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.

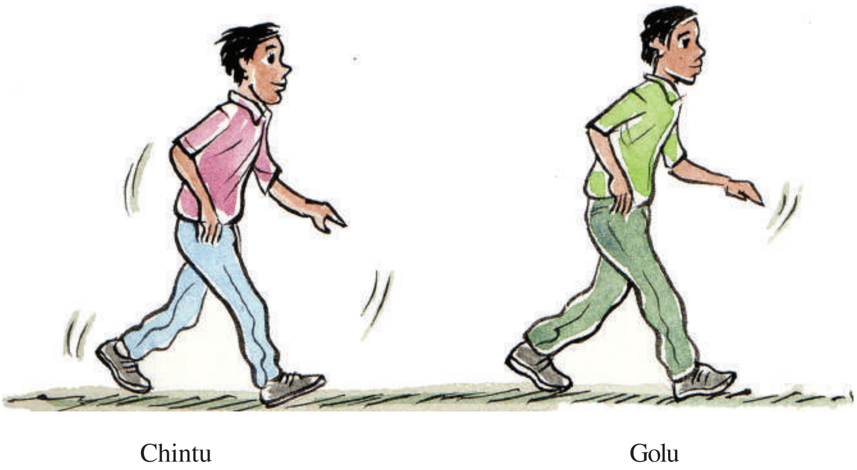


Fig. 9.1 *An example of relative motion*

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.

