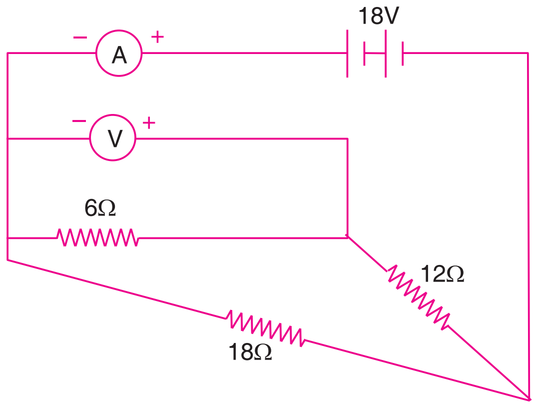


Fig. 16.15

19. You are given three resistors of 1 Ω, 2 Ω and 3 Ω. Show by diagrams, how will you connect these resistors to get (a) 6/11 Ω (b) 6 Ω (c) 1.5 Ω?
20. A resistor of 8 Ω is connected in parallel with another resistor of *X* Ω. The resultant resistance of the combination is 4.8 ohm. What is the value of resistor *X*?
21. In the circuit Fig. 16.16, find
    (i) Total resistance of the circuit.
    (ii) Total current flowing through the circuit.
    (iii) The potential difference across 4 Ω resistor.

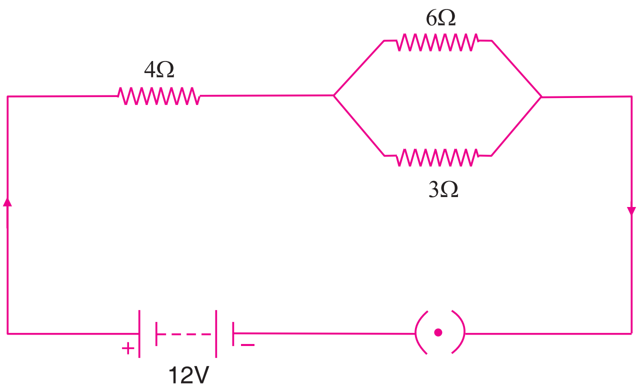


Fig. 16.16

22. How many 132 Ω resistors should be connected in parallel to carry 5 A current in 220 V line?

ANSWERS TO INTEXT QUESTIONS

16.1

1. (i) Unit of charge is Coulomb. 1C charge is the charge which when placed at a distance of 1 m from an equal like charge repels it with a of force of 9×10^9 N.

   (ii) Unit of potential is volt. 1 volt is the potential at a point in an electric field such that if 1C positive charge is brought from outside the field to this point against the field 1 J work is done.

2. $N = \dfrac{Q}{|e|} = \dfrac{10 \times 10^{-6}}{1.6 \times 10^{-19}} = 6.25 \times 10^{13}$ electrons

3. $F = k\dfrac{q_1 q_2}{r^2} \Rightarrow F = k\dfrac{2q_1 \times 2q_2}{(r/2)^2} = 8\text{F}$

4. $F' = 1/4$ F

5. (i) $V = \dfrac{U}{q} = \dfrac{10}{10^{-6}} = 10^7$ V

   (ii) $U = \dfrac{KQq}{r} \quad Q \quad \dfrac{Ur}{Kq} \quad \dfrac{10 \times 0.5}{9 \times 10^9 \times 10^{-6}} \quad \dfrac{5}{9} \quad 10^{-3}\text{C}$

6. Electrons will flow from sphere B to sphere A through the wire till the potentials of the two spheres become equal.

16.2

1. (i) Unit of current is ampere. 1A is the current in a wire in which 1C charge flows in 1 second.

   (ii) Unit of resistance is ohm. 1 ohm is the resistance of a wire across which when 1V potential difference is applied, 1A current flows through it.

2. (i) ammeter (ii) voltmeter

3. A conductor has free electrons, whereas an insulator has no free electrons.

4. 1 volt = 1 ohm × 1 ampere

5. (i) If the whole circuit goes off when one bulb is fused, the bulbs are connected in series.

   (ii) If any one bulb goes off and the rest of the circuit remains working, the bulbs are connected in parallel.

6. (i) Resistance of the wire remains unaffected.

   (ii) Current flowing through the wire is doubled.

7. 1A

8. (i) All the three resistors are connected in series.

   (ii) Resistors 2Ω and 6Ω are connected in parallel and 3Ω is connected in series to the combination of 2Ω and 6Ω.

   (iii) Resistors 3Ω and 6Ω are connected in parallel and 2Ω is connected in series to the combination of 3Ω and 6Ω.

9. In a parallel circuit, every electrical gadget operates separately because they take current as per their requirement.

   Total resistance of the circuit is decreased.

   If one component fails, the circuit is not broken and other electrical devices work properly.

16.3

1. $Q/t = V^2/R$. This implies that more the resistance less the power. Therefore, more heat will flow in 1s in 1 ohm resistor.

2. (i) Heat produced becomes four times (ii) heat produced becomes four times(iii) heat produced will be doubled.

3. $Q = i^2Rt = 1 \times 10 \times 30 = 300$ J.

4. $P = V^2/R$ and energy consumed in series $= i^2Rt$ and in parallel $= (V^2/R)t$

   (i) The bulb with lowest wattage (highest resistance) glows with maximum brightness.

   (ii) The bulb with highest wattage (lowest resistance) glows with maximum brightness.

5. $1 \text{ kW h} = 3.6 \times 10^6$ J

6. (i) Electric heater (ii) Electric kettle

16.4

1. $R = \dfrac{V^2}{P}$, 40W lamp has higher resistance.

2. $I = \dfrac{P}{V} = \dfrac{100 \text{ W}}{220 \text{ V}} = \dfrac{5}{11} \text{A}.$

3. $Q = Pt = 60\text{W} \times 4\text{h} \times 30 = 7200 \text{ W h} = 7.2 \text{ kW h}$

4. $Q = Pt = \dfrac{746}{4} \text{W} \times 3600\text{s} = 671400 \text{J}.$

5. $P = VI = 220 \text{ V} \times 5\text{A} = 1100 \text{ W}$

6. Energy used by television = 0.25 kW × 1 h = 0.25 kW h

   Energy used by toaster = 1.2 kW × 1/6 h = 0.2 kW h

212en17

17

MAGNETIC EFFECT OF ELECTRIC CURRENT

In the earlier lesson you have learnt that, electricity is an important part in today's world of industrialization. Our life is incomplete without it. Whether we work in an office or at home, every thing depends upon the availability of electricity. Appliances like the electric bulb, fan, television, refrigerator, washing machine, motor, radio, everything works due to electricity.

When electric current passes through current carrying conductor or coil then a magnetic field is produced around it. The working of appliances like electric bell is based on this principle. As opposite to this if a continuous change in magnetic field is produced then electric current can be produced. This is how electricity and magnetism have become synonymous today. Transmission of electric current takes place from the distant electricity generation stations through high tension wires, through transformers to homes. This chapter deals with the meaning of safe use of electricity. Along with this the same concepts related to magnetism are explained through simple activities that one can perform on their own.

OBJECTIVES

After studying this lesson you will be able to:

- *identify magnets and explain their properties;*
- *explain the concept of magnetic field and state the properties of lines of magnetic force;*
- *infer that when electricity flows through a conductor, magnetic field is produced around it;*
- *describe electro-magnets and explain the working of electric bells;*
- *explain the force experienced by a current carrying conductor placed in a magnetic field;*

- *describe electromagnetic induction and its importance in different aspects of daily life;*
- *describe alternate current (AC) and direct current (DC) currents and list the appliances that work on these currents;*
- *state the hazards involved in using electrical energy in industries and at home and describe safety measures necessary to minimize them.*

17.1 MAGNET AND ITS PROPERTIES

Magnet has always been a thing of awe use and attraction for humans. According to history, the use of magnets were discovered by the ancient Greeks during the period of Greek Civilization.

Fig. 17.1 *Natural magnet*

They found stones which were able to attract iron and nickel like other substances. This naturally occurring stones (see Fig. 17.1) which was discovered then is called as 'lodestone'. This is an oxide of iron (Fe_3O_4). The property of attraction of small particles of iron towards lodestone is called as 'magnetism'. It has been often seen that the magnetic force of attraction of these natural magnets is much less and thus, these magnets cannot be use for practical purposes. Strong magnets made of iron, nickel and lead are made artificially and used for practical purposes. Those magnets are also called as permannent magnet. So, a magnet is a material or object that produces a magnetic field which is responsible for a force that pulls or attacts on other materials.

These strong magnets can be made in various shapes and creats its own persistent magnetic field. The magnets that are commonly available in different shapes are:

(a) Bar magnet
(b) Horseshoe magnet
(c) Cylindrical magnet
(d) Circular magnet
(e) Rectangular magnet

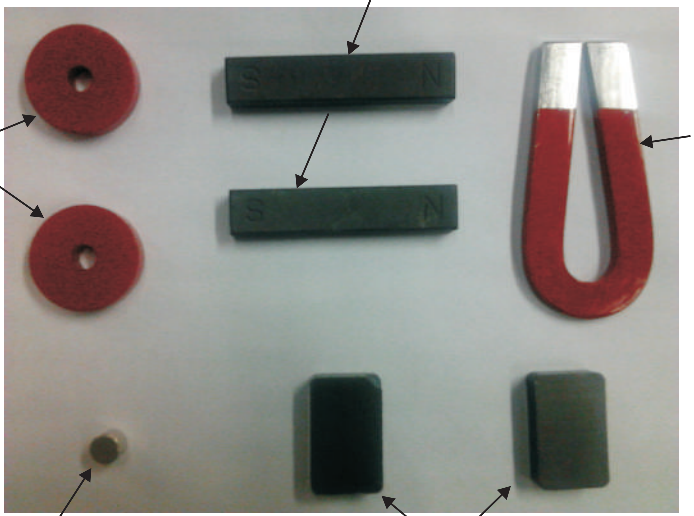
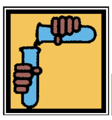


Fig. 17.2 *Magnets of different shapes*

Have you ever observe magnets of any of above shapes arround you? These magnets of different shapes are used in various appliances used at home like tape recorder, radio, motor, door-bell, head phones etc. These magnets are used in various appliances to either hold or separate, control, elevate (lift) substances, changing electrical energy to mechanical energy (motors, loudspeakers) or mechanical to electrical energy (generators and microphones).

If a natural magnet is suspended freely with the help of a string, it always rests in the 'north-south' direction. If the magnet is slightly turned from this direction, it still returns to the same. The end that rests towards the 'north' is named as 'North Pole' while the one which ends at 'south' is named as South Pole. They are represented as 'N' and 'S'.



ACTIVITY 17.1

Take one magnetic needle, two bar magnets, some iron filling, an alpin and do the experimental study of properties of magnet.

Following step may followed:

1. Tie a string at the middle of a bar magnet and hang it with the help of a hook. This bar always rests at the same direction. With the help of the magnetic needle,

find out the direction. By this you will be able to prove that a bar magnet always rests in the north-south direction.

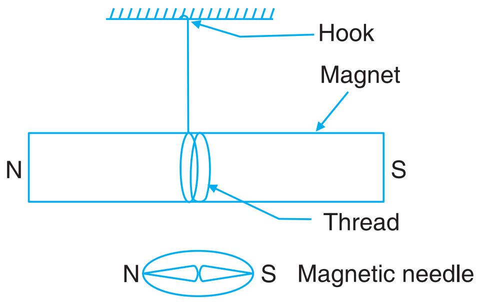


Fig. 17.3 (i)

2. Take iron fillings near the bar magnet. They stick to the magnet. Thus, magnet attracts iron. You would observe that the amount of iron fillings near the poles is maximum while at the middle is negligible.

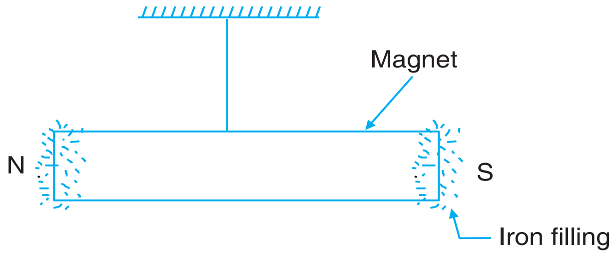


Fig. 17.3 (ii)

3. If you bring any pole of a bar magnet near the pole of a freely suspended bar magnet, then either it will attract or repel the same. Opposite poles of a magnet attract each other while like poles (north-north or south-south) repel each other.

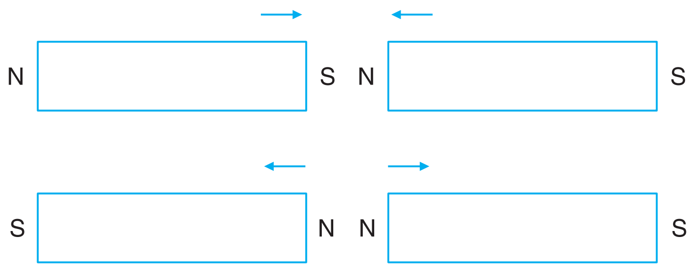


Fig. 17.3 (iii)

4. Take an iron alpin near a bar magnet leave it there for sometime. You will find that the alpin has acquired magnetic properties and iron fillings start sticking to the ends of the alpin as well.

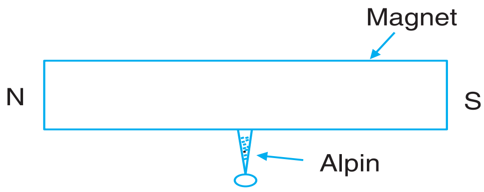


Fig. 17.3 (iv)

5. Break the bar magnet into smaller pieces. Now observe that magnetic properties are retained in the pieces as well. Thus, the two poles of a magnet cannot be separated.

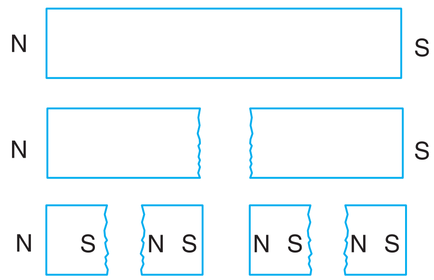


Fig. 17.3 (v)

17.1.1 Properties of Magnets

Through the activity 17.1 we can list the properties of magnetic as follows:

1. Attracts iron towards itself.
2. Freely suspended magnet always rests at the north-south direction.
3. Like poles repel while unlike poles attract.
4. If iron pieces are brought near a strong magnet they also start behaving as magnets.
5. The poles of a magnet cannot be separated.

17.2 MAGNETIC FIELD

Keep a small magnetic needle near a bar magnet. The magnetic needle rotates and stops in a particular direction only. This shows that a force acts on the magnetic needle that makes it rotate and rest in a particular direction only. This force is called torque.

The region around the magnet where the force on the magnetic needle occurs and the needle stops at a specific direction, is called a **magnetic field**. The direction of magnetic field is represented by magnetic line of forces. As shown in Fig. 17.4(i), the direction of magnetic needle changes continuously and it takes the curved path while moving from north to south. This curved path is known as magnetic line of forces. Tangent line draw at any point on magnetic line of force, represent the direction of magnetic field at that point. These magnetic line of forces have following properties:

1. Magnetic line of forces always start from north pole and end at south pole of the magnet.
2. These line of forces never intersect each other.
3. Near the poles magnetic lines are very near to each other which shows that magnetic field at the poles is stronger as compare to other parts.

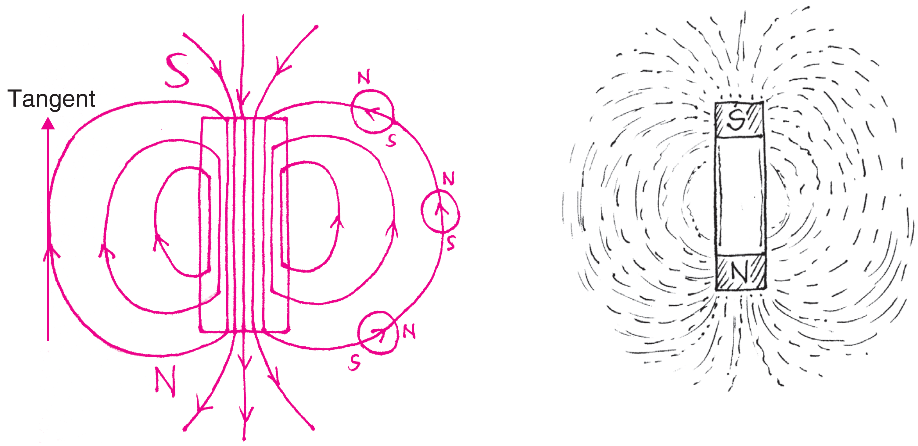


Fig. 17.4 (i)

Our Earth itslef acts as a giant magnet with south magnetic pole somewhere in the Arctic and north magnetic pole in Antaractic. The Earth also behaves like a bar magnet. It's hot liquid centre core contains iron and as it moves, it creates an electric current that cause a magnetic field around the Earth. The Earth has a north and south magnetic pole. These poles are not same with the geographic north and south poles on a map and tilted at an angle of 11.3 degree with repect to it. Due to this, if a magnetic needle is suspended freely, it rests in the north-south direction and is useful for navigation.

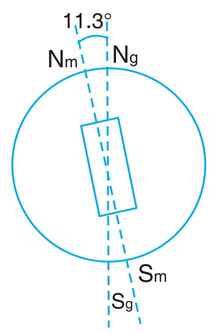


Fig. 17.4 (ii)

ACTIVITY 17.2

You can also detect the presence of magnetic field. For doing this take two bar magnets, one scale and follow the given steps:

1. Keep two bar magnets in such a way that they are laid on the same line and in same plane at a distance of 10 cm.
2. Bring the like poles slowly towards each other. Could you feel something?
3. You will feel two poles are repelling each other.
4. Change the orientation of one of the bar magnets so that opposite poles face each other. You would observe that the two magnets quickly come close together due to force of attraction between them.

With this we can conclude that force acts between the magnets and the region around the magnets in which this force may be experienced is called the 'magnetic field'.

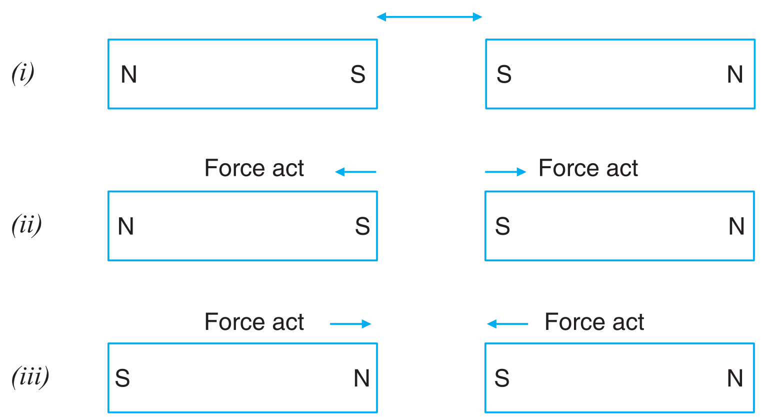


Fig. 17.5

INTEXT QUESITONS 17.1

1. Define magnet and list its properties?
2. What happen, with the properties of magnet when it is broken into two pieces?
3. Name the part of telephone where magnet is used?
4. Hang the bar magnet with the string, it will always rest in which directions

   (i) East-west (ii) West-south

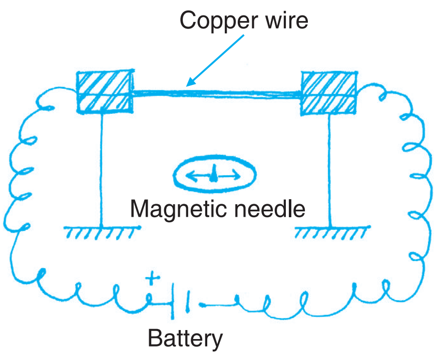
   (iii) North-south (iv) North-east
5. Do magnetic field exist throughout space?
6. The north pole, magnetic needle points towards earth's

   (i) North pole (ii) South pole

   (iii) Centre (iv) None of the above
7. What are magnetic poles?

17.3 MAGNETIC FIELD AROUND THE CURRENT CARRYING WIRE

If an electric current is made to flow in a wire, magnetic field produce arround it. For seeing this take a conducting wire (like copper). Now with the help of connecting wires attach this to the two ends of a battery. Keep a magnetic needle parallel to the conducting copper wire as shown in Fig. 17.6(a). When the circuit is complete the magnetic needle shows deflection. This shows that when electric current flows through a conductor, magnetic field is produced around the conductor. If the current is increased, there is greater amount of deflection. If the direction of flow of electric current is changed (by reversing the end of the battery) the direction of deflection in the magnetic needle is also reversed. If the current flow is stopped the deflection in the magnetic needle also ceases. Thus magnetic field is an effect of flow of electric current through conducting wire. In the year 1820 a scientist from Denmark named H.C. Oersted observed this effect for the first time.



(*a*)

H.C. Oersted (1770-1851)

(*b*)

Fig. 17.6

The principle of the magnetic effect of electric current used in many appliances like motor etc.

17.4 ELECTROMAGNET

An electromagnet is a type of magnet in which magnetic field is produced by the flow of elctric current. For making electromagnet take a piece of paper and give a cylindrical shape.

Make several turns of a copper wire over this from one end to the other. This is called solenoid a long thin loop of wire. When the ends of the copper wires are attached to the ends of a battery (+ and –) current starts flowing through the coil which starts functioning as a bar magnet.

When the flow of current is stopped from the battery, then, its magnetic property ceases. If the +ve and –ve terminals of the battery are reversed, then the poles of the magnet are also reversed.

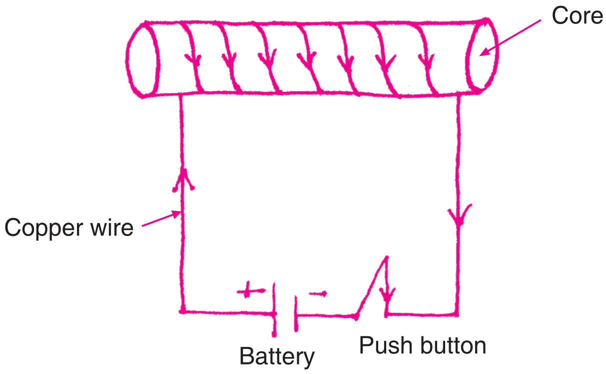


Fig. 17.7 *Solenoid*

For increasing the magnetic field, put soft iron like iron nails inside the core. So Current carry solenoid with soft iron core inside it forms an electromagnet. Electromagnet may be made as strong as one may desire. Electromagnet are widely used as a components in electrical devices such as motor, generator, electrical bells MRI machine etc. Beside that strong electromagnet are also being used in break system of the superfast train in the world, in the cyclotrons and in mega experiments like experiment at CERN laboratory at Geneva. The comparison of a bar magnet and an electromagnet has been illustrated in the table given below.

17.4.1 Difference between a Bar Magnet and an Electromagnet

Bar magnet	Electromagnet
This is a permanent magnet. Its magnetic field remains constant.	This is a temporary magnet. Its magnetism remains till current flows through it.
Its magnetic strength cannot be reduced or increased.	Its magnetic strength may be changed at will by changing the amount of current flow.
This is a weak magnet.	This is a strong magnet. Strength of magnetic field can be controlled.
The poles do not change.	By mere change in the direction of flow of electric current the poles may be altered.

ACTIVITY 17.3

Let us try to make an electromagnet with our hands. For this take thick paper like drawing sheet, copper wire, 9V battery or eliminator through which mill ampere current may flow, switch and iron scale and follow the given steps.

1. Make a cylindrical tube of 15 cm. long with a diameter of 1 cm. by rolling the thick paper sheet.
2. Make around 100 to 150 coils of copper wire around this tube. Please note that core is empty here.

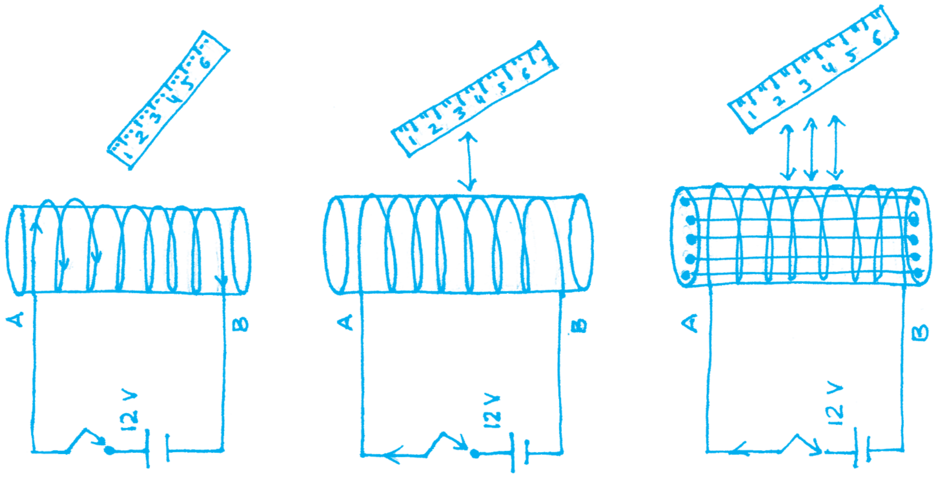
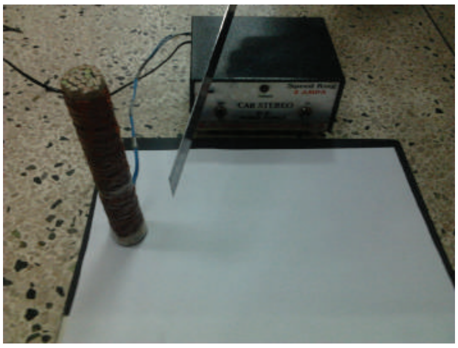
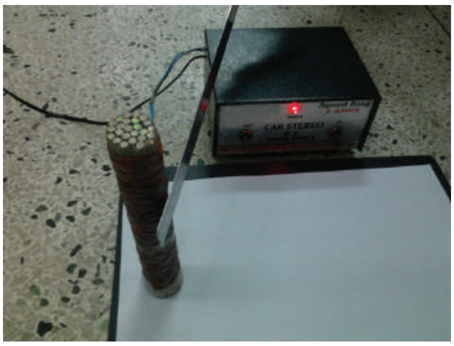


Fig. 17.8 (a)



(i)

(ii)



(iii)

Fig. 17.8 (b)

3. Connect the end of the wires with the help of a switch to the ends of the battery.
4. Take an iron scale near the tube before the switch is on.
5. You will see that no force may be felt over the iron scale.
6. Now the switch it on and allow the current to flow.
7. As current flows the iron scale is pulled towards the tube. This shows that the cylindrical tube works as a magnet. This magnetic property occurs due to solenoid.
8. Now fill iron nails inside the tube (core). You will observe that there is a greater force pulling at the scale. This shows that the electromagnet has become stronger. This happened because from atoms inside the core line up and increase magnetic field.
9. As the current flow is stopped, the magnetic effect of the tube is also lost.

17.4.2 Electric Bell

How does electrical bell work? This electrical device where electromagnetic is used as components. In electric bell 'U' shaped electromagnet is used. This is also called horse shoe electromagnet. Soft iron is placed between the arms of this electromagnet. This is called as 'core'.

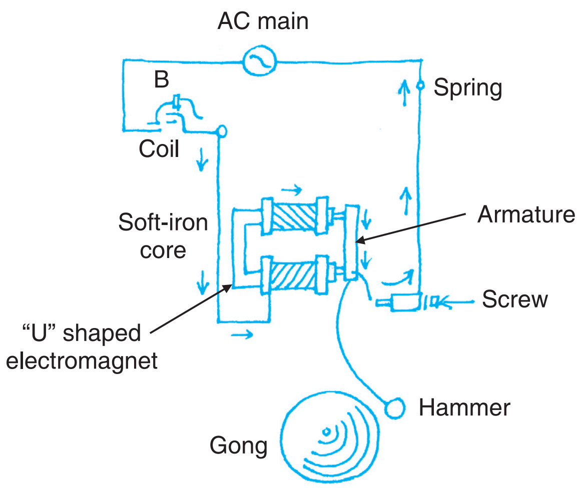


Fig. 17.9 *Electric bell*

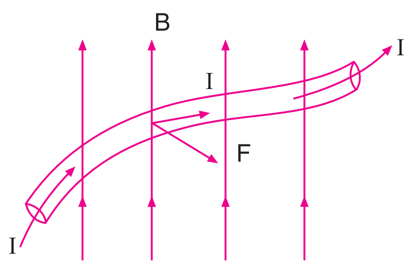
The poles of the electromagnet are connected to a power supply (battery or main). Between this a push button (B) is attached as shown in Fig. 17.9. When the push button is pressed, current starts flowing in the coil of the electromagnet and its soft iron 'core' gets magnetized. This magnetized core pulls the armature attached to the electromagnet towards itself. As a result of this, the hammer attached to the armature strikes the gong and a loud sound is produced. As soon as the armature is attracted by electromagnet the circuit is brought at the contact screw. The electromagnet no more remains magnetic. The armature returns to its original position due to armature spring action.

This process occurs repeatedly. Till the push button remains pressed, the hammer keeps striking the gong of the bell and as a result of this, sound is produced.

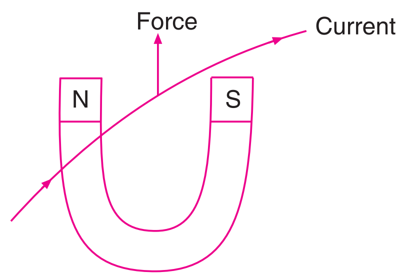
17.5 FORCE ON A CURRENT CARRYING CONDUCTOR PLACED IN A MAGNETIC FIELD

You have seen earlier that, when current flows through a conductor, magnetic field is produced around it. The direction of this field (B) depends upon the direction of flow of electric current (I). Similarly when an electrical conductor is placed in a magnetic field a force acts upon it. The following experiment may be done to observe this.

Let us suspend a piece of copper wire between the poles of a horse shoe magnet in such a manner that the length of the wire is aligned perpendicular to the direction of magnetic field between the poles. As soon as current is allowed to flow through this wire it becomes taut upwards. With this becomes clear that a force acts on the current flowing conductor. The direction of this force always perpendicular to both direction of current and direction of magnetic field and the direction of the flow of current are both perpendicular to the direction of the magnetic field. If the magnet is flipped i.e. the poles are reversed, the conducting wire becomes taut downwards. This force acts on the wire downwards. If the current flowing through the conductor is increased then the force also increases. This force acting on a current conducting wire was discovered by the great scientist Michael Faraday. This principle is used in electric motors.



(a)



(b) Force on a current carrying conductor

Fig. 17.10

The direction of force acting on a current carrying conductor placed in a magnetic field can be found according to the following rule:

Flemings left hand rule

According to Fleming left hand rule the direction of force applied to a current carrying wire is perpendicular to both the direction of the current as well as the magnetic field. It means that, stretch the thumb, the first finger and the middle finger in such a manner that they are perpendicular to each other i.e. the angle between the pairs of fingers is 90°. Then if the first finger shows the direction of the magnetic field and the middle one the direction of current flow, then the thumb shows the direction of force 'F' acting on the current carrying conductor. This rule was originated by John Ambrose Fleming in the late 19th century as a simple way of workout the direction in an electric motor or the direction of electric current in an electric generator.

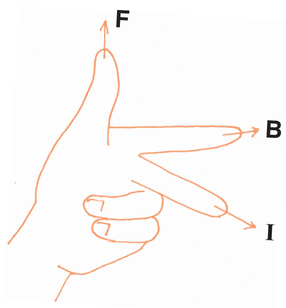


Fig. 17.11 Flemings left hand rule

INTEXT QUESITONS 17.2

1. Presence of magnetic field around an electric wire can be proved by which an behaviour of iron filings
   (i) They form a circular patterns as soon as the electricity is turned on.
   (ii) Try filing fly off the card when the current is on
   (iii) They do not prove anything, because it is magic trick.
   (iv) None of the above
2. Among these which property is not belong to electromagnet?
   (i) It is permanent magnet
   (ii) Its magnetic strength can not be decreased or increased at as well
   (iii) Its polarity can be remove by reversing flow of electric current.
   (iv) It produce strong magnetic field.
3. To findout the direction of force in the electric motor which rules is used?
   (i) Flemings right hand rule
   (ii) Flemings left hand rule

(iii) Right plam rule of right hand

(iv) Left palm rule of left hand

4. Why does an iron core increase the magnetic field of a coil of wire

   (i) The iron atom line up to add the magnetic field

   (ii) Iron attract things includes magnetic fields

   (iii) The iron core actually decrease the field, allowing it to be turned off

5. List the factors affecting the strength of an electromagnet?

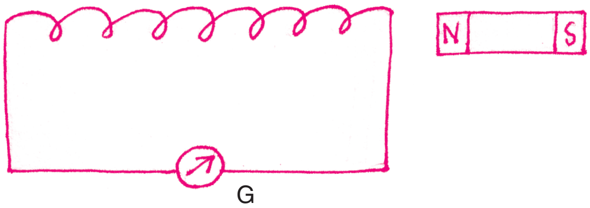
6. What is the role of solenoids in making electromagnet?

17.6 ELECTROMAGNETIC INDUCTION

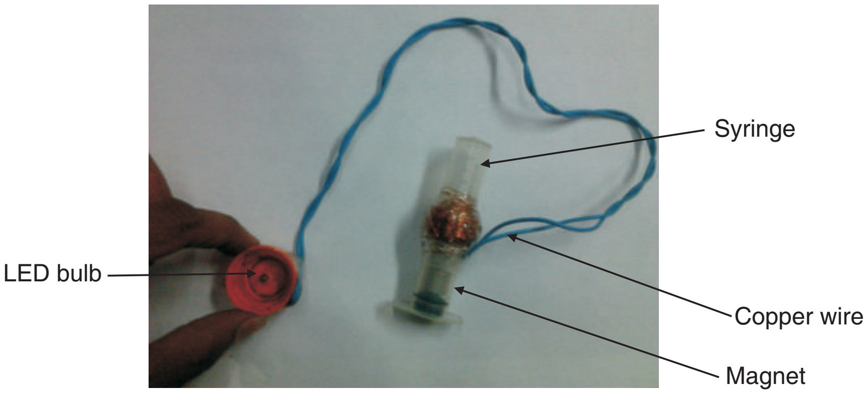
Previously in this lesson, we have seen that magnetic field is created when current flows through a solenoid (a cylindrical core of insulated copper wires). Do you think that the reverse should also be possible? That means conversion of electricity from magnetism. Michael Faraday, a great scientist also think over it and gave a discovery of induction in 1831. After several years of continuous experimentation he discovered that if changes are brought about in the magnetic field then electric current can be produced. If we rotate a coil of a good conducting wire between the poles of a magnet, then the number of magnetic lines of force associated with it are altered. Similarly if a magnet moves within the coil there is change in the same manner. When this occurs, current starts flowing in the coil. So electromagnetic induction is the production of an electric current across a conductor moving through a magnetic field. Generators, transformers some devices which works on this principle.etc working on this principle.

ACTIVITY 17.4

With this activity, we would able to see, how electricity generated through a magnetic field. You will required a strong magnet, copper wire, pipe (a non conductor), a current measuring instrument like galvanometer, a non conductor pipe (for example made up of cardboard, bamboo etc.) on which copper wire is wound to form a coils. First connect both ends of copper wire to the galvanometer, (Fig. 17.12a) keep the magnet parallel to the coil, bring it close to it and take it away. Repeat the process several times. You will see that each time there is a deflection in the galvanometer. With this you will be also observe that the see that the rate of flow of electric current through the coil increases with the rate of change of magnetic field, the faster the change the greater is the amount of a current flow.



(*a*)



(*b*)

Fig. 17.12

To understand the above principle better, we will try to make a simple experiment, Take a disposable syringe (the one with which a doctor administers injections). Make a 150 turns thin copper insulating wire at the middle of the syringe. Join the two ends of copper wire to Light Emitting Diode (LED) through connecting wire. LED may be fixed inside the plastic bottle capas in Fig. 17.12(b). Placed one cylindrical magnet inside the syringes. When you move magnet, holding the syringe in your hand, continues change in magnetic field take place and LED start glowing.

17.7 ELECTRIC GENERATOR

Electric Generator is such a device that converts mechanical energy to electrical energy. Generators are of two types:

1. **A.C. Generator (Alternating Current Generator):** This produces current that flows in such a manner that its direction and amplitude changes constantly with time.
2. **D.C. Generator (Direct Current Generator):** This generator produces current that flows in the same direction in a continuous manner.

17.7.1 Structure and Function of an A.C. Generator

A.C. generators operate on the principle of electromagnetic induction. Alternating voltage or current may be generated by rotating a coil in the magnetic field or by rotating a magnetic field with a stationary coil. The value of the voltage or current generated depends on

- the number of turns in the coil
- strength of the field
- the speed at which the coil or magnetic field roates

The structure of an A.C. Generator has been shown in Fig. 17.13. Here N-S is a strong permanent magnet. ABCD is a nonconductor frame on which copper wire has been coiled several times to form a rectangular coil. The coil is coated with a nonconductor substance like varnish so that they do not touch each other. This coil can freely move between the N-S poles. This rectangular coil is made to rotate between two rings E and F. There are two contact brushes G and H attached to the rings respectively.

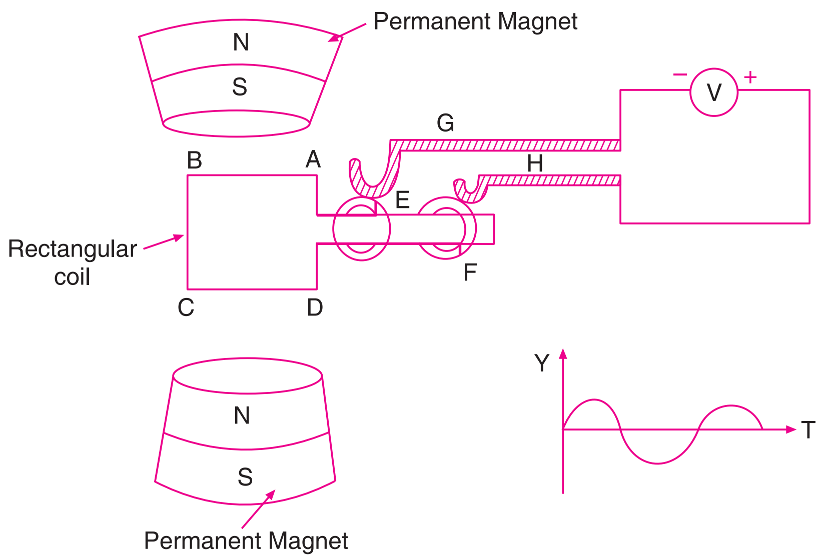


Fig. 17.13 *A.C. Generator*

The rectangular frame ABCD moves between the N-S poles due to mechanical energy. Assume that the plane of the coil in that of the magnet lines of force and the coil starts moving in an anti-clockwise direction. The magnetic field entering into the face ABCD of coil increase from zero to some infinite value and continues to increase till the coil becomes normal to the field. The rate, at which the magnetic field liked with coil charges, is the maximum in the begining and then it decrease continuously. Thus the induced current in the coil is maximum at time, $t = 0$ and decrease passing time. When the coil become normal to the field the rate at which magnetic flux of force charges become zero and hence current in the coil is zero.

When the coil further rotates the face of the coil through which magnetic field enters start changing the directing of current reversed. It keeps increasing till the plane of the coil does not become parallel to the magnetic field lines. Thus maximum current flows through the coil at this juncture. If the coil is rotated further, the area in contact with DCBA increase and the rate of change of magnetic field area becomes less. Thus the amount of current flowing through the coil decreases. When the coil is perpendicular to the magnetic lines of force then, current becomes zero. Now the north pole of the magnet is reversed. Current starts flowing from its original direction. The direction of current produced and its resultant keeps changing with time. Figure 17.14 shows the positions of the coils at different stages and the current in the coil at these instants.

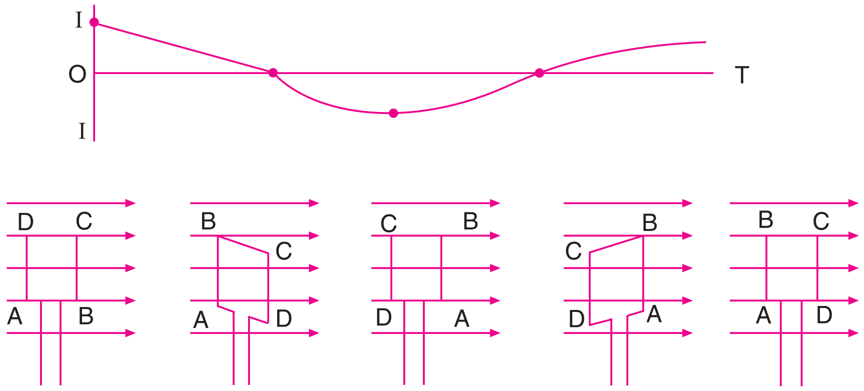


Fig. 17.14

17.7.2 D.C. Generator

This also works like the AC generator. There is just one difference in its structure. There is a half rectangular rings rather than E and F rings as seen in AC generators. The rectangular frame rotates and moves from a position parallel to the magnetic field to an upper one. The brush present creates a connection as electric current starts flowing. We can see thus that current flows in the same direction.

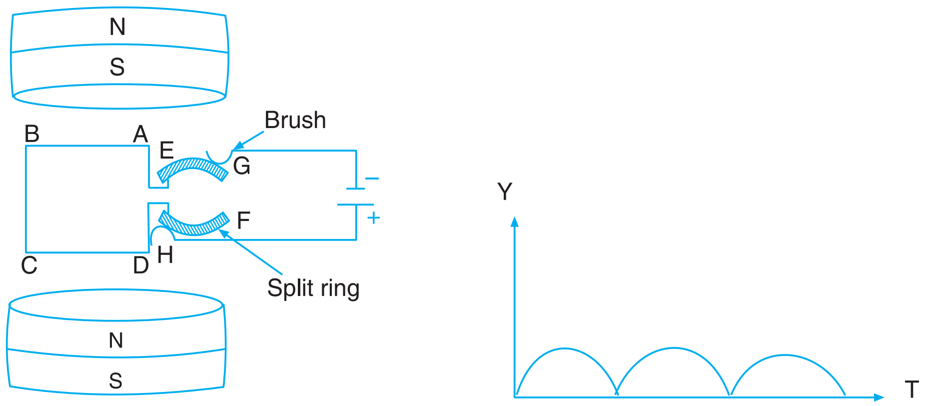


Fig. 17.15 *D.C. Generator*

17.7.3 Alternative Current AC and Direct Current (DC)

In household as well as industrial purposes AC is widely used. The current that flows out from the switch points at homes is AC. The current produced by a battery is

DC. AC can be changed to DC and vice versa. To change AC to DC a rectifier is used.

1. AC is transmitted from electricity generation centers to houses and industries through high voltage transformer (step up transformers) at very high voltage. At the site of delivery like houses and industries the voltage is reduced with the help of step down transformers. In this way transmission cost is reduced as well as wastage of energy is minimized. Transmission of DC causes the loss of a large amount of energy. Transformers cannot be used for DC.
2. Devices like electric motor that work on AC are stronger than those that use DC. They are also more convenient to use. DC generally used in electrolysis, changing the cells, making electromagnet etc.
3. DC of same voltage as AC is more dangerous because in DC direction of flow of current doesn't change. Thus people coming in contact with DC accidentally get stuck to it while when the come in contact with AC, due to change in direction of flow of current they are flung afar.
4. Major portion of AC flows through the upper portion of a wire. Thus where a thick wire has to be installed, several thin wires are coiled together to form a thick wire which will not the case with DC.

17.8 DISTRIBUTION OF ELECTRICAL ENERGY FOR HOUSEHOLD PURPOSES

You may have seen huge electricity poles, transformers, wires etc. around your houses. The production of electricity is done far away from cities at electricity generation centers. These power plants depend upon water, thermal energy, wind or geothermal power. Here electricity is produced usually at 11 KV (voltage), 50 Hertz (frequency). The system by which electricity is transmitted from such centers to the consumer can be divided into two parts.

A) Transmission system.

B) Distribution system.

By using step up transformer voltage is converted transmissions of electricity at the production centre. At the electricity generation centre, by using step up transformer voltage is converted from 11 kV to 132 kV. Then the electricity reaches at low power station through high tension wire. At lower power station it again converted up to 3.3 kV by using step down transformer. In this way by using step down transformer electricity reaches at home at the village of 220 V and 50 Hz. Hertz (Hz) is unit of frequency. The number of cycles completed by AC in one second is called as its frequency. A frequency of 50 Hertz means, AC completes 50 cycles per second. That means AC flows in one direction 50 times while in the other again 50 times in electrical wires, bulbs and other electrical appliances. This means that a bulb lights up 100 times and goes out 100 times in a second. But due to the lack of perception of such small intervals of time, a bulb appears to glow constantly.

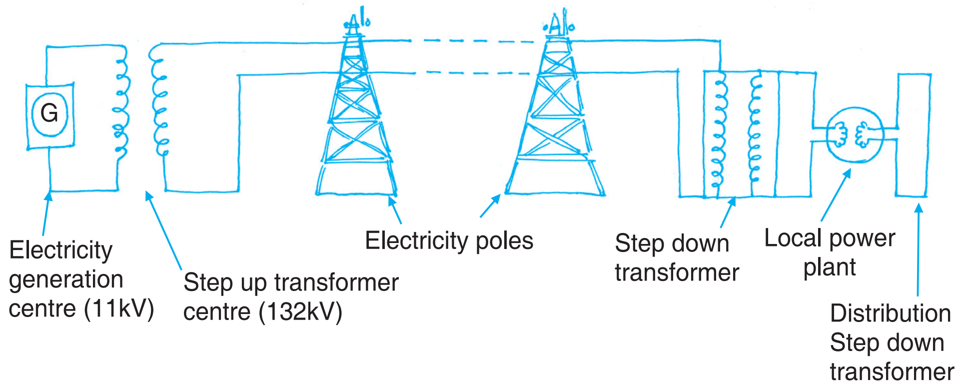


Fig. 17.16 *Distribution of electrical energy*

If the voltage of a transformer is increased then current flow reduces in the same proportion. Thus by using step up transformers we change electricity to higher voltage and reduce the current flow. By transmitting this low current we reduced the losses occured during the transmission.

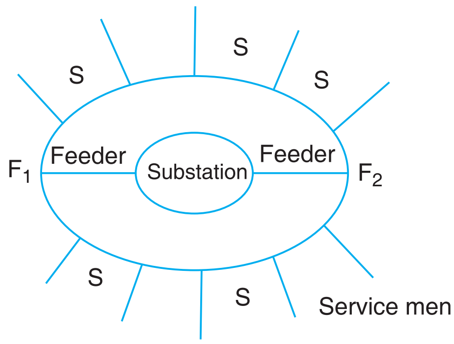


Fig. 17.17 *Ring System*

The distribution system is the arrangement which provides power from substation to the consumer. It involved feeder distrinbutors, sub distributors and service men.Normally there are two types of distribution systems.

1. Tree system 2. Ring system

These days mostly, ring system is used. The arrangement of various component of rings system made distribution is shown in Fig. 17.17.

17.8.1 Household Circuits

Till the poles near our houses, electricity reaches through the distribution system. Two wires from the poles come to our houses. Among these one wire is called as 'phase' while the other is called as neutral. In the phase wire the voltage is 220V while in the neutral the voltage is zero same as that of earth. It is represented as N. Usually the phase wire has a red coloured insulation over it while neutral wire has insulation of any colour other than red or green. Inside the houses wiring is done in parallel mode such that when one lights an appliance in a room it doesn't affect the strength of current in another room.

Household circuits are shown in Fig. 17.18. We use another wire that has green coloured insulation over it which is called as earth wire or earth-connecting wire. All the appliances are connected to this to the earth.

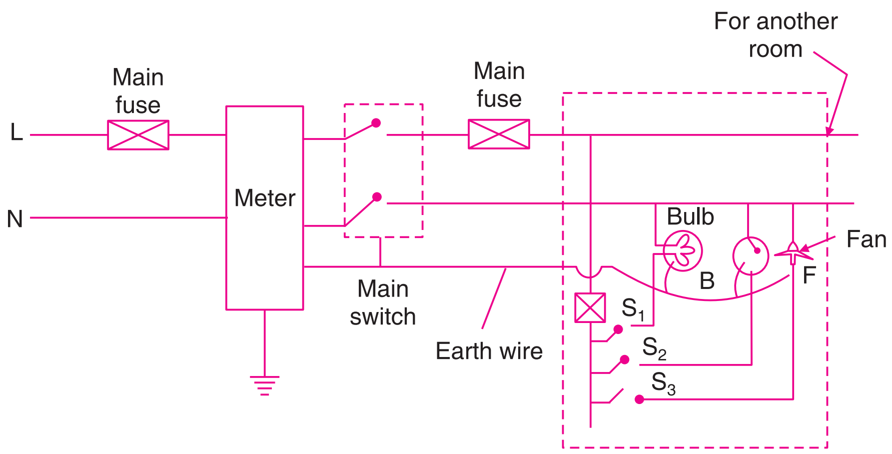


Fig. 17.18 *Household circuit (one bulb, one fan and one plug point)*

This electrical energy is produced by using our natural resources. Population growth growing urbanization is increasing the demand of electricity day by day. This is creating a pressure on our natural resources. Thus it is important today that we use electricity judiciously and not waste it in any way.

17.8.2 Precautions to be taken while using Electrical Energy

If electricity is used in a careful and safe manner it is the largest and most convenient form of energy. If one uses it carelessly it will become lethal.

1. Before working with electricity one must ensure whether it is AC or DC current. DC of the same voltage of AC is more dangerous.
2. Do not touch electricity supply wires with your bare hands. One may even die due to shock from current. AC flungs a person away while one gets stuck to a DC source. The main switch should be switched off in case of any accident. One must separate a person who has received a current shock with the help of a safe nonconductor eg. (rubber, stick, shoes, gloves). Never touch such a person directly.
3. Never use water to extinguish fire caused due to electrical spark.
4. Always ensure that a main supply is switched off before working on electric circuits. Use rubber gloves, shoes and separator device when it is necessary to work on live circuit.
5. In household wiring always use good quality wires, proper thickness and insulation. All the materials should be ISI marked. Connector should be tight and joined should be covered with insulating tapes. Ensure that the safety measures of earthing and fuse are properly done in your household electrical circuit.
6. Ensure that a miniature circuit board (MCB) is there or at least a fuse wire of appropriate load capacity is present.
7. All switches can be switched off by simply closing the single large main switch so that current flow to all appliances is cut off in the emergency.

17.8.3 Accidents Caused by Electricity

You may have often heard that several dangerous accidents have occurred due to electricity at homes or industries. Such accidents by electricity occur due to the following reasons;

- leakage of current
- short circuit
- over load.

1. Leakage of Current

Often due to continuous flow of electric current the insulation over wires gets affected and is scraped off and the wires are left bare. Current leakage occur through such bare wires. Often these bare wires in contact with a metallic surface increase its voltage to that of the main source. The surface of the metal if comes in contact with earth, allows current flow into the earth. When a person touches such appliances gets a severe shock.

2. Short Circuit

If somehow the main and neutral wire come in contact with each other there is a sudden huge spark that takes the form of fire.

3. Overload

If several appliances are connected to the same circuit there is an overload in the circuit. The value of current flow goes above the required value of the circuit. At this juncture the wire fails to bear the load of electric current. This is called overloading. Household appliances are connected parallel to each other in the circuit. The greater the amount of resistance the source would take more of current. You may have seen that during summer when the demand on electricity increases, transformers often burn due to extra load.

17.8.4 Safety Devices used in Electrical Circuits

1. Electrical Fuse

A piece of wire made of lead and tin alloy is used in making fuse. It have its melting point lower and high resistance then that of electrical wire. Due to this, if current in a circuit increase above a particular point the fuse wire gets heated and burns out. Due to this the whole circuit is saved from burning. The fuse wire is connected to the main source in series. Usually 5 A (ampere) fuse is used for household appliances, while 15 A (ampere) fuse is use for power circuits. 15A fuse wires are thicker than 5A (ampere) fuse wires.

2. Miniature Circuit Breaker (MCB)

These days MCB is attached to the household circuit wirings. MCB is a self regulatory switch which saves the circuit from overloading as well as from short circuits. If there is any barrier in the flow of electrical current it immediately stops the flow of current. Fuse is also used for this purpose but MCB is prepared in different shapes varying in use from small to large appliances saving them from high voltage.

3. Earthing of Electrical Appliances

Leakage of electric current in electrical appliances can harm us and may get electrical shock by touching them. Thus as a precaution there is another wire other than phase and neutral which is called as earth wire. The metallic end of all appliances is connected to one end of this wire and the other end is attached to a copper plate and burried deep in the ground. Thus, the body of all electrical appliances is of the same potential difference as that of the earth.

If ever we come in contact with electrical current, the path of earthing would be shorter than that through our bodies and thus we would be saved as current would flow through the alternative (earth) pathway rather than through our bodies.

INTEXT QUESTIONS 17.3

1. The work of an electric generator is to:
   (i) Change chemical energy to electrical energy.
   (ii) Change mechanical energy to electrical energy.
   (iii) Change electrical energy to mechanical.
   (iv) Change electrical energy to chemical energy.
2. Appliance that works on the principle of electromagnetic induction.
   (i) Electric kettle (ii) Electric bell
   (iii) Electric lamp (iv) Electric generator
3. Electric fuse should have the following combination of melting point and resistance:
   (i) high resistance and low melting point
   (ii) low resistance and high melting point

(iii) high resistance and high melting point
(iv) Low resistance and low melting point

4. Which principle states that by changing magnetic field, current produced:
   (i) Coulombs law (ii) Magnetic behaviour of a solenoid
   (iii) Electromagnetic induction (iv) Ohms law
5. Appliance that converts high voltage to low voltage is:
   (i) Step up transformer (ii) Step down transformer
   (iii) Rectifier (iv) Amplifier
6. Fuse wire is made up of
   (i) Silicon and Tin alloy (ii) Tin coated with zinc
   (iii) tin coated with nickel (iv) Tin coated with aluminium
7. According to Flemmings left hand rule the force acting on the current carrying conductor is:
   (i) Parallel to magnetic field and current flow.
   (ii) Perpendicular to magnetic field and current flow.
   (iii) Parallel to magnetic field but perpendicular to the direction of current flow.
   (iv) Perpendicular to magnetic field but parallel to direction of current flow.
8. Which wire saves appliances from damage among those that come into our homes?
   (i) Phase (ii) Neutral
   (iii) Earth (iv) None of the above.
9. Give the three reason of accident caused by electricity.
10. Name one of the tool used to check the current in wire and commonly used in home and industry.
11. Sometimes while touching the electrical appliance we have a shocked. What will the commonly answer for this?
12. Two coils A and B are placed close to each other. If the current in the coil A is changed, will some current be induced in the coil B? Give reason.

WHAT YOU HAVE LEARNT

- Magnetic field is that region around a magnet that deflects a magnetic needle kept in the region due to application of force.
- The electrical appliances like fan, mixer, juicer-grinder, crane etc. that use motors are based on magnetic effects of electric current.

- A change in magnetic lines of force present in conjunction with a current carrying coil produce electric current. This is called as electromagnetic induction.
- The strength of an electromagnet depends upon:- (i) the current that flows through it; (ii) No. of magnetic lines of force in unit length of coil; (iii) Nature of core etc.
- Flemings left hand rule gives the direction of force that acts upon a current carrying conductor placed in a magnetic field.
- Electrical generators are such devices in which mechanical energy is converted to electrical energy.
- Electric current is transmitted at high voltage and low current from one place to another.
- Rectifiers are used to convert AC to DC. Current produced by a battery is DC.
- Household appliances are always connected in parallel so that if the appliance is used, it does not affect electric current taken by other appliances.
- Transformers convert high voltage to lower (step down transformers) or low voltage to higher voltage (step-up transformers).
- Fuse wire has a low melting point and high resistance.
- One must wear rubber shoes and gloves while working with electrical circuits. It is because rubber is a bad conductor of electricity. Thus current does not flow through it.
- During an accident due to electricity switch off the main switch. The person who is a victim of electric shock should be separated from the appliance or lifted from the ground with the help of a non-conductor. The person should not be touched in any case.
- During disaster like fire or earthquake try to switch off the main switch.

TERMINAL EXERCISE

1. Why does a compass needle get deflected when brought near a bar magnet?
2. Explain magntic field using the concept for magnetic line of forces.
3. Write down the properties of magnetic lines of force.
4. Explain the force acting on current carrying conductor in a magnetic field.

5. How is an electromagnet made from a solenoid? Explain. Write down the differences between bar magnet and electromagnet.
6. What is electromagnetic induction. Explain in detail the functioning of any one appliance based on this principle.
7. Describe the advantages of AC over DC.
8. What is the function of an earth wire? Why is it necessary to earth electrical appliances.
9. Make such a household circuit that shows current coming from a pole to the room and at least a fan and a bulb can be lit. Explain the use of socket, switch and fuse as well.
10. Name some devices in which elctric motors are used.
11. How does current reach from electricity production centre to the houses?
12. Explain the structure and functions of AC generator.
13. Explain the magnetic effects of electric current and on the basis of this explain the functioning of the electric bell.
14. What is Flemings left hand rule?
15. When does an electric short circuit occur?

ANSWER TO INTEXT QUESTIONS

17.1

2. it properties does not changed
3. speaker in handset
4. North-South
5. yes, but their strength depends on where you are
6. (ii) South pole, which corresponds to the geographic north
7. Magnetic poles are the surfaces from which the invisible line of magnetic field emanate and connect on return to the magnet

17.2

1. (i)	2. (ii)
3. (ii)	4. (i)

5. (i) Number of turns
   (ii) Current flowing in the coil
   (iii) Length between the poles
6. A solenoid is used for making electromagnets. The use of soft iron rod as core in a solenoid produces strong magnetism.

17.3

1. (ii)	2. (iv)	3. (i)	4. (iii)
5. (ii)	6. (i)	7. (ii)	8. (iii)

9. Leak of current, short circuit, overloading
10. Electrical tester
11. Proper earthing is not there
12. When the current in coil A is changed the magnetic field associated will also changes. As a result magnetic field around coil B also changes. This changes in magnetic field lines around coil B induced an electric current. This is called electromagnetic induction.

18

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SOUND AND COMMUNICATION

In our daily life we have conversation amongst ourselves. We hear the chirping of the birds or horn of the vehicles or mewing of the cat. They are of so many types, so many tones, and so many levels of loudness. In fact usually we can recognize a person by just his or her voice.

We communicate in many ways. Even an infant communicates and does it just with sound, expressions and without words. Adults communicate by talking or writing to each other. Most often it is our voice that enables us to communicate, whether directly or through phone. Even an illiterate person can speak. While talking directly is the most used form of communication, technology has enabled us to use many other ways like telephone, radio, television, text message like paging and sms, and internet. The direct communication and use of telephone, satellite etc. differ in the waves used for sending sound. All make use of waves, but we use sound waves (which are mechanical waves) in talking while electromagnetic radio waves in sending voice through the radio set or telephone.

OBJECTIVES

After completing this lesson, the learner will be able to:

- *describe the characteristics and nature of the wave;*
- *distinguish different types of waves- the mechanical (sound) and the electromagnetic waves;*
- *explain the uses of different kinds of waves; use in communication devices (SONAR and RADAR);*
- *describe the need and importance of communication;*
- *identify and appreciate different type of communication systems and*
- *highlight the use of computers and satellites in communication.*

18.1 CHARACTERISTICS AND NATURE OF THE WAVE

Sound is a result of vibration. The vibration is produced by a source, travels in the medium as a wave and is ultimately sensed through the ear - drum. Let's try to understand it better by an activity. We can do a simple experiment to show the association between vibration and sound.

ACTIVITY 18.1

Take an aluminum wire (about 30 cm in length) or simply a metallic hanger, such as of aluminum then bend it so as to shape it like a bow. Take a rubber band or an elastic string of sufficient length. You may also use a twig, a small piece of a tree-branch. Tie a thread or an elastic string such as a rubber band to the ends of the bow such that string remains under tension. Ask your friend to record that:

(i) If you pluck the string, you can hear some sound. You may have to adjust the curve of the bow to be able to hear the sound. You'd notice that the sound vanishes if you hold the string after plucking. If you look carefully, you can realize that the sound comes only as long as the string vibrates.

(ii) You can check the vibrations. Take a small paper strip (about a cm in length and 2 to 3 mm in breadth), bend it in middle to form a V and place it over the string. You may try the same with string instruments like guitar, sitar, and ektara or even use powder on percussion instruments like tabla, drum or dhol. If you leave a little powder or dust on the tabla, and cause the membrane to vibrate, you may be able to 'see' the vibrations. A gentle touch with finger tips will also tell you that vibrations are associated with sound in all these cases. If you strike a steel tumbler with a spoon, hear the sound and then hold the tumbler with firm hand, the vibrations will cease and so will the sound.

Discuss the observations with your friends. Can you now conclude that the **sound has an association with vibrations**? These vibrations are transmitted in a medium mechanically and that is how sound travels. It travels like a wave. **A medium is a must for mechanical waves like sound to travel**. We speak and expect to be heard. But it will surprise you to learn that without some aid, we can't converse on Moon as we do here. This is because there is no air on moon (actually there is some but very little) and sound needs a medium to travel. In contrast, we can receive electromagnetic waves from distant stars and artificial satellites in space as electromagnetic waves need no medium to travel. **A wave involves a periodic motion, movement that repeats itself**. It also transports energy. Let's understand waves better.

What happens if you throw a stone in a pool of water? You will see a disturbance of a circular shape moving from the point of fall of the stone outwards. We also observe that the disturbance is made up of a raised ring in water which seems to travel outward. Soon there is another similar circular feature originating at the same centre and moving outward. This goes on for quite some time. Even though there appears to be a movement of material, actually it is only the position of the disturbance that is changing. This is a wave and is made up of the raised part (crest) and low part (trough). So crest and trough are essential components of a wave. **A wave transfers energy from one point to the other without the medium particles moving from one point to the other.** Thus wave is clearly different from particle.

Understanding the nature of sound requires observations. We observe a flute player continuously shifting fingers over holes to produce different notes while playing a tune. Similarly a sitar player also keeps pressing the string at different points touching different frets (parda in Hindi). When you strike an empty glass with a spoon and when you strike one filled with water, different notes are produced.

The science of sound helps us in understanding the reasons behind such things. Besides, the understanding of sound has enabled scientists to devise gadgets which are very useful. These include hearing aids, sound instruments like speakers, sound recording and sound amplifying devices etc.. We shall also learn about various technological tools that have been developed to improve communication. By improvement we mean we can communicate to more people, at greater distances, and with more clarity.

18.2 REPRESENTING A WAVE

We need to describe a friend by name, height, colour, gender etc for identifying. Similarly, we have to specify some qualities that we shall call parameters, for wave description. A wave is represented in terms of its wavelength, amplitude, frequency and time period.

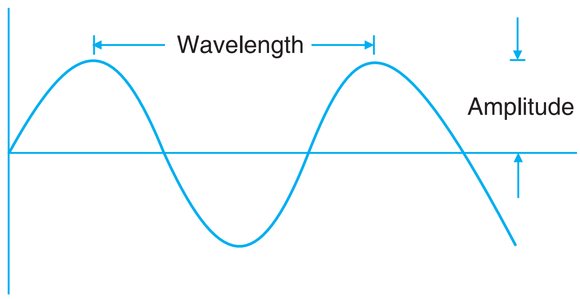


Fig.18.1 *A representation of wave*

18.2.1 Amplitude

The (maximum) height of the wave.

18.2.2 Wavelength

The distance between adjacent troughs or adjacent crests, measured in unit of length such as meters and expressed by symbol λ (lambda). For longitudinal wave, it will be distance between two successive rarefactions or compressions.

18.2.3 Time Period

This defines the time it takes for one complete wave to pass a given point, measured in seconds (s).

18.2.4 Frequency

The number of complete waves that pass a point in one second, measured in **Hertz** (Hz).

18.2.5 Speed or velocity

Wave speed is defined as the distance travelled by a wave disturbance in one second and is measured in meters/second (ms^{-1}). Speed is scalar quantity while velocity is a vector quantity.

Not all of these properties are independent; one can relate some. Period is inversely related to the frequency. This means if the frequency is high, the period will be low. This is understandable because frequency is number of times a wave completes a set of up and down movements (or a set of crests and troughs) in 1s. If these occur more frequently, it has to be done in very short time. Mathematically one may say period

$$T = 1/n$$

Where 'n' is frequency. We just said that wavelength is equal to the distance between two successive crusts or troughs. In one second this distance is covered a number of times given by frequency.

So, $$\text{Velocity} = \text{frequency} \times \text{wavelength}$$

or $$V = n \times \lambda$$

The waves that produce a sense of sound for living beings are called sound waves or audible waves. Only those waves that have frequencies lying in the range of 16 Hz to 20,000 Hz are audible to human beings. However, this range is an average and will slightly vary from individual to individual. Sound waves with frequencies below 16 Hz are called infrasonic waves and those above 20 kHz are ultrasonic waves. Animals like bats are able to produce and sense waves beyond the range of human audibility and use it for 'seeing' in the dark.

18.3 MOVEMENT OF SOUND IN AIR

Sound waves travel in fluids and solids as longitudinal waves. A longitudinal wave is a wave in which vibration or the displacement takes place in the direction of the propagation of the wave. Sound moves due to difference in pressure. If a sound is produced in air, it compresses the adjacent molecules. Due to the compression, the air pressure increases. This causes these compressed molecules to move in the direction of the pressure that is the direction of the wave. But displacement of the molecules causes fall in pressure in the place they left. If the wave is continuing then another rush of molecules comes in, fills the empty or rarified space. This process is repeated and the disturbance propagates. Thus a chain of compressions and rarefactions is generated due to sound. They travel and transport energy. If there is no medium, then produced sound will not be able to push any medium-molecules and sound will not move. That is the reason why we can't hear on moon; there is no air in Moon's atmosphere and sound can't travel.

INTEXT QUESTIONS 18.1

1. Which sound wave will have its crests farther apart from each other - a wave with frequency 100 or a wave with frequency 500?
2. If the velocity of sound is 330 metres per second (ms^{-1}), what will be wavelength if the frequency is 1000 Hertz?
3. What is the approximate audible range of frequency for humans?

18.4 DIFFERENT TYPES OF WAVES

The waves can be of different types. These may be mechanical or electromagnetic. Mechanical wave is a term used for those waves that require a medium for travelling. Its speed is dependent on the properties of the medium such as inertial and elastic properties. In other words the speed of the wave will depend on how easy or difficult is it to displace the particles of the medium (that is to say on their inertia) and on how those particles regain their original positions which is the elasticity.

An electromagnetic wave results from acceleration of charge. It doesn't require a medium to travel. It can travel through vacuum such as light do waves which travel from stars through empty space to reach us. The electromagnetic wave has electric and magnetic fields associated with it. The 2 fields, electric and magnetic, are perpendicular to each other and also to the direction of propagation. When we mention the wave length of an electromagnetic wave, we don't mean any physical separation between any crests or troughs or between rarefactions and compressions. This is because sound wave creates low and high pressure points in traveling through, say, air. But the electromagnetic wave needs no medium so there are no material troughs or crests or material rarefactions and compressions. It moves with the velocity of light viz. 2.997925×10^8 m s^{-1} that is 2.9997925 lac km s^{-1} in free space.

When thinking about movement of sound wave in a medium, we should always remember that the medium is a collection of particles. Movement of one particle can affect the other particles. You may have seen bicycles falling when parked in a row closely and one of them gets pushed accidentally. When the adjacent bicycles start falling in sequence, here also we see a wave, a movement of a disturbance. Here one bicycle imparts energy to the next bicycle, which transfers it to the next and so on. Here also there is a disturbance travelling without the medium component (the bicycles) moving to the end. The Sound wave is a mechanical wave but light waves, infra red rays, X-rays, microwaves, Radio waves etc. are electromagnetic (in short em). Gamma rays are alos em waves and result from radioactive decay of nuclei of atoms. Compared to sound waves, the em are much more energetic. They travel at the velocity of light that is about 3 lac kms per second in vacuum. In comparison, the sound waves travel very slowly. In air, it travels at 330 m s^{-1}. The velocity of sound in some media is given in the table which shows that sound moves faster in the solids than in gases or liquids.

Table 18.1: Velocity of sound in different materials

Medium	Velocity
Steel	5200 m/s
Water	1520 m/s
Air	330 m/s
Glass	4540 m/s
Silver	3650 m/s

Such difference in the velocities of light and sound means if there is an event in the sky, which produces light and sound both, we shall see the light almost instantly but it will be a while before we hear it. When there is a lightening in the sky, we see the light before we hear the sound. Mechanical wave can be either transverse or longitudinal while the electromagnetic wave is only transverse. The transverse wave is one in which the motion of wave and of the particles are perpendicular to each other. In a longitudinal wave, the motions are in the same direction. The sound wave can be of 2 types: Transverse and longitudinal.

We can try to visualize transverse wave by tying one end of a rope to a hook or peg in a vertical wall (or to a door-handle) and holding the other end such that the rope remains loose. We can demonstrate a transverse wave travelling along the rope if we quickly give up- and down- jerk (or even in horizontal plane) to the rope at our end. We see the wave travelling between our hand and the peg while the points on the rope move perpendicular to the rope and wave. This is a transverse wave, as the particles of the medium move perpendicular to the direction of wave movement. In the example of wave when we throw a stone in stationary water in a pond, it is more complex but here we confine to what happens on the surface. We see that on water surface the wave moves from the centre to the shore. If we see a duck or a small paper boat there, it oscillates up and down with water that is goes up temporarily after which they come back to their mean positions without shifting the position horizontally. That makes it a transverse wave.

In a **longitudinal wave**, the displacement of the particles and propagation of the wave are in the same direction. For instance, if we blow a horn, speak, or quickly move an object in air we are pushing the air molecules. These molecules, in turn, push the adjacent molecules which impart their energy to the next ones. After losing energy in the interaction, the molecule is back to its original (mean) position. This results in formation of compressions and rarefactions. So it's the compression (or rarefaction) which is travelling and not the molecules. Just like the distance between two successive crests or troughs is a measure of wavelength for transverse waves, the distance between two successive compressions or rarefactions is termed wavelength of the longitudinal wave.

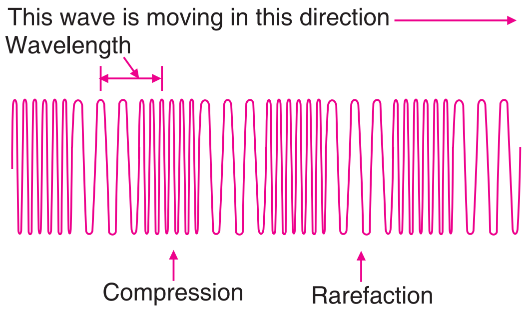


Fig. 18.2 *Formation of rarefactions and compressions in air and indication of wavelength*

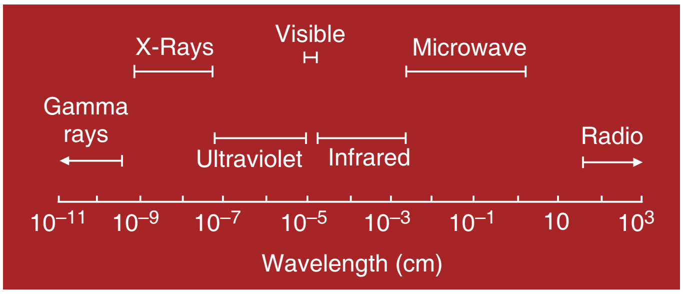
While transverse waves form only in fluids (air and liquid), the longitudinal waves can form in all the three media viz. solid, liquid and gas. One way to visualize a longitudinal wave is to take a spring, fix it between two ends and then pull or press it on one end along the length. Compressions and rarefactions can be seen moving and rebounding along the axis of the spring.

INTEXT QUESTIONS 18.2

1. Does a wave transfer energy or material?
2. How do mechanical and electromagnetic waves differ?
3. What is the difference between a transverse and longitudinal wave?
4. Do transverse waves form in solid?

Table 18.2: Ranges of wavelengths and frequencies of electromagnetic radiations.

Name	Wavelength (Angstroms)	Wavelength (centimeters)	Range of frequency (Hz)	Energy (eV)
Radio	$>10^9$	>10	$<3\times10^9$	$<10^{-5}$
Microwave	10^9-10^6	10-0.01	3×10^9-3×10^{12}	10^{-5}-0.01
Infrared	10^6-7000	0.01-7×10^{-5}	3×10^{12}-4.3×10^{14}	0.01-2
Visible	7000-4000	7×10^{-5}-4×10^{-5}	4.3×10^{14}-7.5×10^{14}	2-3
Ultraviolet	4000-10	4×10^{-5}-10^{-7}	7.5×10^{14}-3×10^{17}	3-10^3
X-rays	10-0.1	10^{-7}-10^{-9}	3×10^{17}-3×10^{19}	10^3-10^5
Gamma rays	<0.1	$<10^{-9}$	$>3\times10^{19}$	$>10^5$



The electromagnetic spectrum

Fig. 18.3 *Various radiations with wavelength and frequency*

18.5 NATURE, MEASURE AND QUALITY OF SOUND

Sound level is measured in units of decibel (dB). Here deci means one- tenth and bel is the level of sound. The term Bel is after the name of inventor of telephone Alexander Graham Bel. Actually it's a unit which compares the levels of power of two sources. Two power levels P_1 and P_2 are known to differ by n decibel if

$$n = 10 \log_{10} P_2/P_1$$

Here $\log_{10}$ means log with 10 (and not e) as base. Here P_2 is the sound which is measured while P_1 is a reference. Normally, the reference is a sound which is just audible. For average human ears, the whisper is about 30 decibel. The normal conversation is about 65 decibels while a jet plane taking off makes a noise of about 150 decibel. Beyond 85 decibels, sound is damaging and can lead to temporary loss of hearing. Prolonged exposure to noise can cause permanent hearing loss. We must be careful not to cause noise even when it means celebration for us. So it is not advisable to play band in a marriage procession (barat) near hospitals where patients can suffer because of noise. Noise raises the blood pressure and causes anxiety. Even if we don't realize, constant noise causes tension. Crackers during festivals are also harmful as they not only pollute air but also create noise.

Do you know

Considering the effect of sound on human health, it becomes necessary to develop an instrument to measure loudness of sound. The Decibel meter makes use of a special crystal called Piezo electric crystal. This has a quality that when subjected to pressure, it generates electrical voltage. In a Decibel Meter, a combination of a mic and piezoelectric crystal is used. Sound causes the diaphragm to vibrate and press the crystal and an electrical voltage generated is measured giving an idea of the sound level. This voltage can be converted into digits using calibration and displayed. Thus one can estimate noise from fire crackers, vehicles and machines and monitor so that people are not exposed to noise above certain level. The fact is that even music played at a very high level can cause deafness if done for a long time.

Different sources sound different. We should not confuse between loudness and pitch. Sound from a metallic tumbler on hitting with a metallic spoon is higher in pitch than sound from a pitcher when hit with a wooden stick. The voice of females is generally higher in frequency than male voice. However, we should also know that voice is not just one frequency. It is a mix of many frequencies, some of which are multiples (called **harmonics**) of the same frequency called fundamental note for the person.

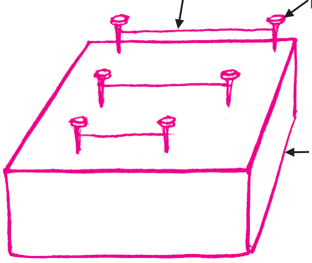
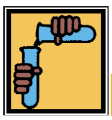


Fig.18.4. *A musical string instrument (which you can make using a metallic box and metallic strings)*

Now, that we know the relationship between wavelength and frequency, we can appreciate why a flute produces a higher pitch (smaller wavelength, larger frequency) when all holes are open. When all holes are closed, it produces the largest wavelength. Actually, the clue lies in relationship $v \propto 1/\lambda$ and by blowing harder we can produce louder notes.



ACTIVITY 18.2

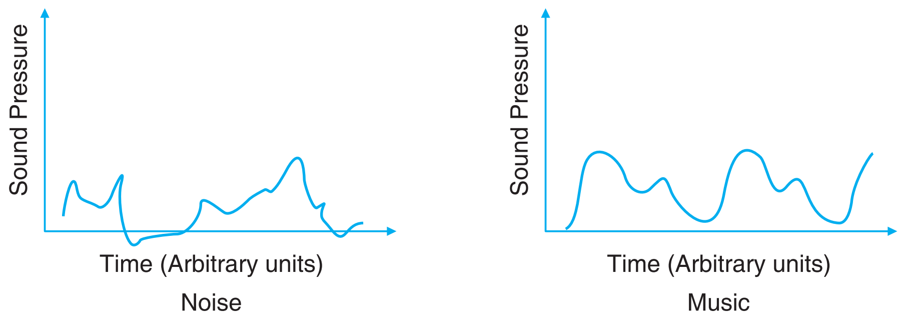
You can do a simple experiment to understand the relation between the pitch of a sound and the wave length. This will help us to understand difference in sounds from a dhol and tabla as well as from a small and a long string. The smaller one will produce a higher frequency.

Take a hollow preferably metallic box such as of toffees or sweets. If unavailable, you may use a ply-board or cardboard box. Take 3 pieces of metallic strings (wire) available from a musical instrument shop or get from a hardware shop. Nails or nuts and bolts (also available from the hardware shop)

The nails/bolts have to be fixed on the box. Hammer the nails to fix them on the box/board using adhesive if needed. Alternatively, drill holes in the board (or top of the box) and using nuts, fix bolts as 3 sets of 2 each. As shown in the diagram, the distance between nails in the sets should be different. For instance, if the 2 nails/ bolts are spaced by 10 cms, make it 20 and 30 cms in the other sets. Now metallic strings, should be stretched one each between 2 nails/ bolts in each of the three sets.

If you pluck the string, you can hear some sound. For each length of string, the sound will be different. The shorter string will produce higher frequency.

Invite a group of friends for a show of this home made instrument. All of you can observe that when you pluck the strings, the pitch of each of the three strings is different. The longer string will allow a longer wavelength to be set up and hence have the shorter frequency (remember that higher wave length means the lower frequency for the same velocity). This is also the principle on which sitar and other such string instruments work. The frequency also depends on the tension in the string which is vibrating. This may be verified with a simple experiment. You may vary the tension in the strings by rotating the bolts or slightly bending the base board if it's flexible. It may be also achieved by passing the string over a metallic base (while one end remains fixed to nail/bolt) and suspending different weights from the other end of the string one by one. You may also fill water in similar glass or steel tumblers but to different levels. When you strike them with spoon, the sounds in them will be different in pitch. The pitch or the frequency will be higher where the air pipe is shorter (water level is higher). The wave length of the sound produced will be proportional to the air column lengths. Which of the 2 in a set of 2 tablas generate higher frequency? Is it the one with smaller diaphragm or bigger? A bigger diaphragm allows bigger wavelength to be set up.



Regularity distinguishes music from noise

Fig.18.5 *Graphical representation of changes in sound pressure with time in musical and noisy sound*

Music is a set of sound that is pleasing to hear and is not random. It refers to the quality of sound as well as the tune. Noise is random and irritates while music has periodicity whether in beats, or rhythm. For instance, in a song, you'd notice that the same tune is repeated after certain period. After a stanza, the singer comes back to the same tune (combination of notes). If we plot sound pressure with time, we'd notice that it is sweet if it changes in a regular fashion. Noise, in contrast, changes in an irregular fashion and irritates. Sound is evaluated by musicians in 3 terms: quality, pitch and loudness. Two sounds may have the same loudness, may be at the same pitch but can still have different quality/timbre. That is how we can distinguish the sounds from Sitar and guitar even when the loudness and the pitch are the same.

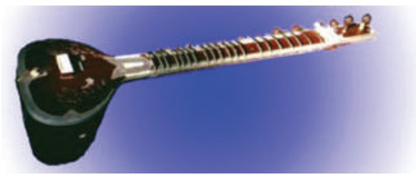
ACTIVITY 18.3

Take a flute and close all the 6 holes of the flute with your fingers (don't use smallest fingers). Blow in to the flute and hear the sound. Now keeping the same positions of the fingers (that is keeping all the holes closed), blow harder. You'd hear a louder sound. If we blow intermittently the sound you hear may be unpleasant but when you blow continuously you can hear a pleasant sound.

In India we see many musical instruments. Flute (Baansuri), Sitar, Sarod, Tabla, drum ghatam (pitcher), and even some Western instruments like guitar, piano and harmonium are quite popular. Some are string instruments where sound is produced by plucking a string and setting it to vibrate such as Tanpura, sitar and ektara. Some like tabla and dholak are percussion instrument where a membrane is made to vibrate by striking with hand or a stick. Then we also have flute and trumpet where we blow air into a pipe to produce sound.

Tanpura

Sarod



Sitar

A set of Tablas

Drum

Flute

Trumpet

Dholak

Fig. 18.6 *Some musical instruments*

Do you know

Flute is believed to be the oldest musical instrument. A flute made with bone from a vulture's wing was found in Ulm (South West Germany) in 2008. It had only 5 holes while modern flutes have 6 or more. It was dated to be about 35,000 year-old.

INTEXT QUESTIONS 18.3

1. What is the unit to measure sound intensity?
2. Why do they have many holes at the side of a flute lengthwise ?

18.6 USES OF DIFFERENT KINDS OF WAVES IN COMMUNICATION DEVICES (SONAR AND RADAR)

SONAR is a technique that makes use of this property of sound. SONAR stands for SOund NAvigation and Ranging. This works on the principle of echo of transmitted sound waves from objects. For instance, if you hit a wall in front with a tennis ball, the ball will bounce back to you. But if the wall is removed, the ball will not come back to you. Thus even with eyes closed, you have a way of knowing whether there is an object or a rebounding surface in front. SONAR works in the same fashion.

Use of sound waves to detect objects is based on the above simple example. The advantage of using sonar wave over electromagnetic waves is that electromagnetic waves lose energy fast in the ocean water because water can conduct electricity. In contrast sonar waves can travel farther in water.

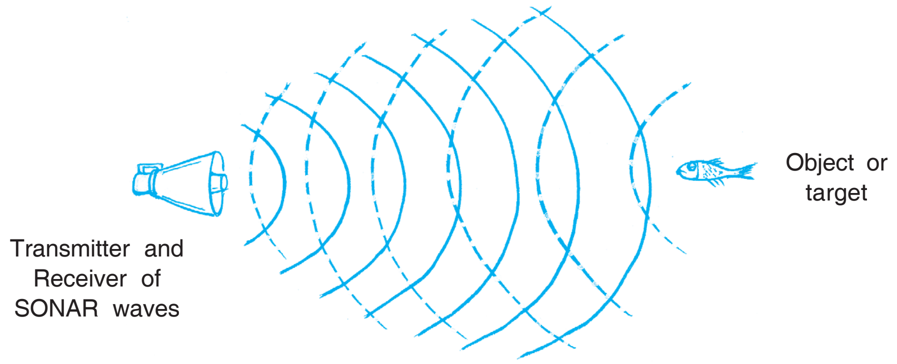


Fig. 18.7 *Working of SONAR: The continuous lines are used for transmitted SONAR waves and the dashed lines are used for reflected SONAR waves.*

There can be two types of SONAR set-ups. One is Passive and the other Active. In Passive SONAR, one detects sound waves that are present around. Leonardo da Vinci did it as early as 1490 AD. He dipped a pipe in water and placed his ear next to the end which was out of water. He used this to detect the waves generated by ships. Today, the techniques are far more sophisticated. SONAR became a topic of very serious studies during the World War II as detection of movements of ships and submarines assumed significance.

? Do you know

Have you ever been to a valley and shouted or clapped to hear echo (or echoes) of your voice or of clapping sound? The echo comes from the hills. It's a reflection of your voice, or of the sound produced by you. Even in a very huge hall or between two fairly distant walls or building, one can hear echo. When the reflection is from a far away object, we can distinguish it as an echo. But if the reflection is from a close by object, it is perceived by mind to be a part of the original sound. The reason most of the people find their voice so pleasing to hear in the bathroom is that there the echo comes quite early, such that it is joined to the original sound. We can discern a sound in time if it is separated by more than 0.1 second. A bathroom is usually too small and the reflected sound comes back well within 0.1 second.

Now Active SONAR is very important. It has two major components:

1. A transmitter consisting of a signal generator, power amplifier and a transducer
2. A detector which may be a single detector or an array of several detectors

One has to ensure that the signal is sent as a narrow beam. If not, then the reflections will be coming from many directions and will be confusing. Theoretically, the distance travelled by the wave is twice the distance between the transmitter/detector and the target to be detected. So if velocity of the sound in water is v, then distance of the object

$$d = \frac{1}{2} \times v \times t$$

where 't' is the time-lapse between transmission and detection of sonic signal.

The wave may be reflected from surface or bottom of the sea, ships, whales or other animals, submarines and other objects. The whole thing looks very simple but in practice, there are several other factors to be considered. For instance, the velocity of sound in a medium depends on the density and bulk modulus of the medium.

18.6.1 Radar

RADAR is an acronym for RAdio Detection And Ranging and is useful in many ways to us:

1. Observation of atmospheric objects and phenomena like clouds, cyclones, rain drops etc. and prediction of weather
2. Air Traffic Control
3. Ship navigation
4. In military use (early warning and fighter control radar)

RADAR is radio wave equivalent of SONAR. In RADAR, a radio wave does the same job as sound wave in SONAR.

The basic elements of RADAR system are:

1. A pulse source and a transmitter with an aerial which'd emit radio waves
2. An object which'd reflect the radio wave
3. A receiver with an antenna and a display system like Cathode Ray Tube (somewhat like a television or a computer monitor)

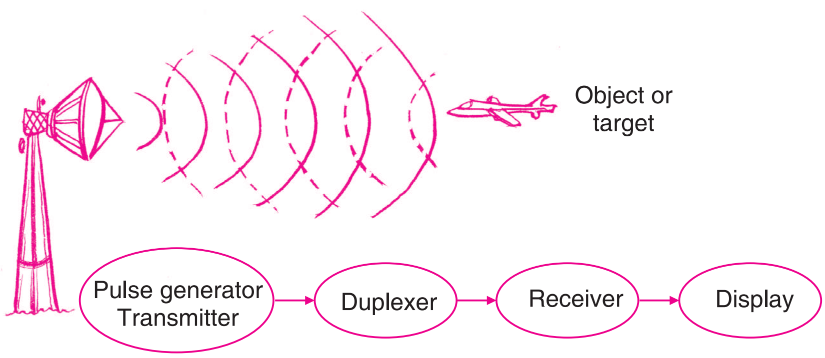


Fig. 18.8 *A simple sketch of components of RADAR*

Transmitter: The transmitter in a RADAR system generates and sends a radio wave. The radio waves go in all directions. If there is any object, the wave is reflected by it. There has to be a receiver to detect the reflected wave. The radio waves are electromagnetic radiation and travels at the velocity of light. It's obvious that the time gap between the outgoing radio wave and arrival of the reflected wave is very small. So what is done is that as soon as a radio wave is emitted, the transmitter is switched off and the receiver is switched on. Thus the reflected wave is not masked by the emitted wave and even a weak reflected wave is not missed by the receiver. If, after certain gap, there is no reflection received, we can presume that there is no object within certain distance and we can switch off the receiver and switch on the transmitter. This process goes on as was the case with SONAR. This is called a pulsed transmitter. However, for detecting moving objects, one can use continuous wave transmitter. If an object is moving away, the frequency of the reflected wave will be lower than the transmitted wave. If the object is moving closer, the frequency will be higher for the reflected wave. This is called Doppler Effect for sound. One can always adjust the receiver such that it doesn't receive the radio waves of the frequency emitted, but receives the radio waves of lower or higher frequencies. Called Doppler RADAR, such RADAR can only detect a moving object because it can't receive the frequency at which a radio wave was transmitted and only a moving object will change the frequency of the reflected wave.

RADAR is useful in air traffic control as it can 'see' in the dark. RADAR can monitor movement of clouds, detect rain drops. It can also detect presence of distant ships and big animals like whale in the sea. It can also be used to estimate the speed of the object approaching or moving away from us. It is used by weather scientists to track storms, tornadoes and hurricanes. Space and earth scientists make its use in tracking satellites and also in mapping earth surface. In fact it is useful even in making auto-open doors in shops or airports. This is because a wave will be reflected and sensed only if there is an obstacle in the way of emitted radio wave.

18.7 NEED AND IMPORTANCE OF COMMUNICATION

Many of our actions are in relation with actions, expectations or thoughts of others. The same is true of others. Communication need not always be verbal though sometimes facial expressions or body language give clues to what is going on in mind. But that is not very common and, generally, thoughts are in mind and we can't read them. Have you ever seen a face that conveyed sadness as if seeking help, you took pity and did something for that person? Possibly yes. But unless you talked, you wouldn't know the requirement exactly. It's by communicating among ourselves that we know each other's thoughts and take actions. Therefore, communication is very important in life and an illiterate person doesn't read or write, communication through sound assumes prime place. Sometimes, sound is heard directly, sometimes through instruments like loud speakers and sometimes it's communicated over large distances using complex equipments.

18.7.1 Different type of communication systems and devices

Some common devices for sound communication, other than independent oral or printed communication, are given below:

(i) Microphone and speakers

(ii) Telephone

(iii) Satellite, Computer and internet in communication

(iv) HAM

(i) Microphone and speakers

ACTIVITY 18.4

To understand that air pushes when in motion, take a candlestick, matchbox, a fan and a loudspeaker. Light the candlestick and hold it in front of a running fan. The flame flickers, and sometimes extinguishes. Air in motion has pushing quality. If you do the same exercise with a burning candle and a loud speaker, a similar thing happens. The reason for the flame getting extinguished is the pressure of the air. In the first case the source is the fan, in the other it is the loud speaker. A loud speaker reproduces sound through the motion of its diaphragm which pushes the air, leading to compressions and rarefactions.

The microphones (mic or mike in short) and the speakers are very common equipments. You see them not only in public meetings and conferences, you come across them even when you use your phone. The work of a microphone and a speaker are opposite of each other. A microphone converts sound into electrical entity (voltage) while a speaker converts the voltage into sound by moving the diaphragm of the speaker and producing vibrations in the air. Basically a microphone has a diaphragm which moves when sound pressure pushes it. This movement can be converted into proportional voltage using several possible transducers. Here a transducer is a device which receives electrical, mechanical or acoustic waves from one medium and converts them into related waves for a similar or different medium.

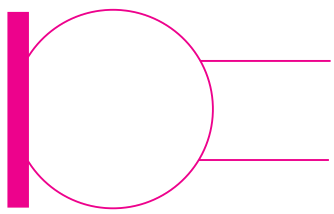


Fig. 18.9 *Symbol of a microphone*

The microphones can be of several types such as electrostatic (condenser/capacitor using plain or RF voltage), piezo-electric (crystal and ceramic), contact resistance (carbon), and magnetic (moving coil and ribbon).

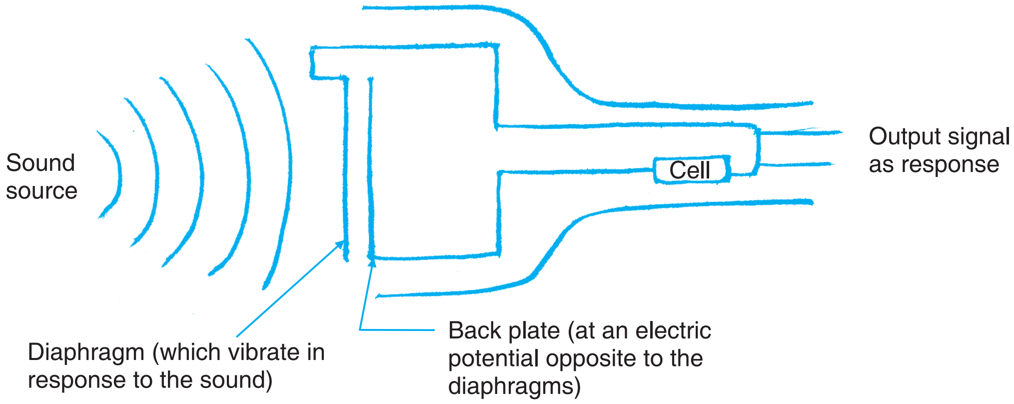


Fig. 18.10 (a) *Structure of a condenser (capacitor) microphone*

The diagram shows a **condenser microphone**. It has a thin diaphragm of thickness 1 to 10 micrometers. One micrometer (or micron) is one millionth of a meter or one thousandth of a millimeter. Close to this plate (metallic or metalised plastic) stands another metallic plate with holes. These 2 plates act as electrodes and are kept at opposite polarities by supplying voltages from –60 to +60 Volts (DC). To behave as a condenser, they should be insulated from each other. When sound wave pushes the diaphragm, it vibrates and the capacitance of the condenser (or capacitor) changes. This is because the capacitance is proportional to the potential difference and inversely proportional to the separation between the plates. Any change in the separation changes the capacitance. The capacitance is also dependent upon the medium but as the medium here remains the same, so we ignore this parameter. The values of the resistance and the capacitance are chosen such that the change in voltage is immediately reflected in the voltage across the resistance in series. Any change in the capacitance (meaning any change in sound) leads to voltage change. The voltage is fed to an amplifier. When the amplified voltage is applied to the coil of a speaker, it reproduces the sound which changes with the input- sound. The functioning of the speaker is just reverse. There, electrical voltage is fed to the speaker coil and the change causes the diaphragm to vibrate and produce sound.

Fig. 18.10 (b) *Condenser microphone*

In a **ribbon microphone**, a corrugated ribbon made of a metal is suspended in a magnetic field. Sound causes the ribbon to vibrate. This means change in magnetic flux through the ribbon. This induces an electric current which drives a speaker. When this current is flown through a coil attaches to diaphragm of a speaker, the diaphragm vibrates and produces sound. Special materials developed using nano technologies are being used to make ribbons that will be light but strong. Being light improves the response to sound. The ribbon microphone senses pressure- gradient and not just pressure. Therefore, it detects sound from both sides.

INTEXT QUESTIONS 18.4

1. Give three examples of devices that make use of microphones or speakers or both.
2. In a condenser microphone, what will happen if the diaphragm is made very heavy?

(ii) Telephone

Invention of the telephone is credited to Alexander Graham Bell. The telephones are of several types: hand sets, mobile phone, satellite phone and through internet. The basic function of a phone is to allow communication of voice both ways. Of late, phones with facility of transmitting images have also become available. The telephone may be with or without wire. In a wired phone, the basic structure is as follows. It has a microphone and a speaker. The microphone receives our voice and converts it into electrical signal. Similar process occurs inside the mouthpiece of the telephone. A basic telephone has 3 main parts:

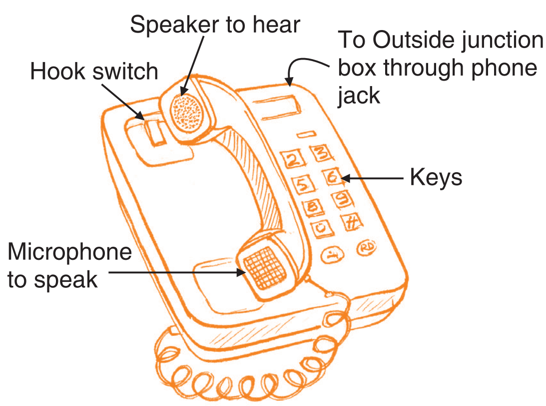


Fig. 18.11 (a) *The basic structure of a wired phone set (In actual phone there is a provision so that your voice does not reach and disturb you)*

(i) Cradle with a hook switch.

(ii) A mouth piece which houses a microphone

(iii) A hearing piece which houses a speaker (usually an 8 ohm speaker)

The phone is rested on the hooks. As soon as the phone is lifted, the hooks pop up and a connection gets made inside the body of the cradle which completes a dial tone ringer circuit. This produces a tone which is actually a mix of 2 tones (2 frequencies). On hearing the dial tone, we know that the phone is connected and we can dial a number. If the number is busy when we dial, we hear another mix of tones. Over the times, the telephone has undergone many changes including introduction of the cordless (for short range) and mobile phones. But as far as basic structure of a telephone set is concerned, it has remained the same.

Now the dialing is by pressing the keys. We speak into the mouth piece and hear the other person through the speaker. In a basic phone, the speaker and the microphones form the ends of the phone set. In this way, the set can be held close to face such that the speaker is close to our ear and the mic to our mouth.

The speech is controlled by a mouth piece which contains a mic. It includes a diaphragm. In the old phones, the diaphragm was made of a 2 metallic sheets between which carbon granules were filled. As one speaks, the diaphragm gets pressed following the same pattern as the sound of a speaker. In turn, the carbon granules also get compressed and decompressed, coming closer and moving away, thus increasing and decreasing the conductivity. A current is sent through the diaphragm. The source of this DC current (a few mA) is a battery at telephone exchange and the current comes to our phone. This leads to varying electrical current. This current will depend upon the sound pressure hence this can pattern the signal being sent through the amplifier and the cable. Now-a-days, there are electronic microphones. This signal (as electrical current) is sent to a junction box outside house using a pair or copper or aluminum wires. There are signals from other houses also reaching this junction box. All of these electrical wires carry voice- signals (sound converted into electrical signal) that are sent through a common coaxial cable, housing many pairs of copper wires, to the telephone company's exchange. From there, they can be routed either through metallic or fiber optical cables. These days, the signals are also routed from the exchange through microwaves using satellites especially for international calls. To avoid our own voice reaching our ears, a duplex coil is placed in the circuit of the microphone. In addition, there is a ringer. When someone calls, it rings a bell and we know that we have to attend a phone call.

The hearing is controlled by a speaker. It consists of a diaphragm with a permanent magnet attached to it on one end and an electromagnet close to the other end. The electromagnet is a piece of soft iron with a coil wound around it. The signal comes and flows through the coil. This causes the iron core to be magnetized. This naturally causes the diaphragm to vibrate in the same pattern as incoming current (voice). This generates sound that we hear.

Mobile phones have brought great convenience in daily life. The basic working principle remains the same in mobile phones also. But for them, the sound doesn't travel through cables or wires. It travels as electromagnetic wave through space via antennas, base towers, switching stations (or even satellite) and then again the antenna. When a number is dialed, the (electromagnetic) field is spread all around through antenna of the mobile. The signal is received by the nearby microwave tower and then by the switching station. This station re-transmits it in all directions (it doesn't know where the intended mobile may be) and a part is available to the other antennas in other places. When an antenna near the intended receiver gets the signal, it also retransmits it and this is received by the antenna of the intended mobile, which rings.

Fig. 18.11 (b) *Mobile*

While fully conclusive evidence may not be available, there are apprehensions about the possible health hazards, such as brain tumour, associated with use of mobile phone. The microwaves, used by mobile phones set-ups, are absorbable by water. It is apprehended by some that prolonged conversation on mobile phone can result is considerable microwave dose to brains which contains fluids. The children's brains contain more fluids and the skull is thinner. Hence they are more susceptible. Experimental evidence exists and common experience suggests that long duration conversations lead to temperature increase in body part close to the mobile phone. A study conducted with the support of World Health Organisation by the International Agency for Research on Cancer, catagorises the radiofrequency electromagnetic fields as group B agents that could possibly be 'carcinogenic to humans'. It may be advisable not to hold them too close to head. One should limit the use of mobiles to the shortest possible durations especially at a stretch and close to the same ear. One may also be advised to use earphones if long duration talk becomes necessary.

(iii) Use of satellites, computers, and internet in communication

(a) Satellites

Satellites are bodies that revolve around planets. All the planets in Solar System, except Mercury, have natural satellites. Moon is a natural satellite of Earth. But we have artificial satellites launched by several countries. You may have some times noticed, after sun- set, tiny points of light moving in the low sky. They are moving too fast to be stars. These are artificial satellites glowing due to scattered Sun light which is below our horizon by that time. The first artificial satellite was by name Sputinik-1 and launched by USSR on October 4, 1957. It carried a radio transmitter. The first American satellite to relay communications was Project Score in 1958. India launched its first artificial satellite 'Aryabhata' from a USSR launching facility on 19th April, 1975. This was followed by Bhaskara-I (7th June, 1979). After developing indigenous launch vehicle SLV-3, India launched 35 kg Rohini-I satellite (18th July, 1980) using a 4- stage SLV-3 vehicle followed by 2 more in the Rohini series. The next was Apple (Arianne Passenger Pay Load Experiment). These were followed by many satellites like Bhaskara-II and INSAT (Indian National Satellite) series which have been used for communication, TV and radio broadcasts. In 1988, the first satellite of IRS series was launched aimed at serious remote sensing work and applications. Since then, India has successfully launched many satellites for remote sensing and communication.

Having satellites in space places us in a privileged position. If we are on ground there is a limit up to which Earth's features can be seen by us. But viewing Earth from a distance has an advantage. It allows us to look at up to half of the planet if the distance is sufficiently large. We can send electromagnetic signals to the other side of the globe through the satellites in space. Therefore, the artificial satellites have come to play a very important role in any country's infra structure. They serve very important role in communication, space research, survey of natural resources like minerals on Earth, weather prediction including movement of clouds, also change in course of rivers, and disaster monitoring (floods, cyclones, tsunami etc.). Communication becomes important for imparting education. The idea that satellites could be used for communication came from Arthur C Clarke in mid forty's. That is the reason the geostationary (or geosynchronous) orbit is also called Clarke orbit. Clarke rose to become one of the greatest science fiction writers.

Electromagnetic waves sent from any part of Earth can't reach just any part of Earth. If sent downwards, they will be limited to a small distance due to curvature of Earth. If transmitted up, they will keep going straight and hit ionosphere, a layer of charges in the space, at 50 kms and more above the ground. Then they will be reflected to Earth and reach some part which is far away from the source. Thus a huge area in- between will be a dark zone where the signal wouldn't reach. Instead of the ionosphere, one may use satellites to retransmit the signals. But we need more than one satellite which can receive the signal sent from ground and re - transmit it in different directions. Therefore, it was thought that several satellites in space could together cover whole of Earth and facilitate communication.

A satellite's position and orbit are critical. The satellite has to be launched using a rocket, lifted into the correct orbit and given suitable energy and momentum in the right direction so that it keeps moving. A satellite could be geostationary which remains stationary with respect to Earth. A satellite in a geostationary orbit keeps moving at the same angular speed as Earth and in the same direction as rotation of Earth. So a geostationary satellite has a revolution time which equals the rotation time of Earth viz. 24 hours. It appears to be in a fixed position to an observer on Earth. It can keep looking at the same spot on earth for a very long time, monitor the changes and transmit the data to ground station. Thus to direct antennas towards the satellite to receive the signal, one doesn't have to keep tracking a moving satellite. That would have demanded expensive instruments on ground for direct TV transmission. This means huge savings because it does away with the need for too many ground antennas. Placing a satellite at 36,000 kms has added advantage that it just falls under the gravitational pull of Earth and is energy - economical though it's more expensive to launch compared to low orbit satellites. Low orbit satellites are placed about 400 kms above ground. But being low, they can see only a small portion of the ground below. There are Polar Satellites that move over the poles. The remote sensing satellites have been placed in comparatively low (less than 1000 km high) orbits in contrast with communication satellites in geostationary satellites which move at 36,000 kms above Earth. The remote sensing satellites should be launched such that they make observation at any place between 10 AM and 2 PM so that the ground is illuminated from the top and images come out clearer.

A geostationary satellite is useful for countries at low latitude such as India. The satellite is placed at an altitude of 36,000 kms, going around in the plane of equator and making one revolution around Earth in 24 hours. However, as Earth also makes one rotation in 24 hours, the satellite looks at the same place on ground all the time. From this altitude, it can view about one- third of Earth. The signal is sent from ground to the satellite as microwave at certain frequency and the satellite re- transmits it to the other parts of Earth at a different (but still as microwave) frequency. Microwave is at wavelengths of the order of a millionth of a meter. The highly directional antennas on Earth receive these microwave signals. Thus satellites make it possible to send TV, radio signals to far away places on Earth, even on the other side of globe.

Orbital radius	Km
Low Earth Orbit (LEO)	160-1,400
Medium Earth Orbit (MEO)	10-15,000
Geostationary Earth Orbit (GEO)	36,000

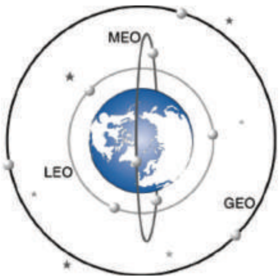


Fig. 18.12 *A satellite moves in Low (LEO), Geostationary orbit (GEO) or in an orbit. LEO goes over the poles in each revolution (Polar orbit) which is used for mapping Earth. This is useful in weather studies because it allows looking at clouds etc. at the same time every day. The geostationary and LEO satellites monitor the same place on Earth.*

(b) Computer and Internet

Today computers are inevitable in daily life. Computers play a major role in publishing industry; designing of houses, controlling the functioning of cars and garments; computerized machining, regulating air traffic, and in simple as well as the most sophisticated scientific instruments. Even at home, majority of the gadgets, whether television, automatic washing machine, television or microwave oven, one finds application of computers. Besides this, they have revolutionized communication.