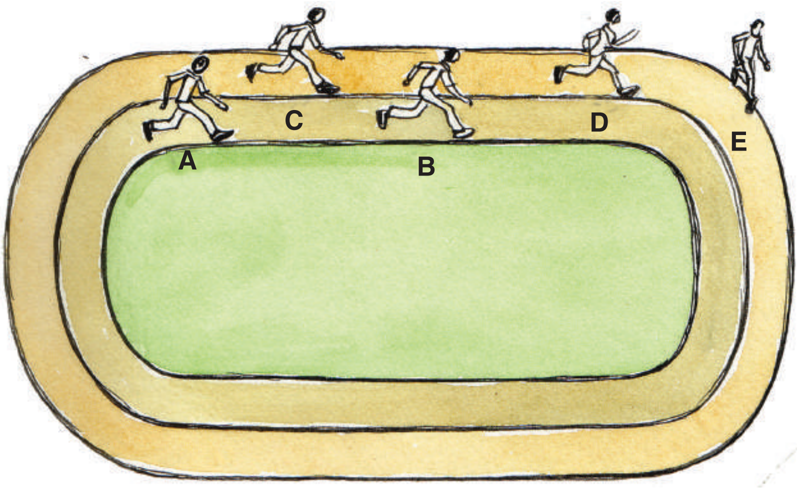


Fig. 9.2

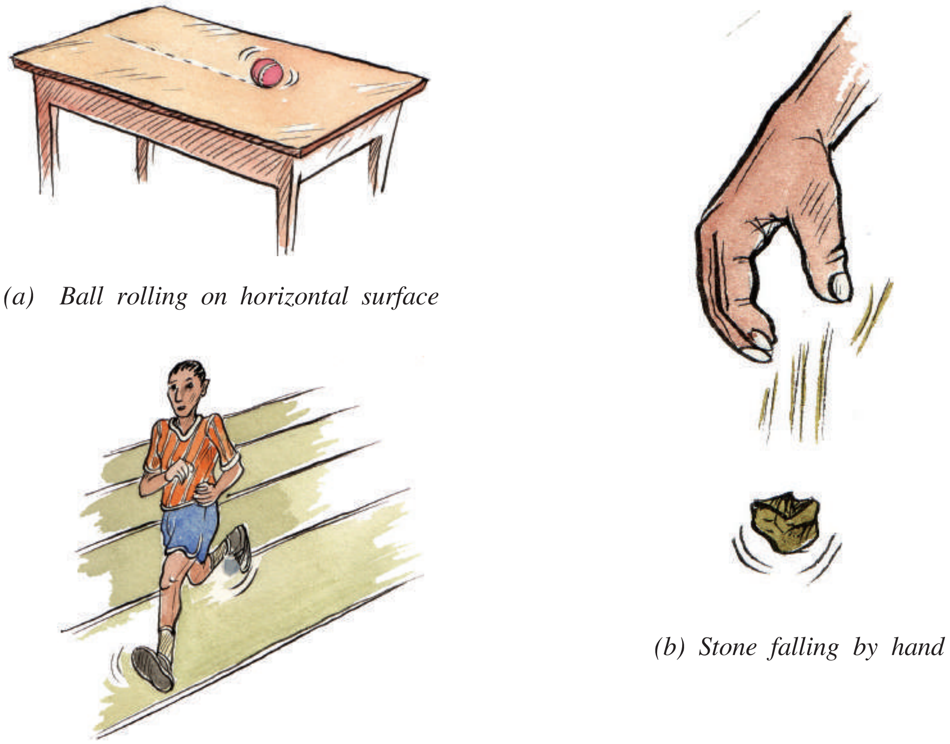
Table 9.1

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.

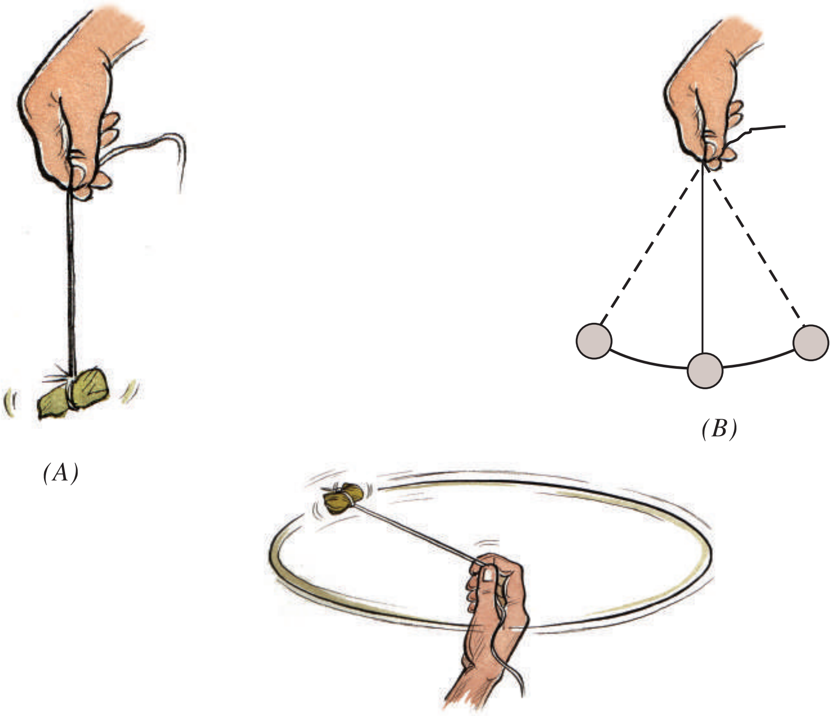
(B) Let the stone comes to rest and bring it to the point of suspension with the help of your hand and release it.

(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)

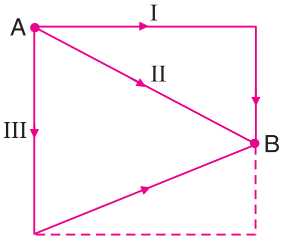
Have you ever noticed that the motion of the branches of a tree? They move to and fro from their central positions (position of rest). Such type of motion is called **oscillatory motion**. In such a motion, an object oscillates about a point often called position of rest or equilibrium position. The 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.

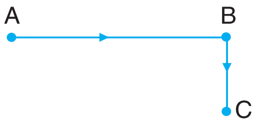
ACTIVITY 9.3

In the following cases measure the distance and displacement and write their values in the table given below:

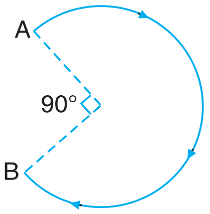
(a) A body moves from A to B

(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.

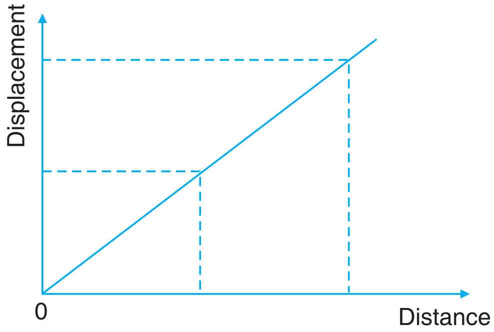


Fig. 9.7

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.

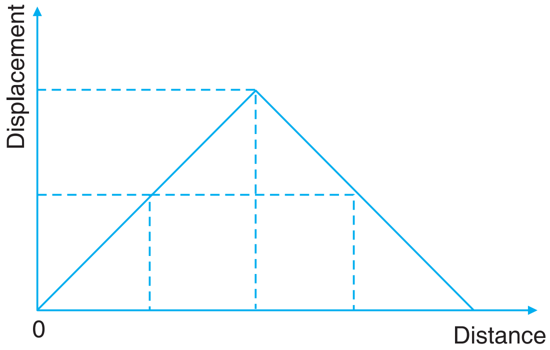


Fig. 9.8

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.

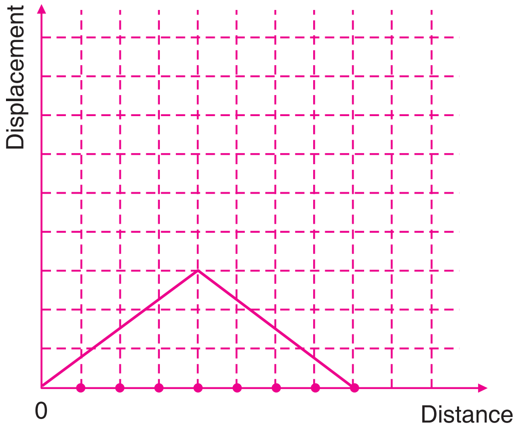


Fig. 9.9

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.

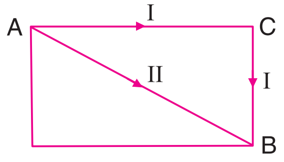


Fig. 9.10

   (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.

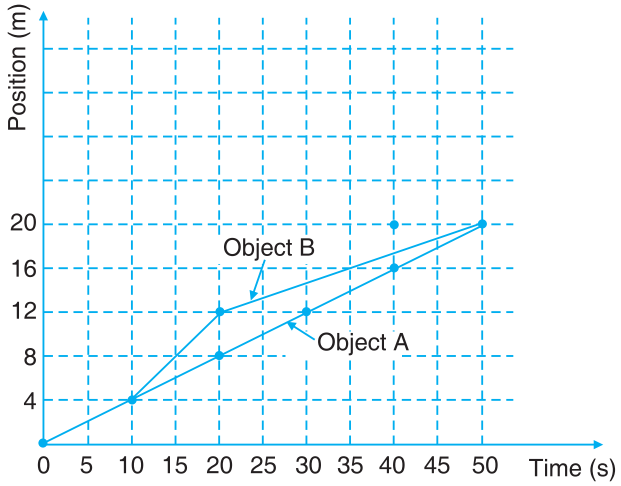


Fig. 9.11 *Graph representing uniform and non-uniform motion*

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.

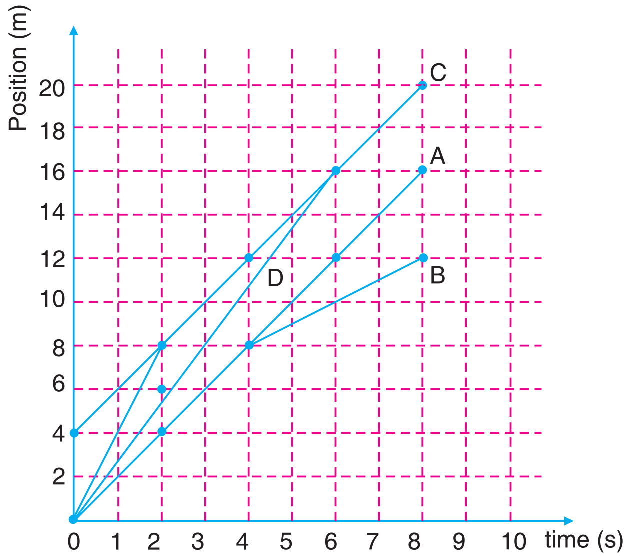


Fig. 9.12

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.