Computers are used for communication to and from aircrafts, ships, and even huge boats; in money transactions and in maintaining and processing financial records such as in Automated Teller Machine (ATM) and banks. In the form of application to internet, computers have emerged as a very strong communication link. Using e-mail, one can send a message, chat live (that is send and receive text) and even talk instantly which has revolutionized communication. Earlier it would be weeks before one could send a message and receive reply from abroad. Today, it's a matter of seconds. This certainly helps the dissemination and growth of knowledge.

(iv) Ham

The term HAM is not from the English language. It was coined taking the first letters from the surnames of those 3 persons who started this way of wireless two way communication. They were S Hyman, Bob Alby and Poogie Murray. It was in 1908 that they started an Amateur Radio Club which has grown to the present worldwide group of amateurs. Even today when mobile phones are so common, the HAM comes handy in case of disasters when all other means of communication break down. HAM uses radio waves. Radio waves are electromagnetic waves in the range (about 10 cm to 10 km, see Fig. 18.3) and hence they travel at a velocity (in vacuum) of about 3 lac kms per second. Sound is converted into electromagnetic signal and transmitted using an antenna. The sound is intercepted by the receiver which converts it back to sound.

INTEXT QUESTIONS 18.5

1. List some uses of satellites.
2. If a satellite equipped with cameras remains fixed at one height above ground even as earth rotates and moves in its orbit, what is its possible use?
3. Arrange the low orbit, geostationary and polar satellites in decreasing order of altitude above Earth (the highest one comes first).
4. Which of the satellites are preferred for communication application?

WHAT YOU HAVE LEARNT

- Sound results from vibration and needs a medium to travel, be it gas (like air), solid or liquid. It is faster in solids than in liquids and is the slowest in the gases.
- Electromagnetic radiations also are waves but they can travel through vacuum.
- Wave, sound or electromagnetic, involves periodic movement, movement that repeats itself.

- A wave is described in terms of wavelength, frequency and amplitude. Velocity is equal to the product of wavelength and frequency.
- Noise is random while music is periodic. Music is pleasing to hear but it is also subjective. Sustained exposure to noise and even music at high decibel harms.
- The functioning of musical instruments like Tabla, Sitar and flute (Baansuri) can be understood as vibrations in membranes, strings and organ pipe.
- Sound Navigation and Ranging (SONAR) and Radio Detection and Ranging (RADAR) are two techniques which have many applications. They make use of sound and electromagnetic (radio wave) waves respectively. SONAR is more useful than RADAR in water as electromagnetic waves lose energy fast in water.
- The inventions of microphone, speakers, telephone, satellite, computer and internet and HAM have revolutionized communication. They all work through the conversion of sound wave/text into electromagnetic waves at transmission end and reconversion to sound wave/text at the receiver's end.
- A microphone (mic) converts sound into electrical signal, while the speaker converts it back into sound. Mic can be of different types like condenser, piezoelectric, contact and magnetic mic.
- Sound pollution can have dangerous implications and hence care should be exercised that the level is kept low. Prolonged use of mobile phone can damage us and there is possibility of serious illness.

TERMINAL EXERCISE

1. Fill in the blanks:

   (i) Sound travels at a .... velocity than light.

   (ii) When there is lightning, we first .... and then hear it.

   (iii) SONAR makes use of .... waves while RADAR makes use of .... waves.

   (iv) Microphone converts sound into .... while speaker converts electric signal into ....

2. Multiple choice type questions

   (i) Which satellite will see a wider area on Earth?

   (a) A low earth orbit satellite (b) A high earth orbit satellite

   (c) A medium earth orbit satellite

(ii) India's first self launched satellite was

(a) IRS (b) Aryabhat (c) Rohini (d) INSAT

(iii) For the same velocity, will a higher frequency of a sound wave mean

(a) Higher wavelength (b) Lower wavelength

(c) The same wavelength

(iv) Sound travels fastest in

(a) Solid (b) Liquid (c) Gas

(v) The most suitable medium for RADAR would be

(a) Gas (b) Liquid (c) Solid

3. Why can't we hear each other on Moon?
4. Describe 2 experiments to show that sound has vibrations associated with it.
5. What is the relationship between velocity, wavelength and frequency?
6. State 3 differences between sound waves and micro waves.
7. What are the differences between longitudinal and transverse sound waves?
8. Will sound move faster in solid or air?
9. What is the basic difference between noise and music?
10. What makes your voice appear more musical when you sing in a bathroom?
11. How is active SONAR different from passive SONAR?
12. What are the relative merits of SONAR and RADAR? Why is it better to use SONAR in water?
13. How does SONAR help in estimating the distance of an object?

ANSWERS TO INTEXT QUESTIONS

18.1

1. The wave with frequency 100 will have its crests farther apart as its wave length will be higher. For sound waves, the velocity 'v' is equal to the product of wavelength and frequency ($v = n \times \lambda$ or $v/n = \lambda$) and thus wavelength and frequency are inversely proportional. So for the same velocity, the lower frequency wave will have a larger wave length. Therefore, for the wave with a frequency of 100 Hz, will have a higher wavelength and the crests will be farther apart compared to the wave with frequency 500 Hz.

2. Wavelength = 0.33 meter
3. About 20 Hz to 20KHz

18.2

1. A wave transfers energy. Even when the material is displaced, it's temporary and it comes back to its normal position such as in case of a ripple in water.
2. Medium is essential for propagation of mechanical waves. Electromagnetic waves can travel through vacuum as well as any medium. But they lose energy in liquids and solids very fast. Sound waves can travel through liquids and solids with much lower losses. The velocity of sound waves is highest in solids (a few thousand metres per second). The velocity of electromagnetic waves in contrast is extremely high: about 3 lakh km per second.
3. In a transverse wave, the direction of propagation of the wave (the direction of energy-transfer) is perpendicular to the direction of oscillations whereas in longitudinal waves, particles of the medium vibrate parallel to the direction of wave propagation.
4. Yes. The sound waves travel in solids.

18.3

1. The unit to measure sound level is decibel. It's one tenth of a bel. Actually the decibel is a comparative scale. For us, the reference is fixed at the just audible sound so we normally speak of sound level in decibels.
2. Flute is an organ pipe in which air columns vibrate. More the length of the air column, more the wavelength of sound produced and hence loss the frequency. Holes are provided by the side of the flute so that by closing the holes length of vibrating air column may be changed.

18.4

1. Telephone, Radio and Television
2. In a condenser microphone, if the diaphragm is made very heavy, the inertia of the diaphragm will be higher. This means it will be difficult for the diaphragm to move rapidly. Its movement can't be fast enough and so it will not be possible to reproduce very high frequencies.

18.5

1. Satellites are useful in communication, surveying, photographing of geographical features of earth and astronomy.

2. If the satellite is stationary but earth below it keeps moving, the view will keep changing. Thus without the satellite moving, the satellite cameras will see whole surface of earth facing it.
3. The geostationary, polar and low satellites. The geostationary satellites are the highest at about 36,000 km. The Polar satellites are lower than them and the Low Earth Satellites (160-1400 km) are the lowest.
4. Geostationary satellites are preferred for communication application. This is because from earth they appear fixed at the same place. Thus if the antennas are directed towards them once, we don't have to worry about tracking them.

19

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CLASSIFCATION OF LIVING ORGANISMS

Do you know that

- earth is the only planet in our solar system of eight planets on which life exists;
- living organisms derive most of their requirements for survival from the non living sources of earth;
- every organism begins life as a single cell;
- there are plants which eat insects;
- mushrooms that we relish as vegetarian food are fungi. Fungi are the group of organisms which subsist on dead and decaying matter;
- certain bacteria live in oceanic vents at temperatures as high as 80ºC to 110 ºC.

Note the temperature at which you feel uncomfortable on a sunny summer day or an icy cold winter night and it will give you an idea of how high the temperature is at which these bacteria survive.

This lesson deals with the diverse kinds of organisms found on earth and the ways and means of studying this vast biodiversity. It also emphasizes the need for conservation of biodiversity.

OBJECTIVES

After completing this lesson, you will be able to:

- *recognize the vast diversity of living organisms in terms of variety of size and complexity;*
- *explain the meaning of biodiversity;*
- *describe the levels of biodiversity;*

- *appreciate the need for classification of living organisms;*
- *justify the rationale underlying the five kingdom classification and the hierarchy in classification of living organisms;*
- *argue in favour of binomial nomenclature with examples;*
- *classify kingdom Plantae upto division; kingdom Animalia upto phyla and the chordates upto classes;*
- *become aware of and take steps towards conserving biodiversity.*

19.1 BIODIVERSITY

19.1.1 What is biodiversity

We find living organisms all around us, even deep under the oceans and in the snow covered Arctic and Antarctica. There are organisms which are single celled and microscopic, as well as animals as large as the elephant, the rhinoceros, the hippopotamus and the whale. Have you seen the movie "Jurassic Park" by Steven Spielberg? From the movie you get an idea of how huge the dinosaurs were which roamed the earth millions of years ago and then became extinct. Also if you were to take a drop of water from the nearby pond and view it under a lens you will be amazed to see the enormous variety of organisms moving about in that drop of water. You might be wondering how many kinds of organisms there would be on earth! It is estimated that about 10 to 15 million different kinds of organisms have been found on earth including the ones that lived in the past. However, scientists have till date identified only over two million of them.

The enormous variety of organisms is termed biodiversity (bios means life and diversity means variety). There is not only diversity in size among organisms but also in complexity. eg. bacteria are simple single celled organisms and humans are made of a trillion cells and are highly complex.

All organisms have come to exist on earth because of **evolution** and are related through ancestry. You shall learn about evolution and its mechanism in the next (Lesson 20) entitled 'History of Life on Earth'. The humans are at the top of the evolutionary ladder. It is sad that lots of different kinds of organisms have been lost due to the impact of human activities. Therefore, we have to be conscious and aware so that damage to the earth on which we live along with other organisms, is avoided.

ACTIVITY 19.1

If you are a stamp collector, make an album or chart of stamps on animals and plants.

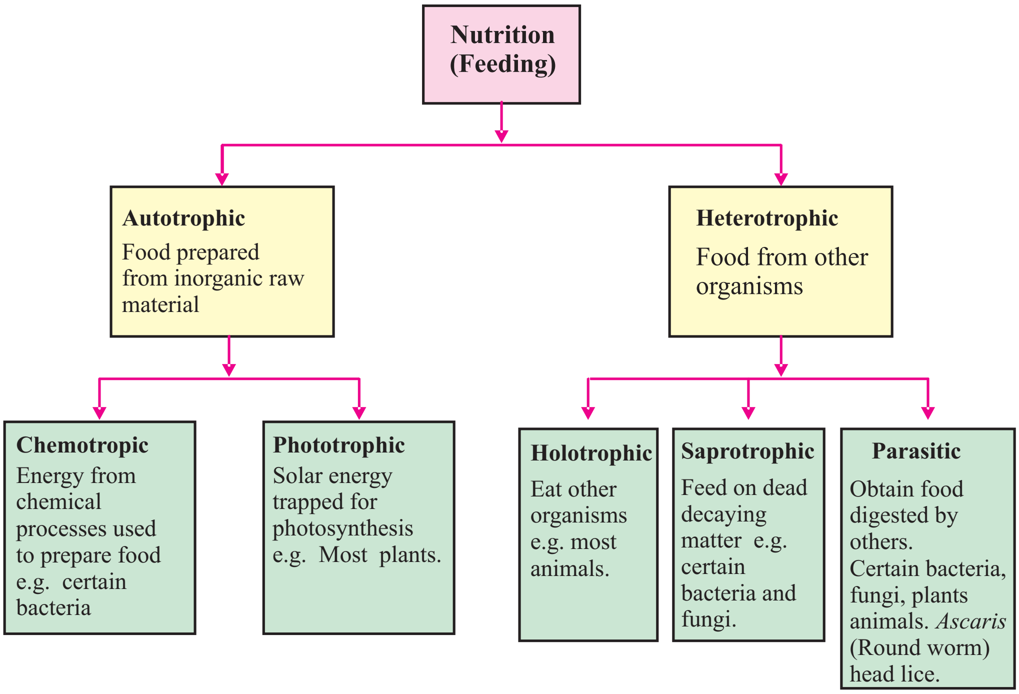
ACTIVITY 19.2

Some calendars are based on birds or wild animals. Collect the pictures from old calendars and make a scrap book.

Apart from variety of size and complexity, there is diversity in modes of feeding, reproduction and other body functions among organisms.

ACTIVITY 19.3

Prepare flow charts by using terms given below in brackets for diversity in reproduction and respiration. Diversity in feeding is given below as a sample:



Use the words given below to draw flow charts like the one given above depicting variety in reproduction and respiration.

Reproduction: Asexual, sexual, single parent, two parents.

Respiration: Oxygen from water, oxygen from atmosphere, Carbon dioxide into water, into atmosphere, gills, lungs, anaerobic, aerobic.

You may seek help of your friends and use other innovative ways of presenting the data.

Organisms live up to 8 km in air and up to 5 km below sea level. This part of the earth which supports life is the **biosphere**. Biosphere has diverse **ecosystems** such as the pond, river, oceans, and mountains, deserts etc. Various kinds of organisms or different species live in these ecosystems. They interact with each other and also interac with the physical components of the ecosystem such as light, temperature etc.

Read the following table and perform the accompanying activities.

Table 19.1 ***Biosphere, ecosystem and species***

Level of Organisation	Images/ pictures of each level	Diversity of features	Activity
Biosphere the physical part of earth on which organisms can survive	 **Fig. 19.1a** *Earth as seen from space*	Oceans, mountains, fresh water bodies, forests, snow clad areas, deserts and grasslands.	Obtain an outline map of the world and mark in different colours, the diverse components mentioned in the adjacent column.
Ecosystem Definite geographical region in which various species of organisms live and interact with each other and the physical environment	 **Fig.19.1b** *Ecosystem*	Oceans, mountains, rivers, ponds, forests, snow-clad areas, deserts etc.	Collect pictures or read from your geography book or see a website to record specific features of the ecosystems mentioned in the previous column.
Species Group of very similar organisms which can interbreed to produce fertile offspring.	 **Fig. 19.1c** *Species*	Different kinds of bacteria, protozoa, fungi, plants and animals	Collect pictures of humans belonging to different parts of the world. They look different. Why are they said to belong to the same species?

19.1.2 Levels of biodiversity

All the varieties of living organisms on earth constitute biodiversity. Three levels of biodiversity have been recognized:

1. Ecological/Ecosystem diversity

Organisms evolved features which helped them adapt to their surroundings or the ecosystems in which they live. There are different ecosystems and even related organisms living in different ecosystems may differ vastly from each other. For example tortoises are terrestrial and turtles are aquatic. Both are related but differ much especially in their feet. **There is diversity of ecosystems**—terrestrial ecosystems include forests, plains, deserts and mountains and aquatic ecosystems are sea, river, pond etc. Organisms living in these have evolved suitable adaptations. India has very diverse terrestrial and aquatic ecosystems.

2. Species diversity

Variety of species living in a certain geographical area constitutes species diversity. Individual organisms belonging to a particular species are similar and are able to undergo reproduction to produce fertile offspring. They cannot interbreed with another species. There is an enormous number of species of organisms as you have already learnt. It refers to the variety of genes contained within species of plants, animals and microorganisms. Can you say how new variations arise in an individual?

3. Genetic diversity

Organisms are made of cells and cells in their nuclei contain chromosomes which bear the genes. Genes control the features of a particular species. Genes of individuals belonging to the same species are similar. Every species has a gene pool. Gene pool means all the different kinds of genes found in a species. The gene pool of a species differs from that of another species.

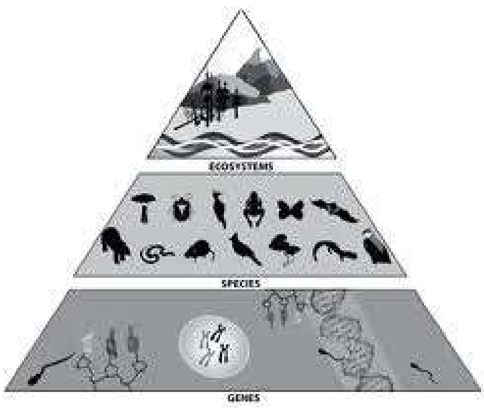


Fig.19.2 Levels of biodiversity

ACTIVITY 19.4

Prepare a chart or flash cards or an album or a power point presentation to depict the three levels of biodiversity. You may use pictures, photocopies of illustrations, photographs, drawings, scanned pictures/photographs etc.

You may even make a model showing various levels of biodiversity.

19.1.3 Patterns of biodiversity

Global Scenario

The entire world is divided into six **biogeographic** regions (Fig. 19.3). The organisms found in these regions are adapted to the climate of these regions. Certain kinds of organisms are common to all regions while some are restricted to certain regions only e.g. elephants are found only in Asia and Africa and nowhere else in the world. Grass is found all over the world.

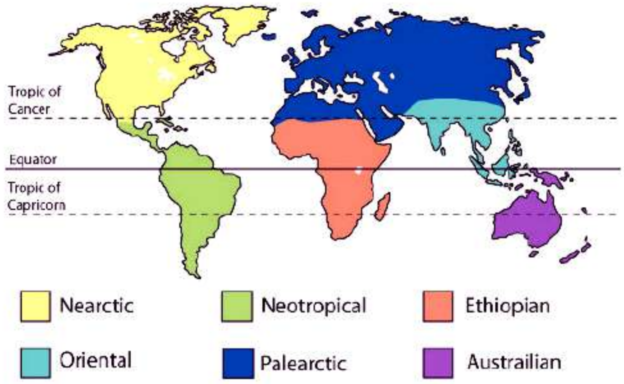


***Fig. 19.3** The six biogeographic regions*

Indian Scene

India has two biodiversity 'hotspots'—the Western Ghats and North Eastern regions (including Eastern Himalayas). (Fig.19.4) '**Hotspots**' are regions of the world where many different kinds of organisms live. Many of these organisms are not found elsewhere e.g. Many species of frogs live only in the Western Ghats of India.

The flora and fauna are our heritage. We must conserve our biodiversity.

***Fig. 19.4** Biodiversity Hotspots of India*

INTEXT QUESTIONS 19.1

1. What does biodiversity mean?

2. Define (i) species, (ii) biosphere (iii) ecosystem.

3. Name the three levels of biodiversity.

4. What is meant by biodiversity hotspots?

19.2 CLASSIFYING AND NAMING ORGANISMS

How may this enormous diversity of living beings be studied and comprehended? This riddle has been solved by categorising diverse kinds of organisms and providing them with scientific names.

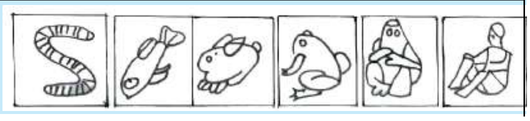
19.2.1 Classification of organisms

You have already learnt that about 10-15 million species are supposed to have evolved on the earth till now.

Try and calculate how much 10 million would be by adding zeroes after 10. Till now, approximately 2 million have been identified and named. How do scientists study and identify organisms? They do it by arranging organisms into groups and subgroups. **Grouping of organism according to similarities and differences is termed classification.** When an organism is classified into various categories a hierarchy is maintained. Accordingly, an organism belongs to Kingdom, Phylum, Class, Order, Family, Genus and Species in hierarchical order. These are groups to which an organism belongs and which express its evolutionary relationship with other organisms.

Thus classification shows evolutionary relationships between organisms and is also termed Systematics. The science of classification or systematics is termed Taxonomy.

The scientific name of a human being is *Homo sapiens*. Humans are classified as follows:

Name of Group	***Characteristic features of the groups into which humans are classified***	
Kingdom Animalia	All animals (Multicellular, eukaryotic, heterotrophs)	
Phylum Chordata	Animals with notochord at some stage of life.	

Subphylum Vertebrata	Animals possessing a back bone.
Class Mammalia	Animals with mammary glands to provide milk for their young.
Order Primates	Grasping hands and feet . Share the group with monkeys and apes.
Family Hominidae	Group shared with primitive humans.
GenusSpecies	*Homo sapiens*

Homo sapiens means the wise hominid.

19.2.2 The Three Domains of Classification

All organisms are now classified into three major domains (Fig. 19.5)

Archaebacteria are thermophilic or heat loving bacteria that live in high temperature vents.

Eubacteria are single celled organisms without well developed nucleus.

Eukarya are all other organisms with a well formed nucleus in their cell/cells. (Eu: true; Karyon : nucleus)

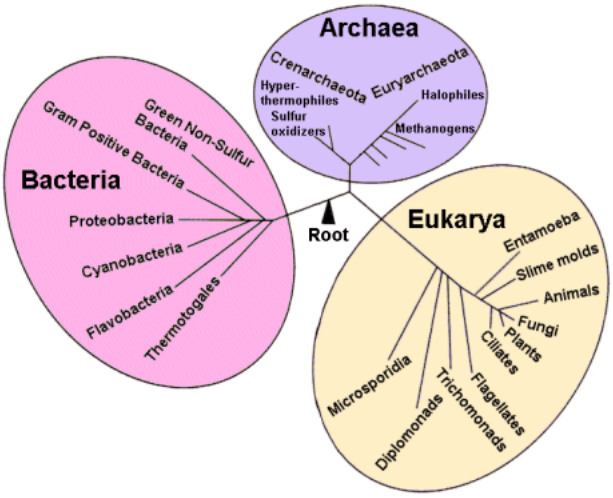


Fig. 19.5 The three domains of life

19.2.3 The Five Kingdoms of Life

Earlier there were only 2 kingdoms of plants and animals. Whittaker in 1969 suggested that bacteria should not be in plant kingdom and protozoa not in animal kingdom. He gave the five kingdom classification. Given below are the 5 kingdoms of life and their typical features.

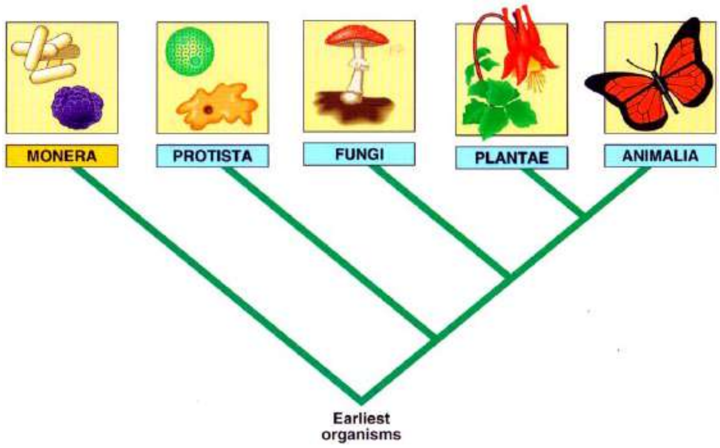
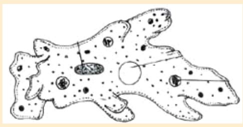
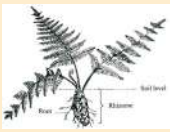


Fig. 19.6 The five kingdom of life

Table 19.2 The five kingdoms of life

Kingdoms	Pictures of examples	Name	Features
Kingdom 1	 ***Fig. 19.7a*** *Bacteria*	**Monera**	Single celled, No well formed nucleus (Prokaryotes)
Kingdom II	 ***Fig. 19.7b*** *Protozoa*	**Protoctista** or Protista	Single celled with well formed nucleus (Eukaryotes)
Kingdom III	 ***Fig. 19.7c*** *Mushroom*	**Fungi**	Eukaryotes, multi-celled saprotrophs
Kingdom IV	 ***Fig. 19.7d*** *Fern and Tree*	**Plantae**	Eukaryotes, multicelled, autotrophs
Kingdom V	  ***Fig. 19.7e*** *Earthworm and cat*	**Animalia**	Eukaryotes, multicelled, heterotrophs

The kingdoms are further divided into divisions (as in bacteria, fungi and plantae) or phyla (as in Protoctista and Animalia). Every phylum includes several classes, Classes are divided into orders. Orders include families.

A family is made up of many genera (singular: genus). Every genus includes several species. Species are segregated from their related species under the same genus through reproductive barriers. This means that members of one species cannot interbreed with members of another species to produce fertile offspring. See fig. 19.1c

INTEXT QUESTIONS 19.2

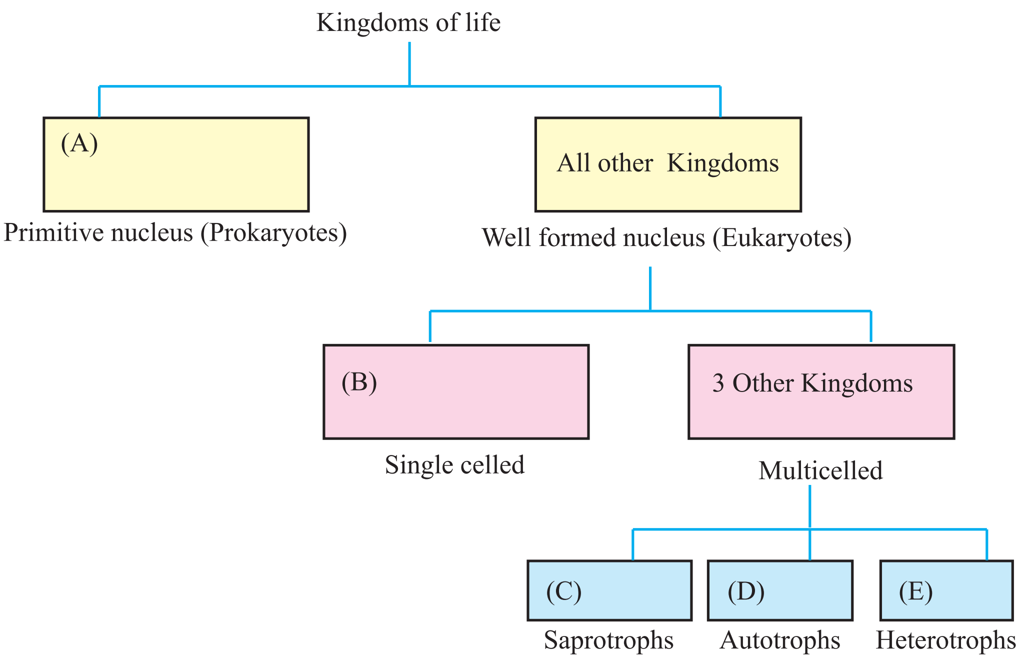
1. What is meant by classification?

2. How has classification made study of diversity possible?

3. Name the three domains into which all the organisms of the world are categorised

4. Name the five kingdoms of life and mention the three features on which this classification is based.

5. Study the table 19.2 on kingdoms of life and fill in the names of kingdom at A to E in the flow chart given below :



19.2. 4 How organisms are named

Every organism has a scientific name beside the name by which it is known in a particular language. For example, mango is its name in English, Aam in Hindi and *Mangifera indica*, its scientific name. In scientific naming, genus and species of the organism are mentioned. eg. *Homo sapiens*.

The Scientific Name

A Scientific name has several advantages and constitutes the specific identity of the specific organism.

- It is understood all over the world.
- It consists of two words, name of the Genus to which it belongs begins with a capital letter and name of the species to which it belongs, begins with a small letter e.g. cat is *Felis domestica* where *Felis* is the genus name and *domestica* the name of the species.
- A scientific name is always written either in italics or underlined.
- Having two names is the Binomial system of nomenclature (naming) introduced by the Swedish naturalist of 18th century, Carolus Linnaeus.

  The term binomial nomenclature pertains to the two word naming system (binomial = two names; nomenclature = naming)

Carolus Linnaeus

19.2.5 Who's Who in the Living World—Classification of Kingdoms Plantae and Animalia

Every organism belongs to one of the five kingdoms of life.

A. **Kingdom MONERA** includes microscopic, single celled organisms with cell wall, no proper nucleus e.g. All bacteria.

B. **Kingdom PROTOCTISTA (PROTISTA)** includes single celled organisms with well formed nucleus e.g. Amoeba, malarial parasite, *Chlamydomonas.* (Fig. 19.8)

C. **Kingdom FUNGI** includes multicellular or many celled organisnms. The body is made of network (mycelium) of fine threads called hyphae. Fungi feed on dead decaying matter (saprotrophs) eg. Mushroom, yeast, bread mould.

Fig. 19.8 Chlamydomonas

D. **Kingdom PLANTAE** includes:

- Multicellular eukaryotes with

- cellulose cell wall and chlorophyll present in their cells
- Autotrophs and thus carry out photosynthesis.

E. Kingdom ANIMALIA includes organisms with the following characteristics.

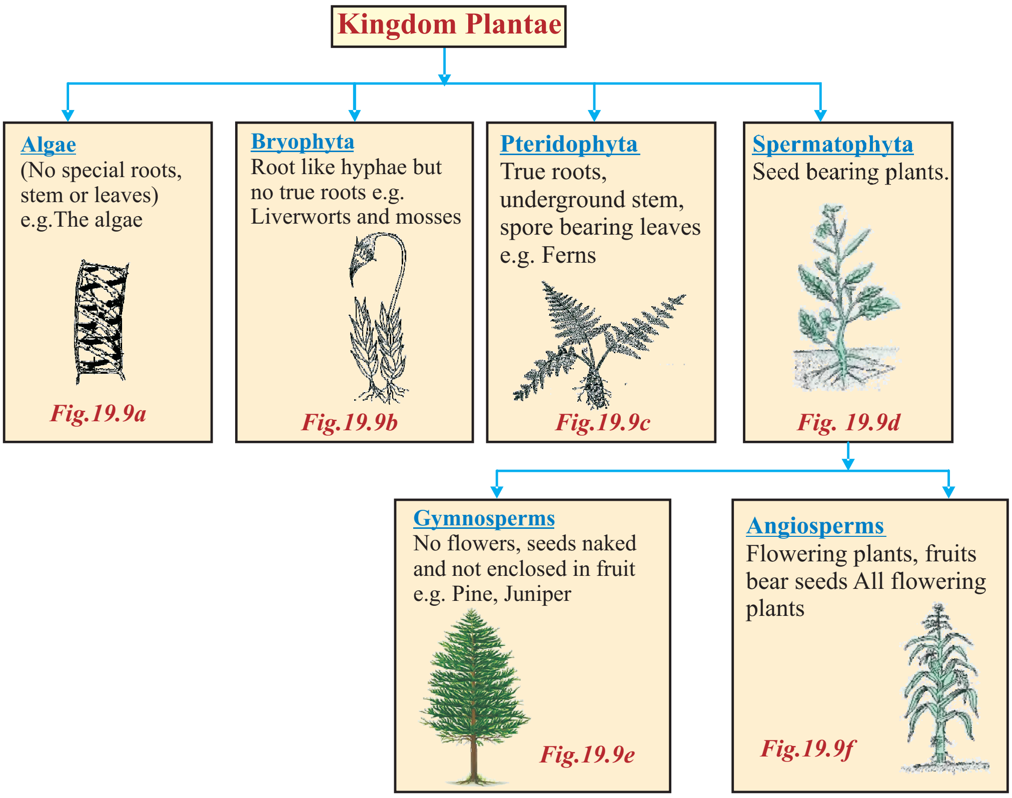
- Multicellular, eukaryotes.
- Hetrotrophic so feed on plants or other animals
- Possess special organs for locomotion or movement from one place to another.
- Possess nervous system with sense organs.

Classification of Plants

Kingdom Plantae is divided into the following divisions.

Classification of Plants

Kingdom Plantae is divided into the following divisions.



Classification of Animals

Kingdom Animalia

Non Chordata (No notochord)

Notochord is a solid rod like tissue in the embryo which becomes the vertebral column or back bone in vertebrates

Chordata (Notochord present)

Phylum Chordata

Phylum Porifera
- Irregular body
- With pores or ostia for entry of water containing oxygen and food.
- Even tiny pieces of sponge can regenerate into full individual
- e.g. Sycon, Sponge

Fig. 19.10a

Phylum Cnidaria
- Tentacles surround mouth.
- Stinging cells present.
- Reproduction by budding or sexual.
- E.g. Hydra, Jellyfish, Corals, Anemones

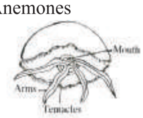


Fig.19.10b

Phylum Platyhelminthes
- Flat body.
- Mostly parasitic worms. Some free living.
- e.g. Tape Worm, Liver fluke, Planaria.

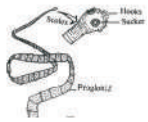


Fig. 19.10c

Phylum Aschelminthes
- Round
- Parasitic/free living
- e.g. Ascaris (round), Pin worms

Fig. 19.10.d

Annelida
- Segmented body
- Excrete by nephridia
- Hermaphrodite (male and female organs in the same individual)
- e.g. Earthworm, leech, Nereis.

Fig. 19.10f

Phylum Arthropoda
- Jointed legs
- Body divided into head, thorax, abdomen
- Body covered with cuticle (layer above skin) made of hard substance called chitin.
- e.g. Insects, spider, scorpions, prawns, crabs.

Fig. 19.10e

Echinodermata
- Flat or globular deep sea animals.
- Have 5 arms or division of body.
- Spiny skin.
- e.g. Star fish,

Fig. 19.10 h

Phylum Mollusca
- Soft, unsegmented body enclosed in hard shell made of calcium carbonate.
- Muscular foot.
- e.g. Oysters, snails, Octopus.

Fig. 19.10.g

PHYLUM CHORDATA

Sub Phylum Vertebrata

Class Chondrichthyes
- Skeleton made of cartilage
- Marine fish
- 7 pairs of gill slits
- e.g. sharks, rays

Fig. 19.10i

Class Osteichthyes
- Bony skeleton
- Found in both sea and fresh water
- Gills for breathing covered by operculum.
- e.g. Rohu, Catla

Fig. 19.10j

Class Amphibia
- Live on land but lay eggs in water where life history is completed.
- Both adapted to both life in water and land.
- Breathe with lungs
- e.g. Salamanders, frogs.

Fig. 1910 k

Class Reptilia
- Land Animals – lay eggs on land
- Body covered with scales
- e.g. Lizard, snake, crocodile, turtle

Fig. 19.10l

Class Aves
- Aerial mode of life
- Light bones
- Beak for feeding
- Wings for flying
- e.g. Birds

Fig. 19.10m

Class Mammalia
- Mammary glands for producing milk for young.
- Body covered with hair
- Hairy skin
- e.g. Cow, mouse, man

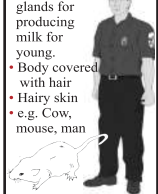


Fig. 19.10n

INTEXT QUESTIONS 19.3

1. Find out the scientific name of the following :

   Frog, cat, China rose, onion.

   You may get them from someone in your neighbourhood who knows Biology or from internet or some Biology book.

2 In the following table, fill in plus (+) for present and minus (-) for absent to show the difference between plants and animals.

Features	Plant	Animal
Chlorophyll		
Muscles		
Nerves		
Locomotion		
Leaves and Roots		
Mouth and Anus		

3. See the pictures of the two arthropods shown below. Mark one similarity and one difference

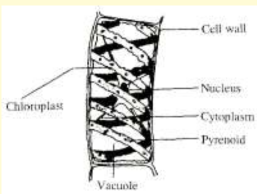
Spider

Honeybee

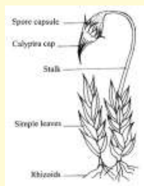
4. Which out of ABCD is

   a. Fungus b. Fern c. Moss d. Alga

A

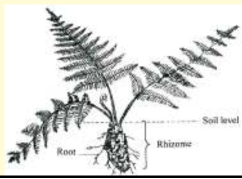


B

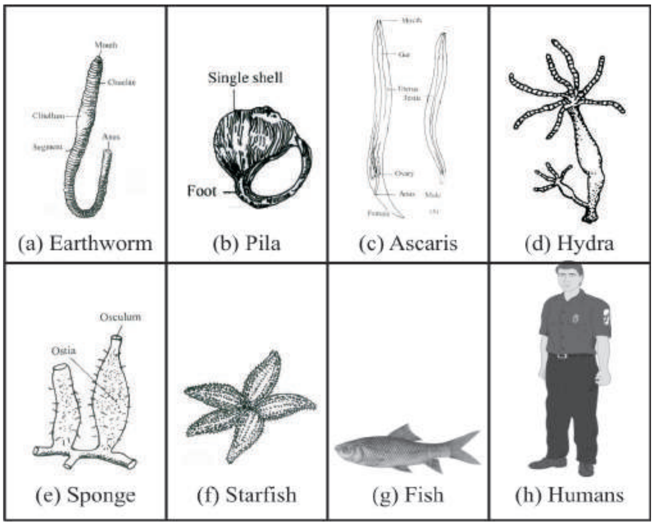


C

D



5.



Write the name of the phylum to which each of the animal shown in the pictures above, belongs.

19.3 CONSERVING BIODIVERSITY

Having got an idea of biodiversity, you must be feeling sad that human activities have put the lives of so many other living beings in jeopardy. Your conscience must be telling you, 'don't all different species have a right to live on earth?' You are right. We must all strive to conserve biodiversity because organisms are interdependent and together maintain a balance in nature. The flora and fauna of our nation is our heritage. We have to conserve our heritage. Let us examine how biodiversity maintains equilibrium and harmony in nature.

19.3.1 Role of biodiversity in maintaining harmony in nature

Biodiversity maintains equilibrium in nature because of which all kinds of organisms are able to survive. The bacteria and fungi recycle organic matter to feed diverse organisms. Algae and plants trap solar energy for photosynthesis and produce food for all living creatures. Insects and bats pollinate flowers. Animals also disperse seeds. Ecosystems such as the forests, deserts, aquatic bodies, wetlands sustain their own typical biodiversity, some of which are part of their unique food chains and food webs.

19.3.2 Conserving Biodiversity

Due to increased land use by humans required for constructing houses and buildings, road and train lines, quarrying and cultivation (agriculture), habitats of plants and animals have been destroyed and biodiversity has been threatened. It is the duty of every human being to protect biodiversity. Conservation keeps ecosystems stable.

Notes

Human populations are also making excessive demands upon environmental resources for food and energy and generating a lot of waste. Many plants have become extinct. Some are close to extinction. Endangered species need to be protected. Fish and mollusc stocks have to be conserved and prevented from overexploitation by humans for food. Animals are poached for fur and ivory. Each year about 10 million birds from the wild are traded some of which die even before reaching the destination. Monkeys and tigers have been killed for making traditional medicines. A ban has been imposed on international trading in animals. You might have heard of Veerappan who used to illegally cut sandalwood trees and sell them.

"Operation Tiger" and "Operation elephants" are projects that have helped in preventing decline in their numbers due to habitat destruction.

19.3.3 What Can You Do?

You can spread awareness regarding the dwindling biodiversity and the necessity of conserving their habitats. You can form a group with your friends and organise painting and chart making competitions, essay writing, declamation and slogan writing contests on conservation of biodiversity and also hold debates on issues of biodiversity conservation in your neighbourhood. You may even write and enact street plays to create awareness. You can use the photographs of birds /trees/animals to make greeting cards.

ACTIVITY 19.5

Collect pictures of 10 trees and animals found only in the biogeographic region to which India belongs.

ACTIVITY 19.6

Take an outline map of India showing different states. Mark the areas where tigers, rhinoceros and elephants are conserved in wild life sanctuaries. If possible, make a trip to a zoo or wild life park or sanctuary or bioreserve park in your neighbourhood. Record what you see.

ACTIVITY 19.7

Write a story, poem or a play, imaging yourself to be a bear or monkey who has been captured from the wild for showing pranks to earn money.

ACTIVITY 19.8

Bird watching is fun. Keep a record of birds that you come across. Use Salim Ali's book, "Birds of India" to identify them.

ACTIVITY 19.9

Find out the common and scientific names of any two bacteria, two protozoans, two fungi, five plants and five animals. To do this you may seek help of someone who know biology or text books in biology or research by surfing on the internet.

WHAT YOU HAVE LEARNT

- An enormous biodiversity occurs on earth.
- Biodiversity is the term given to the variety of organisms that live on earth.
- Biodiversity exists at three levels:
  i) Ecological diversity,
  ii) Species diversity and
  iii) Genetic diversity.
- Since there is an enormous variety of living beings or organisms, their study requires dividing them into groups. Such grouping, based on similarities and differences between organisms is termed classification or systematics. Such grouping expresses evolutionary relationships between organisms as all organisms have resulted through the process of evolution. Study of classification is Taxonomy.
- All organisms are classified into three domains
  a) Archebacteria includes thermophilic bacteria
  b) Eubacteria includes all other bacteria
  c) Eukarya includes organisms other than bacteria

  Further, all organisms are classified into 5 kingdoms which are based on 3 features
  i) Prokaryotes or eukaryotes
  ii) Single celled or multicelled and
  iii) Mode of feeding

- Accordingly absence of well formed nucleus or prokaryotes
  - i) Belong to Kingdom Monera which includes all bacteria.
  - ii) Presence of well formed nucleus or eukaryote but single celled organisms belong to Kingdom Protoctista
  - iii) Multicells feeding on dead decaying matter form Kingdom Fungi, while
  - iv) Photosynthetic organisms that prepare own food constitute Kingdom Plantae and those feeding on others are grouped together into Kingdom Animalia.
- Kingdom Plantae has five divisions namely Algae, Bryophyta, Pteridophyta, and Spermatophyta. Spermatophyta further divided into Gymnospermia and Angiospermia or flowering plants.
- Kingdom Animalia is grouped into non chordates which are further divided into the phyla Porifera, Cnidaria, Platyheminthes, Aschelminthes, Annelida, Arthropoda, Mollusca, and Echinodermata.
- The chordates which have notochord at some stage of life form a single phylum Chordate. Chordate vertebrates are divided into the classes Chondrichthyes (Cartilaginous fish) Osteichthyes (bony fish) Amphibia (Frog, salamander), Reptilia (Lizards, snakes etc.) Aves (Birds) and Mammalia (rats, tigers, horses, humans)

TERMINAL EXERCISES

1. Define biodiversity. Mention its three levels and briefly explain them.
2. What are the global and Indian patterns of biodiversity? What do you mean by a 'hot spot' of diversity?
3. Name the three domains of life and state one distinguishing features of each.
4. Name the five kingdoms of life and state one feature of each of the kingdoms which differs from that of the others.
5. Give an account of the classification of Kingdom Plantae into its divisions. Cite examples.
6. State the difference between chordates and non chordates.
7. Name the phyla to which the following belong: wolf, earthworm, sponge, jelly fish, sparrow, butterfly, starfish, snail, tape worm, round worm
8. To which class of chordates do the following belong? Justify your inclusion into the class by stating any one characteristic feature. Crow, lion, cobra, flying frog, shark, fresh water fish.

9. Write three sentences on why we need to classify and give scientific names to organisms.
10. Why does biodiversity need to be conserved?
11. State three ways by which biodiversity may be conserved?
12. List 10 ways in which organisms help each other survive in nature. What message can you derive from their interdependence?
13. Why have some plants and animals become endangered? State atleast five human activities as causes.
14. Write in a paragraph on "what would happen if living beings did not have scientific names and were not grouped." Mention atleast five consequences.
15. You find some boys pelting stones at a monkey sitting on a tree. Write five sentences which can dissuade those boys.

ANSWERS TO INTEXT QUESTIONS

19.1

1. The various living beings living on earth constitute biodiversity.
2. Species : Group of interbreeding populations

   Biosphere : Livable part of earth

   Ecosystem: an area whose inmates interact with each other and also the physical sorroundings.
3. Ecological diversity, species diversity, genetic diversity.
4. Hot spots are those areas of a country where some typical plants and animals (organisms) are exclusively present.

19.2

1. Classification: Categorising biodiversity into groups based on similarity and differences of organisms.
2. To make study of the enormous diversity possible.
3. Archaea, Prokarya, Eukarya
4. Monera, Protoctista (Protista), Fungi, Plantae, Animalia
5. A=Monera, B=Protoctista, C=Fungi, D=Plantae, E=Animalia

19.3

1. *Rana trigina*, *Felis domestica*, *Hibiscus rosa sinensis*, *Allium cepa*
2. + –, – +, – +, – +, + –, – +
3. Similarity = jointed legs / Head divided into head, thorox and abdomen.

   Differences = No. of pairs of legs
4. A= Algae, B= Moss, C=Fungus, D=Fern
5.

a .	Earthworm	Annelida
b.	Pila	Mollusca
c.	Round worm	Aschehelminthes
d.	Hydra	Cnidaria
e.	Sponge	Porifera
f.	Starfish	Echinodermata
g.	Fish	Chordata
h.	Humans	Chordata

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20

HISTORY OF LIFE ON EARTH

It is a fascinating experience to look-up at the sky on a clear night. Have you not wondered while looking up, when and how our planet earth came into existence? Or how life began and such diverse forms of life that we see around have evolved? These are some of the mysteries that scientists have tried to answer. In this lesson you shall learn how earth was formed, about theories explaining origin and evolution of life forms on this planet. The story will continue upto evolution of humans on earth.

OBJECTIVES

After completing this lesson, you will be able to:

- *describe the physical conditions of primitive earth;*
- *discuss the theory of origin of life (Oparin's theory) and relate it to the changing environment on earth;*
- *become aware of Darwin's major contributions;*
- *modify Darwin's thought to incorporate it in Neo-Darwinism;*
- *identify the levels of organic evolution;*
- *list the evolutionary events in the history of life;*
- *trace stages of human evolution through time.*

20.1 PHYSICAL CONDITIONS OF PRIMITIVE EARTH

The physical conditions on primitive earth were not congenial for life. The earth was extremely hot-a ball of hot gases.

Notes

20.1.1 Solar system and the formation of planet Earth

The universe around us is so enormous that it is difficult even to imagine its dimensions. In a far corner of the Milky Way Galaxy, (one of the billions of galaxies comprising the universe), sits our solar system, like a tiny sand particle on a vast sandy beach. Within this system, Earth, the planet on which we live, is one of the planets revolving around a medium-sized star we call the Sun.

ACTIVITY 20.1

Use any general knowledge book/geography book/science book/book on environment or use the internet to obtain a picture of earth and the other planets in the solar system. Highlight location of earth with a pen and observe it with respect to the sun.

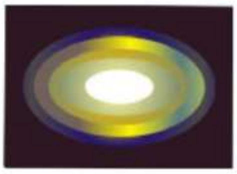
The whole universe formed probably 12 to 14 billion years ago (one billion = 10^9 or 1,000,000,000) as a result of a 'Big Bang' and subsequent expansion. Our solar system came into existence 5-7 GY ago (GY = Giga Year). In its initial stages of formation (4.5 GY) earth was impacted by another planet that caused the spin (that gave us day and night) and tilt (that gave us seasons) of our planet and also led to the formation of moon. For nearly 700 million years (up to 3.8 GY ago), earth experienced frequent and catastrophic bombardment by meteorites of different sizes.

Gradually earth's crust solidified although volcanoes kept on spewing out harmful gases. These gases accumulated and combined to form **methane, ammonia and hydrogen cyanide**. These three gases, all lethal, along with minor gases like carbon dioxide and carbon monoxide, formed the atmosphere of the primitive earth. Thus, the prebiotic (before life arose) atmosphere was so unlike the present one. Note that there was no oxygen then, a gas so essential for nearly all living organisms.

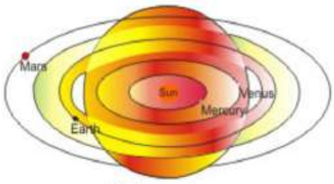
ACTIVITY 20.2

Select 5 friends, each one of you represent one of the 5 stages in the evolution of our planet- earth such as (i) our universe (ii) our galaxy- milky way, (iii) our solar system (iv) planet earth (v) India on this planet. You may dress yourselves in ways that would convey some important information/details about the "characteristics" that each one of you is going to represent. (You can take the help of internet or books or yours elders). Here some graphical representations are given below for your use. You may enlarge the graphics, select the appropriate one for the parts each one of you is playing and display then on your dress. Practice your roles well in the correct sequence and when ready call your other friends and family members and present your show "story of 12-14 billion years."

Universe



Galaxy



Solar system

Earth

At the end you may even arrange for a quiz.

20.2. ORIGIN OF LIFE: WHEN, WHERE AND HOW DID LIFE BEGIN?

There is a general belief that life on earth must have originated, not before 4.0GY and no later than 3.5 GY ago. A more precise estimate is difficult to come up with, since the earliest life, did not leave any evidence in the form of fossils. Some fossils(remains of living beings that once existed on earth) claimed to be cyanobacteria (blue green algae) were found in Australia from rocks dated 3.5 GY. But cyanobacteria are fairly complex and advanced and therefore we may assume that life originated much earlier than 3.5 GY. So, for the present we accept that life originated nearly 3.8 GY ago.

One theory, proposed by the British biologist J. B. S. Haldane and the Russian scientist A. I. Oparin, suggested that life originated in the shallow seas where important organic compounds (such as amino acids), the building blocks of life, were present in high concentrations (forming a 'primordial soup'), thus providing the necessary ingredients for emergence of life. But where did these organic molecules come from? Haldane and Oparin suggested that in the reducing atmosphere (because of the absence of oxygen) of the primitive earth they could have formed from inorganic substances which were washed down with torrential rains as earth cooled and formed a 'primordial soup' in which life originated. Later Stanley Miller and Harold Urey provided experimental support for this hypothesis. Under laboratory conditions they successfully produced amino acids by passing an electric charge (simulating lightning) through a flask containing methane, ammonia and hydrogen in solution. (Fig. 20.1)

Belching: to enie contents violently

('~' means approximately)

GY = Gega Year

On the deep sea floor of the oceans there are sites which have vents or deep cracks through which extremely hot dissolved gases and minerals keep belching out like fountains from the earth's interior. A special group of **archebacteria** thrive near these vents as they are adapted to live at high temperatures exceeding 100°C (and hence their name, *hyperthermophiles*), and derive energy chemosynthetically from the hot gases. Evolutionarily, these microorganisms are very ancient (~ 3.5GY) and probably among the earliest living organisms on earth. These observations lend support to the more recent hypothesis that life evolved around such hydrothermal vents in the oceans.

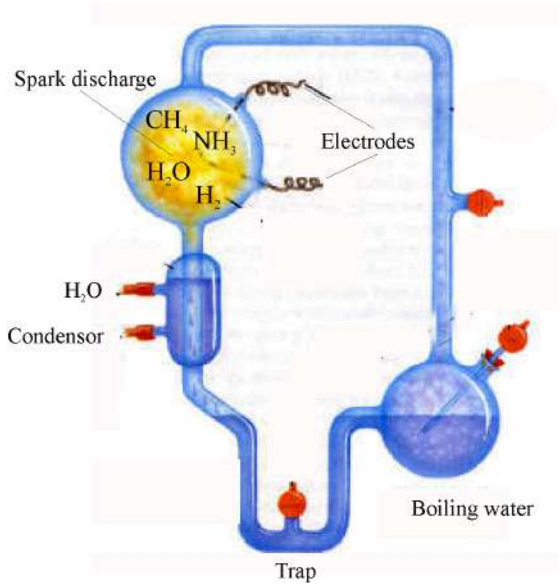


Fig 20.1 *Oparin and Haldane's experiment*

Regardless of where life had begun, how life emerged is still a mystery. Even if we assemble all the organic compounds essential for life we simply cannot produce from them a living organism capable of growing, reproducing and, storing and passing on a hereditary map to its offspring. How was it possible then that life suddenly emerged in a certain 'primordial soup' on the earth 3.8 GY ago? Did life arise from that soup of organic compounds in single step or through a few intermediate stages? Scientists are trying to understand the possible intermediate steps in the origin of life in the hope that one day in the near future they can produce in the laboratory a living form from basic organic molecules.

20.2.1 Diversification of Life

Life on earth started in the form of simplest unicellular (prokaryotic) microorganisms. In course of time these organisms evolved to utilize solar energy through chemical process called *photosynthesis*. You may recall that oxygen is released during this process. It is through the photosynthetic activity of the earliest autotrophs that oxygen built up gradually in the earth's atmosphere making it possible for complex heterotrophic organisms to evolve. For a very long time (nearly 3 GY) after the origin of life, earth had no life forms other than prokaryotes (cells lacking nucleus) comprising different groups of bacteria. There were neither plants nor animals. Eukaryotes (cells with nucleus) probably appeared about a billion years ago, but life was mostly in the form of unicellular (single celled) organisms. Then suddenly, about 600 million years ago, in a geological period called Cambrian, there was a great, almost explosive, diversification of life into multicellular organisms with a variety of body plans and life styles,of all those invertebrates and higher plant groups that you are familiar with. Biologists call this period the '*Cambrian explosion*'. (See box I)

BOX- I The geological time scale

ERA	PERIOD	EPOCH	AGE (Millions of years)	MAJOR EVENT
Cenozoic	Quaternary	Recent		Historic time
		Pleistocene	1.8-0.01	Ice ages; Humans appear
	Tertiary	Pliocene	5-1.8	Ape-like ancestors of humans
		Miocene	23-5	Continued radiation of mammals and angiosperms
		Oligocene	34-23	Origin of most mammalian orders
		Eocene	57-34	Angiosperm dominance and increase in mammalian diversity
		Paleocene	65-57	Major radiation of birds and mammals
Mesozoic	Cretaceous		144- 65	Flowering plants appear Dinosaurs extinct at the end
	Jurassic		208-144	Dinosaur dominance First birds
	Triassic		245-208	Gymnosperm dominance First dinosaurs and mammals
Paleozoic	Permian		286-245	Radiation of reptiles
	Carboniferous		360-286	Extensive vascular tree forests, origin of reptiles
	Devonian		408-360	First amphibians and insects
	Silurian		438-408	Colonization of land by plants
	Ordovician		505-438	First vertebrates (jawless fishes)
	Cambrian		544-505	Origin of most invertebrate phyla
Precambrian			700	Origin of animals
			1,500	Origin of Eukaryotes
			2,500	Oxygenbuild-up in atmosphere
			3,500	Origin of life
			4,500	Origin of Earth

Fossils, the remains of plants, animals and lower living beings provide evidence for the sequence in which different kinds of living organisms came to exist on earth.

When a fossil is collected, the age of the sedimentary rock in which it is found is determined and that age is generally taken as the time in earth's history when that particular animal lived. Paleontologists (Scientists who study fossils)are able to reconstruct the history of life on earth from the fossils collected in sedimentary rocks of different ages. They clearly show that species and higher taxonomic groups (like angiosperms, insects and birds) evolved gradually. (See Box I)

INTEXT QUESTIONS 20.1

1. When did the earth come into existence?

____

2. Why did life not exist on primitive earth?

____

3. What are fossils?

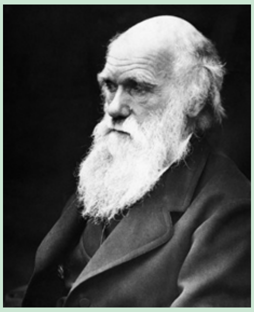
____

4. What is meant by Cambrain explosion?

____

5. From the geological time scale, find out the time in million years ago(mya) when:
   (i) dinosaurs became extinct _______________
   (ii) human evolution began _______________
   (iii) flowering plants became dominant on earth _______________

BOX II
CHARLES DARWIN (1809- 1882)



Charles Darwin is, like Isaac Newton in Physics, a giant in Biology, whose theory of evolution revolutionized our understanding of life and its diversification on earth.

Darwin was born in Shrewsbury, England on February 9, 1809. He developed a passion for nature from early childhood, a trait he probably inherited from his grandfather Erasmus Darwin. His father wanted him to study medicine at Edinburgh but Darwin did not have the aptitude for it. He also did not pursue studies to become a cleric, his father's second choice. Darwin was offered the position of a naturalist on board the ship HMS Beagle which he accepted with excitement and enthusiasm.

The voyage on HMS Beagle was a major turning point in Darwin's life. During the five years (1831-1836) of its voyage he discovered rare fossils in Andes Mountains, collected fascinating animals and plants in Atlantic rain forests of Brazil and made observations on the geographic variation in the famous

Darwin's finches on Galapagos Islands. Darwin gained from all these experiences valuable insights and scientific support for the theory of evolution he was formulating.

Upon return to England, Darwin started accumulating more scientific material in support of his theory of evolution through a mechanism that he called **natural selection**. Darwin's famous book on "Origin of Species" was published in 1859.

Darwin died in 1882 at the age of 73. He was given state funeral and was buried in Westminster Abbey next to the grave of Isaac Newton.

Scientists around the world commemorated Darwin in 2009 by celebrating his birth bicentennial and the 150^{th} anniversary of the publication of his famous book on the 'Origin of Species'.

20.3.1 Diversity of Life Resulted from Evolution

When we explore nature, we observe that

1. There is so much diversity of microbes, plants and animals in the biosphere of our planet.
2. Many animals and plants share common features. We humans are similar to rats, horses, elephants and tigers in possessing hair and mammary glands. Further, we share features like vertebral column with birds, snakes, frogs and fishes. In fact, all living organisms have so many characteristics in common, including DNA, the hereditary molecule.
3. There is so much variation even among individuals of the same species. You can easily notice that all your classmates are not alike; they differ from each other in features like height, facial expressions and skin pigmentation. Likewise, individuals in a school of fish, tomato plants in a vegetable garden, *Aedes* mosquitoes in a water tank, they all show variation in some feature or the other.

These three observations lead us to ask important questions. How and why did such huge diversity of life forms arise? Were the diverse life forms present from the beginning of earth's history or did they arise gradually over a period of time? Why do even remotely related organisms have so many features in common? Is it possible because they all came from a single ancestor? Why is there so much variation within any single species?

ACTIVITY 20.3

Collect the pictures of a plant, any animal and a human being from old news paper or magazines. Paste the pictures and note in the table shown below 3 features in which they are similar and three features in which they differ.

Living being	*Similarity*	*Difference*
	1.	1.
	2.	2.
	3.	3.

ACTIVITY 20.4

Note the eye colour, hair colour, earlobes of five of your friends and compare them with regard to the differences. This will give you an idea of variation which is necessary for origin and evolution of new species.

Name	*Eye colour*	*Hair colour*	*Ear lobes*
Rohan			
Mary			
Salim			

20.3.2 Darwin's Theory of Evolution- Salient Points

Darwin made important observations and drew inferences from them, which helped him in developing his theory of evolution.

The commonness of many features from anatomical to molecular is a clear indication that all organisms evolved from a common ancestor. Darwin concluded that living forms were not created but evolved by descent with modification from ancestral forms going back all the way to the earliest life more than 3.5 billion years ago.

Darwin's next question that needed an answer was-"What is the mechanism by which the origin of species by descent with modification could take place?"

Darwin suggested two very important points with regard to evolution.

(1) All living beings are related through ancestry.

(2) The mechanism which causes diversification of species from ancestors is '**Natural Selection**'.

Darwin made four important observations on his travel on the ship HMS Beagle. (See Box II)

1. All organisms tend to produce **more offspring** than can possibly survive. (e.g. only a few frog's eggs survive and become frogs).
2. In fact, population numbers tends to remain **fairly constant** over long periods of time.
3. Also, organisms in a species show **wide variation** in characteristics.
4. **Some** of the variations are **inherited**, and so **passed on to the next generation**.

From the above mentioned observations Darwin made these two following deductions:

1. Since most offspring do not survive, all organisms must be going through a **struggle for survival, being eaten, suffering from disease** and **competition. The struggle for existence** cause large number of individuals to die.
2. The ones who have characteristics that allow them **to survive and reproduce** better (i.e. possess most useful **adaptations** for surviving in the environment) **will pass on these characteristics** to their offspring. In other words, Nature selects the fittest individuals of the population. Natural Selection is the same as the famous phrase "**survival of the fittest**" coined by Herbert Spencer. Organisms with slightly less survival value will probably perish first, leaving the **fittest** to pass on their **genes** to the next generation.

To sum up, therefore, the best adapted individuals were selected by nature to survive and leave offspring for the next generation. Darwin called this mechanism **Natural Selection.**

In Darwin's time it could not be demonstrated that Natural Selection was the mechanism by which organisms evolved, but later scientists were able to find support for Darwin's theory in nature as well as in laboratory experiments.

ACTIVITY 20.5

Read carefully Box III and justify why many grand parents tell grandchildren that they slept comfortably in the open because there were no mosquitoes and wonder how mosquitoes have reappeared and it is impossible to sit outside after sun down.

20.3.3 Neo-Darwinism

Although Darwin talked about heritable variation, he did not know exactly how heritable characters arose and were passed on from one generation to another. This is because Darwin was not aware of the principles of genetics developed by Mendel a few years before the publication of his book '**Origin of Species'**. Incorporation of Mendelian genetics into Darwinian theory later by evolutionary biologists led to the emergence of **Neo-Darwinism**. Further refinements in the light of advances in population genetics and other areas of biology led to the modern synthetic theory of evolution. It is to Darwin's credit that his basic theory of evolution by natural selection finds support even in the most recent developments in molecular biology. Read **Box III to** learn how natural selection acts on variation to produce new species. Also see figure 20.2

BOX-III

Natural Selection in Action

Although Darwin and many scientists of his time were convinced that natural selection is the right mechanism by which species evolve, they could not prove it experimentally or otherwise. It was felt that since any visible modification in a species evolves slowly over a long time, the effects of natural selection cannot be demonstrated easily. But, now we know that it can certainly be demonstrated, as you can see from the following examples:

1. Industrial melanism in peppered moth (*Biston betularia*) (see Fig.20.2)

***Fig: 20.2a** The* typica *(t) and* carbonaria *(c) forms of* Biston betularia *on the light-coloured trunk of a birch tree*

***20.2 b.** The* typica *(t) and* carbonaria *(c) forms of* Biston betularia *on the soot-darkened trunk of a birch tree*

Peppered moth is a common moth in England and it occurs in two varieties- a light-coloured variety called *typica* and a dark-coloured *carbonaria*. When these moths rest on the light-coloured trunks of trees, the *typica* moths get nicely camouflaged and cannot be spotted by birds that catch and eat them. But the *carbonaria* moths being dark against the light background of the bark stand out and are be easily located by the birds and captured. Because of this, the *carbonaria* moths suffered more predation and therefore always remained in very low numbers in the population. Then the industrial revolution in England in the mid 19^{th} century brought in many coal-based industries and the resulting soot started depositing on the trunks of trees on the countryside. Soon after, scientists noticed that the numbers of *typica* moths started going down drastically while those of the *carbonaria* forms increased.

How did it happen? The soot deposits made the bark black and against the dark background, the *carbonaria* forms now had the advantage of camouflage whereas the *typica* moths became more and more vulnerable to bird predation. Consequently, the *carbonaria* form increased in numbers while *typica* numbers decreased. This is natural selection in action. In the industrialized England the dark *carbonaria* variety of the moth had the selective advantage because they escaped from bird predation more often and lived to leave more offspring for the next generation. Only the best adapted live and leave their genes in the next generation.

2. Evolution of insecticide-resistant mosquitoes

In our desperate efforts to control pest and disease-carrying vector insects, we have been spraying pesticides like DDT in large and larger quantities, but have not been able to eliminate them. When we spray a poisonous chemical on a population of mosquitoes, surely many of them die. But in any population there is variation for resistance and a few genetically resistant individuals survive the spraying. They breed and produce resistant offspring. In the next generation the proportion of pesticide-resistant individuals is higher. As spraying practice continues, the entire population becomes resistant in a few generations and thus a genetically distinct variety of mosquito has evolved on whom DDT has no effect.

INTEXT QUESTIONS 20.2

1. Who is Charles Darwin? Name his famous book on natural selection.

2. Mention his two major contributions.

Notes

3. What is the function of Natural Selection?

____

4. What is meant by Neo Darwinism?

____

5. Name the evolutionary mechanism that causes organisms to evolve.

____

20.4 LEVELS OF ORGANIC EVOLUTION

With progress in various fields of Biology, the theory of evolution by Natural Selection became more and more acceptable.

The unit of evolution, in the modern synthetic theory of evolution, is the **population**. It is the population which evolves and not the individual. **Variation** occurs at the genetic level through mutation and sexual reproduction in the "gene pool" of the population (gene pool means all the different genes in a population of individuals). Natural Selection causes **greater reproduction of the variant genes having adaptive advantage.**

Evolution at the level of the hereditary material or genes that is the gene pool of a population is termed **microevolution. Populations of a species differ due to microevolution**. **Macroevolution or adaptive radiation** is the evolution and diversification at the level of species and genera. eg Dinosaurs evolved as runners, fliers, swimmers due to macroevolution or adaptative radiation.

20.5 MAJOR EVENTS IN THE HISTORY OF LIFE

As we mentioned earlier, all the different life forms that we see on earth now evolved only gradually. Radiometric dating of geological (earths') strata and detailed study of the fossils found in them help us in reading important 'chapters' in the history of life on earth since its origin 4.5 billion years ago. Geologists have given names to different periods of this history (see Box I). You may recall that microscopic, unicellular prokaryotes were the exclusive life forms on earth for nearly three billion years. Dinosaurs ruled the earth for nearly 150 million years and became extinct 65 million years ago. Recall from sub-section 20.2.3, the appearance of eukaryotes and the Cambrian explosion. If you could have traveled 200 million years back in earth's history, you would have found neither birds nor flowering plants anywhere on earth! When did we humans arrive on this planet? Just 2 million years back (see the box on geological time scale)! If you consider the 24 hours geological clock with the origin of life set at **midnight, we can say that humans have come on this planet just less than a minute ago**

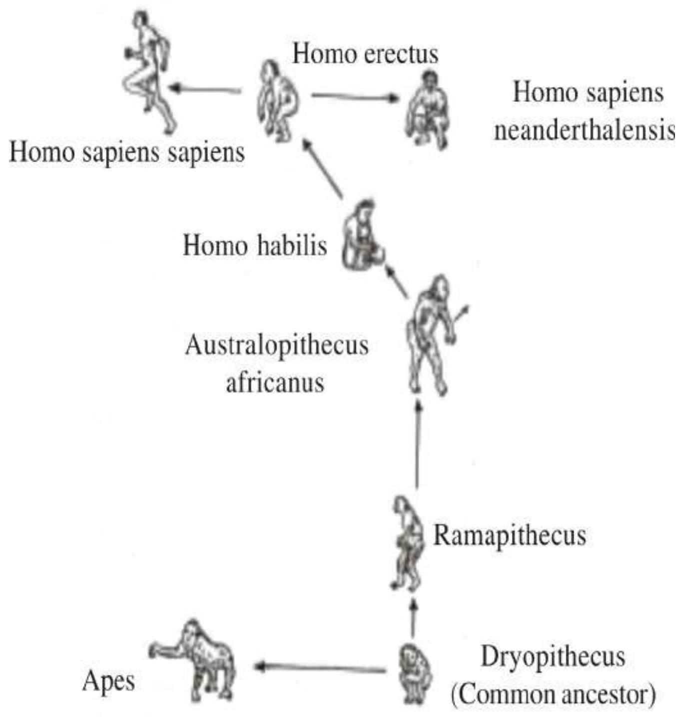
20.6 STAGES OF HUMAN EVOLUTION

When human evolution began, forests had dwindled because of glaciation (ice age). Much of the land surface was however, still covered by forests. The common ancestors of apes and humans had to come down from trees where they lived and walk on the ground using all four limbs. Recent molecular studies have shown that from common ancestors, evolution of apes (Chimpanzee, gorilla, gibbon and orangutan) and that of humans, diverged about 6 million years ago.

The trends of human evolution are towards (i) bipedal gait or walking on two legs and (ii) acquiring a large brain.

Fossil history reveals that human evolution began approximately 1.5 to 2 million years ago. *Australopithecus* is deemed to be the first human like ancestor. Fossils of an australopithecine named 'Lucy' has been found in African rock deposits. Thereafter, fossils of Homo *erectus* which walked on two legs, were unearthed from many parts of the world.

Next to evolve was *Neanderthal* man and *Cromagnon* man. They were both *Homo sapiens*. Modern man, *Homo sapiens sapiens meaning* the wise one evolved about 50,000 years ago. Since then, biological evolution of humans has perhaps not occurred. But vast steps of cultural evolution has made humans land on the moon!



Evolution of humans showing ancestor common to apes and humans

ACTIVITY 20.6

If you have enjoyed doing activity 2 where you and your friends enacted in the story of "12-14 billions years. You can arrange similar show with the heading "origin and evolution of *Homo sapiens sapiens.*

Some changes is required in graphic.

INTEXT QUESTIONS 20.3

1. When did human evolution begin?

2. Who is 'Lucy'?

3. Write the scientific name of Cro-magnon and Neanderthal man

4. With which group of animals do humans share their immediate ancestors.

5. Name the earliest ancestors of modern day humans.

WHAT YOU HAVE LEARNT

- We live on planet earth which is 4-5 billion years old.
- The earth along with other planets, their satellites, the sun, moon, the many galaxies form the universe.
- A solar system consists of a star in the middle with number of planets orbiting around it.
- Our planet earth is a part of its solar system and the sun is the star around which it revolves.
- Age of our earth is about 4.5 billion years.
- In the beginning, the earth was very hot but gradually the surface of earth cooled to form a hard rock.

- Life originated on earth in the distant past from chemical compounds through a series of chemical changes that occurred in water (chemosynthetic theory) proposed by AI Oparin and Haldane.
- Large molecules like proteins were formed which got together surrounded by membrane to produce the precursors of primitive cell. Thus unicellular organisms, came into being.
- It has, however, not been possible to create a cell in the lab.
- In the geological era called Cambrian, there was a great almost explosive diversification of multicellular organisms of different shapes, sizes and functions. This is known as Cambrian explosion.
- Evolution is formation of complex organisms through change from simple ancestral types over the course of geological time.
- Darwin's two major contributions were the idea of :
  (i) shared ancestry and
  (ii) natural selection as mechanism of evolution.
- According to Darwin, organisms produce more offspring than can survive because environmental resources are limited.
- In the organisms' struggle for existence, those with advantageous (variations) characters survive and reproduce to leave more offspring while the disadvantageous variants are eliminated. This is known as natural selection.
- With progress in genetics sources of variations were discovered and Darwin's original theory of natural selection was modified as Neo-Darwinism or modern synthetic theory.
- From the time of origin of earth (4.5 billion years ago) to the present, the entire period is divided into different eras: Precambrian, Paleozoic, Mesozoic, and Cenozoic.
- Major events of evolution were: Cambrian explosion and advent of mammals in the Cretaceous era.
- Human evolution began approximately 1.5 million years ago and main stages were *Australopithecus, Homo erectus* and *Homo sapiens.*

TERMINAL EXERCISES

1. What were the primitive conditions on earth. Tell your friend/cousin/ colleague. Then ask your friend to name the gas which was absent without which today no life can exist.
2. What are the main points of Oparins' theory of Origin of life? Make a five point quiz on it.
3. Mention Darwin's two major contributions to evolutionary ideas.

4. Write a note on NeoDarwinism.
5. List the five major events during geological time period beginning from origin of life. You may begin with origin of animals.
6. State major trends and stages of human evolution. Do you think humans are still evolving? Write five sentences to justify your response.
7. Earlier groups of animals became extinct due to natural happenings. Today, how is it that wild animals have become endangered and are heading towards extinction.
8. Write a ten sentences conversation between your father and yourself justifying the need for conservation of animals living in our forest.

ANSWER TO INTEXT QUESTIONS

20.1

1. 4.5 to 5 billion years ago.
2. Too hot and only certain gases present and reducing atmosphere.
3. Remains of organisms who lived in the past.
4. The time 600 millions years ago when sudden formation of different groups of invertebrates on the earth took place.
5. (i) 144-65 mya (ii) 1.5-2 million years ago (mya) (iii) 57-34 mya

20.2

1. Founder of theory of evolution.
2. (i) all organisms related through ancestry
   (ii) Mechanism of evolution is Natural Selection
3. Fittest individuals in a population survive and reproduce to leave the fit genes in the next generation.
4. Darwin's theory modified in the light of progress in genetics.
5. Natural Selection

20.3

1. 1.5 to 2 million years ago
2. *Australopithecus*
3. *Homo sapiens*
4. Apes
5. Australopithicus

21

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BUILDING BLOCKS OF LIFE — CELL AND TISSUES

When a small wall is built, a number of bricks are arranged end to end. Similarly cells are arranged variously to build the bodies of living beings. In fact, every organism begins life as a single cell which is the fertilized egg. Cells divide to give more cells. Cells form tissues. Tissues make organs. In this lesson, you will learn about structure and functions of the cell, how cells divide, how they collect to make a tissue and also how cells are being used to repair damaged parts through stem cell technology.

OBJECTIVES

After completing this lesson, you will be able to:

- *recognize cell as the structural and fundamental unit of all living organisms and state the cell theory.*
- *Differentiate between prokaryotic and eukaryotic cell;*
- *list the similarities and differences between a plant cell and an animal cell;*
- *describe cell organelles and state their functions;*
- *mention the importance of cell division;*
- *define a tissue and describe in brief the various plant and animal tissues;*
- *give an idea of stem cell technology and its use.*

21.1 CELL- THE STRUCTURAL AND FUNCTIONAL UNIT OF ORGANISMS

The invention of microscope helped in the discovery of the cells. Robert Hooke discovered the cell in 1665. He observed a thin piece of cork under his simple microscope and saw many compartments arranged like the honey comb. He named these compartments **'cells'** (L. cella–compartment).

21.1.1 CELLTHEORYCELLTHEORY

Soon a cell theory was formulated by two German biologists, M J Schleiden (1838) and T Schwann (1839).

The cell theory states that

- Cell is the structural and functional unit of all living beings and bodies of all organisms are composed of cells.
- All new cells arise by division of pre-existing cells.
- The functions of an organism are an outcome of the combined activities and the interactions of the cells that make the organism.

A cell may be defined as **the structural and functional unit of living organisms which is capable of independent existence.**

ACTIVITY 21.1

Write a short paragraph comparing a cell of the body with a brick that forms the house and include the points of the cell theory in the comparison. At the same time think of five points in which a brick differs from a cell of an organism.

21.2 PROKARYOTIC AND EUKARYOTIC CELL

All cells have three basic parts:

- Cell membrabe which limits the cell and gives it shape.
- DNA which may be contained in a nucleus
- Fluid called cytoplasm filling in the space within the cell.

Whether DNA of the cell lies in the cytoplasm or is enclosed within a nuclear membrane, cells may be termed **prokaryotic** are **eukaryotic**.

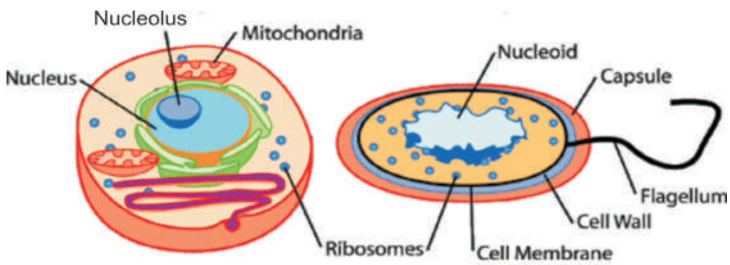
(i) Prokaryotic cell, and (ii) Eukaryotic cell

i. **Prokaryotic cell** ***(Gk. Pro-before; karyon-nucleus)***

These cells do not have a well-organized nucleus. The genetic material is a single molecule of DNA lying in the cytoplasm. Not only is the nuclear membrane absent, cell organelles like mitochondria, lysosomes, endoplasmic reticulum, chloroplast, nucleolus, etc are also not present in prokaryotic cells. Examples: Bacteria and blue-green algae.

(ii) Eukaryotic cell *(Gk. Eu-true; karyon-nucleus)*

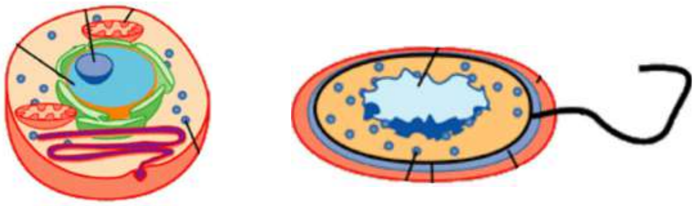
DNA is enclosed in a nuclear membrane forming a nucleus. The genetic material is made of two or more DNA molecules, which are present as a network of chromatin fibres when the cell is not dividing. Membrane-bound organelles, such as mitochondria, endoplasmic reticulum, lysosome, chloroplast, nucleolus, etc. are present within the cytoplasm. Examples: Cells of plants, fungi, protozoa and animals.



Eukaryote **Prokaryote**

ACTIVITY 21.2

Given below are diagrams of cells. Label them as prokaryotic and eukaryotic.



21.3 STRUCTURE OF A TYPICAL EUKARYOTIC CELLSTRUCTURE OF A TYPICAL CELL

Cells within the body of a multicellular organism differ in shape, size and function, but have three basic parts—cell membrane, cytoplasm and nucleus. Generalized ultrastructure of a plant cell and an animal cell are given in fig:21.2.

Study the fig.21.2 and identify the various parts shown in table 21.1

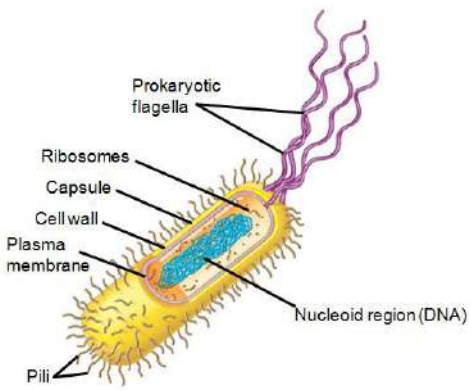


***Fig. 21.2 (a)** Prokaryotic cell*

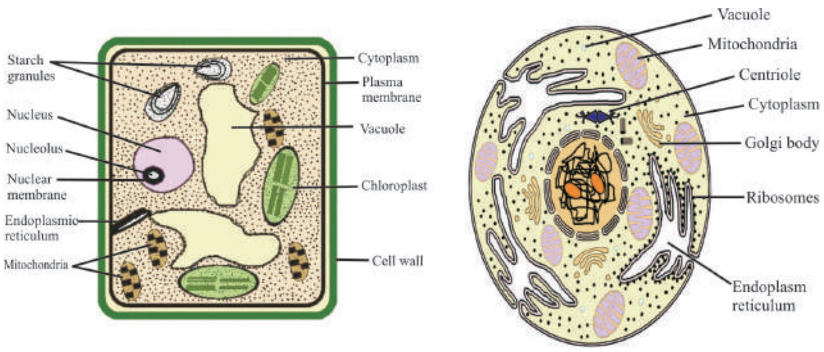
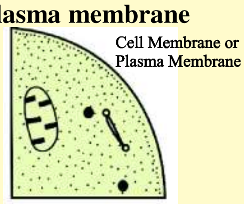
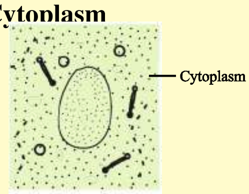
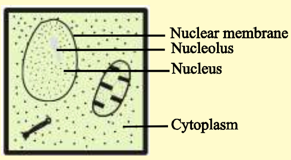
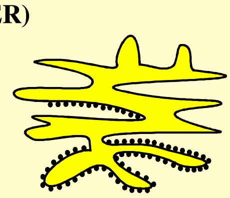
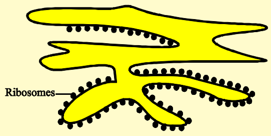
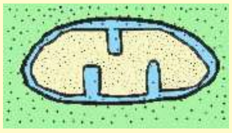
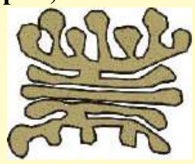
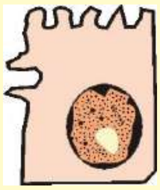
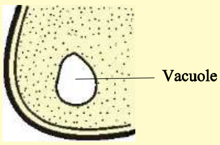


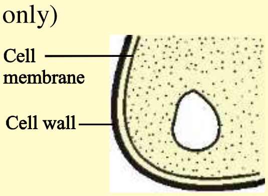
Fig. 21.2 (b)Eukaryotic cells- plant and animal Cell (Diagrammatic)

Table 21.1 Parts common to both animal cells and plant cell

Basic parts	Key features	Functions
Cell Membrane or Plasma membrane 	• A thin delicate membrane enclosing the cell • Forms outermost covering in animal cell and inner to cell wall in plant cell • Selectively permeable.	• Selectively permeable, so allows only selected substances to pass in and out of the cell. • Protects cell from injury. • Maintains shape of cell.
Cytoplasm 	• Translucent, homogeneous, colloidal semi fluid filling the space between plasma membrane and nucleus. • Cell organelles are present in it.	• Helps in manufacture and distribution of substances within the cell and in exchange of materials between different cell organelles.
Nucleus 	• Small ,located in or near the centre of the cytoplasm. • bound by a **nuclear membrane**. • Network of chromosomes present as **chromatin.** • One or more rounded **nucleoli** (*sing*. **Nucleolus**) present in the nucleus.	• Coordinates the activities of the entire cell. • Contains the genetic material or DNA.
Cell organelles found in cytoplasm:		
Endoplasmic reticulum (ER) 	• Irregular network of double membranes in the cytoplasm. • Ribosomes may be present on endoplasmic reticulum.	• Gives rigidity to the cell. • Helps in the synthesis and transport of various proteins and fats within the cell to the outside.

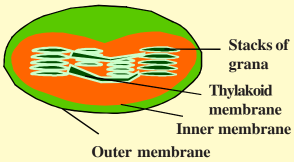
Ribosomes 	• Granules either scattered freely in the cytoplasm or attached to the endoplasmic reticulum.	• Sites for protein synthesis.
Mitochondria 	• Minute sausage shaped or rod shaped granular bodies scattered in the cytoplasm.	• Carry out cellular respiration. • Are called powerhouse of cell because energy gets released and stored in them during respiration.
Golgi bodies (also called **Golgi apparatus** or **Golgi complex**) 	• Stacks of flattened sacs or small vesicles generally located near the nucleus. Similar structures in a plant cell are called **dictyosomes**.	• Help in the secretion and storage of substances such as enzymes, hormones, etc.
Lysosomes 	• Lysosomes are small vesicles or sacs containing digestive enzymes, which destroy and digest the worn out cell parts.	• Help to rapidly destroy and digest damaged cells and their parts –hence these also known as **suicide bags.** They clean up the cell debris.
Parts other than the organelles: The vacuoles and granules are the non-living parts of a cell.		
Vacuoles 	• These are fluid filled membrane- bound spaces. • Large-sized vacuoles in plants and smaller and fewer ones in animals.	• Help in storage of water and other substances.
Granules	• These are small particles, crystals or droplets.	• Granules containing starch, fat, etc. serve as food for the cell.

II. Parts found in Plant Cell only

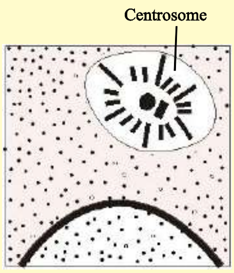
Name of the part and structure	Key features	Functions
Cell wall (plant cell only) 	• Outer, rigid, protective, supportive and semi-transparent covering of a plant cell made of **cellulose**.	• Provides a definite shape and rigidity to the cell. • Protects the plasma membrane and internal structures.

Notes

Change of colour from green to red during the ripening of tomato and chilies is due to the transformation of chloroplasts into chromoplasts. The orange colour of carrot (root) is due to chromoplasts.

Plastids 	• Plastids are of three types—**chloroplasts, chromoplasts** and **leucoplasts**. • Chloroplasts are green. They possess photosynthetic pigment—chlorophyll and carotenoids. • Chromoplasts contain yellow, orange or red coloured pigment. • Leucoplasts are **colourless** plastids.	• Chloroplasts help in photo-synthesis. • Chromoplasts provide colour to the flowers and the fruits. • Leucoplasts help in the storage of food.

III. Parts found in Animal Cell only

Name of the part and structure	Key features	Functions
Centrosome 	• Small body lying above the nucleus. Consists of two small granules called **centrioles**.	• Participates in cell division and help in spindle formation during cell division.

Protoplasm

Protoplasm is the living substance of the cell. The nucleus and cytoplasm together form the protoplasm.

ACTIVITY 21.3

You can make a beautiful model of a plant cell and / or an animal cell. For this, use differently coloured insulation wires and bindis of different size, shape and color. On a piece of thermocol or cardboard make the limiting membranes of the cell and nucleus with the help of wires. Use bindis to depict the organelles.

Note: Instead of bindis and wires you can use other materials like straws, plastercine etc. you may even use cotton and different coloured wool to make the model.or else,enclose within 5"/3" oval loop of wire some white cotton to make a base and use differently coloured wool to make various shapes representing the different organelles.

21.3.1 Differences between a plant and an animal cell

The differences between a plant cell and an animal cell are given in Table 21.2.

Table 21.2 Differences between an animal cell and a plant cell

Feature	Plant cell	Animal cell
Size and Shape	Larger in size and rectangular in shape.	Smaller in size and oval in shape.
Cell wall	Cell wall is made up of cellulose.	Cell wall absent.
Vacuoles	Vacuoles are large. In a mature plant cell, usually a single large central vacuole is present.	Vacuoles are mostly absent or if present are small in size and scattered.
Golgi bodies	Golgi bodies are diffused in the plant cells and are called dictyosomes.	Golgi bodies are well-developed and present near nucleus.
Centrosome	Centrosome and centrioles are absent.	Centrosome and centrioles are present.
Plastids	Present	Absent
Storage of reserve food	Reserve food is stored in the form of starch or oil.	Reserve food is stored in the form of glycogen.

INTEXT QUESTIONS 21.1

1. Mention whether the following statements are true (T) or false (F). Rewrite the wrong statements correctly.
   i) Cell membrane permits inflow and outflow of all molecules. T/F
   ii) Chloroplast and not chlorophyll is an organelle. T/F
   iii) Ribosomes are often called suicide bags. T/F

2. Name the part of the cell which:
   (i) provides rigidity to the plant cell. ______________
   (ii) bounds semi-fluid content of the cell. ______________
   (iii) helps in intra-cellular distribution of molecules, enzymes and nutrients within the cell. ______________

3. Match the following items in Column A with those in Column B.

Column A		Column B	
1.	Master of the cell	**a.**	chloroplast
2.	Powerhouse of the cell	**b.**	endoplasmic reticulum
3.	Protein factories of the cell	**c.**	mitochondria
4.	Kitchen of the cell	**d.**	nucleus
5.	Circulatory system of the cell	**e.**	ribosome

4. All cells of organisms have 3 basic parts. Draw and name them.

5. Explain in your own words the three salient points of the cell theory in one sentence each.

21.4 CELL DIVISION –PRODUCTION OF NEW CELLS

Just as clothes wear out with time, continuously used utensils become weak and crack. So do cells of the body wear out and need to be replaced.

New cells are required not only for replacement of worn out cells, but also for repair of cuts and injuries, for growth and for reproduction. New cells are obtained through cell division. But how does a cell divide to give two new identical cells?

21.4.1 Types of cell division

There are two types of cell division.

a) Mitosis: In mitosis, a cell gives rise to two identical daughter cells. Mitosis is needed for growth, and repair of worn out parts.

b) Meiosis: Cell division involved in production of sex cells which give rise to the egg in female and sperm in male.

21.4.1 Mitosis

Major events of both kinds of cell division are largely similar in both animal and plant cells. We will describe mitosis in an animal cell here .

(i) The sequence of events in mitosis:

Read each step of the cell division and correlate with the Figure 21.3

- The chromosomal material (chromatin network) inside the nucleus condenses to form **chromosomes** (b).
- The nuclear mem-brane disappears. (c)
- The centrosome (in animal cell) divides into two equal parts called centrioles, each of which migrates to opposite sides to orient the spindle which forms in the cytoplasm(c).
- A spindle of fibres appears between the centrioles.

- Each chromosome consists of two chromatids which are held by a centromere. The chromosomes arrange in the middle or equator of the spindle (c).
- Centromere splits. The chromatids (daughter chromosomes) of each chromosome now have their own centromere. The chromatids, now termed chromosomes separate from each other and subsequently, move to the opposite poles of the spindle.(d)
- Chromosomes lose their identity, and turn into a network of chromatin threads at the two poles.(e)
- Nuclear membrane reappears around each of the two new clusters of the chromatin material, formed at the poles.(f)
- In the middle of the cell, at the two sides a furrows appear in the cell membrane. The furrows deepen to divide the parent cell into two new identical daughter cells.

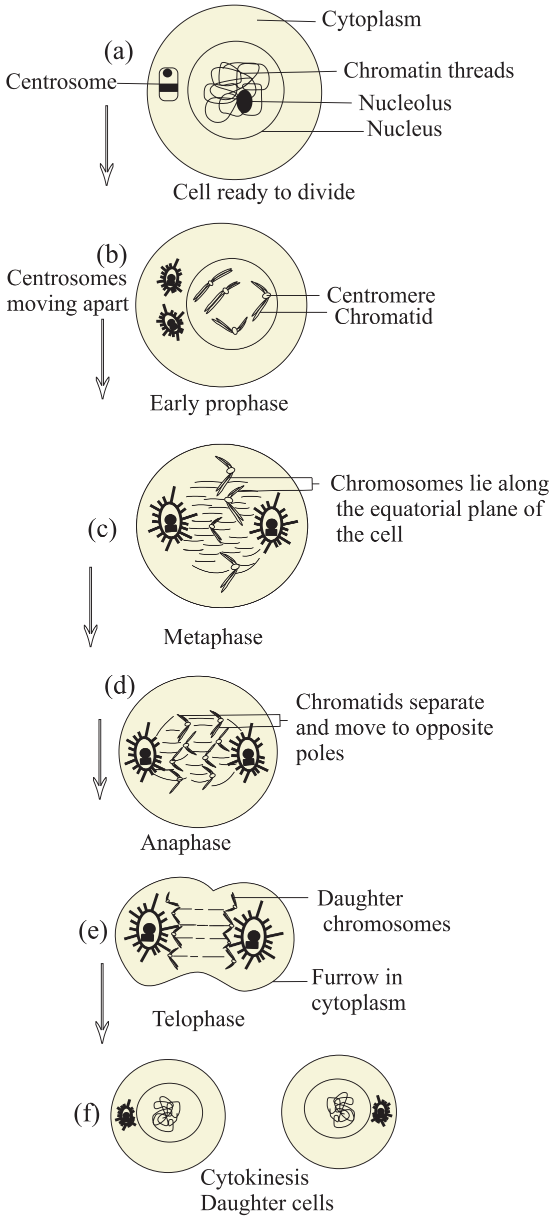


Fig.21.3 Stages of Mitosis

(ii) Two main differences in mitosis in a plant cell and an animal cell

- In plant cells, there is no centrosome but a spindle forms in the cytoplasm.
- Upon the completion of mitosis, the cytoplasm in plant cell does not constrict (furrow is not formed). Instead, a cell plate or a new cell wall is laid down in the cytoplasm in the middle of the cell. It divides the original cell into two daughter cells.

(iii) Significance of mitosis

- The daughter cells receive the same number of chromosomes as the parent cell. In other words **mitosis is an equational division in which the two daughter cells are identical to each other and to their parent cell.**
- Mitosis helps in wound healing and replacement of cells lost during wear and tear.
- It is responsible for the growth of an organism by addition of new cells.
- It is the method of asexual reproduction in single celled organisms like amoeba.

21.4.2 Meiosis

Meiosis is necessary for sexual reproduction. In animals, meiosis takes place in reproductive organs, such as the testis and the ovary, that produce eggs and sperms; and also in flowering plants it occurs in the anthers and ovaryto produce pollen grains and the ovule, respectively.

(i) Stages of meiosis (See figure 21.4 as you read)

Broadly, meiosis is completed in two phases (Fig.21.4).

Phase I: Two cells with half the number of chromosomes in each are formed at the end phase I. this is, therefore, a reduction division.

Phase II: The second division is equational as in mitosis and produces four cells at the end, each with half the number of chromosomes.

Sequence of events during meiosis— first meiotic division

- Chromatin fibres condense into chromosomes.

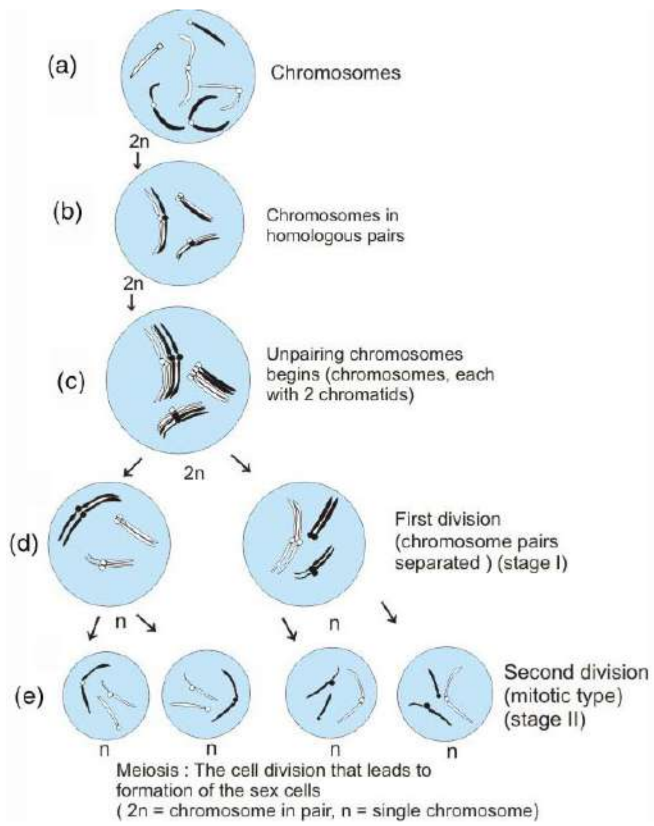


Fig. 21.4 Meiosis -the cell division that leads to formation of egg/sperms

- The chromosomes arrange in matching (or homologous) pairs. A matching pair means one chromosome having been received from the mother and the corresponding one received from the father. Both chromosomes of a pair bear same genes, but not necessarily the same alleles.
- Each chromosome in such a pair is made of two chromatids as duplication of chromosomes occurs before cell division begins. Thus, each pair of chromosomes is now a group of four chromatids.
- The nuclear membrane disappears, the homologous chromosomes which had paired now begin to separate and move apart.
- The cytoplasm divides into two cells, each of which has half the number of chromosomes originally present in the cell. Each chromosome is still made up of two chromatids as centromere has not divided.
- Meiosis II begins. it is exactly like mitosis.
- At the end of meiosis II, four cells form, each with half the number of chromosomes of the parent cell.

(ii) Significance of meiosis

- During meiosis, the number of the chromosomes is halved in the resulting sex cells so that when the male cell and the female cell combine during fertilization, the normal number of chromosomes in the species is restored.
- Also during meiosis, new combination of genes are obtained in the gametes that result from meiosis.

INTEXT QUESTIONS 21.2

1. A seedling grows into a small plant. What kind of division causes this — mitosis or meiosis?

2. Our nails have to be cut occasionally. Which kind of cell division makes the nails long?

3. Name the type of cell division that occurs during the following events:

   i) repair of skin and injury ________________

   ii) formation of eggs and sperms in animals ________________

   iii) increase in the length of stem in plants ________________

4. Out of the following organs where does meiosis occur?

   Hair, liver, testis (male reproductive organ), cheek cell, ovary (female reproductive organ)

21.5 TISSUES

The house runs smoothly when different members of the family and the helpers perform different household work. Similarly different tissues perform different functions.

Various tissues of an organism work in co-ordination with each other in order to perform different processes that occur in the body.

A tissue can be defined as a group of cells similar in size, shape, performing the same function and having a common origin.

Plants are able to produce new tissues throughout their life. Animals can replace only some tissues under certain conditions. Muscles of heart and nervous tissue can never be formed again if damaged.

21.5.1 Plant tissues

Plant tissues are of two types:

- meristematic tissue, and
- permanent tissue.

a) **Meristematic tissue:** Found at the growing points of a plant such as at the tips of the roots, stems and branches. (fig.21.5) The main characteristics of meristematic tissue are as follows:

   - aggregate of living cells, compactly arranged without intercellular spaces,
   - thin-walled and may be rounded, oval, polygonal or rectangular in shape.
   - The cells are small and have a large nucleus
   - They are capable of dividing indefinitely and add new cells to the plant.
   - They are usually found in the apices (open ends)of root and shoot.

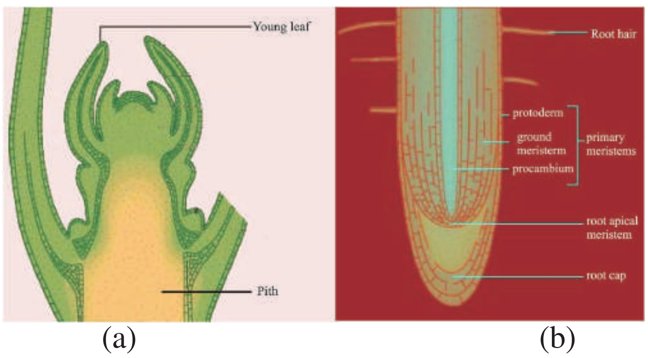


Fig. 21.5 (a) Longitudinal section of stem tip sharing apical meristem ***(b)*** *Meristematic tissue*

ACTIVITY 21.4

Uproot a weed and observe the various apices Draw and label the apices.

b) Permanent tissue: It is made up of cells, which have lost their ability to multiply. The permanent tissues are of three types.

i. **Protective tissue:** This tissue is made of cells with thick walls and occurs on the surface of leaves, stem and roots. (Fig. 21.6a)

ii. **Supporting tissue:** It provides support to various parts of the plant. This tissue includes cells that fill up the interior of potatoes, which store food; found in the leaf stalks etc. (Fig. 21.6b)

iii. **Conducting tissue:** It is also called the **vascular tissue**. It provides passage for the fluids to move up and down in the plant. It is of two types– **xylem** and **phloem** (Fig.21.6). Xylem is located more towards the centre of the stem. It allows water and minerals absorbed from the soil to travel upwards in the plant. **Phloem** serves to conduct the food (sugar) synthesized in the leaves to flow downward and upward so that food reaches all other regions.

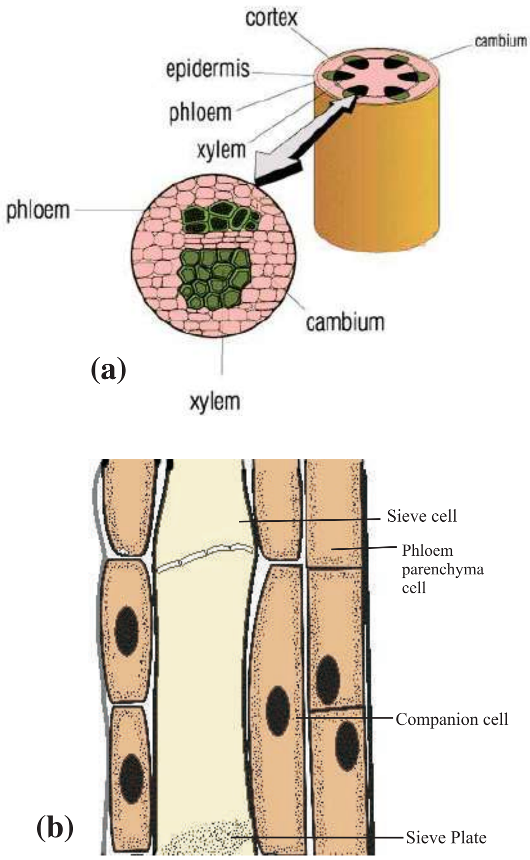


Fig.21.6 Conducting tissues- showing (a) xylem and phloem (b) Phloem cells

21.5.2 Animal Tissues

Animal tissues are grouped under four main categories: **epithelial, connective,** muscular and nervous tissues.

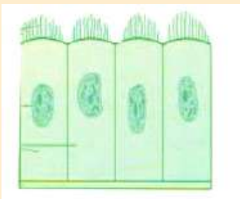
a) Epithelial tissue

- Thin protective layer (or layers) of cells.

- Generally located on the outer surface of the body, on the surface of the internal organs and the lining of the body cavities.

There are three distinct types of epithelial tissues namely Squamous, Cuboidal, Columnar Epithelium (Table 21.3, Fig. 21.7).

Table 21.3 Different types of epithelial tissues

Type	Nature of cells	Example/location	Function
Squamous epithelium  *Fig. 21.7(a)*	Hexagonal or irregular cells with thin walls.	Cells of the outermost layer of skin.	Protection of underlying parts in the body from injury, harmful substances and from drying up
Cuboidal epithelium  *Fig. 21.7(b)*	Thick cuboidal cells.	Some parts of kidney tubules and in glandular ducts.	Secretion
Columnar epithelium  *Fig. 21.7(c)*	Tall-elongated cells At some places have cilia at free ends (**ciliated columnar epithelium**)	Inner lining of the stomach and the intestine. Inner lining of trachea (wind pipe)	Secretion, absorption Lashing movement of cilia pushes the material forward

b) Muscular tissue

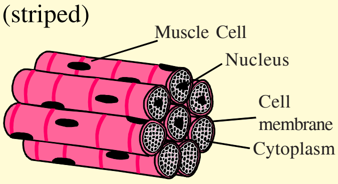
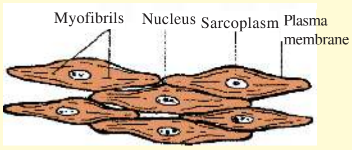
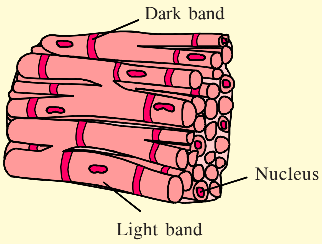
The muscular tissue consists of long, narrow cells called muscle fibres. Muscle fibres are the muscle cells. They are so named because of their long fibre like shape. Muscles bring about movement of body parts and locomotion in organisms.

Types of muscular tissue

- In human beings, three types of muscles are present Striated muscles, Unstriated muscles and Cardiac muscles (Table 21.4 fig. 21.8).

  (a) Striated muscle (b) Unstraited muscle (c) cardiac muscle

Table 21.4 Types of muscular tissues

Type	Nature of muscle	Example/location	Function
Striated or striped Their contraction is under ones control so called voluntary muscles	Multinucleated cells, show bundles of light and dark bands (striped) 	Muscles of arms, legs, face, neck, etc.	Cause movements that are under the control of our will
Unstriped or unstriated Also called smooth muscles as they lack transverse striations. Movement not under our will and hence called involuntary muscles.	Slender tapering cells 	Wall of blood vessels, urinary bladder, uterus, etc. muscles of alimentary canal contract to push that show peristalsis or food down.	Movement of the parts or contents of the part not under the control of our will.
Cardiac muscles (heart muscles) Exclusively present in the heart. They contract and relax rapidly, rhythmically and tirelessly, contracting and relaxing endlessly from early embryonic stage until death.	Striped seen on muscle fibre, short and branched, joined by intercalated discs. 	Heart muscles.	Contract and relax on their own.

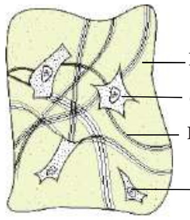
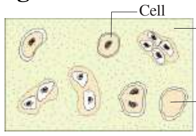
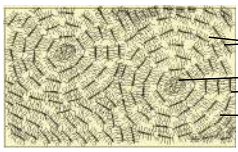
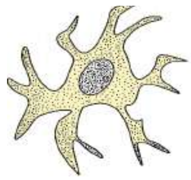
(c) Connective tissue

Connective tissue, as the name suggests, connects organs. Basically, connective tissue has matrix, connective tissue cells and connective tissue fibres. Example of connective tissue are areolar tissue, adipose tissue, cartilage, bone and blood.

Functions of connective tissue:

- It binds different structures with one another, e.g. Tendons bind bone to a muscle; ligaments connect bones.
- forms a supporting framework. e.g. cartilage and bones in the body.
- Adipose connective tissue helps in storage of fats. It also forms shock-proof; cushions around kidneys, ovaries and eyeballs.
- Blood is also a connective tissue.

Table 21.5: Types of connective tissues

Type	Nature of tissue	Example/location	Function
Fibrous tissue 	Cells usually separated from one another by intercellular spaces. This space is filled with solid or liquid material.	Tendon Ligament Adipose (fat) tissue	Connect muscle to bone; connect two bones; packing and binding of most organs; store fat
Cartilage 	Thick: semi-transparent and elastic.	In nose, ears, walls of windpipe and at ends of long bones	Provide support and strength
Bone  	Hard and porous; consists of both living cells and rigid mass of non-living cells.	Ribs, thigh bone, backbone, etc.	Provide support and strength; help in movement
Fluid connective tissue	Contains both cellular and fluid parts	Blood and lymph	Transport of gases and chemical substances; protection from disease- causing germs

NERVOUS TISSUE

Nervous tissue consists of nerve cells or **neurons**. A bundle of nerve fibres or axons of nerve cells forms nerves. A nerve cell or neuron is a structural and functional unit of the nervous system (Fig.21.10). A typical nerve cell consists of the following parts:

- Cell body or cyton
- Dendrons and dendrites

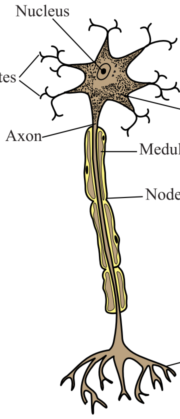


Fig.21.10 A nerve cell or neuron

- Axon

(See also Fig. 23.3 of lesson 23 entitled 'Control and Coordination')

Cell body or cyton has a prominent nucleus and cytoplasm, cell organelles like mitochondria, golgi-bodies, etc. are also present in the cytoplasm.