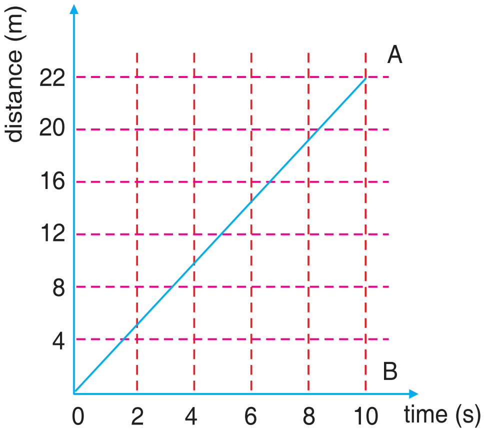


Fig. 9.13

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

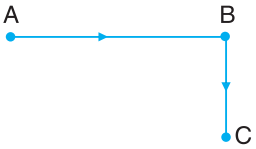
$$\text{velocity} = \frac{\text{Change in position}}{\text{Time taken}}$$

ACTIVITY 9.5

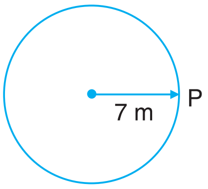
Observe the motion of an object in the following situations. Find speed and velocity in each situation and comment over the situation which you find different from other.

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.

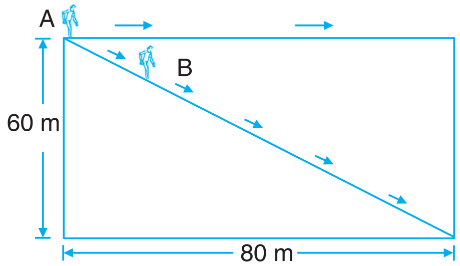


Fig. 9.15

Solution: The displacement of both the former in same i.e.,

$$\sqrt{60^2+80^2} = \sqrt{3600+6400} = \sqrt{10000} = 100 \text{ m}$$

$$\therefore \quad \text{Velocity } A \text{ and } B, \qquad v = \frac{\text{displacement}}{\text{time taken}} = \frac{100 \text{ m}}{30\times 60\text{s}} = \frac{1}{18} \text{ ms}^{-1}$$

$$\text{speed of } A = \frac{\text{Distance travelled}}{\text{time taken}} = \frac{(80+60)\text{m}}{30\times 60\text{s}}$$

$$= \frac{140}{3800} \text{ ms–1} = \frac{14}{18} \text{ ms}^{-1}$$

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

$$= 50 + 100 = 150 \text{ m}$$

$$\text{and} \qquad \text{total time taken} = 30 + 45 = 75 \text{ s}$$

$$\therefore \qquad \text{Average speed} = \frac{150 \text{ m}}{75 \text{ s}} = 2\text{ms}^{-1}$$

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 × 10 + 8 × 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

$$= \sqrt{30^2 + 40^2} = \sqrt{900 + 1600} = \sqrt{2500}$$

$$= 50 \text{ m}$$

$$\therefore \quad \text{The average velocity} = \frac{\text{total displacement covered}}{\text{total time taken}}$$

$$= \frac{50 \text{ m}}{(10+10)\text{s}} = \frac{50 \text{ m}}{20 \text{ s}} = 2.5 \text{ ms}^{-1}$$

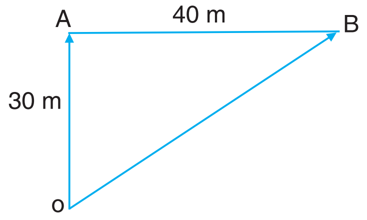


Fig 9.16

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) $5/18 \text{ ms}^{-1}$
(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.