Several thread like extensions called **dendrons** arise from the cell body. One of them is long and called **axon**. The axon may be or may not be covered by myelin sheath or medullary sheath. This sheath is constricted at intervals which are known as **nodes of Ranvier**.

The space between axon endings of one nerve cell and the cell body or cyton of another nerve cell is the **synapse**.

ACTIVITY 21.5

Collect pictures of, or draw these organs of the body which contain (a) muscular tissue (b) connective tissue (c) epithelial tissue and (d) nervous tissue

21.6 STEM CELL TECHNOLOGY

Stem cells are undifferentiated (unspecialized) cells in our body which have the capacity to undergo mitosis and differentiate into specialized cell types and can redivide to produce more stem cells. Stem cells may be obtained from an embryo, the umbilical cord and bone marrow in adults.

Medical research shows that stem cell therapy can replace tissues damaged due to human disease. A number of adult stem cell therapies already exist, such as bone marrow transplant to treat blood cancer. Stem cells have potential uses as given below:

- To replace damaged tissues
- To study human development
- To test new drugs
- To devise methods of gene therapy

INTEXT QUESTIONS 21.3

1. Name the following:

   (i) The kind of tissues present at the stem tip of a flowering plant.

(ii) The tissue which connects muscle to the bone.

____

(iii) The kind of tissue which forms the inner lining of blood vessels.

____

(iv) Undifferentiated cells which can divide through mitosis and differentiate into specialized cell types.

____

2. Where do you find the following in the human body?

(i) Nodes of Ranvier

____

(ii) Ciliated epithelium

____

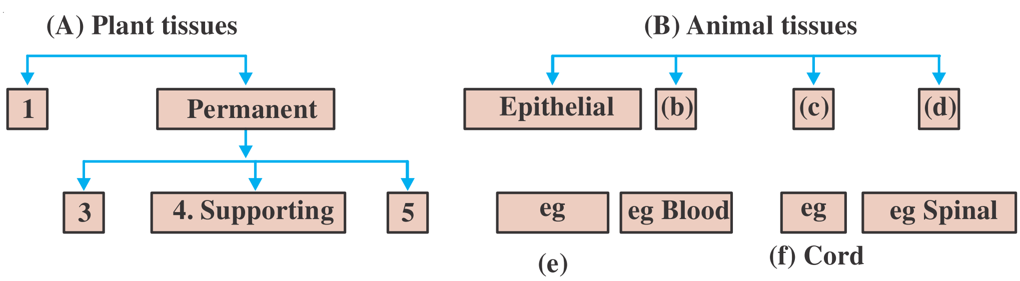
(iii) Smooth muscles

____

(iv) Fluid connective tissue

____

3. In the flow chart given below fill in the blanks



WHAT YOU HAVE LEARNT

- A cell is the structural and functional unit of all living beings.
- Cell membrane is selectively permeable; it allows only selected substances to pass through it.
- Nucleus controls all metabolic and other activities of the cell, hence it is called the master of the cell.
- Endoplasmic reticulum helps in intra-cellular transport, hence it is known as the circulatory system of the cell.

- Ribosomes help in protein synthesis inside the cell. Hence, they are called protein factories of the cell.
- Mitochondria are miniature biochemical factories, where foodstuffs are oxidized and energy is released which is stored in the form of ATP.
- Tissues can be defined as a group of cells more or less alike in size, shape, performing the same function and having a common origin.
- A permanent tissue is a group of cells in which growth is either stopped completely or for the time being.
- In epithelial tissue, cells are closely placed and form a continuous sheet. The cells of epithelial tissue rest on basement membrane.
- The muscular tissue consists of long narrow cells called muscle fibres which are held together by connective tissue.
- Blood and lymph are fluid connective tissue, they flow to all body parts, hence these are called connective tissues.
- Stem cells are biological cells which can divide through mitosis and differentiate into specialized cell types and can self renew to produce more stem cells.

TERMINAL EXERCISES

1. Name the kind of plant tissue found
   (i) at the growing parts of the plant.
   (ii) at the root tip.
   (iii) in vascular bundles.
   (iv) in the inner lining of the intestine.
   (v) Connecting the adjacent muscle fibres.

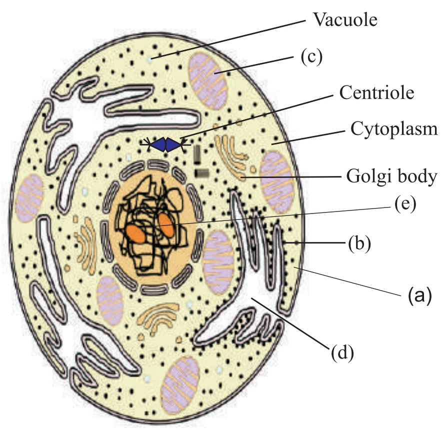
2. State one point of difference between the following (one key difference only).
   (i) Cytoplasm and protoplasm
   (ii) Cell wall and cell membrane
   (iii) Ribosomes and mitochondria
   (iv) Blood and lymph
   (v) Cell and tissue
   (vi) Cartilage and bone
   (vii) Meristematic tissue and permanent tissue

3. Answer these questions.
   (i) Which cell organelle is responsible for the release of energy in the form of ATP?
   (ii) What is the significance of cell membrane?
   (iii) Why are mitochondria known as the 'powerhouse' of the cell?
   (iv) What will happen to a cell if its nucleus is removed?
   (v) Is this statement true or false: Plant cells have chloroplasts, but no mitochondria? Justify your answer.
   (vi) Mention three features found only in plant cells and one found only in animal cells.
   (vii) Name three kinds of permanent tissues found in plants. Write one function of each.
   (viii) What is a protective tissue? Why is epidermis considered as a protective tissue?
   (ix) What is stem cell technology? Give its two uses in disease control.

4. Given below is an incomplete table relating to certain structures found in animal/ plant cell, their location and function. Study the table and then give the appropriate answer in terms of structure, location and function for the blanks numbered from 1 to 9.

Structure	Location	Function
1 ________	2 ________	Photosynthesis
3 ________	Animal cell	Spindle formation during cell division
Cell wall	4 ________	5 ________
6 ________	7 ________	Selectively permeable membrane
Nucleolus	8 ________	9 ________

5. Given alongside is a figure of a cell.
   (i) Is this a plant cell or an animal cell?
   (ii) Name the parts labelled a, b, c, d and e.
   (iii) Which of these parts help(s) in protein synthesis?
   (iv) Which of these parts is also known as the powerhouse of the cell? Give reasons in support of your answer.
   (v) Write the most important function of part labelled 'a'.



ANSWERS TO INTEXT QUESTIONS

21.1

1. (i) F. It allows only selected substances to pass into and out of the cell.
   (ii) T.
   (iii) F. Lysosomes are often called suicide bags.
2. (i) Cell wall
   (ii) Plasma membrane
   (iii) Cytoplasm
3. 1. (d)
   2. (c)
   3. (e)
   4. (a)
   5. (b)
4. Cell showing cell membrane, cytoplasm and nucleus
5. (i) Body of all the living organisms are made of cells
   (ii) New cells arise by division of pre-existing cells
   (iii) Function of the body rebuilt from functions of its cells

21.2

1. Mitosis
2. Mitosis
3. (i) mitosis (ii) Meiosis (iii) Mitosis
4. testis, ovary

21.3

1. (i) Meristematic (ii) Fibrous tissue
   (ii) Unstriped or unstraited muscle (iii) Stem cells
2. (i) Nerve cell
   (ii) Inner lining of stomach/inner lining of intestine/inner lining of trachea (wind pipe).
   (iii) Wall of blood vessels/urinary bladder/uterus
   (iv) Blood and lymph
3. (A) (i) Meristematic, (3) Protective (5) Conducting
   (B) (b) Connective (c) Muscular (d) Nervous (e) Skin (f) Limb

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22

LIFE PROCESSES-1 NURTRITION, TRANSPORTATION, RESPIRATION AND EXCRETION

The activities by which living organisms take in food, derive energy, remove waste from their body and respond to changes in the environment are called **life processes**. In this lesson, you will learn about basic life processes, namely nutrition, respiration, transportation of nutrients and fluids in the body, and excretion.

OBJECTIVES

After completing this lesson, you will be able to:

- *emphasize the need for energy requirement for life processes;*
- *explain the steps in photosynthesis;*
- *appreciate the various modes of heterotrophic nutrition in living organisms;*
- *realize the importance of the process of nutrition in humans, identify nutritional disorders and explain the concept of balanced diet;*
- *outline the need for and steps in the process of respiration;*
- *explain the fundamental aspects of transport of material(food, waste etc.) in plants and animals (e.g. humans);*
- *explain the process of excretion in humans.*

I. NUTRITION

22.1 WHY DO WE NEED FOOD

How do you feel if you do not have food for a day or two? You may feel exhausted and weak. But if you do not get food for a few days, will you survive and grow? You will probably say 'No'. We know that living beings need food to survive. Food provides the essential raw material that our body needs to grow and stay healthy. It also provides energy to carry out various life processes.

In other words, **food** serves to :

- **provide energy to carry out life processes, such as respiration, digestion, excretion etc.**
- **help in growth of the body and repair of worn-out and damaged cells and tissues.**
- **help in the production of enzymes and hormones in the body.**

22.2 NUTRITION

Nutrition is defined as a process by which living beings obtain food, change food into simple absorbable forms and use it to make substances needed by the body.

22.2.1 Types of Nutrition

You already know that only plants can make their own food. Animals eat plants or other animals. There are two main modes of nutrition—autotrophic nutrition and heterotrophic nutrition.

a) Autotrophic nutrition (*autos:* self; *trophos:* food)

The green plants, algae and cetain bacteria manufacture their own food through **photosynthesis**. They are termed **autotrophs** and their mode of nutrition **autotrophic nutrition**.They are the **producers** of the food chain as all organisms depend for food on them.

b) Heterotrophic nutrition (*heteros:* different; *trophos:* food)

The organisms, which depend on other organisms for their food, are called **heterotrophs** and their mode of nutrition is **heterotrophic nutrition.**

Heterotrophic nutrition is of various types

(i) Holozoic nutrition (*Gk: holos* = whole; *zoic* = animal)

Holozoic nutrition includes ingestion, digestion and absorption of food as in *Amoeba*, frogs and human beings.

(ii) Parasitic nutrition: Have you ever been bitten by a head louse or a bed bug or had worms inside the body? These organisms that live on or inside other living organisms, and derive their food from them are called **parasites** and the nutrition is called parasitic nutrition. *Cuscuta* or Dodder plant (Amar bel) is a parasite on green plants.

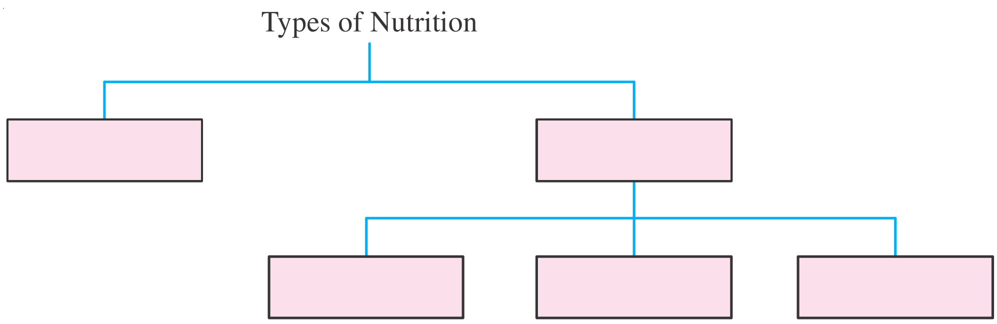
(iii) Saprotrophic nutrition: You must have seen a white cottony growth developing on your wet leather shoes or belts especially when they get wet during rainy days. This is a fungus. The fungus grows and feeds on substances, which were once part of the living organisms, such as stored food, wood, leather and rotten plant products. Some common examples are mushrooms, bread mould, yeast, etc. Organisms that derive their food from dead and decaying **organisms** are called **saprotrophs.** Saprotrophs help in cleaning the environment by decomposing the dead and decaying organic matter.

INTEXT QUESTIONS 22.1

1. Give two examples of autotrophs. Why do you call them so?

2. Why are autotrophs termed 'producers' of food chain?

3. Fill in the blanks in the flow chart given below:



4. The parasitic and saprotrophic modes of nutrition do not need the three processes required by holozoic animals. Which processes are these?

5. Classify the following as saprotrophs or parasites: leech, yeast, head louse, mushroom

22.3 NUTRITION IN PLANTS—PHOTOSYNTHESIS

(Photo :light; synthesis : make)

Photosynthesis is 'a biochemical process by which green plants manufacture their own food using carbon dioxide and water as raw materials in the presence of sunlight and chlorophyll'. **Oxygen is released as a by-product in this process.**

Photosynthesis is the only process by which solar (sun's) energy is converted into chemical energy. The overall equation of photosynthesis is given here.

$$\underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{12H_2O} \longrightarrow \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Water}}{6H_2O} + \underset{\text{Oxygen}}{6O_2\uparrow}$$

22.3.1. Essential raw materials for photosynthesis

i. Chlorophyll

To carry out photosynthesis, plants require as raw materials, carbon dioxide (CO_2), water (H_2O), light and chlorophyll. Light gives energy for photosynthesis. **Photosynthesis takes place in chloroplasts in the cells of leaves**. The green colour of plants is due to chlorophyll. Chlorophyll is in the chloroplasts. It can trap light.

ii. Sunlight

Sunlight is absorbed by chlorophyll as solar energy.

iii. Carbon dioxide and water

Carbon dioxide and water are combined in the chloroplast with the help of a number of enzymes to yield **sugar** which is converted into **starch**. Oxygen formed during photosynthesis diffuses out into the atmosphere through the stomata (Fig.22.1).

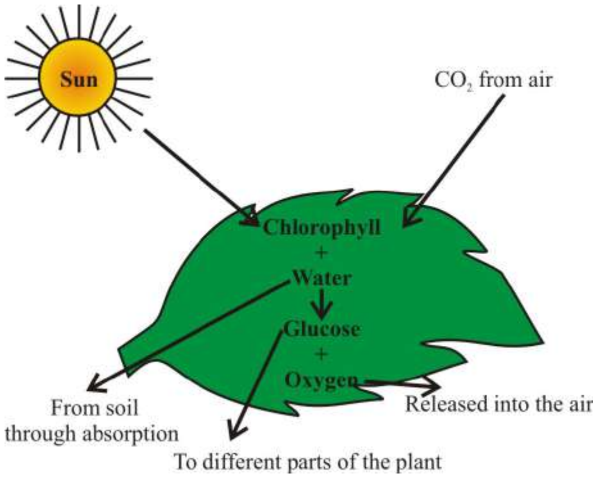


Fig. 22.1 Photosynthesis in a leaf

22.3.2 The mechanism of photosynthesis

Photosynthesis occurs in two steps—(i) the light reaction and (ii) the dark reaction. In the light reaction, light is captured by chloroplast. The reaction occurs in the chloroplasts. In the dark reaction glucose is formed. Dark reaction occurs in chloroplasts. The dark reaction and light reaction occur simultaneously.

What happens to the end products of photosynthesis?

- As seen in fig.22.1, glucose is formed in photosynthesis. It is either used up by the cells or is converted and stored in the form of starch. The other end product oxygen is released into the atmosphere. Energy is released during photosynthesis.

22.3.2 Significance of Photosynthesis

i. Photosynthesis is responsible for providing food to all living beings.

ii. Carbon dioxide produced during respiration by all living beings is used up during photosynthesis and does not accumulate in the atmosphere.

iii. Oxygen released during photosynthesis is used for respiration by living beings.

INTEXT QUESTIONS 22.2

1. In two sentences, justify the term photosynthesis (photo+ synthesis).

____

2. What makes plants look green? What does the green pigment of plants do for them?

____

3. Glucose and starch are two food substances manufactured in the plants. Which one is formed during photosynthesis and in which form is it stored.

____

4. What role does stomata play in photosynthesis?

____

22.4 NUTRITION IN HUMANS

The food that we eat, consists of many different items of food. You may prefer to take more of one type of food and less of another. Does your diet fulfil your body's requirement? Does it satisfy your taste buds or body needs? Think.

For healthy growth and development of the body, you need to eat food that provides enough of all essential nutrients. What does the term nutrient mean?

Nutrients are the chemical substances present in our food which nourish our body.

Nutrients are broadly divided into three groups.

(i) Energy-yielding nutrients—carbohydrates and fats

(ii) Body-building nutrients—proteins and

(iii) Growth-regulating nutrients—vitamins and minerals

a) Carbohydrates

Carbohydrates are the main source of energy in our diet. Carbohydrates may be in the form of sugars, starch or cellulose.

Dietary carbohydrates

Types of Carbohydrates	Source
Sugar	Fruits, milk, sugarcane
Starch	Potato, wheat, rice, sweet potato
Cellulose (Roughage)	Salads and raw vegetables

b) Fats

- Keep the body warm.
- Help in the transport of fat-soluble vitamins
- Some common sources of fats are edible oil, ghee, butter, meat and nuts like groundnuts.
- One gram of fat on oxidation given about 37 kilo joules (9 kilocalorie) of energy.

edible oil, ghee, butter, meat and nuts like groundnuts

c) Proteins

You must have often heard your mother insisting on your having a glass of milk or a bowl of cooked pulses (dals) or an egg. All these are rich in proteins. Growth of body tissues is the main function of proteins.

d) Vitamins

You have often heard your mother saying 'Eat carrots and your eyesight will improve'. This is because carrots contain vitamin A. What are vitamins? Table 22.1 lists certain vitamins. They are necessary for normal growth, and maintenance of the body, and are required in relatively small amounts. Deficiency of a particular vitamin causes disease. Overdose of certain vitamins, such as vitamins A and D, is harmful.

Vitamins may be water-soluble or fat-soluble.

Water-soluble: Vitamins B—complex (B_1, B_2, B_4, B_{12}) and C

Fat-soluble: Vitamins A, D, E and K

Table 22.1: Types of vitamins, their sources, functions and deficiency diseases

Vitamin	Sources	Functions	Deficiency disease
A	Milk, carrots, tomatoes, egg.	keeps eyes and skin healthy.	Night blindness (Poor vision in dim light)
B_1	Milk, peas, cereals, green vegetables, meat	Growth and development	Beri-beri (a disease which affects the nervous system)
B_{12}	Liver, eggs, milk, fish	Form red blood corpuscles	Anaemia (deficiency of red blood corpuscles)
C	Amla, tomatoes, citrus fruits, water chestnut(Singhara)	Healthy growth, strong blood vessels	Scurvy (a disease in which gums swell up and bleed)
D	Sunlight, milk, whole grains and vegetables	Form strong bones and teeth	Rickets (a disease which affects bones in children making them soft and deformed)
E	Vegetable oils, milk, butter, whole grains, vegetables	Protects cell membranes	Affects fertility
K	Green vegetables like spinach and cabbage	Helps in the clotting of blood	Excessive bleeding from wounds

e) Minerals

Minerals such as iron, calcium, sodium, potassium, iodine etc. are required by the body in small quantities. Table 22.2 indicates the sources and functions of some important minerals.

Table 22.2: Some important minerals, their sources and functions

Minerals	Sources	Functions
Iron	Green leafy vegetables, turnip, sprouts, yeast, liver, eggs, meat	Forms haemoglobin,
Calcium	Milk and milk products	Forms strong bones and teeth, and needed for muscle movement, clotting of blood
Potassium	Green and yellow vegetables	For growth and keeping osmotic balance of cells and blood
Iodine	Sea food, iodized salt	Body metabolism, development of brain

f) Water

Water is an important part of our diet. It makes 65-70% of our body weight. Water regulates the body temperature, and provides is a medium for biochemical reactions taking place in the body.

g) Raw vegetables

Raw vegetables help in bowel movement. They form the 'roughage' needed to prevent constipation.

22.4.1 Balanced diet

Now that you are aware of the components of diet, try to analyze your own food intake. Do you include all the food components in your diet?

For healthy growth and development, you need to eat foods that provide all the essential nutrients in the correct proportion. **Eating a variety of foods in proper quantity every day constitutes a balanced diet.** A balanced diet contains adequate amounts of essential nutrients such as carbohydrates, fats, proteins, vitamins, minerals and water. The proportion may depend on age, sex, pregnancy etc.

ACTIVITY 22.1

Make a list of food that you consumed in the last seven days. Tabulate as shown below. Discuss with your parents/friends/siblings if your diet is balanced, if not, work towards making it balanced.

Day	Food taken	Nutrients taken	Items containing the nutrients
1 2 3 4 5 6 7	Lunch	Carbohydrates Protein Fats Vitamins Minerals	
1 2 3 4 5 6 7	Dinner	Carbohydrates Protein Fats Vitamins Minerals	

INTEXT QUESTIONS 22.3

1. Why should raw vegetables and fruits be a regular item in lunch/dinner?

2. I ate one gram of starchy food and you ate one gram of fatty food—who shall get more energy you or me?

3. What is common between vitamins A and D and B and C to group them together?

22.5 DIGESTION-THE PROCESS OF NUTRITION IN HUMAN BEINGS

The food that we eat cannot be used by the cells in the body in the form in which it is eaten. Conversion of complex food material into smaller substances so that it can be absorbed by the cells is called **digestion**. Taking in of food is termed **ingestion**.

22.5.1 The digestive system

Alimentary canal is a long continuous tube constituted made by mouth, pharynx, oesophagus, stomach, small intestine, large intestine, and rectum. The glandular organs, salivary glands, liver and pancreas and the alimentary canal form the digestive system. (Fig.22.2)

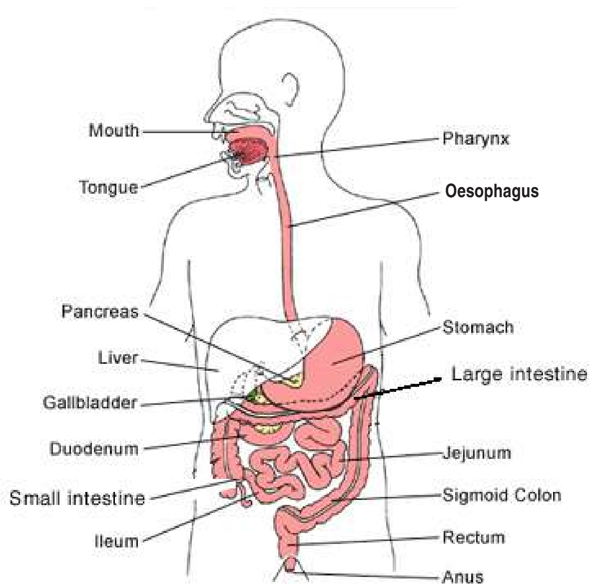


Fig. 22.2 Alimentary canal in human beings

22.5.2 Enzymes

The process of digestion requires enzymes present in the digestive juices secreted by the organs of digestive system. They convert complex substances into simpler ones. **Enzymes are chemicals which speed up chemical reactions taking place in cells**. Almost all enzymes are complex proteins and remain unchanged during the chemical reaction. They can, therefore, be used repeatedly.

22.5.3 Processes involved in nutrition

The entire process of nutrition includes the following steps: ingestion, digestion, absorption, assimilation and egestion.

a) Ingestion and digestion

The process of taking in food through the mouth is called **ing*estio*n**. The digestion of food starts from the mouth and ends in the small intestine.

i. Mouth: Carbohydrates, such as starch, are broken down or digested to form sugar. Saliva contains an enzyme salivary amylase that breaks down starch into sugar. It also helps in lubricating the food and making it easier for swallowing.

ACTIVITY 22.2

Taste a piece of bread or chapatti by biting it. What is the taste? Now chew well with teeth and roll with tongue. What is the taste now and why?

ii. Oesophagus: There is no digestion in this part, also called **gullet** .The oesophagus or the food pipe by the contraction of muscles in its wall pushes the food into the stomach. Muscle movement is termed **peristalsis** and helped food travel down the alimentary canal.

iii. Stomach: The stomach is a highly muscular organ. The gastric glands present in its walls secrete gastric juice containing hydrochloric acid (HCl) and enzymes like **pepsinogen**. HCl activates pepsinogen into **pepsin** and kills bacteria. Proteins are broken into smaller fragments called peptones by the enzyme **pepsin**.

iv. Small intestine: The food moves from the stomach to duodenum, which is the upper part of the small intestine. Emulsification of fat (fat is broken into fat droplets) takes place with the help of the bile juice secreted by the live and stored in gall bladder. **Bile does not have any digestive enzymes** but it creates an alkaline medium which is essential for the action of pancreatic enzymes.

The **pancreatic juice** contains three enzymes.

- **Trypsin**—converts peptones and proteoses to smaller peptides.
- **Amylase**—converts starch into maltose.
- **Lipase**—converts fats into fatty acids and glycerol.

The digestion of proteins into the end products amino acids, carbohydrates into glucose, and fats into fatty acids and glycerol is completed in the small intestine.

The inner surface of the small intestine contains thin finger-like projections called **villi**, which increase the surface area for absorption of digested food into the blood capillaries lining the villi. The blood then carries the absorbed food to different parts of the body and undigested food is pushed into the large intestine.

Jaundice is caused by liver infection

When a person suffers from jaundice, the skin looks pale with a yellowish tint due to large amounts of **bilirubin a bile pigment** in the blood. The urine becomes deep yellow. Jaundice is caused by the Hepatitis virus. The virus is of different types and now there is an injection that provides immunity from the virus. The infection usually comes from infected water.

v. **Large intestine:** This part of the body absorbs water from the undigested food and solid waste is lubricated to form the faeces. The faeces pass on to the lower part of the large intestine, called the rectum, and are thrown out of the body through the anus.

b) Absorption

Blood capillaries in the villi pick up digested food and take it to all cells.

c) Assimilation

The absorbed food supplied to cells is used to release energy and also to build up the cell components. This is called assimilation.

d) Egestion

The process by which the undigested food material or waste is released from the body is called egestion.

ACTIVITY 22.3

Prepare a chart with the figure of alimentary canal and write down one or two main events of digestion occurring in front of each part. For example, in front of the stomach you can write

$$\text{HCl} \longrightarrow \text{Acidic medium}$$

$$\text{Protein} \xrightarrow{\text{Pepsin}} \text{Peptones}$$

It will help you understand and remember.

INTEXT QUESTIONS 22.4

1. Name the enzyme secreted by stomach that converts proteins into peptones.

2. What is the movement of muscles of oesophagus that pushes down food called?

3. In which part of the alimentary canal do the pancreas and liver pour their secretions?

4. Name the enzymes present in the pancreatic juice that digests proteins, carbohydrates and fats.

5. Name the acid that takes part in digestion process.

22.6 DEFICIENCY DISEASES OR NUTRITIONAL DISORDERS

A disease that occurs due to lack of adequate and balanced diet is called **deficiency disease.**

Intake of improper or inadequate diet in human beings is called **malnutrition**. Malnutrition is harmful for children as it retards their mental and physical growth Deficiency diseases due to inadequate nutrition are of three types:

a. Protein Energy Malnutrition (PEM)
b. Mineral deficiency diseases
c. Vitamin deficiency diseases

a) Protein Energy Malnutrition (PEM)

Deficiency of proteins in the diet causes PEM. This is the prime reason why your parents insist that you should drink milk; eat pulses and other sources of proteins. Two diseases caused due to PEM are – **Marasmus** and **Kwashiorkor** (Fig. 22.3a, b).

i. Marasmus

It affects children up to one year of age. This occurs in children deprived of mother's milk. The symptoms of this disease include:

- loss or wasting of muscles,
- body develops loose folds of skin,
- ribs become prominent,

Fig.22.3(a) Child suffering from Marasmus

- body growth and development slows down.

It can be cured by ensuring mother's milk for infants and by having a diet rich in protein, carbohydrates, fats, vitamins and minerals.

ii. Kwashiorkor

Amongst children of age group 1-5 years, protein deficiency causes kwashiorkor. The symptoms of this disease are:

- enlargement of liver due to water retention,
- darkening of the skin with scaly appearance,
- hair becomes reddish-brown,
- legs become thin, and
- retardation of physical and mental growth.

Fig. 22.3(b) Child suffering from Kwashiorkor

Eating a protein-rich diet that consists of milk, meat, groundnut, soyabean, jaggery, etc. can cure this disease.

b) Mineral deficiency diseases

The two common mineral deficiency diseases are – goitre and anaemia.

i. **Goitre:** Caused due to prolonged iodine deficiency which causes enlargement of thyroid gland. Iodized salts and seafood are good sources of iodine. (see figure 23.11 in the lesson-23, Control and Coordination)

ii. **Anaemia:** Iron deficiency causes lesser production of haemoglobin (respiratory pigment), resulting in anaemia. An iron-rich diet consisting of spinach, apple, banana, guava, eggs, groundnuts, etc. can help to cure anaemia.

c) Vitamin deficiency diseases

You have already studied about vitamins and their deficiency diseases in table 22.1.

22.6.3 Food Adulteration

Why do we prefer to buy food products sold in sealed packets and items made by a standard reliable company? A simple answer is that the manufacturer selling its products in sealed packets or brands ensures delivery of good quality product.

Any attempt to mix items of food with cheaper, sub -standard, edible or inedible substances is called food adulteration. Table 22.3 shows adulterants of different food items

Table22. 3: Some food items and their common adulterants

Food item	Common adulterants
Cereals	Straw, husk, stones, inferior quality grains, infected or insect infested grains
Pulses	Straw, kesari dal, inferior quality grains, infected grains, metanil yellow dye
Milk	Starch, water, milk of other animals, extraction of fats, synthetic milk
Edible oils	Mineral oil, argemone oil, artificial colours
Turmeric (haldi)	Starch coloured with chromate or metanil yellow dye
Coriander	Powdered cow/horse dung, saw dust, starch
Black pepper	Dried papaya seeds

ACTIVITY 22.4

Food Adulteration

Take any five food items present in your house eg. pulses, rice, channa, black pepper, wheat, coriander seed etc. look for the various adulterants (if any) present in each of the five food items. Now state whether these adulterants are edible or inedible. Record your observations in a tabular form.

INTEXT QUESTIONS 22.5

1. Give the full form of PEM and name the diseases due to PEM.

2. If the diet continuously lacks in vitamin A, which disease may be caused?

3. Why does our government frequently advertise the necessity of consuming iodised salt?

22.7 TRANSPORTATION

The distribution of food and oxygen to all parts of the body as well as removal of body wastes is performed by a transport system within the body of all living organisms. Our body also secretes many hormones, which have to be carried to their target organs. The flow of fluid (blood or lymph) within the body for transport purposes is termed circulation and the organs for circulation constitute circulatory system.

22.7.1 Transport of Materials in Plants

(i) Transport of water

Roots of plants take up water and minerals from the soil. How does this water move up from roots to leaves for photosynthesis? You have already learnt about conducting tissues of plants – **xylem** and **phloem** in lesson 21.

Tracheids and vessels, which are non-living cells of xylem, transport water picked up by root hairs (Fig.22.4) from soil to the leaves.

The upward movement of water and minerals from soil termed 'ascent of sap' is against gravity and is due to transpiration pull. Transpiration is the process in which a lot of water evaporates (as water vapour) from **stomata**. This evaporation creates a vacuum and pulls up water through the xylem. This is transpiration pull.

(ii) Transport of food material

Sugars and other food molecules synthesized in the leaves are transported to other parts of the plant through phloem. Sieve tubes are living cells of the phloem, which transport food (Fig.22.5). Transport of food material from leaves to other parts of the plant is called **translocation**. This food may then be stored in fruits, stem or roots.

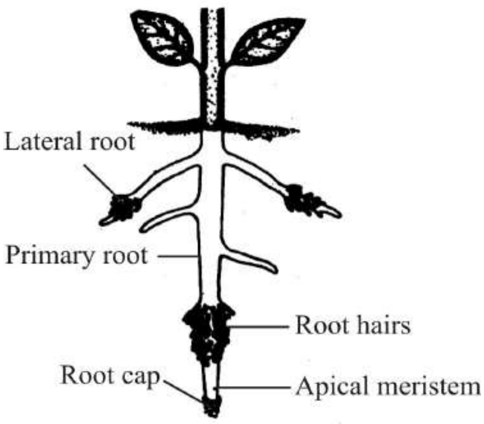


Fig.22.4 Root hairs

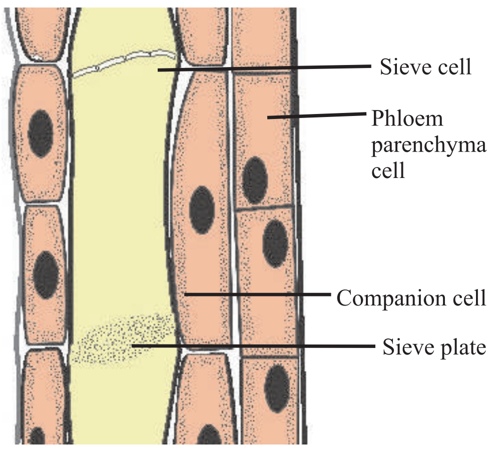


Fig.22.5 Sieve tubes in phloem

22.8 TRANSPORTATION IN HUMAN BEINGS

Human circulatory system consists of

(i) Centrally located muscular pump called **heart**, and

(ii) **Blood vessels**, which are tube-like structures, connected to the heart (Fig.22.6).

Blood vessels are of three kinds:

- **Arteries:** Carry blood from heart to various parts of body.
- **Veins:** Bring blood from various parts of body to the heart.
- **Capillaries:** Thin vessels between the artery and the vein. The capillaries allow the exchange of materials between blood and tissues.

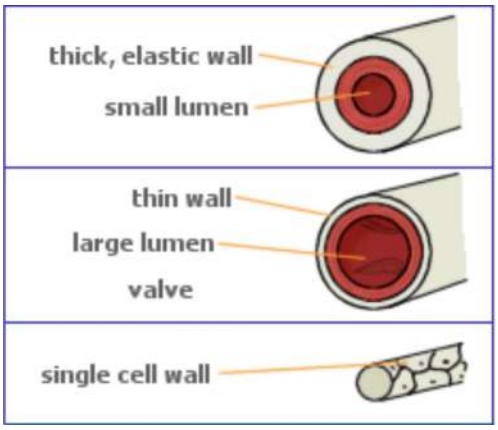


Fig. 22.6 Arteries, veins and capallaries

(iii) Circulating fluid—blood, tissue fluid and lymph

22.8.1 Heart

Heart is a powerful muscular organ lying between lung. It is four-chambered- two (right and left) atria (*sing*. atrium, also called auricles), and two (right and left) ventricles. (Fig. 22.7a).

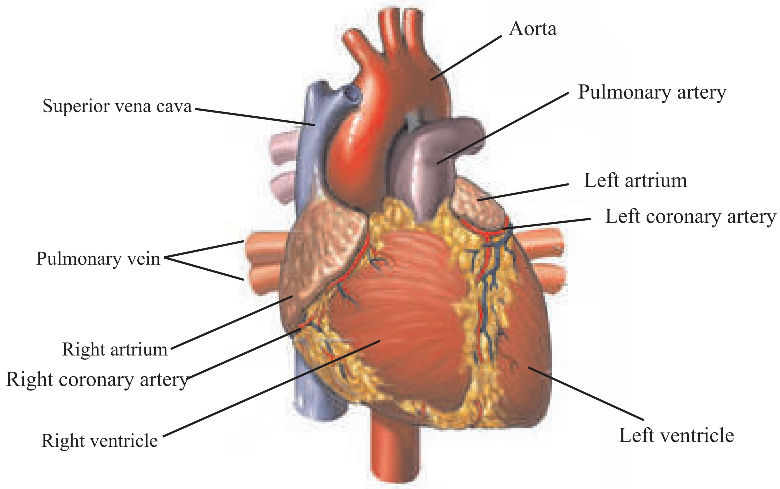


Fig. 22.7(a) The human heart

The heart is made of specialised muscle cells, also called cardiac muscle fibers, which contract and relax all the time without getting tired. The contraction and relaxation follows a rhythm called **heartbeat.** Heart pumps blood into the blood vessels.

Rhythmic heart beat results in the proper transport of substances to the various organs by means of blood. In one minute, normal human heart beats about 72 times. Abnormalities in heartbeat can be seen by taking **ECG** or **Electrocardiogram** (Fig. 22.7b).

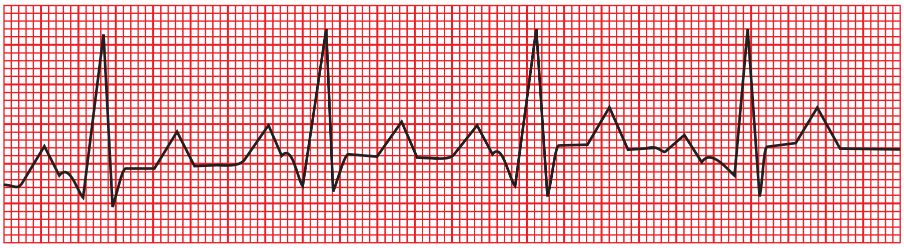


Fig. 22.7ECG or Electrocardiogram

The oxygen laden blood from the left ventricle gets pumped into a large artery called **aorta**. It carries oxygenated blood to all parts of the body. The general plan of human circulatory system is given in Fig 22.8

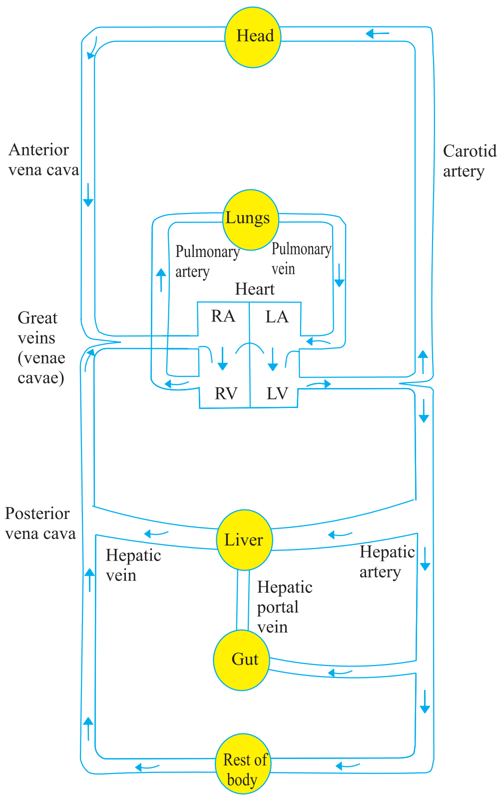


Fig.22.8 General plan of the human circulatory system

ACTIVITY: 22.5

Find out the addresses of three hospitals/ clinics/nursing home nearest your house where treatment for heart diseases is taken up.

You must have noticed that veins bring oxygen depleted and carbon dioxide laden blood to the heart and arteries take oxygen laden blood away from the heart. But here are two exceptions – the pulmonary artery carries carbon dioxide laden blood and the pulmonary vein carries oxygen laden blood.

Blood Pressure

It is the force with which blood pushes against the walls of the arteries. It is generally measured in terms of how high it can push a column of mercury. When ventricles contract, pressure of blood inside the arteries is highest. In a healthy young human being, it is about 120 millimetres of mercury (120 mm Hg). When the ventricles relax, pressure of blood inside the arteries is comparatively less It is about 80 millimetres of Hg (80 mm Hg) in a healthy young man. Thus, a healthy young man has a normal blood pressure of 120 / 80 mm of Hg. The instrument used to measure blood pressure is called **sphygmomanometer.**

Pulse rate

The systemic contraction of the heart can be felt as a jerk in certain arteries like the radial artery in the wrist and neck artery below the jaw which are superficial in position. This is called **arterial pulse. Pulse rate is the same as the rate of heartbeat.**

ACTIVITY 22. 6

Locate and hold the radial artery present in your wrist. Try and count the number of beats in a specified time. It is called 'pulse' and will give you an idea of the number of times your heart beats in a minute.

ACTIVITY 22. 7

Visit the local medical centre and get your pulse rate and blood pressure checked and also that of your family members. Do you find any difference in blood pressure and pulse rate of your family members?

INTEXT QUESTIONS 22.6

1. Why is a system of transportation/circulation necessary for organisms?

2. Which kind of blood vessels are responsible for the exchange of nutrients and respiratory gases between blood and tissues?

3. What is so special about heart that it continues beating without getting fatigued?

22.8.2 Circulatory Medium

Our body has three different types of fluids

- Blood—found in heart and blood vessels (arteries, veins and capillaries)

- Tissue fluid—found in spaces between cells in organs
- Lymph—found in lymph vessels and lymphatic organs (e.g. spleen and tonsils)

Blood

Blood is a connective tissue that circulates throughout the body. It is made up of a fluid medium called **plasma** in which float two types of **blood cells**, called red blood cells, white blood cells and cell fragments called blood platelets. Blood cells are manufactured in the bone marrow. (Fig.22.9)

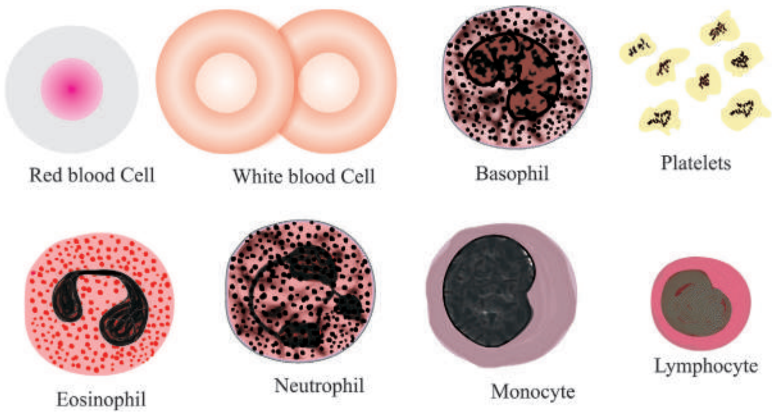


Fig22.9. *Types of blood cells*

(a) Red blood cells (RBC or Erythrocytes)

- These are circular in shape, and contain a red coloured pigment called haemoglobin
- No nucleus is present in RBC
- RBC carry oxygen to tissues and bring back carbon dioxide from tissues

(b) White blood cells (WBC or Leucocytes)

- Since they carry no pigments, they are colourless
- They have irregular shape
- They prevent body from infections by eating up germs or by producing antibodies to fight antigens.

(c) Blood platelets (Thrombocytes)

- These are very small fragments of cells
- They have no nuclei
- They participate in clotting of blood

Functions of blood: Blood carries nutrients, oxygen, carbon dioxide, hormones and waste material to the relevant parts of the body. Some medicines when taken in the body are also distributed through blood.

22.8.3 Blood groups and blood transfusion

You must have heard that blood has to be arranged for a person undergoing a surgery (operation) or in the case of an accident or in case of persons suffering from thallasemia. This arrangement is to replace blood lost from the patient. Injecting blood into the body from outside is called **blood transfusion**. Blood transfusion is successful only when the blood of **donor** (who gives blood) and of the **recipient** (who receives blood) match. Unmatched blood transfusion causes agglutination (clumping together) of red cells due to which the recipient may even die.

On the basis of types of proteins present in the blood, a system of blood groups known as **ABO system** having four blood groups named A, B, AB and O is recognized in human blood (Table22.4). **Antigens** present on membrane of RBC of transfused blood is counteracted by **antibodies** present in the plasma of recipient.

Table 22. 4: Human blood groups and their compatibility

Blood group	Antigens on RBC	Antibodies in plasma	Can donate blood to	Can receive blood from
A	A	b	A, AB	A, O
B	B	a	B, AB	B, O
AB	AB	None	AB	A, B, AB,O
O	None	a, b	A, B, AB, O	O

The persons with blood group O can donate blood to all and so ‘O’ group is called **universal donor** and AB group can receive blood from donors of all blood groups and is called **universal recipient**. Can you say why?

22.8.4 Lympthatic system

Lymph is also a circulatory fluid and flows in the lymph vessels.

- It is light yellow in colour.
- It always flows only in one direction from tissues to heart.
- Cells called lymphocytes present in lymph eat up germs and prevent body from infections.
- It returns proteins and fluids from circulation to tissues.

22.8.5 Disorders related to circulatory system

1. **Heart attack**: Like all other organs, heart also needs nutrients and oxygen. When arteries supplying the heart become thick due to age or faulty diet

consisting of excessive fatty food, muscle cells of the heart cannot beat in the proper rhythm. Heart attack occurs which can be detected in an abnormal ECG. Immediate medical attention is then required.

2. **Anemia:** When haemoglobin level falls below a certain point, the condition is called anemia. It makes the person weak and look pale and inactive. Iron in the diet helps remove anemia.

3. **Leukemia:** This is blood cancer. The bone narrow makes excessive WBCs and few RBCs.

4. **Hypertension:** It is another term for high blood pressure and leads to headache, dizziness and fatigue. Normal blood pressure is 120/80. Proper diet, exercise, medicines and tension free mind helps to cure high blood pressure.

INTEXT QUESTIONS 22.7

1. Which blood cells would you categorise as (i) transporters of oxygen and carbon-dioxide (ii) enemies of germs that enter the body.

2. Sheena has blood group O+ and Veena has AB+. Whose blood would be useful if it has to be transfused into an accident victim of unknown blood group and why?

3. What makes RBC s look red? What is the role of this pigment?

4. In which function is lymph similar to blood?

22.9 RESPIRATION

We can live without food for s everal days but we cannot live without breathing even for a short while. Breathing provides oxygen to the cells of our body for oxidation of food in order to generate energy for various activities.

22.9.1 Respiration in Plants

Plants do not have any special respiratory organs. Roots take up oxygen from air trapped in the soil by means of root hairs. Root hairs are embedded in the soil. Oxygen in the air surrounding them diffuses into the root hair and from there into the roots. Carbon dioxide given out, similarly, diffuses out through roots. Stomata in leaves opens to let in oxygen and release carbon dioxide.

In the older parts of roots or bark of woody plants, tiny openings called **lenticels** are present. It is through these lenticels that oxygen reaches the inner living tissues and carbon dioxide moves out.

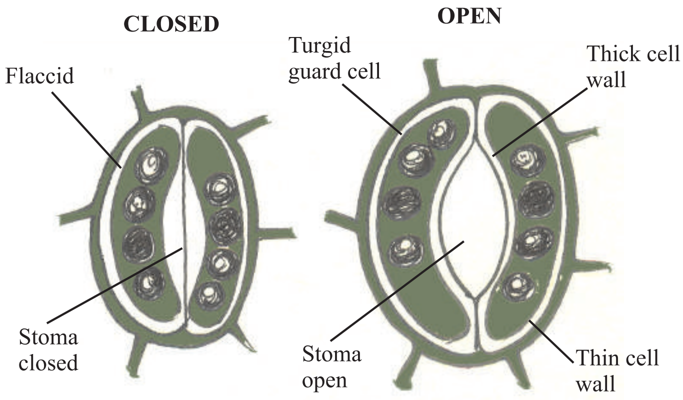


Fig22.10 Opening and closing of stomata (showing inner and outer surface)

Guard cells help in the opening and closing of stomata. When guard cells get filled up with water, they swell and become turgid. The two guard cells curve away from each other opening the stomata. When guard cells become flaccid, stoma closes. Minerals also play a role in making guard cells turgid or flaccid.

22.9.2 Breathing and Respiration in humans

Respiration may be divided into two steps.

- **Breathing** involves inhalation of air containing oxygen and exhalation of carbon dioxide.
- **Cellular respiration** is responsible for release of energy by oxidation of food (glucose), and its conversion into ATP (adenosine triphosphate)—The energy module.

***Respiration* is different from breathing.**

Breathing is the physical process of respiratory gaseous exchange between the organism and the environment by diffusion. It takes place in the lungs. On the other hand, **respiration** involves oxidation of food and release of energy which takes place in the cells along with respiratory gaseous exchange.

22.9.3 Respiratory system in Humans

Respiratory system

Respiratory system of human beings has the following parts (Fig22.11).

- External nares or nostrils.
- Nasal cavities inside the nose.
- Internal nostrils opening into pharynx.
- Pharynx that leads into the wind pipe or trachea.
- Trachea divides into two bronchi (one bronchus) which lead into the two lungs.

See figure 22.11 and locate the trachea, the windpipe

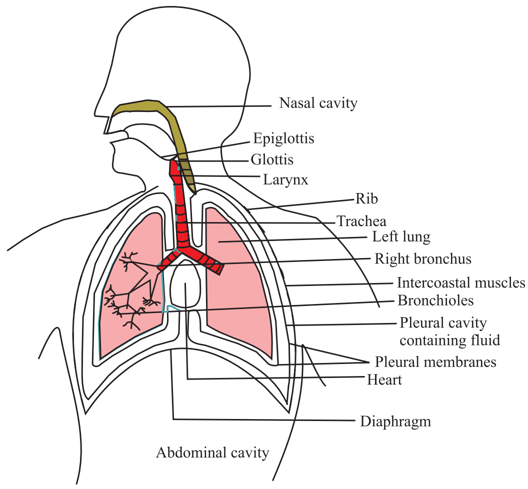


Fig. 22.11 Respiratory system in human beings

The **opening** of the pharynx into the trachea is called **glottis**. Trachea is thin walled but its walls do not collapse even when there is not enough air in it as it is supported by rings of cartilage. Trachea bifurcates into **bronchi.**

Lungs enclose within them branches of bronchi called **bronchioles** which branch further and end in very thin walled sac-like structures called **air sacs or alveoli** (sing. alveolus). See the figure of respiratory system.

The voice box or **larynx** is present on the trachea

22.9.4 Mechanism of breathing or ventilation of lungs

Lungs are located in the chest cavity or the thoracic cavity. Below the chest cavity is the abdominal cavity. These two cavities are separated from each other by a dome-shaped (upwardly arched) muscular sheet called diaphragm (see figure22.11). The movement of diaphragm helps in breathing. Breathing, also called ventilation involves two processes:

(i) Inhalation (drawing the air inwards) (Fig.22.12a) is the result of increase in the volume of the thoracic cavity. This increase is caused by the changes that take place in the position of diaphragm and ribs.

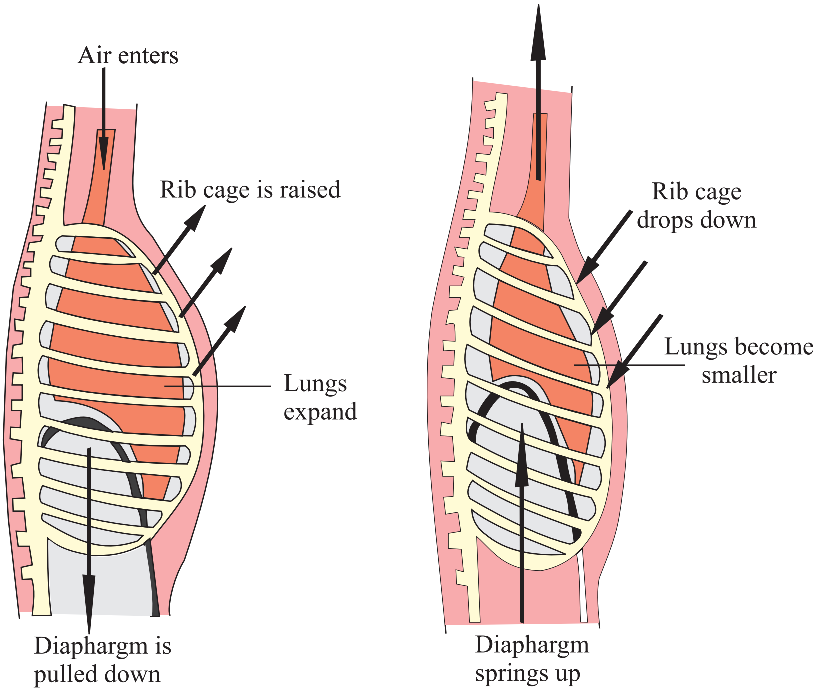
- Diaphragm straightens out due to contraction of its muscles.
- Ribs are raised upward and outward and volume of chest cavity enlarges by contraction of rib muscles.. As volume of chest increases pressure of air in it decreases.
- Atmosphereic air rushes in and reaches the alveoli. It brings in oxygen which diffuses into the capillaries from the alveoli.

(ii) **Exhalation** (Fig 22.12b) is the result of decrease in the volume of the thoracic cavity.

This decrease in the volume is caused when:

- Diaphragm relaxes and resumes its dome shape, arching upwards.
- Ribs are lowered downwards and inwards.
- Thoracic cavity is compressed and the pressure inside the lungs is increased.
- The alveolar carbon dioxide diffuses out and is pushed out through the trachea and nose.
- This breathing out of carbon dioxide laden air is called exhalation.

If you take long breaths, you can feel your chest go up and down.



(a) Inhalation (b) Exhalation

Fig22.12. How the thorax changes shape during breathing

22.9.5 Breathing Rate

When at rest, an adult human breathes about 16 to 18 times per minute. Breathing rate increases during physical exercise, disease, fever, pain and under stress.

ACTIVITY 22.8

Check your breathing rate at rest. Now run for 5 minutes or climb 15 stairs and then check breathing rate. Do you find any difference? You will observe that you start panting and your rate of breathing increases as you run or climb the stairs.

22.9.6 Exchange of gases between blood and tissues

Inhalation fills in the alveoli of lungs with oxygenated air. This oxygen has to reach the various tissues of the body. Thus as the first step, blood capillaries on alveoli (Fig22.17) pick up oxygen from alveoli and carbon dioxide brought by the capillaries from the tissues is exchanged for oxygen. Oxygen diffuses into alveoli.

In the tissues, oxygen gets used up and carbon dioxide is accumulated which is now exchanged for oxygen in blood. The carbon dioxide picked up by blood from tissues is carried to the heart by veins.

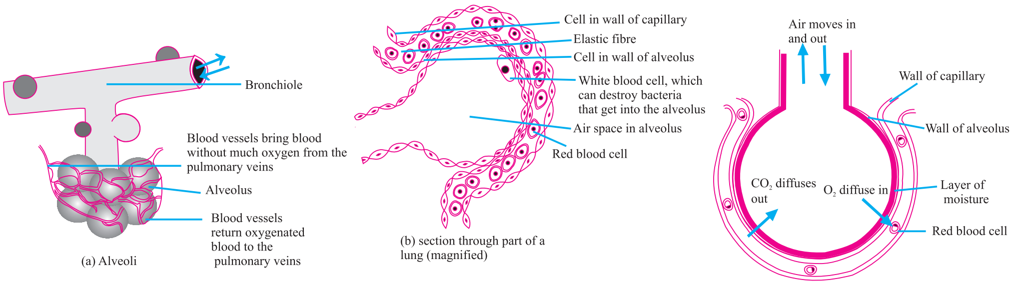


***Fig.22.13** Exchange of gases between blood and alveoli*

22.9.7 Cellular Respiration

Once inside the tissues, oxygen acts upon the digested food (glucose) which has reached the cells of the tissues. As a result energy and carbon dioxide are released. This occurs in the **mitochondria** of the cells and is called **cellular respiration**.

Do you know why mountaineers and sea divers carry oxygen cylinders and wear oxygen masks? As we climb higher and higher altitudes, the air pressure becomes lower and lower. Reduced oxygen supply causes breathing troubles and oxygen masks facilitate breathing. People living in hilly areas have evolved adaptation such as increased number of red blood corpuscles and large thoracic cavity. Divers carry oxygen masks because we derive our respiratory oxygen from air and not water.

Artificial respiration

A victim of an accident like drowning, electric shock or inhalation of poisonous gas suffers from “asphyxia” or lack of oxygen. The symptoms are blueing of lips, fingernails, tongues and stoppage of breathing. In such cases mouth-to-mouth respiration is given.

You must have realised how important respiration is for survival. Medical technology has introduced certain gadgets like the “oxygen mask” and “ventilators” which assist the patient in respiration during breathing problems. Often these help the patient to overcome such problems.

INTEXT QUESTIONS 22.8

1. Why does the trachea not deflate (collapse) during exhalation?

2. The sequence of parts of human respiratory are jumbled. Place them in the right order. Nasal cavity, trachea, pharynx, internal nostrils, bronchi, lungs.

3. You have learnt in Physics that when volume increases, pressure decreases. How does this principle find a place in the process of breathing?

4. Once oxygen reaches cells, which of its organelles takes over respiration?

5. Why are the alveoli supplied with capillaries?

IV EXCRETION

Many chemical reactions take place inside body cells. Some products of these chemical reactions are not needed by the body. They may even be harmful if they accumulate in the body. Their removal from the body is called **excretion**.

22.10 HUMAN EXCRETORY SYSTEM

In human beings, excretion is carried out by an organ system known as the urinary system or the excretory system. See the figure (Fig 22.14) and locate the following parts:

- Two bean shaped kidneys, located below the diaphragm in the abdomen and towards the back.
- Two excretory tubes or ureters, (one from each kidney).
- One urinary bladder, ureters open into it.

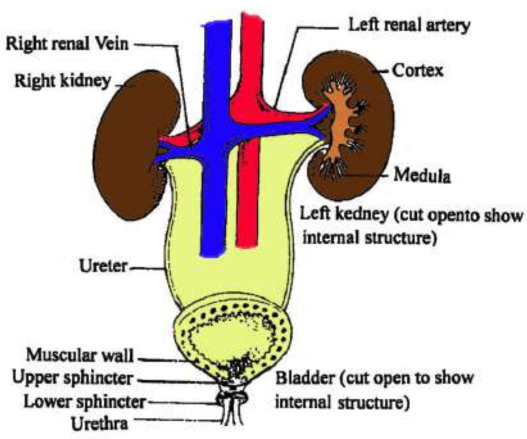


Fig.22.14 Human excretory system

- A muscular tube called urethra arises from the bladder. The urinary opening is at the end of urethra.

22.10.1 Structural and functional unit of the kidney — Nephron

Each kidney is made of tube like structures called nephrons (renal tubules). A nephron is the structural and functional unit of the kidney. The cup-shaped upper end of nephron is called Bowman's capsule, has a network of capillaries within it called **glomerulus**. Glomerulus is a knot of capillaries formed from the artery which brings blood containing wastes and excess of water to the kidney. Bowman's capsule leads into a tubular structure. The tubular part of the nephron or renal tubule has three sub-parts, the proximal convoluted tubule (PCT), a thinner tube called loop of Henle and the distal convoluted tubule (DCT) (Fig. 22.15). Blood capillaries surround these tubules.

22.10.2 Mechanism of excretion

Filtration and reabsorption are two important processes of excretion.

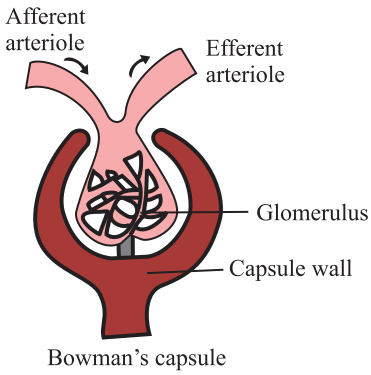


Fig.22.15(a) Bowman's capsule

Blood entering the glomerulus gets **filtered** in the Bowman's capsule and is called the nephric filtrate. The red blood corpuscles and proteins do not filter out. (Fig 22.15a) .They remain in the blood stream

The filtrate entering the renal tubule not only contains waste but also useful substances. The useful substances get **reabsorbed** from the tubule into the blood capillaries surrounding the tubule. Excess water and salts like sodium and chloride also get reabsorbed into the blood from the renal tubule. Thus, waste alone which is primarily in the form of urea enters into collecting tubules from various renal tubules. It is the urine.

From the kidneys, the urine enters the ureters to reach the urinary bladder where it is temporarily stored. Urine is thrown out periodically through the urinary opening.

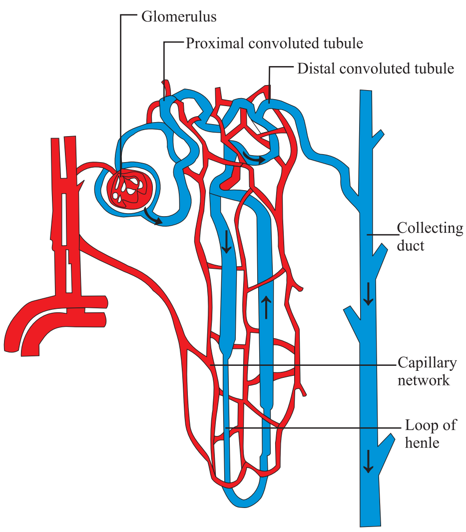


Fig.22.15 (b) Structural and functional unit of the kidney— Nephron

Functions of kidneys

- Kidneys not only excrete nitrogenous wastes but also regulate the water content of the body (osmoregulation), and

- Keep the normal mineral balance in the blood. When this balance is upset, a person can fall sick.

22.10.3 Other organs that remove waste from our body

Apart from kidneys, lungs, skin and liver also remove wastes. Sweat glands in the skin remove excess salts when we perspire. Lungs remove carbon dioxide Fig. 22.16.

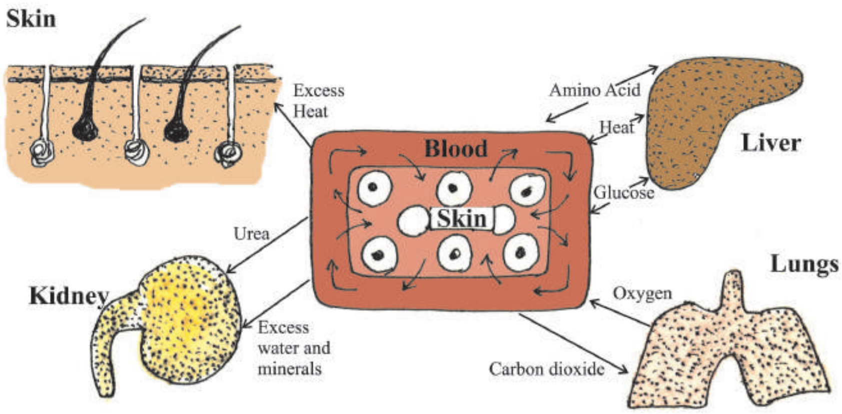


Fig. 22.16 other excretory organs

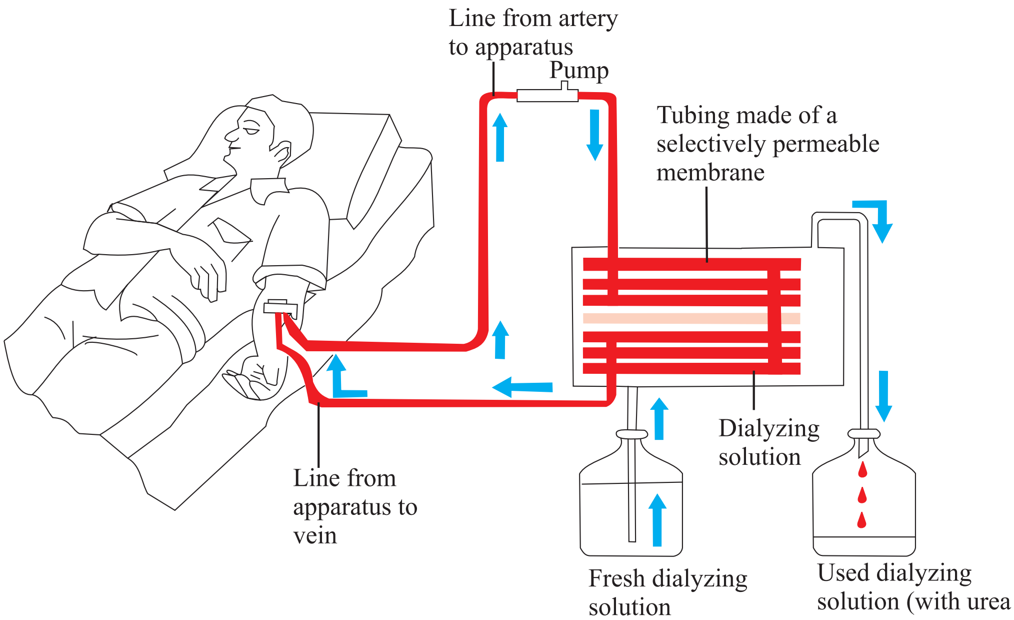
22.10.4 Maintenance of the internal environment

A person gets sick if the balance of substances such as mineral ions, water or even hormones inside the body is upset. Maintenance of the correct amount of water and mineral ions in the blood is termed **osmoregulation**.

22.12.5 Kidney failure, dialysis and kidney transplant

Certain diseases or sometimes an accident may lead to kidney failure. Since the number of nephrons is as large as almost one million in each kidney, a person can survive even with one kidney. However, in case both the kidneys are damaged, it is difficult to remain alive. Modern technology can now save such patients with the help of new techniques like dialysis and kidney transplant. Fig. 22.17 shows the set up of an artificial kidney. A tube is inserted in an artery in the patient's arm or leg. The tube is connected to the kidney machine. This plastic tube has two membranes so as to form one tube within the other. In the inner tube flows blood from patient's artery. This blood is surrounded by fluid (dialysis fluid) in the outer tube, separated from it by the membrane of the inner tube. Wastes move out of blood into the fluid. The blood cleaned of its waste goes back from the kidney machine into the vein in the arm or leg and back into the body. The dialysis fluid carrying waste is removed from the machine. This technique is termed **dialysis**.

Nowadays, a surgeon may sometimes remove a non-functioning kidney from a patient and replace it with a kidney donated by another person. Care, however, has to be taken so that a foreign kidney gets accepted by the body of the recepient.



Kidney dialysis

Fig22.17 Artificial Kidney

INTEXT QUESTIONS 22.9

1. Name the organ of the excretory system, which stores urine before its removal from the body.

2. Draw a rough diagram of the nephron and label only the part where filtration occurs?

3. What happens to the useful substances that move into the glomerulus along with nitrogeneous waste?

WHAT YOU HAVE LEARNT

- Nutrition is a process by which living beings procure food or synthesize it and change it into simple absorbable form by a series of biochemical processes in the body.

- The photosynthesis provides food for all. It is the ultimate source of energy for all living organisms. It is essential for sustaining life.
- A balanced diet contains adequate amount of essential nutrients such as carbohydrates, fats, proteins, vitamins, minerals and water. The amount of these nutrients in diet depends upon a number of factors, such as age, sex and nature of work an individual performs.
- Conversion of complex food material into smaller substances so that it can be absorbed by the cells is called digestion. The digestive system enables conversion of ingested food into its simpler form. The process of digestion requires a number of enzymes.
- The absorption of food occurs mainly in the small intestine. The simple soluble food molecules are absorbed from the small intestine into the blood which takes them to all the cells of the body.
- A disease that occurs due to lack of adequate and balanced diet is called deficiency disease. Deficiency diseases caused due to malnutrition are of three types: protein energy malnutrition (marasmus and kwashiorkor); mineral deficiency diseases (goitre and anaemia); and vitamin deficiency diseases (xerophthalmia, rickets, beri-beri, pellagra).
- The distribution of food and oxygen to all parts of the body as well as the removal of body wastes is performed by a transport system within the body of all living organisms.
- Heart in humans is four-chambered, two upper chambers are called atria and lower chambers are ventricles. Heart is made of cardiac muscle fibres.
- Every human being belongs to one of four blood groups: A, B, AB and O. Blood transfusion can be between matching blood groups. The persons with blood group O can donate blood to all and 'O' group is called universal donor and AB group can receive blood from all and is called universal recipient.
- Breathing is the physical process of respiratory gaseous exchange between the organism and the environment by diffusion. On the other hand, respiration involves oxidation of food and release of energy along with respiratory gaseous exchange.
- In human beings, excretion is carried out by an organ system known as the urinary system or the excretory system.
- A nephron is the structural and functional unit of the kidney.

TERMINAL EXERCISES

1. Multiple choice type questions.

i. Rickets is caused due to deficiency of:
   a) Iron
   b) Vitamin D
   c) Proteins
   d) Carbohydrates

ii. One gram of a substance was oxidized. The energy released amounted to 9.0Kcal. The substance was of the type:
   a) Carbohydrates
   b) Fats
   c) Vitamins
   d) Proteins

iii. A person living in the hilly regions of Shimla developed swelling in his neck region. The doctor said his thyroid gland got swelled up. Name the nutrient deficient in his diet.
   a) Calcium
   b) Iron
   c) Phosphorus
   d) Iodine

iv. The vitamin that helps in the clotting of blood is:
   a) Vitamin A
   b) Vitamin D
   c) Vitamin E
   d) Vitamin K

v. In human beings, gas exchange between the environment and the body takes place in the :
   a) larynx
   b) bronchi
   c) alveoli
   d) trachea

vi. RBCs of human beings who live in high altitude regions:
   a) increase in number
   b) decrease in number
   c) decrease in size
   d) increase in size.

vii. Lungs have a large number of alveoli for:

a) maintaining a spongy texture and proper shape.

b) more surface area for diffusion of gases.

c) more nerve supply.

d) more space to increase volume of inspired air.

viii. The main function of lymph is to:

a) transport O_2 to the brain.

b) transport CO_2 to lungs.

c) return interstitial fluid to blood.

d) return RBCs and WBCs to lymph vessels.

2. Name the following.

i. A fluid that transports fatty acid and glycerol.

ii. The valve present in between the chambers on the right side of the human heart.

iii. The respiratory pigment present in RBCs.

iv. The iron containing pigment in RBCs.

v. The phase of cardiac cycle in which the auricles contract.

3. Give on epoint of difference between the following.

1. Autotrophic and heterotrophic nutrition
2. Breathing and respiration
3. Arteries and veins
4. Blood and lymph
5. Auricular systole and ventricular systole

4. Match the columns A and B.

	COLUMN A		COLUMN B
1.	Sponge-like organs located in the chest cavity	a.	trachea
2.	Chamber acting as a common passage for food and air	b.	bronchioles
3.	Elastic tissue that forms a flap over the top of the larynx	c.	epiglottis
4.	Main passageway to the lungs	d.	pharynx
5.	Small tubes that branch from the bronchi	e.	bronchi
6.	Small air sacs in the lungs	f.	lungs
		g.	alveoli
		h.	larynx

5. Given below is an example of a certain structure and its function.

   'Kidney and excretion'

   Fill in the blanks on a similar pattern.

   1. Alveoli and ____________
   2. Diaphragm and ____________
   3. 'C'-shaped cartilage rings and ____________
   4. Erythrocyte and ____________
   5. Left ventricle and ____________
   6. Pacemaker and ____________

6. What is a balanced diet? Name three items of a diet that provide three different nutrients?

7. What are the main steps of photosynthesis? Is sunlight essential for photosynthesis and why?

8. A patient complains of lack of appetite, exhaustion and is losing weight. Diagnose the deficiency. What kind of diet would you suggest for the patient?

9. Deficiency of which vitamin causes night blindness. What would you suggest to prevent this deficiency?

10. Where does the digestion of starch, proteins and fats take place and what is the role played in digestion by liver and pancreas?

11. Which component in your diet will not be digested if the enzyme lipase is not secreted?

12. Explain how oxygen leaves the blood from the tissue capillaries and carbon dioxide enters the blood in the tissue capillaries.

13. Explain the usefulness of large surface area provided by alveoli for respiration in human beings.

14. Why do arteries have a thick or elastic wall?

15. What are the four types of blood groups present in humans? Prepare a table with two columns to show the different human blood groups and names of compatible blood groups in the other column.

ANSWER TO INTEXT QUESTIONS

22.1

1. Green plants, algae and bacteria (any two); they undertake photosynthesis to manufacture their own food.

2. They are the food for all the oorganisms in a food chain
3. Types of nutrition: Autotrophic, Heterotrophic:—Holozoic, Parasitic, Saprophytic/ saprotrophic
4. Digestion of the ingested food.
5. Parasitic: leech, head louse; saprophytic: Yeast, mushroom.

22.2

1. Photo means light and synthesis means manufacture. Plants manufacture food in presence of light.
2. Chlorophyll; necessary for photosynthesis.
3. Glucose during photosynthesis stored as starch.
4. Let in CO_2, from the atmosphere let out O_2 is to the atmosphere.

22.3

1. Easy bowel movement / prevents constipation/, forms roughage.
2. You
3. Vitamin B and C.—Water soluble vitamin

   Vitamin A, D, E and K.Fat soluble:-

22.4

1. Pepsin
2. Peristalsis/ peristaltic movement
3. Small intestine
4. Trypsin digests proteins, Amylase digest carbohydrates, Lipase digests fats
5. HCl (Hydrochloric acid)

22.5

1. Protein Energy Malnutrition; Marasmus and Kwashiorkor
2. Night blindness; Beri Beri, Pellagra; Anaemia, Scurvy; Rickets; Excessive bleeding from wounds (any two)
3. Because it contains Iodine which is necessary for formation of thyroid hormones/ prevention of diseases due to deficiency of thyroid hormone/prevention of goitre.

22.6

1. To circulate O_2 / products of digestion of food/ removal of waste
2. Capillaries
3. Valves prevent mixing of oxygen laden blood with carbon dioxide laden blood.

22.7

1. (i) RBC
   (ii) WBC
2. Sheena's blood because O group is universal donor.
3. Haemoglobin; carries oxygen to tissues and brings back carbondioxide from tissues.
4. Prevent body from infections; returns proteins and fluid from circulation to tissues.

22.8

1. It is supported by rings of cartilage.
2. Nasal Cavities; Internal nostrils; Pharynx; Trachea; Bronchi; Lungs.
3. During inhalation, chest cavity enlarges and air pressure in it decreases so air from outside rushes in.
   - Diaphragm straightens out.
   - Ribs are raised upward and outward
   - Volume of chest cavity increases;pressure of air is it decreases
   - Air rushes into the alveoli
4. Mitochondria
5. For the exchange of gases (O_2 and CO_2)

22.9

1. Urinary bladder
2. Bowman's capsule labeled in the figure of nephron.
3. Get reabsorbed into the blood capillaries surrounding the tubule.

23

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CONTROL AND COORDINATION

We observe our body regularly, but few of us are able to appreciate what a well-harmonized machine it is! When we eat food, digestive juices are secreted, but these are secreted only when there is some food in the food canal and so long as the food has to be digested. Our muscles move only when stimulated. Our body temperature remains constant even when outside temperature fluctuates. Can you tell how various organs perform their functions together accurately at the right time? How does the right physiological activity occur at the exact moment? Do you know which organs are responsible for our thoughts, feelings, emotions and behaviour? We shall try to get answers to some such questions in this lesson.

OBJECTIVES

After completing this lesson, you will be able to:

- *explain the role of nervous system and hormonal system in control and coordination of various activities of the body;*
- *recognize major components of the nervous system and enlist their functions, emphasizing their role in informed decision making;*
- *explain the role of nerve cells (neuron) in the transmission of nerve impulses;*
- *identify the location and explain the functions of spinal cord in evoking a reflex action;*
- *analyze the role of some of the endocrine glands in regulating our growth and behaviour; and*
- *appreciate the role and relevance of reflex, voluntary and involuntary actions as well as hormones in efficient functioning of the human body.*

23.1 NERVOUS SYSTEM AND ENDOCRINE SYSTEM

Have you ever wondered how the various organs perform their respective functions in harmony and at the appropriate time? The **nervous system** and the **endocrine system** ensure that the body works in a controlled and coordinated manner. The nervous system includes the brain, spinal cord, sense organs and nerves while the endocrine system operates through certain chemicals called **hormones** which are produced by specialized glands and are secreted directly into the blood. The nervous system works with the endocrine system to communicate, integrate and coordinate the functions of various organs and systems in our body.

Some examples from our daily life will help us to appreciate the complexity of processes coordinated by the nervous and endocrine systems to help us execute several simple and difficult tasks. Do you know why we feel hungry? Yes! You are right. We want food when our body needs energy. The eyes see the food; brain registers this information and a series of coordinated activities are initiated. Appropriate activities in the nervous system instruct the relevant muscles in the hands and the fingers to pick up the food and put it into the mouth. When sufficient food has been eaten, signals from the hunger centre in the brain indicate a sense of fullness and the individual stops eating. The food reaches the alimentary canal and several digestive juices (for example, gastric juice, bile and pancreatic juice under the influence of specific endocrine glands) are secreted that help in digestion. After a series of digestive processes, food is absorbed into the blood stream to fulfill the energy requirement. Several other processes involved in digestion are not mentioned here. Many of these processes cannot be directly observed but they play a vital role in the digestion of food and providing energy for our day-to-day functioning. As you would have realized; eating is not as simple as it seems to be!

The above example illustrates that the nervous system and the endocrine system **work together as a team** to control and coordinate all our activities such as our physical actions, our thinking processes and our emotional behaviour.

It is noteworthy that sometimes we may not even be aware of the role that the nervous and endocrine systems play in our health and well being. For example, we do not have to remember to breathe or to digest food.

Execute: To carry out or put into effect

There is another set of action, known as the **reflex action** that are usually executed in response to an urgent or dangerous situation. For example, immediate removal of hand if it comes in contact with a hot object.

Do you now appreciate that the nervous and endocrine systems have a vital role to play in the smooth functioning of our lives on an everyday basis. Let us understand the structure and functioning of these systems in some more detail.

INTEXT QUESTIONS 23.1

1. Can you think of a real-life example, when team work helped you to achieve something that you could not have done by yourself? Please write about this incidence in 3-5 sentences.

2. Give one example of coordination of a process taking place in our body which is brought about by both the nervous system and hormonal system.

23.2 THE NERVOUS SYSTEM

The functioning of the nervous system depends on detecting a stimulus in the internal or external environment and responding to it.

A stimulus is an agent or an environmental change which can initiate a response in the body. The stimuli can be of several types. It could be physical (touch, prick, pressure), auditory, chemical, radiant (light), heat or cold, or electrical.

23.2.1 Neuron (Nerve cell)

Let us find out how **neurons** (individual cells of the nervous system) communicate with one another and other tissues to receive and transmit information throughout the body. The generalized structure of a neuron is shown in fig. 23.1**.** It consists of three parts-

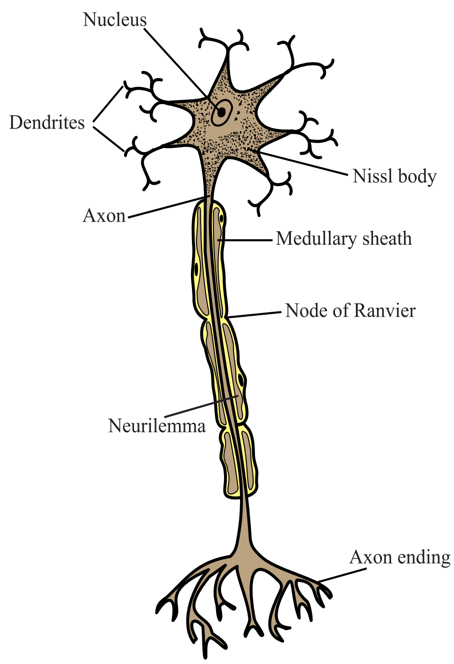


Fig 23.1: A neuron (nerve cell)

(i) **Dendrites** are branched cytoplasmic projections from the cell body. The dendritic tip of the nerve cells receive impulses and sets off a chemical reaction that creates an electrical impulse which is further transmitted to the cell body.

(ii) The **cell body** contains a well defined nucleus, surrounded by cytoplasm. It has cell organelles like any other cells. The cell body further transmits the impulse to the axon.

(iii) **Axon**: One branch arising out of the cell body is very long in comparison to others. This branch is called **axon or**

nerve fibre. In most neurons, it is covered by an insulating fatty sheath called *neurilemma*. The fatty sheath is missing at intervals which are called **Node of Ranvier**. The absence of *neurilemma* helps Node of Ranvier to generate electrical activity and in transmission of nerve impulse. The end portions of the axon have swollen ends like "bulbs" which store chemicals called **neurotransmitter**. Axon bulbs are closely placed near the dendrites of another neuron. This junction of two neurons in called **synapse** and the space at the synapse separating the two neurons called **synaptic cleft**. (Fig 23.2) There are many synapses between the millions of nerve cells present in our body.

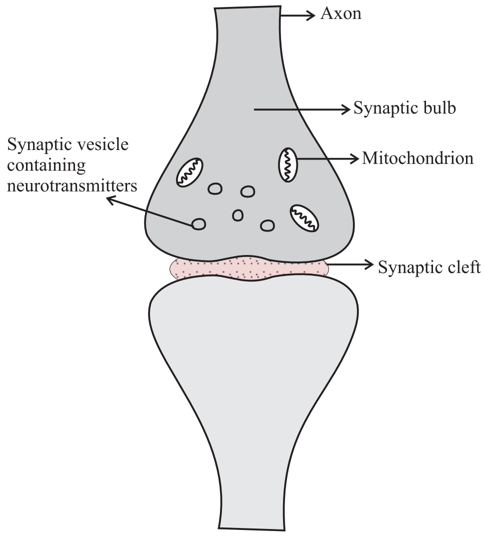


Fig 23.2: A synapse

Through the synapse the impulse passes from one neuron to the next neuron. When an impulse reaches the end of first neuron, a neurotransmitter is released in the synaptic cleft of the synapse. These chemicals cross the gap or synapse and start a similar electrical impulse in the next neuron. Finally, the impulse is delivered from neurons to other cells, for example the muscle cells or glands to elicit the desired action.

There are three types of neurons: (Fig 23.3).

1. **Sensory neurons** convey the impulse from receptor (sense organ) to the main nervous system. (brain or spinal cord).
2. **Motor neurons** carry the impulse from the main nervous system to an effector (muscle or gland).
3. **Association (Connecting) neurons** are located in the brain and spinal cord and interconnect the sensory and motor neurons.

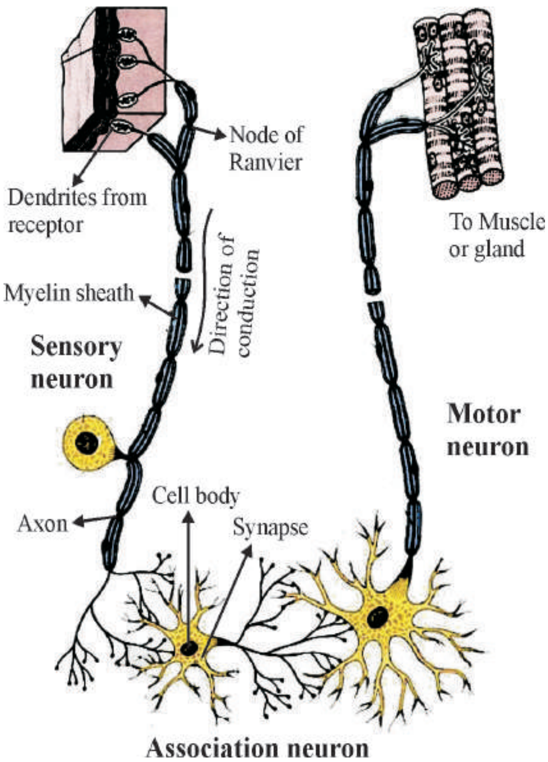


Fig 23.3: Three types of neurons (sensory, motor and association), synapse between them and the direction of transmission of nerve impulse

23.2.2 Nerves

Nerves are thread-like structures which emerge from the brain and spinal cord and branch out to almost all parts of the body. A **nerve is formed of a bundle of nerve fibres (axons) enclosed in a tubular sheath** (figure 23.4). It may be compared to an underground electric cable containing numerous conducting wires, each insulated from the other. The medullary sheath of the axon acts like an insulation preventing mixing of impulses between the adjacent axons.

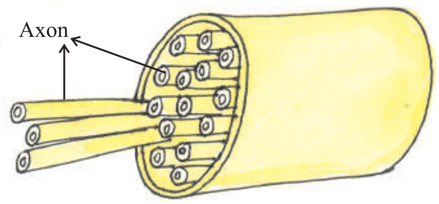


Fig 23.4: A nerve formed of a bundle of axons

There are three kinds of nerves:

(i) **Sensory nerves** that contain sensory fibres. These nerves bring impulse from the receptors (sense organs) to the brain or spinal cord. *Example:* Optic nerve arising from the eye and ending in the brain.

(ii) **Motor nerves** which contain motor fibres. These nerves carry impulse from the brain or spinal cord to the effector organ like muscles or glands. *Example*: a nerve arising from the brain and carrying impulse to the muscles of the eye.

(iii) **Mixed nerves** are those that contain both sensory and motor fibres and perform a mixed function. *Example*: a spinal nerve.

Do you know

Spinal nerves are the nerves that emerge from the spinal cord and cranial nerves are the nerves that emerge from the brain.

23.2.3 Sense organs

As shown in figure 23.5 receptor organ like nose, eyes and /or ears receive the stimulus. The stimulus than reaches the spinal cord and the brain through sensory nerves where it is integrated. The message is then send by the motor nerves to the required organ (muscles or gland) for suitable action. In this ways a response is generated.

23.2.4 Major divisions of the nervous system

Before going any further, it may be useful to know the major divisions of the nervous system as summarized in the chart below. It shows that the nervous system has two main divisions: **Central Nervous System (CNS)** that includes brain and spinal cord and **Peripheral Nervous System (PNS)** which includes the

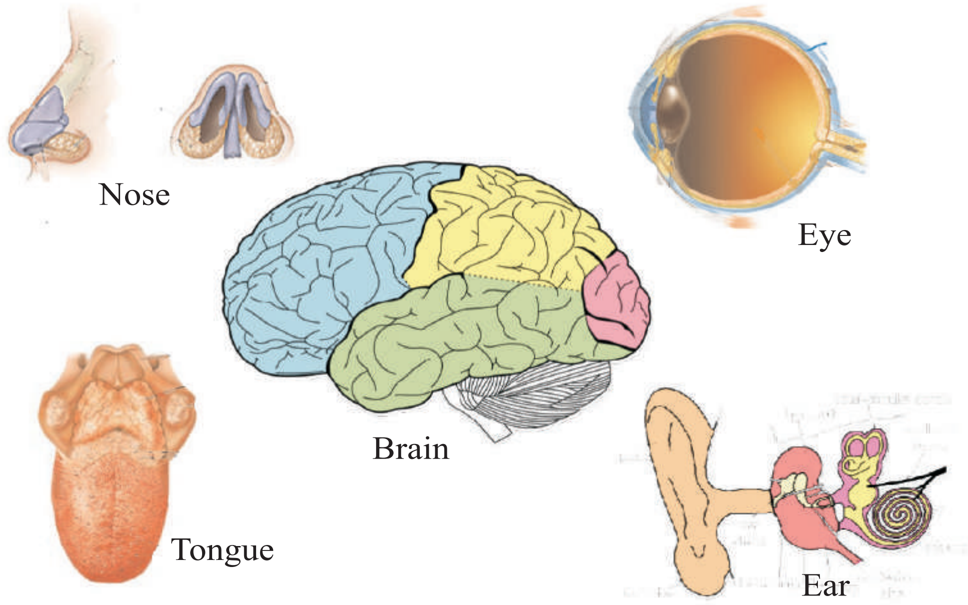


Fig 23.5: Major functions of the different areas of the brain

nerves arising from the brain and spinal cord. The major division of the nervous system are summarized in the chart given below:

Nervous System

- **Central Nervous System (CNS)**
  - **Brain**
    - **Cerebrum** Controls conscious and unconscious mind, intelligence, memory, reason, etc.
    - **Cerebellum** Maintains balance of the body.
    - **Medulla oblongata** Controls involuntary actions - heart beat breathing, peristalsis
  - **Spinal Cord** (Controls reflex actions, conveys impulses)
- **Peripheral Nervous System (PNS)** (Carries impulses to and from CNS)
  - **Somatic Nervous System**
    - **Cranial nerves (12 pairs)**
    - **Spinal nerves (31 pairs)**
  - **Autonomic Nervous System (ANS)** Pair of chains of ganglia, close to or embedded in the organs.
    - **Sympathetic** Accelerate heart beat, dilates pupil, constricts blood vessels, releases sugar from liver.
    - **Parasympathetic** Restores normal body condition

INTEXT QUESTIONS 23.2

1. The structural and functional unit of nervous system is (encircle the correct alternative out of the following)

   (a) Nephron (b) Neuron (c) Synapse (d) Axon

2. Consider that you are passing by a garbage disposal area and you immediately cover your nose. Arrange the events below in a logical order by marking them from 1 to 5 to trace the events that happen in the nervous system from detection of foul smell (stimulus generation) to covering your nose (response).

   (i) At the end of the axon, electrical impulse releases chemicals

   (ii) Stimulus received on the dendritic cells of a neuron sets off chemical reaction that creates an electrical impulse

   (iii) Electrical impulse transmitted through cell body and axon

   (iv) The chemicals cross the synapse and reach the next neuron. Similarly, the electrical impulse crosses several neurons

   (v) Finally, the impulse is delivered from neuron to the gland that helps in recognition of the foul smell and muscle cells that help in covering the nose

3. With the help of a suitable example, explain the term 'stimulus.'

23.3 THE CENTRAL NERVOUS SYSTEM

Central Nervous System (CNS) is regarded as the "information processor" in the body. It consists of the **brain** lying under the skull, and the **spinal cord** contained within the vertebral column.

23.3.1 The Brain

The brain is a very delicate organ. It is well protected within the bony cranium (brain box). As shown in the fig. 23.6(a), it is further protected by three **meninges** (that is, membranous coverings) which continue backward over the spinal cord. These meninges are: (i) **Dura mater,** the outermost tough fibrous membrane, (ii) **Arachnoid,** the thin delicate middle layer giving a web-like cushion, and (iii) **Pia mater,** the innermost highly vascular membrane, richly supplied with blood. The space between the covering membranes is filled with a watery fluid known as **cerebrospinal fluid** which acts like a cushion to protect the brain from shocks.

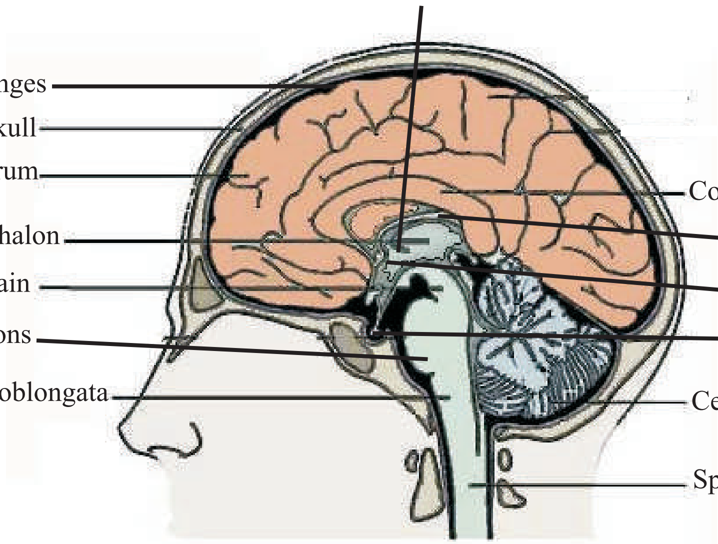


***Fig 23.6** (a) Brain located inside the head (sectional view)*

Do you know

You may have heard about **Meningitis** which is a serious health problem caused by inflammation of meninges. It is commonly caused by micro-organisms such as bacteria, virus, fungi and amoeba that infect the meninges and the cerebrospinal fluid surrounding the brain and spinal cord. Meningitis is a contagious disease and can spread through coughing, sneezing, kissing, sharing eating utensils, toothbrush etc. Good hygiene is helpful in preventing the disease. Effective vaccines are also available to protect against meningitis. A person with meningitis suffers with high fever, lethargy, irritability, headache, photophobia (eye sensitivity to light), stiff neck, skin rashes and seizures. (Seizures: Sudden attack of illness, especially a stroke or an epileptic fit)

Patient / care givers should seek prompt medical assistance for correct diagnosis and effective treatment.

The brain consists of three important parts: Cerebrum, Cerebellum and Medulla.

(a) **Cerebrum:** It is the largest portion of the brain, vertically divided into two halves: right and left **cerebral hemispheres**. Their outer surface is highly convoluted with ridges and grooves. The outer portion or the cortex of the cerebrum contains cell bodies of the neurons which is the basic unit of nervous tissue. Being grayish in colour, it is called the **gray matter**. The inner portion of the cerebrum consists of "**white matter**" which mainly contains the axons or nerve fibres of the neurons.

The highly developed cortex or gray matter enables us to think, reason out, invent, plan and memorize. Overall, the cerebrum is the seat of **intelligence,**

consciousness and will-power. It controls all voluntary actions. Cerebrum helps us to make well thought out and informed decisions, for example, decisions related to the career choices you make. Fig. 23.6 (b) shows some major functions associated with the different areas of the brain.

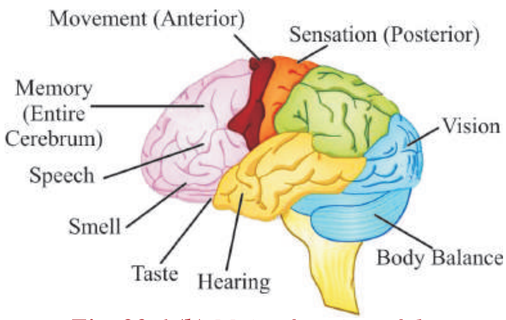


***Fig. 23.6 (b)** Major function of the different areas of the brain*

(b) **The cerebellum** is a much smaller area of the brain located below the cerebrum. It has no convolutions, but has numerous furrows. This also has an outer cortex made-up of gray matter and an inner white matter.

The main function of the cerebellum is to maintain the 'balance' of the body and coordinate muscular activity. The cerebrum and cerebellum work in close coordination. For example, if you stand up and walk, the impulse for this activity arises in the cerebrum. The act of walking involves coordinated working of many muscles. Proper coordination and timing of contraction and relaxation of muscles is the responsibility of the cerebellum.

Do you know

An alcoholic, when drunk, generally walks clumsily. It is because under the effect of alcohol, the cerebellum is unable to co-ordinate muscular movements properly.

(c) **The medulla oblongata** is the lowest portion of the brain located at the base of the skull. It is roughly triangular and is continued behind as the spinal cord. Its function is to control the activities of our visceral organs like the alimentary canal, movement, breathing, beating of heart and many other involuntary actions. Injury to the medulla generally results in death as the involuntary and vital functions like breathing and heart beat may be stopped.

23.3.2 The Spinal cord

As mentioned above, the spinal cord is an integral part of the central nervous system. It extends from the medulla oblongata and continues downward almost throughout the length of the backbone, and lies within the neural canal of the vertebral column or the backbone. Figure 23.7 shows the internal structure of the spinal cord. In the spinal cord, the arrangement of the gray and white matter is reversed from that in the brain. The gray matter containing the cell bodies of motor neurons lie on the inner side, while the white matter on the outer side. The white matter contains axons running longitudinally to and from the brain and even crossing from one side to the other. There is a small central canal in the centre which runs through the entire length and continues with the cavities of the brain. It is filled with **cerebrospinal fluid** which acts as a shock proof cushion and forms a medium for the exchange of food materials, waste products, and respiratory gases with neurons.

Externally, the spinal cord is covered by the same three membranes – dura mater, arachnoid and pia mater in continuation with those of the brain.

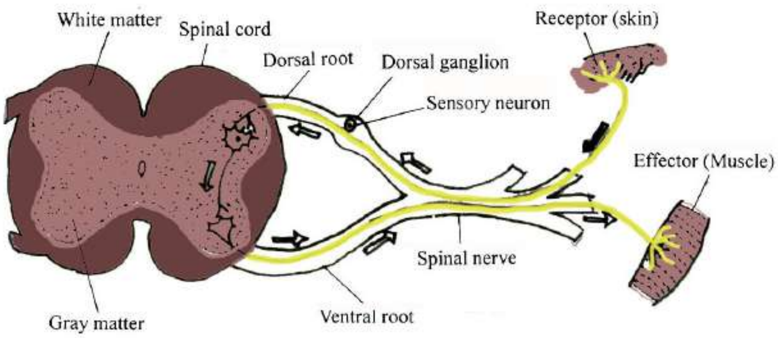


Fig 23.7 : Diagrammatic sketch of the internal structure of spinal cord and nervous pathway in spinal reflex

Functions of spinal cord

The spinal cord is concerned with the following three functions:

(i) It controls the reflexes below the neck.

(ii) It conducts sensory impulses from the skin and muscles to the brain, and

(iii) It conducts motor responses from the brain to muscles of the trunk and limbs.

INTEXT QUESTIONS 23.3

Fill in the blanks:

(i) The central nervous system consists of ________ and ______________.

(ii) The two functions of the cerebrum are __________ and _____________.

(iii) The major function of cerebellum is to maintain ________ of the body.

(iv) The _________________ part of brain controls the activity of all internal organs of our body.

(v) The outer and inner region of the cerebrum are composed of _______ and ____________ matter respectively.

23.4 REFLEX ACTION

We may be faced with an urgent and dangerous situation that requires immediate response and does not provide us with the time to think and reach a decision. Such responses are achieved through reflex action. The word 'Reflex' is used to convey sudden and immediate action in response to something. When there is a sudden dust storm what do you do to your eyes/ you immediately close your eyes to prevent the dust particles from entering your eyes. What is your reaction when you touch a hot pan while making food, you remove your hand to avoid the hot pan? In both those cases there is an instant and automatic reaction. There are certain actions in our body that are spontaneous and do not need any processing by the brain. Such actions or responses are called **reflex actions**. Reflex actions are involuntary actions that occur without conscious thought processes. For example: (i) When some particles fall into your eye, there is immediate flushing of tears to wash them out (glandular secretion) (ii) When your hand accidentally touches a hot pan, you withdraw it instantaneously (muscular movement) figure 23.8 (iii) You shiver when it is very cold (muscular contractions) or sweat when it is too hot (glandular secretion).

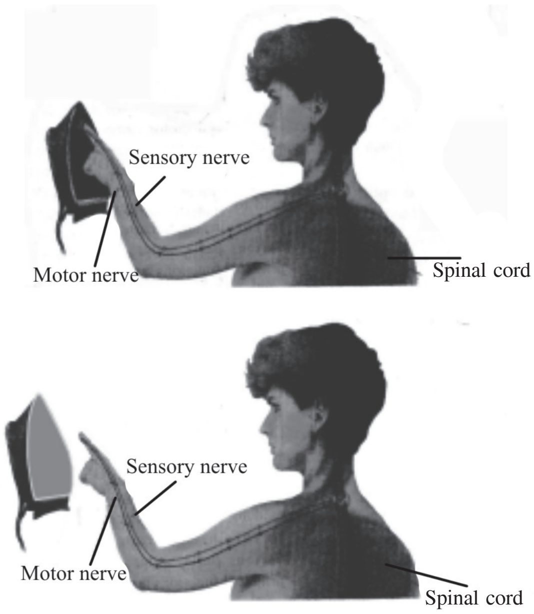


Fig 23.8 (a) and (b): A simple reflex of withdrawal of hand on touching a hot iron, brought out by spinal cord

Do you know

A ***reflex action*** may be defined as a spontaneous, autonomic and mechanical response to a stimulus controlled by the spinal cord and without the involvement of the brain. All involuntary actions or reflexes are initiated by some kind of sensory stimulations resulting in either a muscular action or a glandular secretion.

23.4.1 Types of reflexes

Reflexes are of two types (1) natural (inborn) reflexes and (2) conditioned (acquired) reflexes.

1. **Natural (inborn) reflex:** Close your eyes and try to follow the rhythm of your body. What do you feel? You feel that you are breathing gently. You also feel

your heart and pulse beating. All such activities in which no previous experience or learning is required are termed as **natural reflexes**. These reflexes are inborn, i.e. inherited at the time of birth. Other examples are: swallowing, coughing and blinking of eyelids.

2. **Conditioned (acquired) reflex:** What happens when you are able to smell your favourite food even without actually eating it? You are right. Your mouth starts watering (salivation) in anticipation! This phenomenon is based on your past experience by which you are able to associate a particular aroma with the specific food that you like. Aroma of the food item would not have initiated salivation if you had never eaten the food before. Such types of actions which develop during the lifetime due to experience or learning are termed as **conditioned reflex.**

   In the above example of conditioned reflex, salivation occurs at the smell of the food as the brain is able to remember the taste of the food and works in an unconscious way. Such reflexes are not inborn and hence conditioned reflexes are **acquired.**

   In order to preserve the conditioned reflex, it is necessary to reinforce it periodically. For example, once the reflex is formed, the mere smell of the food initiates salivation. However, if repeatedly the smell of the favourite food item is not followed by the food itself, you will stop reacting to the smell with salivation after a certain time.

A reflex arc may be represented as follows:

Stimulus $\rightarrow$ receptor in the sense organ $\rightarrow$ afferent (sensory) nerve fibre $\rightarrow$ CNS $\rightarrow$ efferent (motor) nerve fibre $\rightarrow$ muscle (to contract)/gland (to secrete)

INTEXT QUESTIONS 23.4

1. Name the two types of reflexes.

2. Given below are the different components of a reflex arc in a haphazard manner. Arrange them in the correct order in the space provided below:

   Sensory neuron, Effector, Stimulus, CNS, Receptor, Response, Motor neuron

3. Now that you are aware of the well-thought out voluntary actions that are co-ordinated by the cerebrum and immediate response actions or reflex actions, co-ordinated by the spinal cord, try to identify whether the following situations

may be best managed by well-thought out **voluntary actions** or quick response **reflex actions**. Please provide at least one reason for your choice.

Situation	Appropriate action voluntary action or reflex)	Reason for your choice
You need to immediately stop your bicycle as a speeding motorbike comes in front of your bicycle.		
You have scored good marks in all the subjects in class X and now need to choose between science and commerce stream. Your family feels you should study science while you like numbers and would like to study commerce.		
You are cleaning your cupboard, a sharp needle pokes you and you remove your hand immediately.		
You have moved to a new neighborhood and are trying to make new friends.		

23.5 PERIPHERAL NERVOUS SYSTEM

It connects the central nervous system with the sense organs, muscles and glands of the body and, includes the **sensory and motor nerves**. The peripheral nervous system consists of two sub divisions: (i) **Somatic nervous system** that conveys information from brain and spinal cord to skeletal muscles and regulates voluntary action. and (ii) **Autonomic nervous system** which control the involuntary action of many internal organs, smooth muscles, heart muscles and glands. (Fig.23.9)

2.5.1. Somatic nervous system

This consists of two sets of nerves – the cranial nerves and the spinal nerves

(a) **12 pairs of cranial nerves** emerge from the brain. For example optic nerve (for eyes) and auditory nerve (for ears);

(b) **31 pairs of spinal nerves** emerge from the spinal cord.

23.5.2. Autonomic nervous system

The autonomic nervous system (ANS) consists of a pair of chain of nerves and ganglia on either side of the backbone. This system controls the involuntary actions of the internal organs. As you may see in figure 23.9, there are two parts of the autonomic nervous system - Sympathetic and Parasympathetic.

The **Sympathetic Nervous System** (**SNS**) becomes more active during times of **stress.** It prepares the body for action. Its action during the stress response

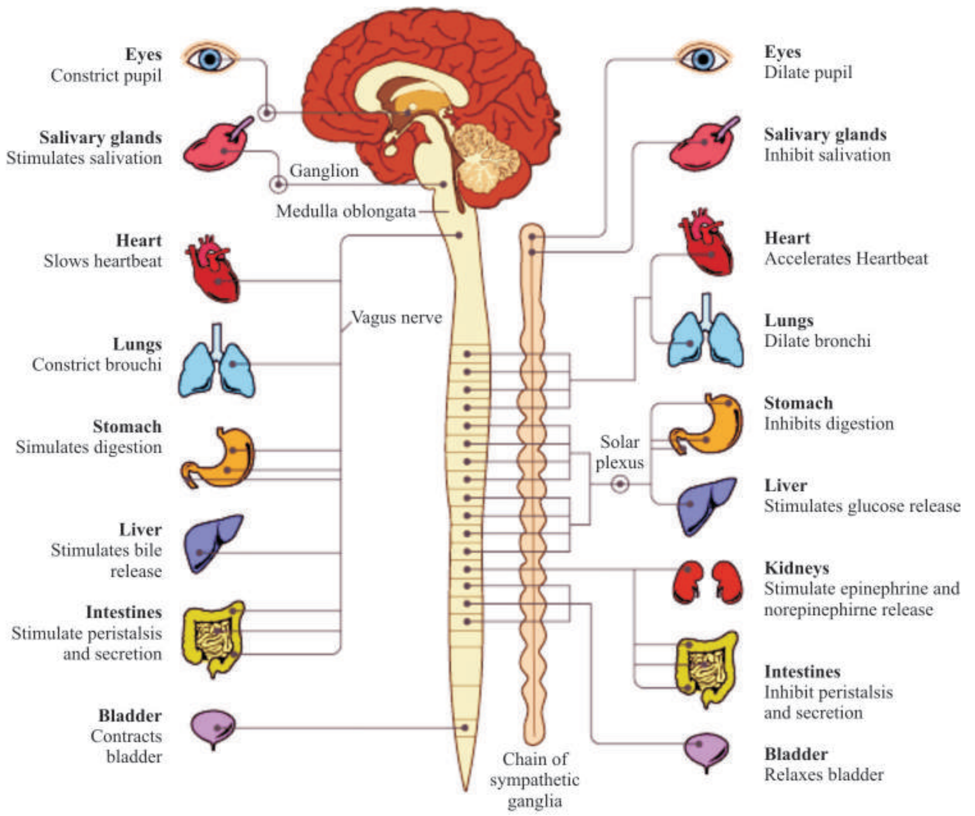


Fig 23.9: Autonomic nervous system showing the opposing effects of the two parts - sympathetic and parasympathetic

comprise the **'fight-or-flight response'** that is manifested largely under the influence of the hormone, *adrenaline*. The **Parasympathetic Nervous System** executes actions that do not require immediate response, for example producing of saliva and tears, digestion etc..