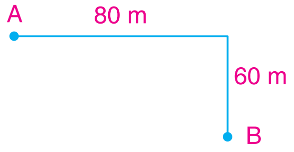


Fig. 9.17

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?

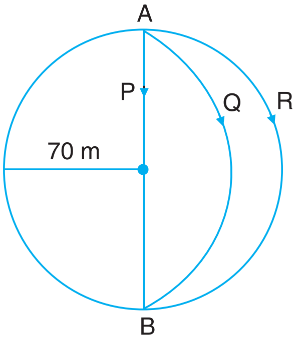


Fig. 9.19

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.

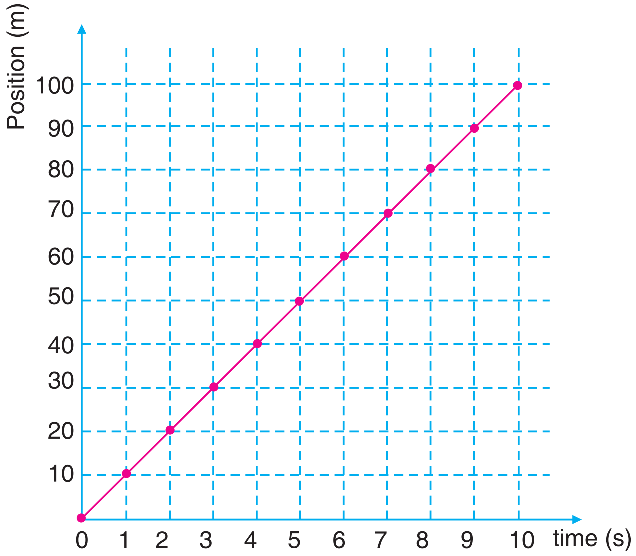


Fig. 9.20 *Position-time graph for the motion of a particle on the basis of data given in table*

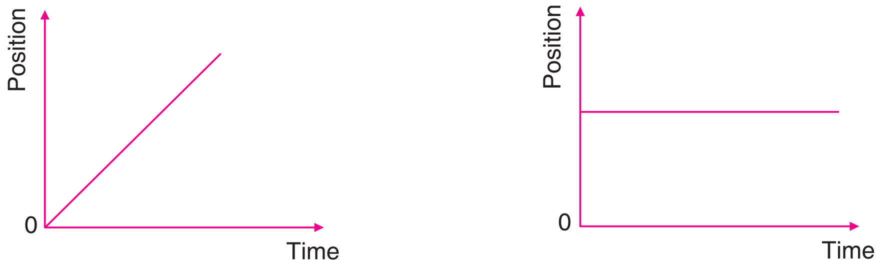
We note from the data that displacement of the object in 1st second, 2nd second,....., 10th second is the same i.e., 10 m. In 10 second, the displacement is 100 m. Therefore, velocity is $\frac{100\text{ m}}{10\text{ s}} = 10\text{ ms}^{-1}$ for the whole course of motion. Velocity during 1st second = 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.**

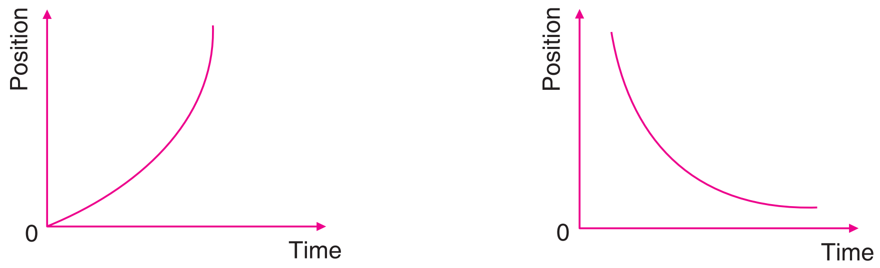
As you see Fig. 9.20, for uniform motion position-time graph is a straight line.