The functions of sympathetic and parasympathetic nervous systems may seem opposite to each other but in reality they are complementary rather than being antagonistic.

INTEXT QUESTIONS 23.5

1. How many pairs of cranial nerves are present in our body?

2. Name the two parts of autonomic nervous system.

23.6 ENDOCRINE SYSTEM

All of us observe the changes and development taking place in humans from the age of infancy to adulthood and old age. You may notice more pronounced changes in height and weight in the initial years and also very significant developments of secondary sexual characters during adolescence. In fact, our body undergoes changes as long as we live. These changes are regulated by special glands in our body known as the **endocrine glands**. The main function of these glands is to produce chemical secretions called **hormones.** Hormones play an important role in control, coordination and regulation of the functioning of tissues, organs and systems in the body. Well harmonized mechanisms regulate the release of very precise quantities of hormones to achieve optimal functioning of the human body. **The endocrine system is responsible for the chemical coordination in our body.**

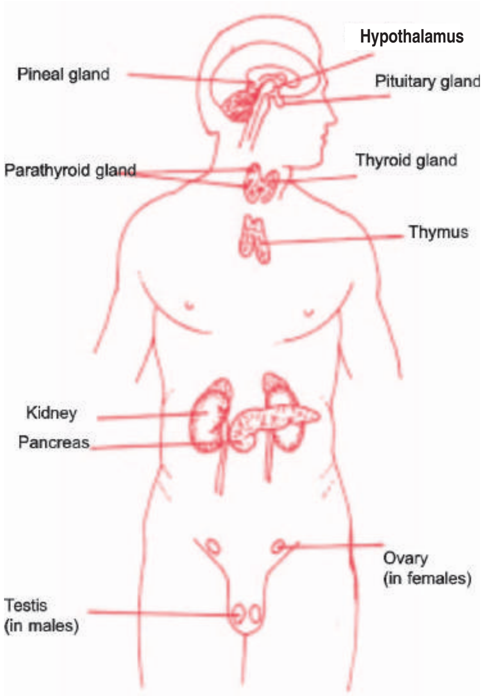


Fig 23.10: Endocrine glands

Do you know

The term hormone has been derived from the Greek word *hormaein* that means to set in motion or to spur on.

A **hormone** is a chemical secreted by an endocrine gland and carried by blood to a target organ situated elsewhere in the body to stimulate a specific activity.

Did you know that hyperactivity and hypoactivity of these glands can cause diseases? Let us learn about some important endocrine glands, the hormones they secrete and the effect they have in the body. Some of the endocrine glands are as follows:

Pituitary gland: This is a small gland located at the base of the brain. This gland plays an important role in the growth of a child from puberty to the full reproductive maturity. The pituitary gland secretes **Gonad Stimulating Hormone**, which regulates the activity of gonads (ovary in females and testis in the males). There is an increase in the activity of this gland at the time of puberty which stimulates the ovary and testes to produce the sex hormones **progesterone** and

oestrogen in females, and **testosterone** in males. These hormones initiate the development of secondary sexual characters. You will read more about secondary sexual characters in the lesson, "Reproduction". The disorders caused by the increased or decreased activity of the pituitary gland include:

- **Cushing's Disease:** It is caused by the hyperactivity of pituitary gland. In the males, this disease may lead to excessive growth of hair. In some cases, it may even cause atrophy of testes leading to impotency. In the females, this disease causes sterility and masculinization, for example, growth of beard and moustaches.
- Deficiency (hypoactivity) of growth hormone (GH) or **Somatotropic Hormone** (STH) secreted by pituitary gland causes **dwarfism** (retarded growth of the long bones) which adversely affects the height of a person. On the other hand, its excessive secretion or hyperactivity causes **gigantism** (excessive growth of long bones) making a person very tall.

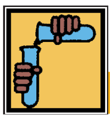
Thyroid gland: It is responsible for the speed of metabolism in our body. The thyroid gland is therefore essential for life, growth and development.

When the thyroid gland becomes overactive and produces more thyroid hormone than is necessary for optimal functioning, the condition is called **Hyperthyroidism**. When the thyroid gland becomes underactive and produces less thyroid hormone than is necessary, the condition is called **Hypothyroidism.**

Cretinism is a condition of severely stunted physical and mental growth due to untreated congenital deficiency of thyroid hormone (hypothyroidism) or from prolonged nutritional deficiency of iodine.

Goitre is a disease of the thyroid gland characterized by an enlargement of the gland, visible externally as a swelling on the front of the neck. Simple goitre is caused by a deficiency of iodine in the diet. (Fig. 23.11)

Fig 23.11: Goitre



ACTIVITY 23.1

Find out what the Government of India recommends for prevention of iodine deficiency and goitre. (Hint: You could get this information from the news papers, radio, television, internet or your kitchen!)

Pancreas: This gland secretes two hormones **insulin** and **glucagon** which help in the metabolism of glucose in our body. Hyposecretion of insulin causes **diabetes mellitus** in which glucose is present in excess in the blood.

INTEXT QUESTIONS 23.6

1. Fill in the blanks:
   (i) A hormone is transported by the .... to the target organ.
   (ii) Hypoactivity of thyroid gland causes .... leading to cretinism in young children.
   (iii) Pancreas secretes two hormones, which help in the .... of glucose in our body.

2. Each of the following statements has one correct response. Please choose the correct option and encircle it.
   (i) If a pathologist were to collect a hormone, where would it be collected from?
   (a) Blood (b) Brain
   (c) Specific endocrine gland (d) Any part of the body
   (ii) Hyperactivity of the pituitary gland causes:
   (a) Dwarfism (b) Gigantism
   (c) Cushing's disease (d) Cretinism.
   (iii) The neurons that carry impulses from sense organs to the brain or spinal cord are:
   (a) Sensory neuron (b) Motor neuron
   (c) Association neuron (d) Connecting neuron
   (iv) The parts of a reflex are connected to:
   (a) Brain (b) Spinal cord
   (c) Both brain and spinal cord (d) A synapse
   (v) Two neurons are connected to each other through:
   (a) Their axons
   (b) Their dendrons
   (c) The dendrites of the first neuron and the dendrites of the second one
   (d) Synapse
   (vi) An axon is:
   (a) A nerve fibre (b) A bundle of dendrites
   (c) A bundle of nerve fibres (d) The sheath of a nerve fibre.
   (vii) An individual reported to the neuro-physician with a body temperature much higher than normal. After several investigations, the neuro-

physician diagnosed that a tumor in a specific area of the brain was causing this symptom. Where do you thing the tumor may have been located?

(a) Cerebrum (b) Cerebellum
(c) Hypothalamus (d) Diencephalon

(viii) Where is the subconscious mind located?

(a) Thalamus (b) Hypothalamus
(c) Cerebellum (d) Cerebrum

(ix) Hyposecretion of insulin causes:

(a) Diabetes (b) Goitre
(c) Cretinism (d) Gigantism

(x) Which part of our brain helps in maintaining the balance of our body?

(a) Cerebrum (b) Cerebellum
(c) Medulla (d) Hypothalamus

(xi) Sudha likes to sleep in and someone always has to wake her up in the morning. However, during exams she is able to get up without an alarm or any other help. Which part of the nervous system helps her to deal with this situation?

Sleep in- sleeping beyond waking hours

(a) Parasympathetic nervous system (b) Medulla
(c) Sympathetic nervous system (d) Cerebrum

WHAT YOU HAVE LEARNT

- Nervous system and endocrine system are the two systems that control and coordinate various functions in the body.
- The human nervous system is studied under two divisions: The central nervous system and the peripheral nervous system.
- The central nervous system consists of brain and the spinal cord while the peripheral nervous system is further divided into somatic nervous system and autonomic nervous system.
- The autonomic nervous system has two parts – sympathetic and parasympathetic, which cause physical reactions opposite to each other.

- The neuron is the basic unit of nervous system. There are three types of neurons – sensory, motor and association or connecting neurons.
- A synapse is the function of the branches of the axon of one neuron with the dendrites of another neuron. It is here that the transfer of nerve impulse from one neuron to another neuron takes place.
- The reflex action is defined as a spontaneous, automatic and the mechanical response to a stimulus controlled by the spinal cord without involvement of the brain.
- The pathway followed by sensory and motor neurons in a reflex action is called reflex arc.
- Our body has a number of endocrine glands which produce chemical secretions called hormones.
- These hormones are carried by blood to the target organ situated elsewhere in the body to stimulate a specific activity.
- Pituitary gland plays an important role in the growth of the child from puberty to the reproductive maturity, i.e. upto the age of adolescence.
- Pituitary glands secretes many hormones which influence the development of secondary sexual characters among boys and girls. These hormones stimulate the production of eggs and sperms from ovaries and testes respectively. These hormones have profound influence on the behaviour as well as body shape, turning the child into an adult.
- Under secretion of thyroid gland cause cretinism and goitre.
- Pancreas secrete two hormones – the insulin and glucagon, which help in the metabolism of glucose in the body.

TERMINAL EXERCISES

A. Tick the correct answer of the followings

1. The three protective coverings over the brain also called:

   (A) Membranes (B) Layers

   (C) Meninges (D) Sheaths

2. Which part of the brain controls the body temperature?

   (A) Cerebrum (B) Cerebellum

   (C) Hypothalamus (D) Medulla oblongata

3. The spinal cord is extended from the medulla upto the whole length of the vertebral column and lies within the:
   (A) Neural canal (B) Vertebral canal
   (C) Spinal canal (D) Eustachian canal

4. Which one of the following hormones is secreted by the pancreas?
   (A) Prolactin (B) Thyroxin
   (C) Adrenalin (D) Insulin

B. Answer briefly:

1. What is the nature of the membranes covering the brain? What is the name of the fluid that fills the space between these membranes? What is its role?

2. Describe the three regions of the brain.

3. Differentiate between the following pairs of terms:
   (i) Sensory nerve and motor nerve
   (ii) Cerebrum and cerebellum.
   (iii) Sympathetic and parasympathetic nervous system

4. Define the following terms:
   (i) Receptor
   (ii) Synapse
   (iii) Hormone
   (iv) Neuron
   (v) Impulse
   (vi) Stimulus
   (vii) Effector

5. Given below is a table regarding various hormones secreted by the pituitary gland, and functions of these secretions. Fill in the blanks (1 to 4);

Hormones secreted	**Functions**
Somatotropic hormone	____________(1)__________
_________(2)___________	Helps in the metabolism of glucose in our body
Thyroid hormone	__________(3)_________
_________(4)___________	In males it stimulates the secretion of testosterone.

6. Imagine that you did not score good marks in your science exam. Do you:
   (a) tear the mark sheet and not let your parents know about it?
   (b) decide that you are not a good student and cannot study science any further?
   (c) discuss your mistakes with the teacher and ask for help from the teacher or another student who has done well and is willing to help you?

   Please choose one of the three options above and provide two reasons for your choice

7. Imagine that you have gone out with three friends. One of them starts smoking and offers the cigarette to the rest of you. One of your friends accepts the offer hesitatingly and also encourages you to try smoking. One amongst you refuses to smoke and says that he did not know that he was in bad company. This person leaves the group in a huff. You also do not want to smoke but at the same time you have been friends with this group for many years now and would like to continue your friendship.

   Please describe in 2-4 sentences how you will communicate with your friends in an attempt to save your friendship without accepting their offer to smoke.

   Please note: There is no single correct answer. The learner needs to demonstrate use of assertive communication skills.

8. After a week, you go out again with the two friends who had asked you to try smoking a cigarette. This time they tell you that it is smart or stylish to smoke and in order to be part of the group, you should also smoke. Would you like to continue/ not continue being friends with them?

   Please state your decision and provide at least two reasons for your decision.

   Please note: There is no single correct answer. The purpose of this activity is to enable the learner to appreciate that friends never pressurize to do things that someone is uncomfortable with. The learner also needs to realize that exploitative relationships, including friendships should be terminated.

9. When a barefoot person accidentally steps on a pin, what will be her/ his immediate response? Explain how this reaction is processed by the nervous system?

10. Give one function performed by each of the following:
    1. Cerebrum
    2. Cerebellum
    3. Hypothalamus
    4. Medulla oblongata
    5. Cerebrospiral fluid

ANSWERS TO INTEXT QUESTIONS

23.1

1. There is no single correct answer. There may be diverse examples. For instance, in farming, a group of people till the land, another group sows the seeds, someone else takes care of the crops and only then everyone enjoys the bounty of a good harvest
2. Secretion of digestive juices

23.2

1. (b) Neuron
2. The sequence should be: ii, iii, i, iv, v
3. A stimulus is an agent or an environmental change which can initiate a response in the body. The stimuli can be of several types. It could be physical (touch, prick, pressure), auditory, chemical, radiant (light), heat or cold, or electrical.

23.3

1. (i) Brain and spinal cord
   (ii) Intelligence and consciousness
   (iii) Balance
   (iv) Medulla/ medulla oblongata
   (v) Gray matter, white matter

23.4

1. Natural reflex and conditioned reflex.
2. Stimulus — receptor — sensory neuron — CNS — motor neuron — effector — response.
3. Correct response has been provided in italics for the column on 'Appropriate Action.' However, there is no single correct reason for the choice that the learner makes. The evaluator needs to keep in mind that the learner is providing logical reasons for their choice.

Situation	Appropriate action voluntary action or reflex)	Reason for your choice
You need to immediately stop your bicycle as a speeding motorbike comes in front of your bicycle.	*Reflex Action*	It is an emergency and there is no time to process information through the central nervous system.
You have scored good marks in all the subjects in class X and now need to choose between science and commerce stream. Your family feels you should study science while you like numbers and would like to study commerce.	*Well thought out voluntary action*	As the learner will have to live with the subject/ career choice that she/he makes, it is important to give priority to their individual choice. This decision should note made impulsively.
You are cleaning your cupboard, a sharp needle pokes you and you remove your hand immediately.	*Reflex Action*	It is an emergency and there is no time to process information through the central nervous system.
You have moved to a new neighborhood and are trying to make new friends.	*Well thought out voluntary action*	It is important to choose friends who care for you and wish you well. Hence, it has to be a well thought out action.

23.5

1. 12 pairs
2. Sympathetic and parasympathetic

23.6

Answers to Question I

1. Blood
2. Goitre
3. Metabolism

Answers to Question II

i-(a);	ii-(c);	iii-(a);	iv-(c);	v-(d);	vi-(d);
vii-(c);	viii-(d);	ix-(a);	x-(b);	xi (c)	

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24

REPRODUCTION

You are well aware that a family continues generation after generation and also that organisms produce their own kind. This process of reproducing one's own kind ensures the continuance of the variety of organisms that inhabit the earth. Reproduction is a characteristic feature of every living being and has its own role to play in the body just like the other biological processes such as respiration, circulation, nutrition and others.

In this lesson, you shall learn how new organisms gain life, grow and become ready to give rise to another generation of similar individuals. You shall also learn the importance of reproductive health and hygiene so as to prevent the spread of sexually transmitted diseases. This will enable you to make correct choices at the appropriate time.

OBJECTIVES

After completing this lesson you will be able to:

- *appreciate that reproduction is a characteristic feature of organisms for the continuance of their species and that asexual and sexual reproduction are the two different modes of reproduction;*
- *identify the different types of asexual reproduction in organisms;*
- *identify the sex organs and describe in brief the process of reproduction in flowering plants;*
- *state facts about reproduction in animals with special emphasis on human reproduction;*
- *identify the changes in the human body upon reaching puberty and emphasize importance of reproductive health and hygiene;*
- *identify the major organs of reproduction in humans (both male and female), state their location in the body and relate each organ with its function;*

- *mention the reproductive events leading to pregnancy and parturition, and express concern regarding negative consequences of adolescent pregnancy;*
- *demonstrate awareness regarding the prevention and transmission of Sexually Transmitted Diseases (STDs) and Reproductive Tract Infections (RTIs) caused by microbes;*
- *express awareness of increase in population growth and suggest methods of population control.*
- *understand modes of transmission and prevention of Human Immuno Deficieny Virus (HIV)/Acquired Immuno Deficiency Syndrome (AIDS) and utilize this information in making safe informed choices.*

24.1 REPRODUCTION

You must have heard from your parents what a joyful event it was when you were born! Your parents, elder relatives or family friends might have told you how happy they were to see you take your first steps! And then, as an infant, how you got frightened when a dog barked! Ask your parents about your infancy and childhood. They would certainly remember many anecdotes of the past while you as a teenager are now busy understanding changes within yourself as you grow into an adult. Note the changes as you progressed from infancy to childhood and thence to adolescence.

ACTIVITY 24.1

As you do so, make an album of your photographs from infancy to date. If there are no photographs, collect pictures of infants and growing children to get an idea of how changes take place in the body as one grows up.

As you read this lesson, you shall begin to realize that a naturally occurring feature of all organisms is to grow up. Microbes, plants, animals all need to grow up to an extent when they are able to perpetuate their own species. Thus, the species lives on from one generation to the next. The biological process involved in the perpetuation of species is called reproduction. **Reproduction may be defined as the biological process by which organisms give rise to their own kind.** Reproduction may occur in two ways:

— Asexual reproduction

Species: a group into which animals, plants etc. that are able to breed with each other are place and identified by a Latin name. The members of the group look similar and behave in the same way because they possess the same genes e.g. The Asians, the Europeans, the Africans are all human beings belonging to the species scientifically named *Homo sapiens.*

Offspring: The young ones of living organisms

— Sexual reproduction

Bacterial and protozoan offspring may be produced by single individuals. This is termed **asexual reproduction.** Certain animals and many plants reproduce asexually as shown in figures 24.1 to 24.3. When two individuals are involved in reproduction, it is termed **sexual reproduction**. In sexual reproduction, male gamete fuses with female gamete to mark the beginning of a new individual. This is a more common mode of reproduction in plants and animals.

24.2 ASEXUAL REPRODUCTION

Reproduction by single individuals takes place in many ways in lower organisms like bacteria and protozoa and some algae. In plants, asexual reproduction is by vegetative propagation. Animals like sponges and hydra reproduce both asexually and sexually.

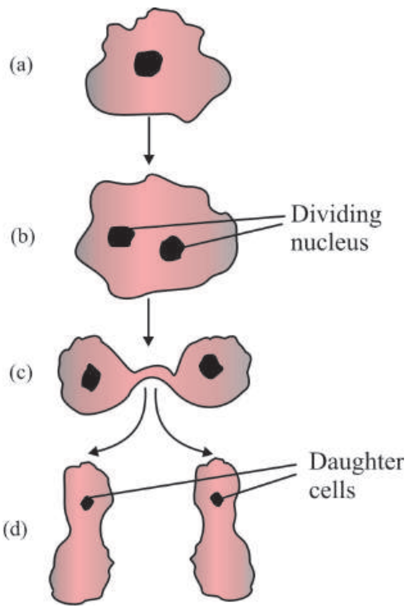


Fig. 24.1 Binary Fission in Amoeba

(i) Asexual reproduction in lower organisms

Asexual reproduction is of various types:

(a) Binary fission: A cell may divide to give rise to two individuals and lose its own identity as in binary fission that takes place in amoeba and bacteria (figure 24.1).

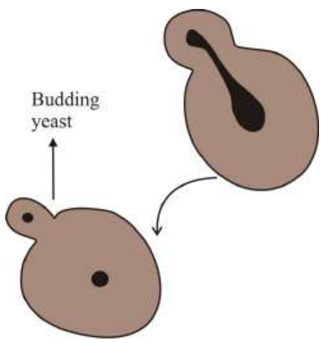


Fig. 24.2: Budding in Yeast

(b) Budding: In budding, a bud forms from the body of the mother cell and remains attached to it. The parental nucleus elongates and then divides into two, one of which moves into the bud. Example: yeast (figure 24.2).

In animals like sponges and hydra which are multicellular; a bud arises from some part of the body, enlarges and then detaches from the parent body after all its body parts have been formed (figure 24.3).

Multicellular: organism made up of many cells.

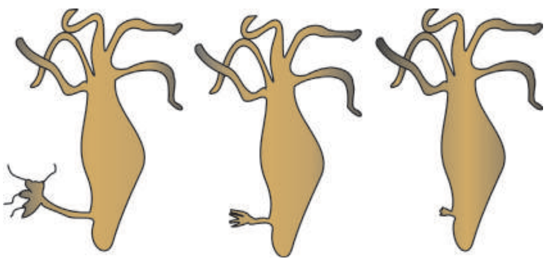


Fig. 24.3: Budding in Hydra

(c) Spore formation: The cytoplasm and nucleus of algae such as *Chlamydomonas* divide successively to form 4 to 8 spores. Spores are also formed for reproduction in fungus, moss and fern. Spores are single cells which upon their release from the parent plant develop into new individuals (figure 24.4).

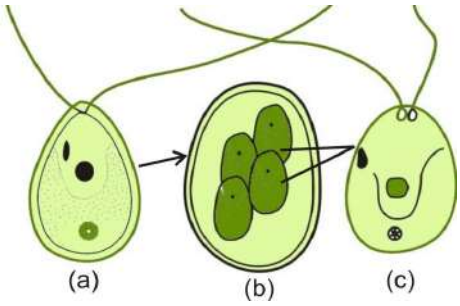


Fig. 24.4 Spore formation in Chlamydomonas

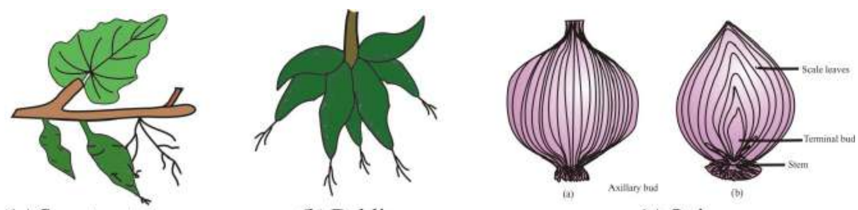
(ii) Asexual reproduction in plants

Vegetative Propagation: In nature, new plants may arise from root, stem or leaves that is from the vegetative parts of the plant as shown in fig. 24.5 (a to h). This form of asexual reproduction in plants is termed **vegetative propagation.**

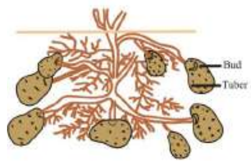
Table 24.1: Modes of vegetative propagation with examples

Mode of reproduction	Specialised plant part	Examples
(A) Natural Methods (a) Roots (fig. 24.5 a&b)	Adventitious roots	Sweet potato, Dahlia
(b) Stem	(a) Runner (fig. 24.5g)	Lawn grass,
	(b) Sucker(fig. 24.5h)	Chrysanthemum
	(c) Bulb (fig24.5c)	Onion
	(d) Tuber (fig.24.5d)	Potato, Canna
	(e) Rhizome (fig. 24.5e)	Ginger
(c) Leaves	(f) Adventitious buds (fig. 24.5f)	*Bryophyllum*
(B) Artificial Methods (fig. 24.6 a to c)		Rose, Money Plant
(a) Cutting		Jasmine,
(b) Layering		Grapevine
(c) Grafting		Citrus, Mango
		Orchid, Chrysanthemum, Asparagus.

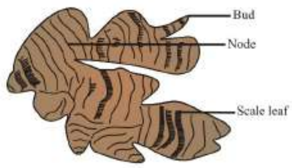
New plants may be formed from roots (fig. 24.5 a,b) or stem (24.5 c,d,e) or leaves (fig.24.5f) or when a stem grows to a distance and then enters soil and strikes roots to form a new plant (fig. 24.5 g,h)



(a) Sweet potato *(b)* Dahlia *(c)* Onion



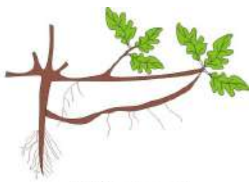
(d) Tuber of potato



(e) Rhizome of ginger

(f) Adventitous buds in Bryophyllum

(g) Runner of grass

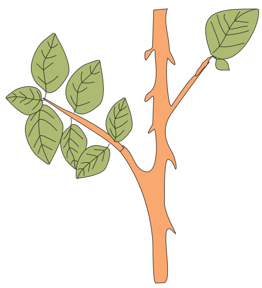


(h) Sucker of Chysanthemum

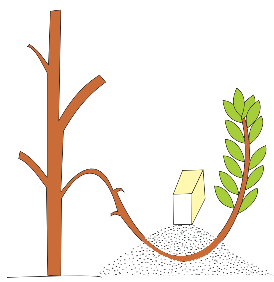
Fig. 24.5 (a to h) *Natural vegetative propagation in plants*

(iii) Artificial propagation in plants

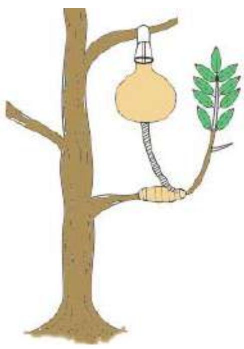
Humans have taken hints from natural methods of vegetative propagation to grow many plants through artificial propagation. Fig. 24.6 shows the various methods by which farmers and nursery owners multiply desired plants using the method of artificial propagation.



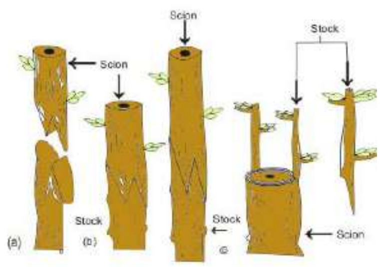
(a): *Cutting: A piece of branch is cut and embedded in the soil. Roots form and a new plant results.*



(b): *Layering: A branch of the plant is laid on the ground and a portion is embedded in the soil. This part strikes root and gives rise to new plant.*



(c): *Vegetative reproduction by gootee*



(d): *(a) The lower part of the stem or scion is cut in a wedge, (b) The shoot of the plant to be used as a stock is cut off. The stem is slit vertically and the scion is inserted into the stock and tied with a tape (c) The graft union occurs within a short time*

Fig. 24.6 (a to d): *Artificial vegetative propagation in plants*

ACTIVITY 24.2

1. Take a branch from a champa tree or a money plant. Grow it. Observe how the branch produces a full fledged plant.

2. You may even try to grow some grass picked up from the wild. What do you find? Under which conditions does the grass reproduce to form a carpet of grass? Write your observations in the space provided below:

(iv) Other methods of asexual propagation

In the laboratories, researchers have raised offspring from single parent through **tissue culture**. Dolly was a sheep, an exact copy of her mother, raised through **cloning**.

(a) Micro propagation

Researchers have standardized the methods of **tissue culture**. Every living cell or every part of a plant has been found to be **totipotent**, that is, it has the potential to give rise to more plants. Can you explain why? Try and answer after you have finished reading this lesson and can understand that all the cells of an individual arise from a single cell, the zygote and hence all cells have the same genes. Genes control growth, development and all the life processes.

From a piece of plant, say root of carrot, or a leaf, cells can now be cultured in adequate nutrient solution to form an undifferentiated mass of cells called **callus** which can then give rise to new plantlets. The raising of plants through tissue culture is termed **micropropagation.** (figure 24.7)

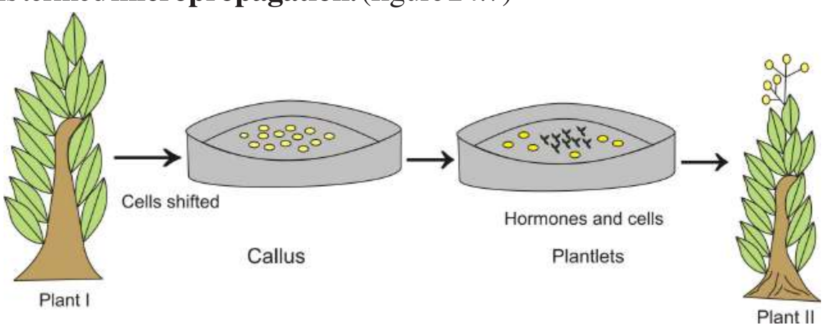


Fig. 24.7 Steps of Micropropagation (a) Leaf taken from a plant (b) Cells form undifferentiated mass (callus) (c) Hormones and nutrients added to cells (d) New plant grows from callus

Surrogate mother: A female animal in whose womb an embryo from another female of the same kind is developing.

(b) Cloning

A clone is the genetic copy of the parent. The sheep Dolly, when born was an exact copy of her mother. Her mother's udder cell nucleus was transferred into the egg of a "surrogate mother", after removing the nucleus. Dolly's mother provided her genes while the surrogate mother provided the womb (Fig. 24.8) for Dolly to develop from an embryo to a full fledged individual.

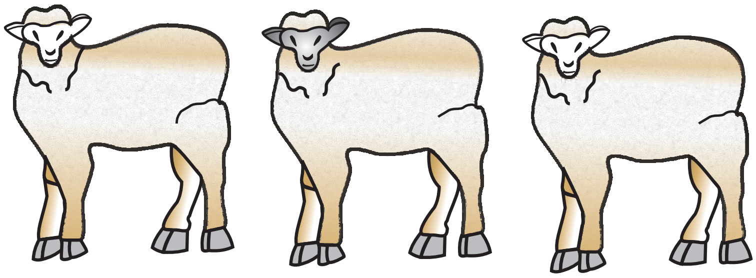


***Fig. 24.8** Cloning of the Sheep Dolly*

INTEXT QUESTIONS 24.1

1. Define reproduction.

____

2. State one point of difference between asexual and sexual reproduction.

____

3. Why is binary fission considered to be an asexual form of reproduction?

____

4. Define vegetative propagation with the help of an example.

____

5. Define the following (i) callus (ii) clone

____

24.3 SEXUAL REPRODUCTION IN PLANTS

You already know that sexual reproduction requires fusion of male and female gametes. We shall now understand how sexual reproduction takes place in flowering plants.

(i) Sexual reproduction in plants

The reproductive organ of flowering plants is the flower (Fig. 24.9). **Stamens (Androecium)** which produce pollen are the male part. **Pollen grains** contains male sex cells. There may be several stamens in each flower. Each stamen (**Androecium**) has two parts. The upper part is known as **anther** which bears pollen. It is held on the lower part called **filament**.

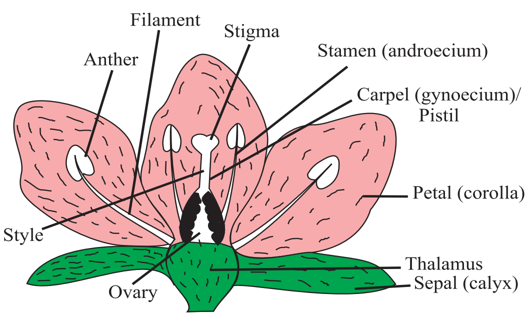
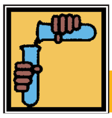


Fig. 24.9 TS of a Typical Flower

The **pistil** (**Gynoecium**) is the female part and its basal part is the ovary carrying eggs or ovules or female sex cells. The parts of the pistil are the stigma, style and ovary. In most plants, each flower bears both male and female parts. They are termed **bisexual.** In some plants there are male flowers with only androecium and female flowers bearing only gynoecium. They are **unisexual**.



ACTIVITY 24.3

1. Procure a wilted flower and look for the stamen and pistil. Identify the different parts and then check the terms for these parts in the pictures given in your book.

2. Do you think we should pluck flowers from the plants?
   State 'Yes' or 'No' choosing points from the following
   - look nice on plants
   - are living
   - where will butterflies go? Provide food for the butterflies
   - are organs of reproduction?

3. What do you think will happen if we pluck all the flowers that bloom on a plant? Write your answer in the space provided below:

(ii) Pollination and fertilisation

For fusion of their nuclei, pollen and ovule are brought together by several agencies like the wind, water, and insects. This transfer of pollen grain from anther to the stigma of a flower is called **pollination. Self pollination** is when pollen of a flower falls on its own stigma and fertilizes the ovule. **In Cross pollination** pollen from one flower falls on the stigma of another flower of a different plant of the same species and then fertilizes the ovule of that flower. Agents like wind, water or insects help to transfer pollen from one flower to another.

For **fertilization or fusion of nuclei of pollen and ovule**, pollen is brought by any pollinating agent mentioned above, on the stigma of the pistil. Each pollen grain forms a pollen tube and pollen grain nucleus reaches the ovule as pollen tube pushes through the pistil (Figure 24.10). The fertilized ovules develop into seeds which are capable of germinating into seedlings and new plants (Fig. 24.11).

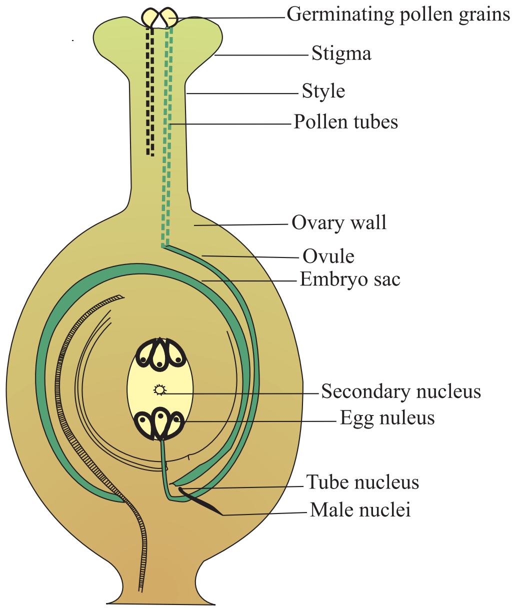
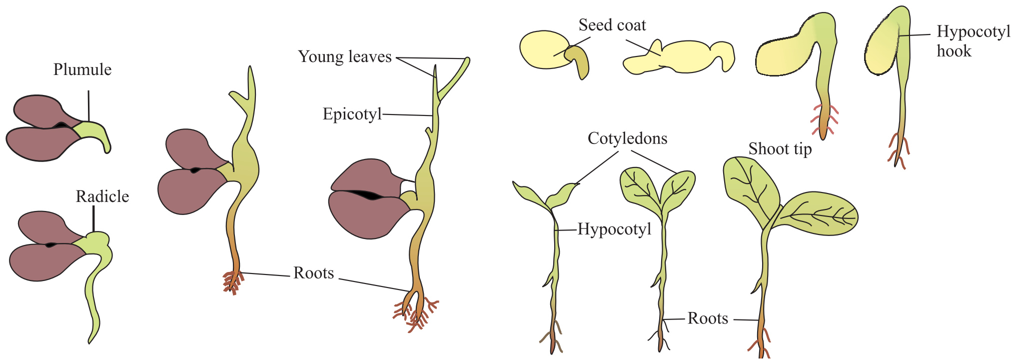


Fig 24.10: Fertilization in Plants



(a) Gram seed to new gram plant　　*(b) Maize seed to new maize plant*

Fig. 24.11 : Seed germination in (a) gram and (b) maize

Once seeds are formed, they get dispersed or are carried away from the parent plant and then germinate under favourable conditions.

INTEXT QUESTIONS 24.2

1. What purpose does the flower serve in a plant?

2. Give one point of difference between self pollination and cross pollination.

3. What will happen if the pistil of the flower is removed?

4. Trace the path of the pollen after it lands on the stigma.

5. What is germination of seed?

ACTIVITY 24.4

Now that you have an idea of how plants reproduce, find answers to the questions below and perform the related activities.

1. Have you seen plants growing from buildings or near walls? Think and express how this may happen. Express your views in the space provided below:

2. Grow wet seeds which take less time to germinate (e.g. gram, moong). After they have sprouted. Sow them in pots. Maintain them till they become seedlings. Maintain a record of the time period showing maximum growth, flowering and formation of seeds.

24.4 SEXUAL REPRODUCTION IN ANIMALS

As mentioned earlier (24.1 section i)) lower animals like the sponge and hydra can reproduce through asexual methods. They can, however, also reproduce sexually. In all animals, the female produces eggs and the male produces sperms. An egg and a sperm fuse to form the zygote which then develops into the embryo and the embryo into a full-fledged individual. The development may occur partially or completely, inside the egg. Such animals that lay eggs include fish, frog, reptiles and birds and are thus called **oviparous.** In mammals such as cats, dogs, cows and humans, the baby develops inside the mother's womb. They are termed **viviparous.**

In tapeworms and earthworms both female and male sex organs are in the same individual. Such individuals are termed **hermaphrodite**. Sexes are separate in all other animals, and the male individual has male organs like testes etc.while the female has ovaries etc. Humans also belong to the animal kingdom. They are mammals and hence viviparous.

24.5 REPRODUCTION IN HUMANS

The period from infancy to reproductive maturity in humans includes childhood and adolescence. The pictures given below show the progression of human life through stages of infancy, childhood, adolescence, adulthood, and finally ageing.

Figure Showing different of stages of Human Life

24.5.1 Adolescence in human beings

ACTIVITY 24.5

Look at the pictures depicting stages of human life. Write down two to three sentences that come to your mind about each of these stages. Encircle with a pencil the picture showing that stage of life at which you are now. Label the appropriate stages as infancy, childhood, adolescence, adulthood and old age.

The body undergoes natural changes as one grows into the reproductive period of life. These changes begin around the age of 10-11 and last till 18 to 19 years of age. This stage of life is called **adolescence**. The time period when changes occur in humans make them capable of reproduction, is called **puberty.** Not only humans, but no organism becomes mature and capable of reproduction soon after birth and needs to reach maturity and adulthood in order to do so. The period between birth and maturity is very short in animals. Perhaps it is the longest in humans.

Read carefully the table given below wherein changes during adolescence are listed. It is important to remember that although these changes occur in all adolescents, the timing and pace of changes may differ from individual to individual. This just goes to prove that each of us is unique!

Table 24.2 shows changes at puberty. The changes are physical, physiological and psychological.

Table 24.2 Changes at puberty and adolescence

Physical Changes	Remarks
1. Increase in height • Bones elongate • Muscles develop • Height increases	It is one of the most perceptible change during adolescence. Increase in height is dependent on the genetic make up, nutritional status, and physical activity levels of an adolescent.
2. Changes in body shape • Chest and shoulders broaden in boys • Increased fat deposition below the waist (around hips) in girls	Adequate nutrition is necessary for proper growth. Adolescents need a balanced combination of food items that provide energy (known as carbohydrates and fats), that help in growth (known as proteins) and protect from infections by enhancing immunity (known as vitamins and minerals). Depending on whether you are a vegetarian or a non-vegetarian, choose appropriately from the following five groups of food items. 1) cereals and millets, 2) vegetables and fruits, 3) milk, milk products, meat, fish, egg, 4) pulses, 5) fats and sugar *Please refer to the health and hygiene lesson 32 for more information on balanced diet.* **Chips, soda, chocolates, pastries and burgers should not replace a meal and should not be consumed on a regular basis.** • Regular physical exercise helps in proper growth.
3. Changes in the voice • In boys, voice box or larynx enlarges and is visible as the "Adam's apple"	• Boys develop a deep voice. Their voice sometimes cracks when the larynx or voice box is enlarging and voice control is lost during that time. • Girls develop a high pitched voice.

4. Development of sex organs In both the females and males, sex organs mature during adolescence. More details on the structure and functioning of sex organs are provided later in this lesson.	• Girls and boys become capable of reproduction. It is important to observe proper hygiene and wash all parts of the body, including external genital organs in girls and testicles in boys. • It is normal for adolescents to feel sexual excitement and masturbate. When a boy becomes sexually excited in a dream, he may experience an erection and ejaculate in his sleep. This is known as 'wet dream' and is normal. • Breast development is one of the first signs of puberty in girls. Variation in the size and shape of breasts is normal and depends on the amount of fat stored in them. Size of the breasts is not correlated with production of milk or giving pleasure.
5. Appearances of secondary sexual characters • Axial (arm pits) hair and pubic hair appear. • Breasts develop in girls. • Facial hair begins to grow in boys.	

Do you know

If a female notices any change in her breasts, for example, a lump, changes in breast shape, discharge from nipples, pits or hollow in the skin around the breast, she should consult a health worker/doctor immediately

Physiological Changes	Remarks
1. Increased activity of sweat and sebaceous (oil) glands	• Overactivity of oil glands may cause acne and pimples on the face. The acne usually go away once the hormonal changes stabilize. However, these can be reduced by washing face with soap and water several times in a day, eating lots of fruits and vegetables, drinking several glasses (at least 8-10) of water everyday and avoiding fried and fat rich food items. Avoid picking pimples as they could get infected and leave scars. Consult a health worker/ doctor if the acne are particularly troublesome. • Regular cleaning and washing will help prevent odour due to increased sweating.
2. Increase in appetite Body requires more nutrition as it grows.	At adolescence, the body grows rapidly and this makes adolescents more hungry.
3. Increase in the level of hormones in blood Levels of growth hormone and sex hormones in blood increase.	• The growth hormone secreted by anterior pituitary gland controls growth. • Under the influence of hormones from anterior pituitary, sex organs begin to secrete sex hormones. The testes secrete testosterone in males and ovaries secrete oestrogen and progesterone in females.

4. **Menstruation**	Many females have a period every 28 days. Some have them every 21 days and in others the cycle could be of 35 days. Periods usually last for 4 days but could be shorter or longer. Many adolescent girls have irregular and painful periods that settle down as girls grow up. If the problem persists, a medical doctor should be consulted.

4. Menstruation

- In human females, reproductive phase begins at puberty and lasts till the age of 45 to 50 years.
- A girl is born with fixed number of ova (eggs). However, these begin to mature only at puberty. One ovum matures at a time and is released from the ovary once in 28 to 30 days. This happens under the influence of a hormone from anterior pituitary FSH or Follicle Stimulus Hormone. One ovum (egg) is shed alternately from each ovary every month.
- The egg (ovum) travels down the fallopian tube to reach the uterus.
- At the same time, the wall of the uterus under the influence of another hormone from anterior pituitary called LH or Lutenising Hormone thickens to receive fertilized egg. If there is no fertilization, the thickened lining of uterus and blood vessels are shed off and cause bleeding. This is called **menstruation** (Fig 24.12) and is also known as period.

The first menstrual bleeding is called **menarche**. Stoppage of menstruation at an age usually between 45 years and 55 years is termed **menopause**.

Many females have a period every 28 days. Some have them every 21 days and in others the cycle could be of 35 days. Periods usually last for 4 days but could be shorter or longer. Many adolescent girls have irregular and painful periods that settle down as girls grow up. If the problem persists, a medical doctor should be consulted.

Menstruation is not an illness. If the girl feels comfortable, she could do anything that she does normally. Some girls may get cramps and pain in the abdomen. Exercise may help to prevent the pain. Paracetamol and/ or other pain killer as suggested by a doctor may help if the pain is difficult to bear.

Girls use sanitary towels, cotton wool, clean cloth or tampons to absorb blood during their periods but it is important to change these frequently (every 6-8 hours) to prevent infection from reaching vagina. If reused, cloth should be washed with a mild detergent and dried in the sun.

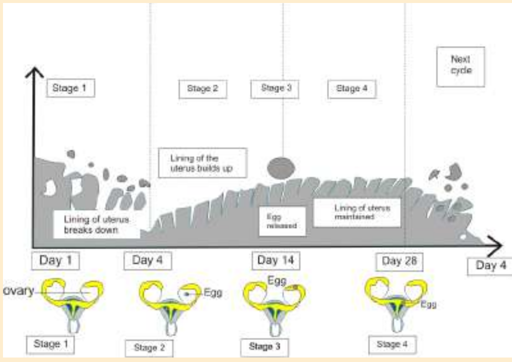


***Fig. 24.12** Graphical Representation of menstrual Cycle*

Adolescents may be biologically capable of reproduction but they are not ready to shoulder the responsibilities of parenthood. Adolescent girls are not physiologically mature for child bearing and many a time, both the adolescent mother and her baby suffer from complications. Adolescent parents are not likely to have good opportunities of education and livelihood and may not be able to provide for their child. Eventhough the legal age at marriage is 18 for girls and 21 for boys, child marriage is still a problem in our country. Data from the National Family Health Survey conducted in 2005-6 show that 27% young women and 3% young men in the age group of 15-19 were married at the time of the survey. Furthermore, findings from the same survey show that 30% females in the age group of 15-19 have had a live birth by the age of 19 years

Can you reason out?

Can you give two reasons as to why menstruation does not occur during pregnancy?

Hints (i) Menstruation occurs when fertilization does not happen and the egg as well as thickened lining of uterus and blood vessels are shed off

(ii) During pregnancy, the growing foetus is attached to thickened uterine wall.

Psychological changes

Mental, emotional and intellectual maturity develops gradually:

- Adolescents are capable of abstract thinking.
- They experience mood swings.
- They become self conscious.
- Self image and identity becomes important.
- Friendship is very important to them.
- They start getting interested in one another in a sexual way.
- Opinions expressed by peer that are different from their personal beliefs could be a source of stress and anxiety as it is important for them to **fit in** with the group norms

Adolescents should definitely enjoy this phase of their lives but also invest in their future! It is important to strike the right balance!!

Initiating and nurturing friendships and positive relationships is a vital part of growing up. However, it is important that relationships are built on equality, mutual respect and love. Relationships that lack these attributes could be exploitative and cause physical, emotional and psychological harm that may prevent young people from realizing their potential. Sexuality is an important part of growing up but decisions related to sex and sexuality should be based on appropriate information, an understanding of consequences and most importantly a sense of responsibility.

Striving for independence is a very important part of adolescence. Young people need to remember that they should be able to take responsibility for their independent decisions

ACTIVITY 24.6

The following chart gives the average rate of growth in the height of boys and girls with age. The figures in columns 2 and 3, give the percentage of the height which a person has reached at age given in column 1. For example by age 11, a boy has reached 81% of his full height. These figures are only representative and there may be individual variations.

Use the table for yourself and your friends and work out how tall each of you is likely to be. Is it not fascinating that each one of you is likely to be slightly different from the other!

Age in Years	% of full height	
	Boys	Girls
8	72%	77%
9	75%	81%
10	78%	84%
11	81%	88%
12	84%	91%
13	88%	95%
14	92%	98%
15	95%	99%
16	98%	99.5%
17	99%	100%
18	100%	100%

Present height (cm)/% of full height at this age x 100

(as given in the chart)

Example:

A boy is 9 years old and 120cm tall. At the end of the growth period he is likely to be 120/75x100 = 160 cm tall.

ACTIVITY 24.7

- Have a frank and honest discussion with your friends about the kind of changes you are undergoing in your body and mind. You may find certain commonalities and some things that are unique to each of you.
- Is there a change during adolescence that makes you happy and a change that makes you nervous and anxious? Share it with your friend. You may go to

website of NIOS and Adolescence Toll free phone number 18001809393 for more information related to these changes

- Quote at least one incident when you experienced a mood swing. In your opinion, were you able to handle it well? If not, what could you do the next time to either prevent the mood swing or manage it better.

24.6 THE ORGANS OF REPRODUCTION IN HUMANS

Reproduction in humans require two individuals - a male and a female.

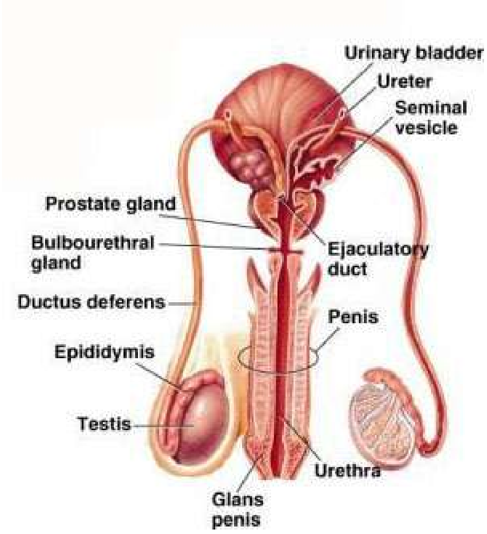


Fig. :24.13 Male Reproductive Organs

(i) The male reproductive organs

The male reproductive organs are shown in Figure 24.13. The functions of its parts are tabulated in table 24.3.

Table 24.3 Reproductive organs of human male

Organ	*Function*
A pair of testes	Generate Sperms
Two sperm ducts or vasa diferentia (Singular: Vas deferens)	Each arises from the testis and passes up into the body to join together and form the ejaculatory duct.
One ejaculatory duct	Is a common duct for passage of urine and sperms.
One Penis	Muscular organ which helps to transfer sperms into female body.

Do you know

The testes lie outside the body within the scrotal sac. This is to ensure that the temperature at which sperms are being produced is 2°C less than body temperature as required for sperms to stay alive.

(ii) The Female reproductive system

The figures 24.14(a) and 24.14(b) are figures of (1) the human female reproductive system and (2) section of the female reproductive tract showing the movement of the egg released from the ovary/fertilised in the fallopian tube and zygote undergoing development till it reaches the uterus and implants in its wall for further development.

The female reproductive system is located in the lower abdomen. The organs of the female reproductive system and their functions are tabulated in Table 24.4. The ovary and oviduct are commonly found in all female animals and the uterus in those who do not lay eggs but give birth to young.

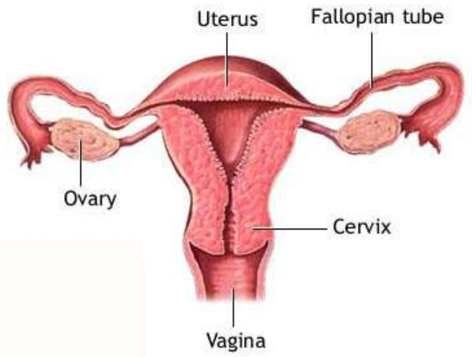


Fig. 24.14 (a) Female Reproductive Organs in Humans

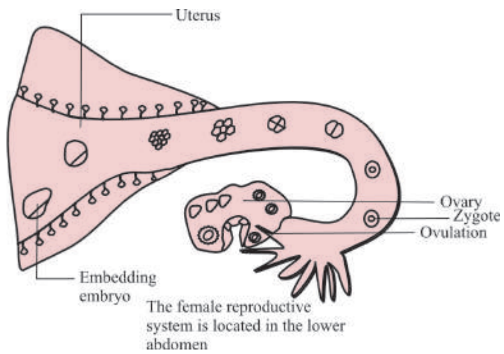


Fig. 24.14 (b) The Female Reproductive System showing the movement of fertilised egg

Table 24.4 The human female reproductive organs and their functions

Organs	*Function*
A pair of ovaries	Produce ova
Two fallopian tubes	Are the oviducts through which eggs pass from the ovaries into uterus
One uterus	The womb in which the embryo develops
One cervix	The opening of uterus
One vagina	Female opening

INTEXT QUESTIONS 24.3

1. Define the terms (i) adolescence (ii) puberty (iii) hermaphrodite (iv)oviparous (v) viviparous (vi) foetus

2. Name the hormones secreted by the testes and ovary.

3. Name the part of the female reproductive system where the egg gets fertilised by the sperm.

4. State the function of (i) uterus (ii) vas deferens

5. Consider the three case studies given below. Please provide your suggestions for managing these situations in 2-4 sentences each.

   Case 1: Your friend, Suresh is extremely shy and withdrawn because he is growing hair at many places in his body. His voice is croaky and sometimes he gets dreams which make him feel ashamed of himself. How will you convince Suresh that what he is undergoing is absolutely normal and natural?

   Case 2: Rehman, your friend , is disappointed because he is the same age as most of the friends but in comparison to others, he looks baby-faced and has no facial hair. How will you get him out of this 'odd man out' feeling? Suggest two ways.

   Case 3: Your cousin Madhu is prevented from entering the kitchen and entering places of worship during menstruation and Madhu feels that she is being punished for something that is normal and definitely not her fault. Based on your understanding of menstrual cycle, do you think this is a correct practice? If not, please provide at least two reasons to convince your aunt to stop this practice.

6. Your friend Kiran would not look at boys during her periods as she had heard from someone that if she did so she would become pregnant.

Write a letter to Kiran that helps her realize that she is holding on to a false belief.

24.7 FERTILISATION AND EMBRYONIC DEVELOPMENT IN HUMANS

Observe figure 24.15 (a to g) carefully. It shows the steps of reproduction in humans. The figure (a) and (b) are the human gametes, **sperm, the male gamete** generated in

Notes

the testis (spermatogenesis) and **egg or ovum, the female gamete** produced in the ovary through the process of oogenesis.