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

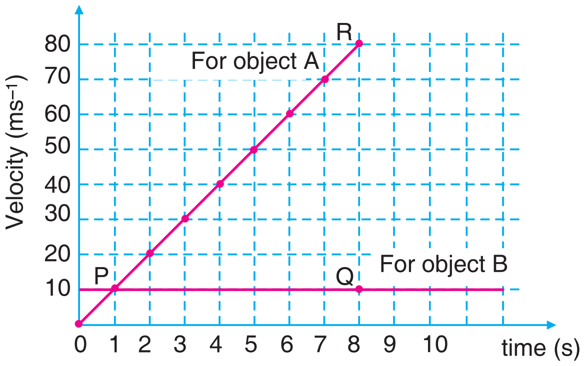


Fig. 9.22 *Velocity-time graph for the motion of object A and B on the basis of data given in table*

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.

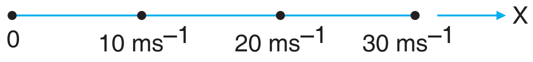


Fig. 9.23 *Changing velocity*

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.

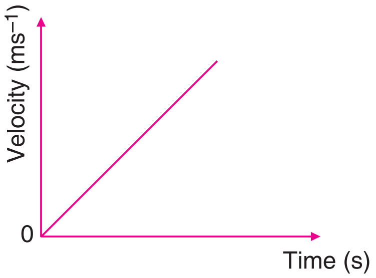


Fig. 9.24 *velocity-time graph of an object moving with uniform acceleration*

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.

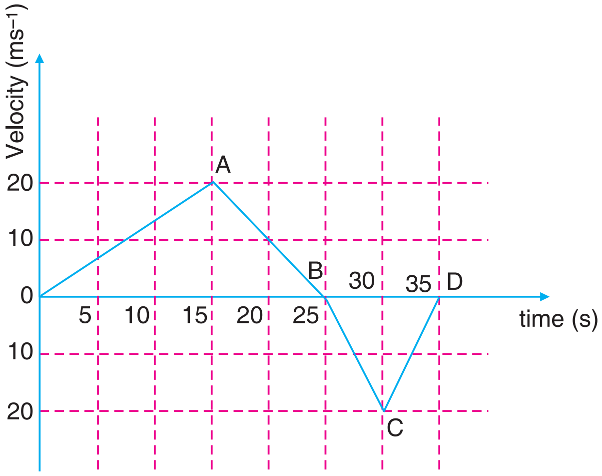


Fig. 9.25

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.

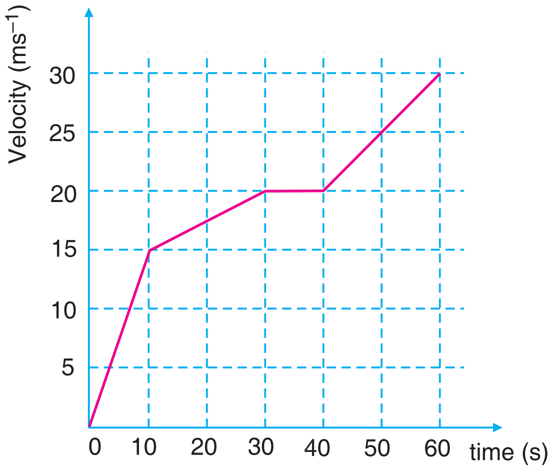


Fig. 9.26

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 $= \frac{30-20}{60-40} = \frac{10}{20} = 0.5\ \text{ms}^{-2}$

For all the above time intervals the acceleration-time graph can be drawn as shown in Fig. 9.27.