- The nuclei of sperm and egg fuse inside the egg, forming the zygote. This fusion is termed **fertilisation** and takes place in the fallopian tube (the oviduct). (fig24.15 (c)).
- The fertilised egg or zygote begins to divide repeatedly and upon reaching a stage containing cells and a cavity called blastocoel, gets embedded (e) in the thickened uterine wall in which many blood capillaries have formed.

Genesis: to give birth or to generate

Gametes: Reproductive cells that fuse during fertilization to form a zygote which develops into an embryo. For example,
Male gamete = sperm
Female gamete = egg or ovule

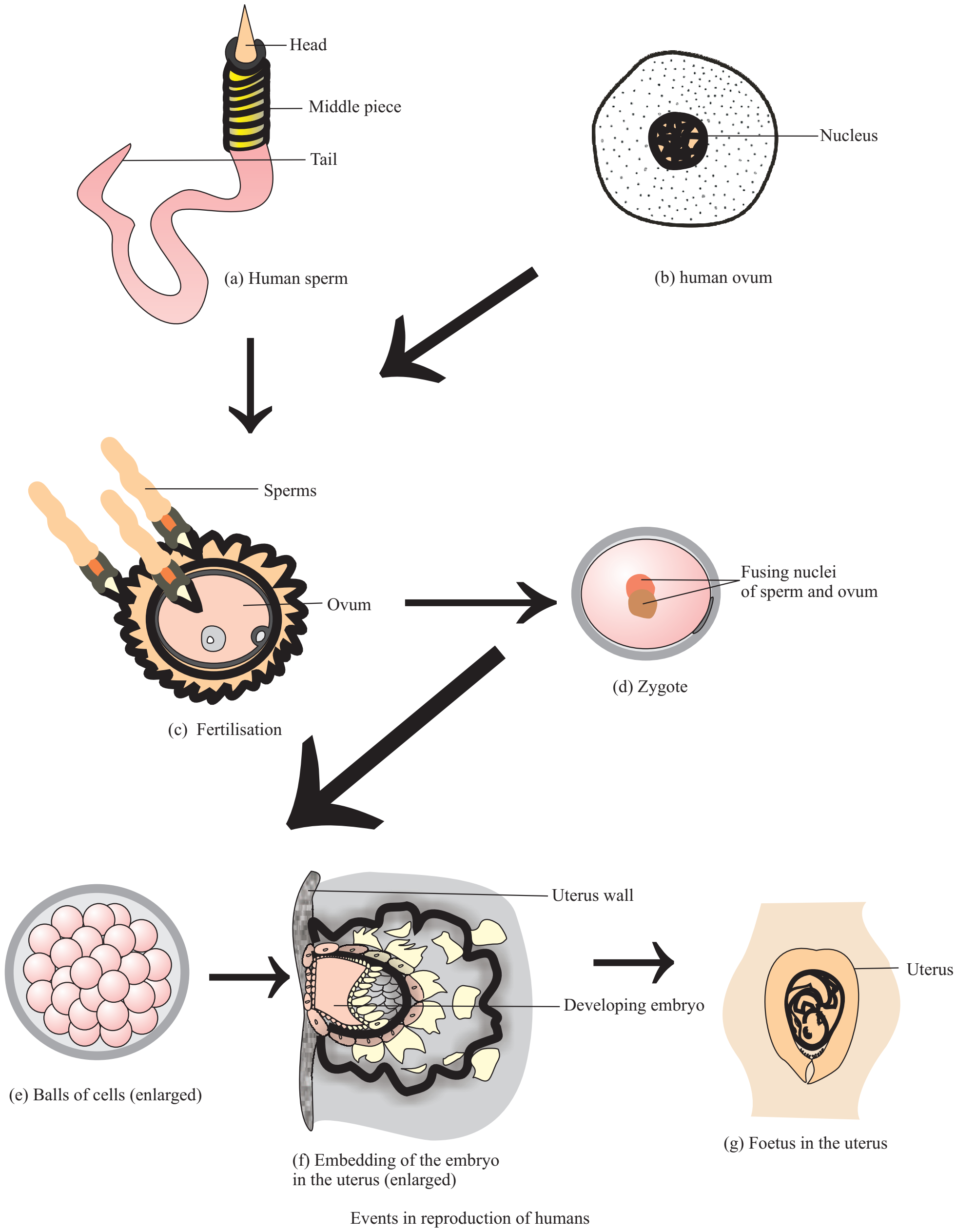


Fig. 24.15: Events in reproduction of humans

- In case fertilisation does not occur the egg disintegrates. The thickened wall of uterus along with capillaries breakdown leading to bleeding or menstrual flow (menstruation). In human female menstruation occurs every 28 to 30 days (fig. 24.12)
- The embryo, now called foetus develops (f) and (g) into a full fledged individual in 280 days inside the uterus and is born under the influence of a hormone from posterior pituitary, called oxytocin.

INTEXT QUESTIONS 24.4

1. List, in a sequence the events that lead to the birth of a new individual.

2. Name the hormones responsible, for attaining reproductive maturity, and for formation and maturing of sperms and eggs in humans.

3. Given below is a list of hormones related to reproduction. List influence on functions in the space given below:

   FSH, LH, Estrogen, Testosterone, Oxytocin

Hormones	function

24.8 HUMAN POPULATION

You may be aware that the population of India is more than a billion and continues to grow. In terms of numbers, India may overtake China that is currently the most populous nation of the world in the next two decades.

It is not difficult to imagine that a strong force of one billion people working together can achieve all the development goals and even more. However, India lags behind on several development indicators and needs to make systemic and consistent investments in education, health, employment and social welfare before its vast human potential can be realized. Young people like you have an important responsibility to take the country forward.

ACTIVITY 24.8

1. Suppose you are the Prime Minister of India. State three key areas in which your government will invest for improving the pace of development in the country so that the vast human potential can be realized?

___

___

2. India is struggling with issues related to a large population. On the other hand, countries like Japan and Sweden are worried that their population is not growing and are giving incentives to young people in their country to contribute towards population growth. Please fill the table below to identify the major advantages and problems that countries with large and small populations face.

India (Large Population)		Sweden (Small Population)	
Advantages	Problems	Advantages	Problems

24.8.1 Making Informed Choices about Family Size

The decisions that individuals make about the size of their families will contribute towards limiting the size of the population of the country. Decisions related to family size are motivated by people's aspirations and resources. In a large segment of Indian society, there is pressure on the young couples especially, the females to prove their fertility and bear male children. Undoubtedly, children are a valuable component of the family. However, unplanned pregnancy may compromise the health and well being of both the mother and the child. In addition, if the parents are not ready to provide for the child both in economic and emotional terms, the child may not get the opportunities for holistic growth and development.

All of us recognize that planning is an important part of decision making but it is important to have correct and appropriate information to make informed decisions. Planning the size of the family and the timing of child birth helps to achieve better quality of life as there are likely to be sufficient resources to spend on food, education, health and well being of all the members of the family. Whose decision would that be?

Some of the modern methods for preventing pregnancy, also known as '*contraception*' are outlined in Table 24.5 below. Contraceptive methods are broadly classified into two categories: temporary and permanent methods. With the use of temporary methods, fertility returns after stopping the use of these methods. Hence, they are appropriate to delay the birth of the first child and/ or increase birth interval between two children. Permanent methods are irreversible for all practical purposes and are appropriate for couples who have completed their families and do not want any more children. Contraceptive methods should be adopted based on the couple's need and after consultation with a trained medical practitioner.

Table 24.5: Common Methods of Contraception

Device	Function
Temporary Methods	
Condoms in males/ Diaphragms in Females	Physical barrier that prevents sperm from meeting the egg
Intra Uterine Contraceptive Device (IUCD), for example, Copper T	Inserted in female body by medical practitioner to prevent implantation of the growing embryo.
Oral contraceptive pills	Pills interfere with ovulation and prevent release of ova from the ovaries. As a result, fertilization cannot occur. These should be started under guidance from a trained medical practitioner.
Permanent Methods	
Vasectomy in males /Tubectomy in females	Are surgical methods for tying up the tube vas deferens through which sperms travel in males and in females blocking fallopian tube preventing fertilization.

The government has established a number of health service delivery institutions at different levels where contraceptive methods are available free of cost or at heavily subsidized rates. Clients may also seek counselling services at these centres.

24.9 REPRODUCTIVE TRACT INFECTIONS AND SEXUALLY TRANSMITTED DISEASES

Reproductive Tract Infections (RTIs) refer to infections of reproductive organs. These illnesses may occur due to poor genital hygiene, for example, poor menstrual hygiene among girls. Importantly, RTIs include the illnesses that are transmitted from one person to another during sexual contact and are known as Sexually Transmitted Diseases (STDs).

24.9.1 STDs

These infections may be transmitted during vaginal or anal intercourses, or genital skin contact. Gonorrhea, syphilis, herpes, chlamydia, warts and chancroid are common STDs. Human Immuno-deficiency Virus (HIV) can also be transmitted through sexual contact.

Symptoms of STDs include,

- Itching or soreness of genitals or anus
- Blisters, sores, lump, rash in uro-genital areas
- Discoloured discharge that may be foul smelling from vagina in females and penis in males
- Pain during urination
- Women may also complain of pain in lower back and abdomen

Some infected persons may not show any symptoms and may pass on infection to their partners unknowingly.

Did you know that compared to men :

- women acquire STIs more easily as the disease causing organisms can stay inside the vagina for a longer time?
- women are also likely to be asymptomatic (without showing symptoms of STD) for longer periods of time after acquiring the infection?
- young women are more susceptible to acquire STDs as their vaginal mucosa is immature?

It is important to see a doctor if any of the symptoms of STDs occur. Prompt and complete treatment can cure most of the Sexually Transmitted Diseases. Untreated STDs can lead to infertility. The sexual partner of the infected person should also seek medical advice and treatment. Unless the infected individual is cured, s/he should avoid sexual intercourse. STDs can be prevented by:

- having one faithful sex partner
- having safe sex with correct and consistent use of condoms

Notes

T-lymphocyte: A type of white blood corpuscle that defends the body against infectious agents

24.10 HIV/AIDS

Human Immunodeficiency Virus (HIV) causes Acquired Immuno-Deficiency Syndrome (AIDS). HIV is a retro virus, i.e., its genetic material is RNA. It destroys vital cells of the immune system making the body vulnerable to several infectious agents. It infects T-lymphocytes and makes thousands of copies of the virus. HIV-infected individual may remain asymptomatic for 10-15 years. Gradually, the number of T-helper cells of the immune system decrease in number to a low when the victim loses resistance against other diseases. This is the stage of full-blown AIDS.

It is estimated that across the world, 30 million adults and 3 million children below the age of 15 live with AIDS. HIV may be transmitted from one infected individual to another individual by the following mechanisms:

- Unprotected sexual intercourse
- Infected blood
- Infected syringes and needles: Injection-drug users may acquire HIV through this route by sharing infected needles. Similarly, HIV may be transmitted if infected needles are used for tattooing, acupuncture
- Infected mother to her baby in utero (in the womb), during child birth and through breast milk

As discussed under prevention of STDs, HIV transmission can be prevented by:

- Having one faithful sex partner
- Having safe sex with correct and consistent use of condom

In addition, HIV transmission can be prevented by:

- Using sterilized needles for blood donation or transfusion or getting injections
- Pregnant women infected with HIV should seek advice from medical practitioner on the safest mode of delivery and seek counselling regarding breast feeding the baby.

Anti-retro viral therapy is available to check the progression from HIV infection to full-blown AIDS and has been shown to be effective.

You have just learnt how HIV/AIDS is transmitted. It is not transmitted through kissing, holding hands, hugging, sharing toilets, sharing clothes, food and drink, sneezing, coughing or mosquitoes. Hence, AIDS positive individuals should not be stigmatized or discriminated against.

INTEXT QUESTIONS 24.5

1. Name any four sexually transmitted diseases.

2. Name four devices which prevent fertilization in humans.

3. Expand the abbreviations (i) HIV and (ii) AIDS.

WHAT YOU HAVE LEARNT

- Reproduction is a characteristic of all living beings.
- It is the biological process of producing offspring of one's own kind.
- Reproduction may be asexual or sexual.
- In asexual reproduction offspring are produced by single individual.
- In sexual reproduction, a male individual and a female individual are needed.
- Hermaphrodites like tapeworm and earthworm have both male and female organs in same individual.
- Asexual reproduction in protozoa is by binary fission, in yeast and hydra by budding. In plants, parts like roots, stem and leaves may give rise to new plants. This is called vegetative propagation. Plants may be artificially propagated by layering, cutting, goottee etc. Recent laboratory methods are micro propagation and cloning.
- Sexual reproduction requires the fusion of male and female reproductive cells/gametes. In plants, flower is the reproductive part. Its stamens are the male part and pistil, the female part.
- The male gametes is the pollen of one plant may reach the female gamete of the same flower or same kind of flower by being transferred on the stigma of the pistil by agencies like wind, water or insects.
- Fusion of male and female gametes is called fertilisation.
- After fertilisation, ovules form seeds. Seeds can germinate into new plants.
- Reproductive maturity in humans begins during puberty in the adolescents. During adolescence, boys and girls undergo physical, physiological and psychological changes.

- Sexual reproduction in animals begins with fusion of sperm and egg (ova). Sperms develop testes, the male organ and ova in ovary, the female organ. Animals may lay eggs (oviparous) or the embryo may develop completely inside the uterus (viviparous).
- Male and female reproductive parts in humans are: Male- a pair of 2 testes, 2 vas diferentia, one ejaculatory duct passing through penis. Female: - a pair of ovaries, 2 oviducts or fallopian tubes, one uterus, one vagina opening to the outside.
- Reproductive events are under the control of hormones.
- After fertilisation, the embryo which implants in the mother's uterus becomes the foetus. Foetus completely develops in the mother's womb.
- India has the largest human population after China. Population is one of the greatest resources for the country. Planning the size of the family and the timing of child birth helps to achieve better quality of life as there are likely to be sufficient resources to spend on food, education, health and well being of all the members of the family. There are several methods of contraception that can be used based on the needs of the couple.
- Certain diseases are transmitted through sexual acts. These are sexually transmitted infections due to virus and bacteria and HIV-AIDS caused by HIV virus.

TERMINAL EXERCISES

1. Name the biological process by virtue of which a species continues from generation to generation?
2. Mention two differences between asexual and sexual modes of reproduction?
3. Mention an example for each of the following methods of reproduction.
   (i) Budding (ii) Spore formation
   (iii) Binary fission (iv) Vegetative reproduction
4. Why is vegetative reproduction considered as a type of asexual reproduction?
5. Mention the specialized parts that are responsible for vegetative mode of reproduction in the following plants
   (i) Ginger (ii) Grass
   (iii) Onion (iv) Potato

6. How is artificial vegetative propagation different from natural vegetative propagation. How is the former beneficial to humans?

7. How is a callus developed in tissue culture? Give the steps.

8. Why is it said that all living cells are totipotent? Explain.

9. Label the following parts in the given diagram
   (i) part that produces pollen.
   (ii) part of the flower that receives the pollen.
   (iii) part that contains ovules.
   (iv) the part of the flower that holds the anther.

10. Justify the following statements:
    (i) Birds, reptiles and frogs are called 'Oviparous'.
    (ii) Human are 'Viviparous'.
    (iii) Earth worm is a 'hermaphrodite'.
    (iv) The sheep 'Dolly' was a clone of her mother.

11. Trace the events after pollination that lead to seed formation

12. Identify (a) (b) (c) and (d) in the following table

	Reproductive organ of Human		**Function**
1.	Testes	1)	Produces the hormone.........(a)......
2.	........(b)......................	2)	The womb in which the embryo develops
3.	Cervix	3)	........(c)...........................
4.	........(.d..)......................	4)	Arise from he testis and later join together to form ejaculatory duct.

13. List the physiological changes that arise at puberty in
    - human female
    - human male

14. Mention the psychological changes that are experienced by the adolescents.

15. Mention the fate of the thickened uterine lining in human of in case fertilisation does not occur.

16. Do you agree with the statement "A strong force of one billion Indians can achieve all the developmental goals and lot more"? Why/Why not?

17. Why is it that -
    (i) Women acquire STIs more easily as compared to men?
    (ii) Young women are more susceptible to acquire STIs as compared to men?

ANSWERS TO INTEXT QUESTIONS

24.1

1. Biological process by which organisms give rise to offspring of their own kind.
2. **Asexual** — offspring produced by single individual
   Sexual — two individuals are involved in producing offspring
3. Cell divides to give rise to two offspring while losing its own identity
4. New plants may arise and grow from roots, stems or leaves. e.g. *Bryophyllum*
5. (i) Undifferentiated mass of cells in culture medium (callus)
   (ii) Genetic copy of the parent, e.g. Dolly – the cloned sheep.

24.2

1. It serves as reproductive organ of the plants.
2. **Self pollination** — When pollen of the same flower on the stigma and then fertilizes the ovule of the same flower.
   Cross pollination — Pollen from one flower falls on falls stigma of another flower of the same species to fertilize the ovule of The latter.
3. Fertilisation leading to seed formation for new generation of plants will not be possible.
4. Pollen grain forms a pollen tube and pollen grain nucleus reaches the ovule as pollen tube pushes through the pistil. The pollen nucleus fuses with nucleus of ovule.
5. Fertilized ovules develop into seeds which are capable of germinating into seedlings and subsequently growing into new plants.

24.3

1. (i) Stage of life at the age between 11 to 19 years when physical and physiological changes take place in the body is called adolescence.
   (ii) The time period when changes occur that make human capable of reproduction.
   (iii) Both male and female sex organs are in the same individual.

(iv) Development of an embryo may occur upto an extent or upto completion inside the egg.

(v) Baby develops inside the mother's womb/ giving birth to young ones.

(vi) Developing embryo implanted in the uterus wall of the mother.

2. Testosterone and oestrogen
3. Developing embryo
4. (i) Embryo develops inside uterus

   (ii) Sperms pass through these into ejaculatory duct
5. Analysis case studies attempted by student incorporating knowledge gained on adolescence and puberty.

24.4

1. Human sperm and Human ovum "formation of zygote "developing embryo" foetus in the uterus "born after development is complete"
2. FSH and LH
3.

Hormone	Function
FSH	Egg mature
LH	Egg shed
Estrogen	Secondary sexual characters in female
Testosterone	Secondary sexual characters in male
Oxytocein	Uterine contractions for deliver the baby

24.5

1. Syphilis, Gonorrhea, herpes, Chlamydia
2. IUCD – Copper T, Oral contraceptive pills, vasectomy in male/tubectomy in female, MTP.
3. (i) HIV – Human Immunodeficiency virus

   (ii) AIDS – Acquired Immuno Deficiency Syndrome

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25

HEREDITY

Why does a human baby look like a human being and also resemble closely or distantly the parents, a grandparent or even cousins or uncle/aunt? Why is a kitten like a miniature cat to look at? Why does a seedling acquire the same kinds of leaves, stem or flowers as the parent plants? Why do, for that matter, all organisms resemble, in structure, their parents? The passing down of similar characters generation after generation is termed **'heredity'**. Heredity is controlled by genes. Differences in gene combinations lead to **'variations'** or differences even among members of the same family. The science of heredity and variation is termed **Genetics.**

In this lesson you shall learn some fundamental aspects of genetics such as Mendel's laws, chromosomes, genes, how DNA duplicates, what makes a fertilized egg male or female and what kind of advice helps to prevent hereditary disorders.

OBJECTIVES

After completing this lesson, you will be able to:

- *define the term heredity and variation;*
- *state pattern of Mendelian inheritance;*
- *describe the location, structure and function of chromosomes and genes and briefly explain DNA fingerprinting and its significance;*
- *outline the process of DNA replication;*
- *give an account of the four blood groups in humans and the manner of their inheritance;*
- *explain the chromosomal basis of sex determination in humans;*
- *list certain hereditary disorders and mention hazards of consanguineous marriage;*

- *emphasize the relevance of genetic counseling;*
- *briefly describe the human genome;*
- *outline the salient points of genetic engineering.*

25.1 HEREDITY AND VARIATION

Heredity

The passing down of characters from parents to offspring is termed **heredity**. Heredity is controlled by genes.

Variation

Look around and you shall find so many differences even between individuals of the same kind. For example, in the rose garden, the colour of rose flowers on different plants are different, puppies, of the same mother dog are different in their coat colour (Colour of their hair or fur). All such individual differences are termed **variations**. Variations are due to genes or environment. Now perform the following activity to find variation in the ear lobes of human beings

ACTIVITY 25.1

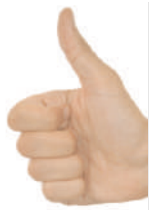
Check your ear lobes and those of your friends and family members. The lower end of the ear lobe may be attached or free as shown in the figure 25.1. This feature of the ear lobe is hereditary. Observe the ear lobes of your parents and your siblings (brothers and sisters) and note from which of your parents you have inherited this feature. You may similarly try and observe the rolling of your tongue and notice

Fig. 25.1 *Ear lobe, whether free of fixed, is hereditary*

who all in your family can roll their tongues. Similarly, you may note who all in your family can curve the tip of the thumb backwards and who all cannot, for this ability is also hereditary. Note any two other features such as colour of the eyes or the shape of the nose or any other feature among your friends. Differences that you note are termed **variations**.

You may perform other activities to find out about the occurrence of variation for yourselves. For example the variation with respect to the ability to rolling the tongue or having the hitch hikers thumb (figure 25.2 a and b)

(a)



(b)

Fig. 25.2 (a) Rolling Tongue (b) Hitch hikers thumb

25.2 CONTRIBUTION OF GREGOR JOHANN MENDEL, THE FOUNDER OF GENETICS

The question about heredity intrigued many scientists of yesteryears. Gregor Johann Mendel (1822 -1884), an Austrian monk undertook the laborious task of finding the answers. He selected some pea plants, grew them year after year, compiled a lot of data, analysed and postulated certain laws of inheritance for the first time. His remarkable work, however, got recognized years after his death when Correns, Tschermak and Hugo de Vries came to the same conclusions as Mendel did, after independently carrying out experiments in their own countries.

Gregor Johann Mendel (1822-1884)

25.2.1 Mendel's Laws of Inheritance

Mendel's laws state that:

1. Every feature or character (for example colour of flowers, height of plant, colour and texture of seed, colour and texture of pods and location of flower on the plant) is controlled by a pair of **factors**. During the formation of gametes, one factor goes to one gamete and its pair to another gamete. **Thus the two factors of a pair segregate or separate during gamete formation.** Upon fertilization, the combination of factors expresses the feature. (**1st law).**

2. Out of the two factors controlling a certain feature, the **dominant** one may express inspite of the presence of the other. The other factor expresses only in the absence of the dominant factor and is termed **recessive (2nd law).**

For example: factor for tallness in the pea plant always expresses in the offspring but dwarfness expresses only if factor for tallness is not present.

Mendel also postulated two other laws called 'law of parental equivalence' and, 'law of independent assortment'. They are not elaborated here.

The first law defined here is universal. Scientists later observed deviations from the other Mendelian laws.

Sutton in 1902, working with grasshopper chromosomes confirmed that **Mendelian** factors **were present in chromosomes.** Still later the **term 'gene' replaced the term 'factor.'** In other words genes are present on chromosomes.

INTEXT QUESTIONS 25.1

1. What is meant by the terms (1) Heredity and (2) Variation.

2. Why is Mendel considered as the founder or father of genetics?

3. Formulate a sentence to demonstrate your understanding of the terms **'dominant'** and **'recessive.'**

4. Name the scientist who discovered that Mendelian factors are present on chromosomes.

5. Give the synonym for Mendelian factor.

25.3 CHROMOSOMES AND GENES

Genes are responsible for heredity. They are present on chromosomes at fix points.

25.3.1. Chromosome

The nucleus of every cell (except RBC of mammals) contains a fixed number of chromosomes. In all the cells of eukaryotes, chromosomes show the following typical characteristics -

1. They are present in **pairs**, one from the father and the other from the mother.
2. They can be **seen only during cell division.** In a non-dividing cell, they appear in the nucleus as a jumbled up network termed **chromatin**.
3. The paired chromosomes are present **in a fixed number.** A fixed set of chromosomes is termed the '**diploid**' (paired) number and designated as 2n.
4. Each chromosome is made of one molecule of the chemical called DNA or deoxyribonucleic acid and some proteins.
5. Before cell division, the DNA molecule of a chromosome replicates (duplicates) to give two molecules of DNA which are called '**chromatids.**' The two chromatids of a chromosome remain attached at a point called **centromere** and separate to form two chromosomes during cell division.

In the bacteria, only **one chromosome** (that is only one molecule of DNA) is present and since there is no well formed nucleus, the single chromosome lies in the cytoplasm in the region termed **nucleoid.** (Fig. 25.3a and 25.3b)

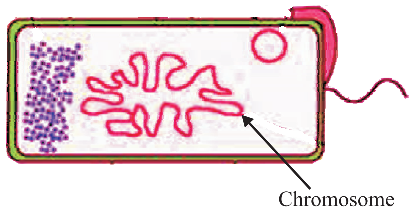


Fig. 25.3a Bacterial chromosome

25.3.2 Human chromosomes

Every cell of a human being contains 46 chromosomes. In other words, the diploid number in humans is 46. This can be expressed as 2n=46. Since gametes contain only half the number of chromosomes or the **haploid** number, a sperm and an ovum or an egg has only 23 chromosomes.

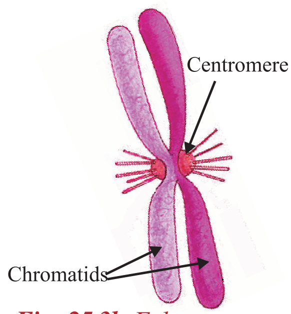


Fig. 25.3b Eukaryote chromosome

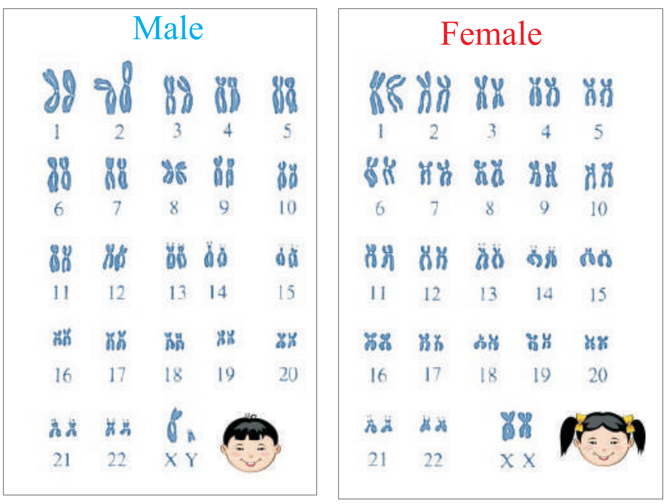


Fig 25.4 Human Chromosomes

Every species has a fixed number of chromosomes.

Each chromosome seen in the figure (25.4) possesses two identical chromatids joined by the centromere. The chromatids become independent chromosomes when they acquire a centromere at anaphase of cell division and ultimately move to different cells.

The chromosomes may be photographed from dividing cells at metaphase stage of mitosis and then displayed in pairs as in figure 25.5.

A pair of similar chromosomes (one received from the father and one from the mother) containing the same genes are termed **homologous chromosomes.**

Out of the 23 pairs of chromosomes, 22 pairs are termed **autosomes**. The 23rd pair (X and X in females and X and Y in males) are called **sex chromosomes.**

X chromosome has several genes, some of which are necessary for survival. Y chromosome bears genes for maleness only. One such gene is the 'testes determining factor'.

25.3.3 Genes

Genes are present on chromosomes. The Genes are the 'Mendelian factors,' present in pairs (one received from the father, other from the mother), on the chromosomes. Thus, one member of a pair of genes present on the chromosomes has its pair on the homologous chromosome at the same location.

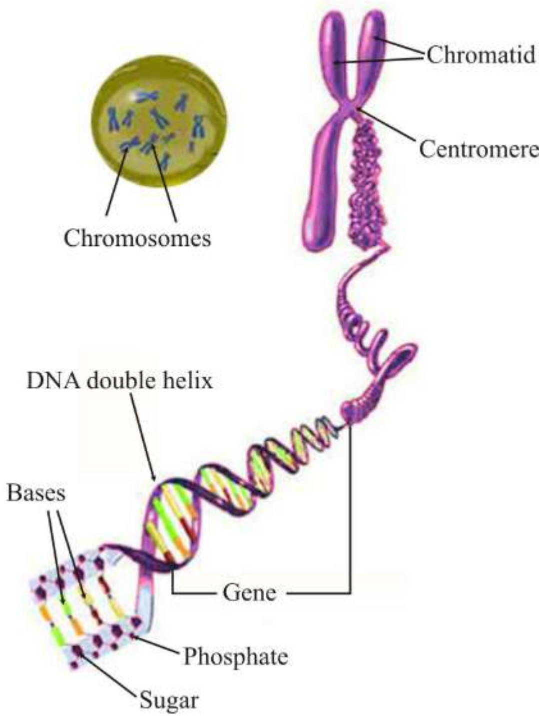


Fig 25.5 Location and Appearance of Chromosome and Genes

Genes are the bearers of hereditary characters or the units of heredity. It has already been mentioned that a chromosome contains one molecule of the chemical called DNA. Genes present on chromosome are **segments of DNA.** (**figure** 25.5)

Since every individual begins life as a single cell, the DNA contained in all the cells of an individual is identical.

25.3.4 DNA fingerprinting

You might have heard that criminals can now be identified by DNA tests called "**DNA fingerprinting**". This is because DNA of an individual is the same in each and every cell of the body and also resembles the DNA of parents. Needless to say this is because children inherit DNA from their parents. Just like the fingerprint, DNA of every individual is unique and even if a hair or drop

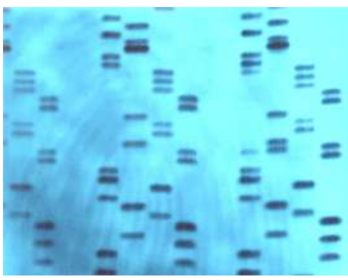


Fig. 25.6 DNA Fingerprint

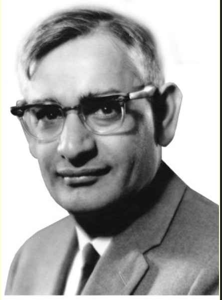
of blood or semen of the criminal is left at the site of the crime, it can be used to detect the DNA of the criminal and compared with that of the suspect to ascertain the truth. (Figure.25.6)

Did you know

Dr. Hargobind Khorana was the creator of man-made gene

It is a matter of pride that Nobel laureate Dr. Hargobind Khorana who was born in our country systhesized an artificial gene in the laboratory for the first time.

Dr. Khorana got the Nobel Prize in 1970 for this contribution to molecular biology.



Dr. Hargobind Khorana

25.4 THE DNA MOLECULE

A DNA molecule is a **polynucleotide.** (poly = many) It is made of units called **nucleotides,** each of which contains

- A nitrogenous base
- A deoxy ribose sugar
- A phosphate

There are four nitrogenous bases **Adenine, Guanine, Thymine** and **Cytosine** and hence four kinds of nucleotides in a DNA molecule.

The various combinations of these nucleotides in a segment of DNA form the different genes.

In physical structure, a DNA molecule is a double helix containing two polynucleotide strands.

25.4.1 DNA replication

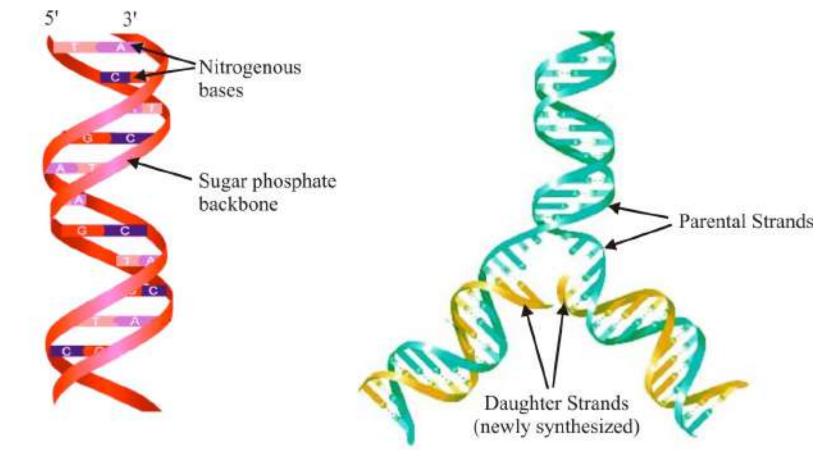
Cell division takes place in a manner so that one cell divides into **two identical cells** with the **same number of identical chromosomes.** Therefore, prior to cell division, every chromosome should contain two **chromatids** made of two identical DNA molecules. This is achieved through the process of **DNA duplication** or **DNA replication**. (Figure 25.7) The major steps of DNA duplication are simplified below.

i. The double stranded DNA molecule unwinds with the help of certain enzymes to expose two strands of DNA.

ii. A DNA polymerase enzyme catalyzes the formation of a new daughter strand which can form a double helix with one strand of parental DNA molecule. So two DNA molecules, each with a parental strand and a new strand get generated.

iii. The two identical DNA molecules then become two chromatids which remain attached by a centromere.

Thus, upon DNA replication, each chromosome contains two identical molecules of DNA housed in its two chromatids. During cell division, the two chromatids, separate out as two chromosomes, one each, passing into the two daughter cells.



(a) Structure of DNA

(b)Replacting DNA molecule

***Fig 25.7** DNA Structure and Replication*

INTEXT QUESTIONS 25.2

1. Name the sex chromosomes.

2. How many autosomes do humans have?

3. Why does an organism (except bacteria) have diploid number of chromosomes?

4. State any two typical features of chromosomes.

5. Define a gene with respect to its chemical nature.

6. State the three major steps in DNA replication.

7. Why is DNA fingerprinting a fool proof test?

25.5 BLOOD GROUP INHERITANCE IN HUMAN

Every one of us is born with genes inherited from our parents. Our blood group depends on the combination of a pair of genes, one of which is inherited from each parent.

There are four blood groups A, B, AB and O. Every human being has one blood group out of the four. The genes which control the inheritance of these blood groups are designated as IA, IB and i. When a foetus (growing young one in mother's womb) develops, its blood group is determined by the combination of any of the two above mentioned genes, one received from each of the parents.

The gene combinations and the resultant blood groups are shown in the table 25.1

Table 25.1: The combination of genes and the resulting blood group

Gene combination	Blood group
IA IA or IA i	A
IB IB or IB i	B
IA IB	AB
ii	O

From the table you can make out that gene IA and IB are dominant and i is recessive. Apart from these blood groups, human beings may also belong to the groups designated as Rhesus positive (Rh+) or Rhesus negative. Most humans are Rh+. Some are Rhesus negative (Rh-). The Rh+ gene is dominant over Rh- gene.

ACTIVITY 25.2

Designate the blood group as either Rh+ or Rh- from gene combinations given below.

Gene combination present in the zygote	**Rh+/Rh- blood group**
Rh+ Rh+	1. ____________

Rh+ Rh- 2. ____________

Rh- Rh- 3. ____________

Why should you know your blood group?

In case of any emergency such as an accident, or a diseased condition, blood transfusion may be required. Only a matching blood group of the blood donor can be transfused. A person with blood group A can donate blood to patient with blood group A and AB. AB can receive blood from any of the four blood groups. O can receive blood only from O but donate blood to all four blood groups. Sometimes there may not be time or facility available for prior ascertaining of the blood group. Immediate blood transfusion is possible if the blood group is known. If unknown, the safest blood group for transfusion is O negative (O group and Rh-). B can donate to B and AB. O is the universal donor and AB is the universal recipient.

The entire human race can be divided into four groups on the basis of blood groups. Do you think further distinctions made by human beings on the basis of caste, creed and gender are justified?

25.6 SEX DETERMINATION IN HUMANS

The combination of sex chromosomes with autosomes determines whether the foetus will be a boy or a girl. (figure 25.8). The foetus develops from the zygote which is formed by the fusion of the two gametes, the male gamete or sperm and the female gamete or egg. Gametes are haploid [(have only 'n' number of chromosomes) while the zygote is diploid (2n)].

Ova or eggs are of one kind only. These contain 22 autosomes and a single X chromosome. Sperms are of two kinds (i) having 22 autosomes and one X chromosome, or (ii) having 22 autosomes and a Y chromosome (see figure 25.8).When X bearing sperm fuses with the egg, a female child results with 44 autosomes

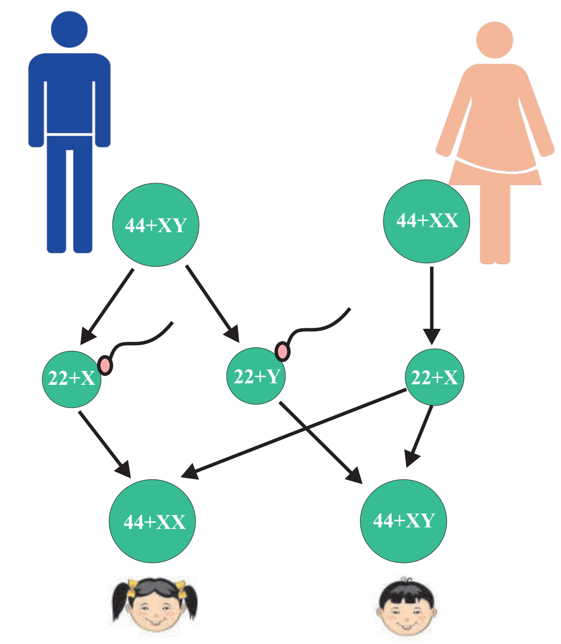


Fig. 25.8 Chromosomal basis of sex determination in Humans

and two X chromosomes. If Y bearing sperm fuses with the egg then a male child results with chromosomal constitution of 44 autosomes and one X and one Y chromosome.

You have already learnt about cell division earlier and know that at metaphase chromosomes are clearly seen lying at the equator and may be studied under the microscope or by taking a photograph. You can then easily identify and state that the chromosomes in a male human are 44 autosomes +XY and those in a female are 44 autosomes+ XX. It is, therefore, wrong to blame a woman if she does not bear a male child as is done in some ignorant families of our country. Sex of an individual is purely due to chance and neither the mother nor the father can be blamed.

The Pre-natal Diagnostic Techniques (Regulation and Prevention of Misuse) Act, 1994, was enacted and brought into operation from 1st January, 1996, in order to check female foeticide. The Act prohibits determination and disclosure of the sex of foetus. It also prohibits any advertisements relating to pre-natal determination of sex and prescribes punishment for its contravention. The person who contravenes the provisions of this Act is punishable with imprisonment and fine.

INTEXT QUESTIONS 25.3

1. What is a gene made of?

2. To which blood group would a person having genes IAi belong?

3. If a Y bearing sperm fuses with an egg, what will be the sex of the individual developing from the zygote?

4. How many X chromosomes can be found in the cells of the body of (i) a boy, and (ii) a girl.

5. How many molecules of DNA are present in one chromosome?

25.7 HEREDITARY DISORDERS

You already know that genes control all features of an organism. Some times a gene may change or **mutate** either in the gamete or zygote. Mutated gene may not remain normal. Also, sometimes a defective gene present in the parent may not be expressed in the parent as the dominant normal member of its pair may mask the effect of the defective gene. But if the child inherits the defective gene from both the parents, the presence of the defective pair of genes has a harmful effect. **Such a disorder is termed hereditary or genetic disorder**.(figure 25.9)

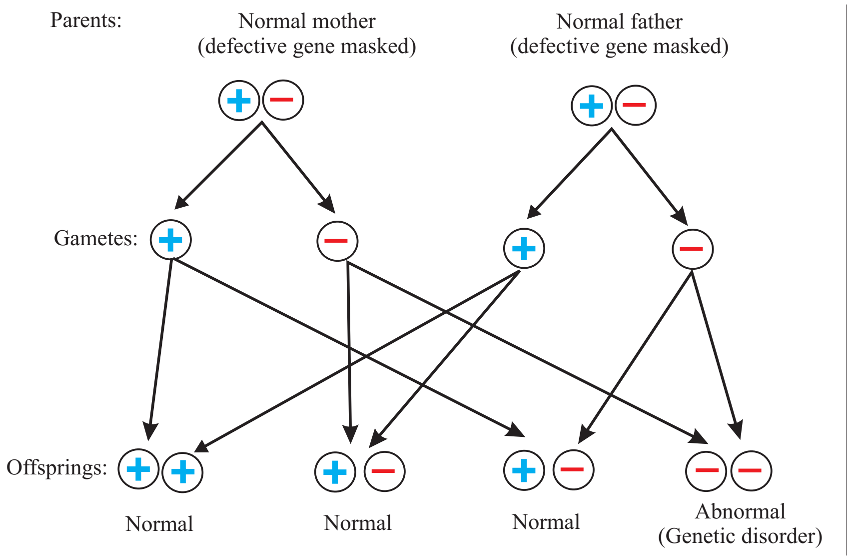


Fig 25.9 Hereditary or genetic disorder

There are several kinds of hereditary disorders, some of which may be caused due to presence of only one defective gene which is dominant or sometimes by the presence of two defective recessive genes. As shown above genetic disorders cannot be cured by medicines. Scientists are trying to discover methods by which a defective gene occurring in an individual may be removed or replaced by a normal gene. This is called **gene replacement therapy.**

25.7.1 Common genetic (hereditary) disorders

There are several genetic (hereditary) disorders. Three common hereditary disorders are Thallasemia, Haemophilia and Colour blindness.

(i) Thallasemia

Patients suffering from this disorder are unable to manufacture haemoglobin, the pigment present in red blood corpuscles which carries oxygen to tissues. This is because the pair of genes controlling haemoglobin production are defective. Thallasemics (persons suffering from thallasemia) require frequent blood transfusion in order to survive. The thallasemia gene is present on an autosome.

(ii) Haemophilia

Those persons suffering from haemophilia have either a defective gene or lack genes, which control production of substance responsible for blood clotting. In the absence of such substance blood does not coagulate. Once bleeding starts, it does not clot easily.

(iii) Colour-blindness

Different kinds of colour-blindness have been detected but in the most common form of the disorder, a person is unable to distinguish the blue colour from green. Again this is due to the presence of a defective gene or absence of the gene, responsible for colour vision.

The genes for both haemophilia and colour-blindness are located on X-chromosome, and hence, the disorder is passed down from mother to the son because a boy receives the X chromosome from the mother and Y chromosome from the father. In the mother, with two X-chromosomes, the defect does not show up. Also in the daughter, the effect of defective gene on X-chromosome inherited from mother may be masked by a normal gene on the X-chromosome, inherited from her father. Since X chromosome bears the defective gene, the son suffers from the genetic disorder, as male has only one X chromosome and one Y chromosome and so the defective gene does not get masked.

25.8 GENETIC COUNSELLING

Thallasemia is an autosomal genetic disorder, while, haemophilia and colour blindness are sex-chromosomal or X-chromosomal disorders. You would now appreciate why marriages between close relatives termed consanguineous marriages are discouraged. In marriages between relatives, chances of inheriting defective genes by the offspring is enhanced as both parents, being related may possess the same defective genes. If recessive, the two defective genes express when passed on to offspring by both parents. Therefore, it is essential to know the probability of a genetic defect in the offspring and seek the advice of genetic counsellors who are professionals. Genetic counselling helps one to know the chances of inheritance of a genetic disorder so that people can make informed decisions.

25.9 THE HUMAN GENOME

You can well imagine that human beings are complex in structure, behaviour and body functions. Thus, many genes control the features that make a human being. In 2003, it became possible to identify many of these genes of humans – their location on the chromosomes and the combinations of nucleotides that constitute them. All the various genes together constitute the **genome**. Knowing the human genome can help in finding and devising therapies for many genetic defects. This promises hope for people suffering from genetic disorders, as the location of every gene of the human genome is now known.

25.10 GENETIC ENGINEERING

Genetic Engineering is also called recombinant DNA technique. In this technique, gene from an organism of a species can be transferred to become part of the or genome of an organism belonging to another species which is then termed GMO **genetically modified organism**. The transfer is possible through "plasmids" present in bacteria. Plasmid is a circular DNA molecule found in bacteria. It is not part of the bacterial chromosome. Transfer is also possible through viruses that attack bacteria and are called bacteriophage. These carry genes from a cell culture (bacterial cells grown in a culture dish) and transfer into bacteria. A bacterial "clone" containing the required gene may then yield the "foreign" gene which can be used for replacing a defective gene during gene therapy. Genetic engineering also has many other benefits. Try and find out at least two such benefits. You may take the help of books or internet. (figure. 25.10)

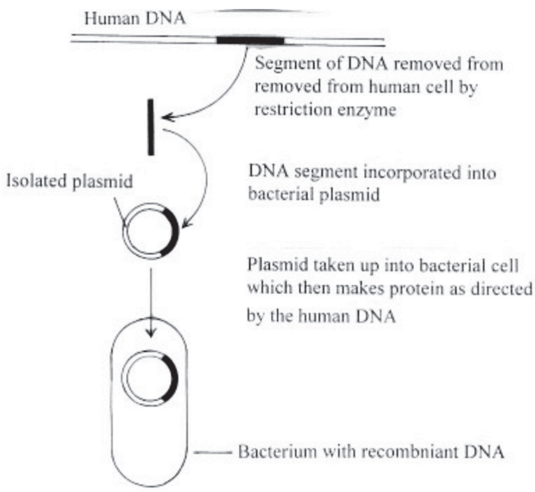


Fig. 25.10 Major steps in genetic engineering.

INTEXT QUESTIONS 25.4

1. What will be the blood group of an individual with genetic combination IA IB?

2. How can a person be normal for a trait even when carrying one defective gene for that trait?

3. Which is the safest blood group for donation if an accident victim of an unknown blood group has to be given immediate blood transfusion?

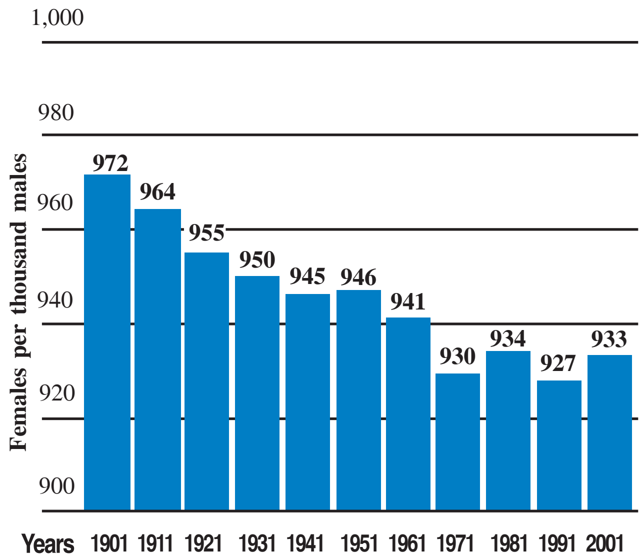
4. On which kind of chromosome, the autosomes or the sex chromosomes, are defective genes causing, Thallasemia, colour blindness and Haemophilia located?

5. Name the therapy in which a defective gene is substituted by a normal gene.

6. The given box diagram represents the ratio of females to males or the sex ratio in our country for 10 decades (1901 to 2001). Answer the following questions in the light of your knowledge of sex determination and the data presented in the box diagram.

- What does the bar diagram show? ________________
- As per scientific knowledge regarding sex determination, what should be the sex ratio or the male to female ratio at a given point of time. ____________
- Assign one reason to the trend showing deviation from the expected sex ratio.

  ____
- In what ways is such a trend unfavourable? ______________________
- Suggest a way by which such a trend can be stopped. __________________



Graph related to sex ratio is included here

- Do you notice any reversal in the trend? What would you attribute it to?

  ____

WHAT YOU HAVE LEARNT

- Passing down of characters from parents to children is called heredity.
- Children of same parents differ because they possess different combinations of parental genes. These difference are termed variations. We are all human beings but can be distinguished easily from each other due to variation.
- Heredity and variation are due to genes and their varied combinations.

- Study of heredity is called Genetics.
- Mendel was the first to postulate laws of inheritance (heredity) and he said that heredity was due to "factors" and that every feature was controlled by a pair of factors which separate into different gametes during gamete formation.
- Another Mendelian law of inheritance stated that in a pair of genes one may be dominant and the other recessive. The dominant gene of the pair masks the effect of the recessive member of the pair.
- Sutton found out that "Mendelian factors" were the genes and that genes are present on chromosomes.
- Chromosomes are present in pairs in the nucleus and each is made of one molecule of DNA and proteins.
- The diploid number of chromosomes in humans is 46, of which 22 pairs are autosomes and 2 chromosomes X and Y are sex chromosomes.
- Genes are made of DNA. They are segments of the DNA molecule of the chromosome.
- A DNA molecule is a polynucleotide. Each of its nucleotides is made of a nitrogenous base, a sugar, and a phosphate.
- A DNA molecule is made of two strands of DNA helically coiled around each other.
- Before cell division, DNA in every chromosome replicates forming two identical DNA molecules which are present as the two chromatids forming the chromosome. In DNA replication, the two strands of a DNA molecule unwind and each acquires a new strand so that two molecules of DNA are formed.
- Sex determination in humans is based on combination of sex chromosomes. Females have two X-chromosomes, while males possess one X and one Y chromosome.
- Defective genes or absence of genes may cause genetic disorders e.g.thallasemia, haemophilia and colour blindness.
- Thallasemics lack genes responsible for production of haemoglobin so they need frequent blood transfusion for survival.
- Haemophiliacs bleed profusely. Their blood cannot coagulate as they lack genes for factors necessary for blood clotting. Hence their bleeding does not stop easily.

- Colour-blind people cannot distinguish the colour blue from the green due to defective genes for colour vision located on X-chromosomes.
- Thallasemia is an autosomal genetic disorder while, haemophilia and colour-blindness are sex chromosomal disorders.
- The collection of all the genes of a species constitute its genome. Human genome has been unravelled that is, location of all human genes on the chromosomes is now known.
- Genetic engineering involves transfer of a gene from one species into member of another species with the help of plasmids. Organisms carrying foreign genes, that is, genes of another species are called genetically modified organisms or GMO.
- DNA fingerprinting is a technique with the help of which the identity of a person can be known from the genetic make up.

TERMINAL EXERCISES

1. Which statement is true for 'genes'? Select the correct answer
   (a) Genes are imaginary factors.
   (b) Genes are fragments of DNA.
   (c) Genes are present in the cytoplasm.
   (d) Genes are not inherited.
2. What are "factors" named by Mendel called today?
3. What is the chemical nature of a gene? Name the three components of this chemical.
4. Where are genes located?
5. State two differences between autosomes and sex chromosomes.
6. Define heredity, variation, genetic disorder and sex chromosomes.
7. Why does DNA have to be duplicated before cell division?
8. Mention the main steps in DNA replication.
9. What will be the blood group of the following which contain the genes I^Ai.
10. Why is haemophilia found mostly in boys?
11. With the help of a line diagram explain the chromosomal basis of a zygote developing into a male child.

12. What is the basis of sex determination in humans?

13. Write notes on any one genetic disorder.

14. What is meant by "gene replacement therapy"?

15. Rahul's maternal grandfather (mother's father) was colour-blind. What are the chances of Rahul being colour-blind if his father has normal colour vision?

ANSWERS TO INTEXT QUESTIONS

25.1

1. (i) Passing down of similar characters generation after generation.
   (ii) Differences in gene combinations.
2. He had initiated work on heredity/genetics.
3. (i) The gene which may express in spite of the presence of the other (Dominant).
   (ii) Expression only in the absence of the dominant gene. (Recessive).
4. Sutton
5. Gene.

25.2

1. X and Y
2. 22 pairs or 44 chromosomes
3. Because one chromosome of a pair is received from father and one from the mother.
4. (i) present in pairs, (ii) seen only during cell division, (iii) present in fixed number etc. (any other).
5. Genes are segments of a DNA molecule. So it is made of Deoxyribonucleic acid or DNA.
6.
   - Unwinding of double helix.
   - Formation of new molecules of DNA complimentary to each DNA strand
   - Winding of one new and one parental DNA strand
7. Because DNA of every individual is unique.

25.3

1. DNA
2. Blood group A
3. Male
4. For boy – 44 autosomes and one X and one Y chromosomes

   For girl – 44 autosomes and 2 X chromosomes
5. One molecule of DNA

25.4

1. AB
2. The other member of the pair is dominant and masks the effect of the recessive gene.
3. 'O' positive.
4. Thallasemia – autosome, colour blindness and haemophila on X chromosome.
5. Gene replacement therapy.
6.
   - Bar diagram shows the proportion of females in the population over a decade
   - 1:1
   - Female foeticide;
   - Male to female ratio becomes lopsided
   - Banning sex tests of unborn baby; increasing awareness
   - Yes, awareness and education/ No- with reasons.

MODULE - 6
NATURAL RESOURCES