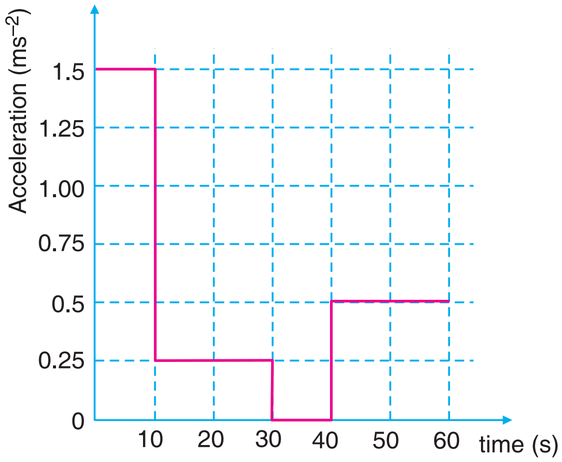


Fig. 9.27

INTEXT QUESTIONS 9.3

1. Describe the motion of an object shown in Fig. 9.28.

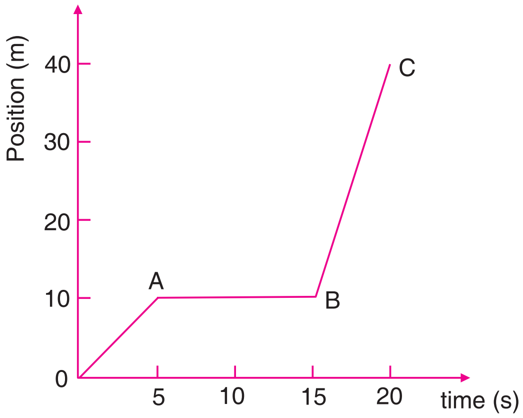


Fig. 9.28 *Position-time graph of an object*

2. Compare the velocity of two objects where motion is shown in Fig. 9.29.

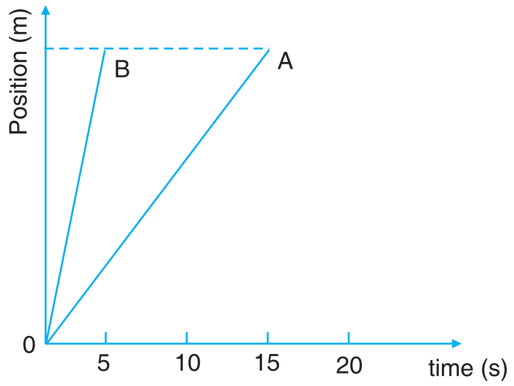


Fig. 9.29 *Position-time graph for object A and B.*

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

$$\text{Acceleration} = \frac{\text{Chnage in velocity}}{\text{Time interval}}$$

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

$$\text{or} \qquad v = u + at \qquad \text{...(9.1)}$$

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 $$s = ut + \frac{1}{2}at^2 \qquad \text{...(9.2)}$$

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 $$v^2 = u^2 + 2as \qquad \text{...(9.3)}$$

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.

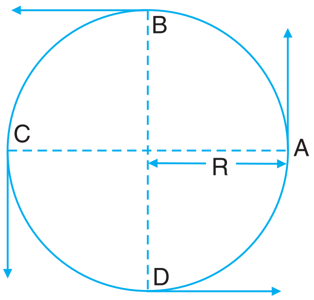


Fig. 9.31 *Circular motion*

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.

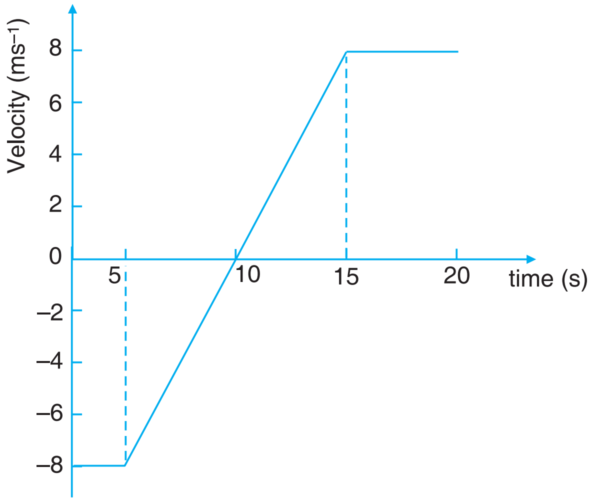


Fig. 9.32

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.

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).

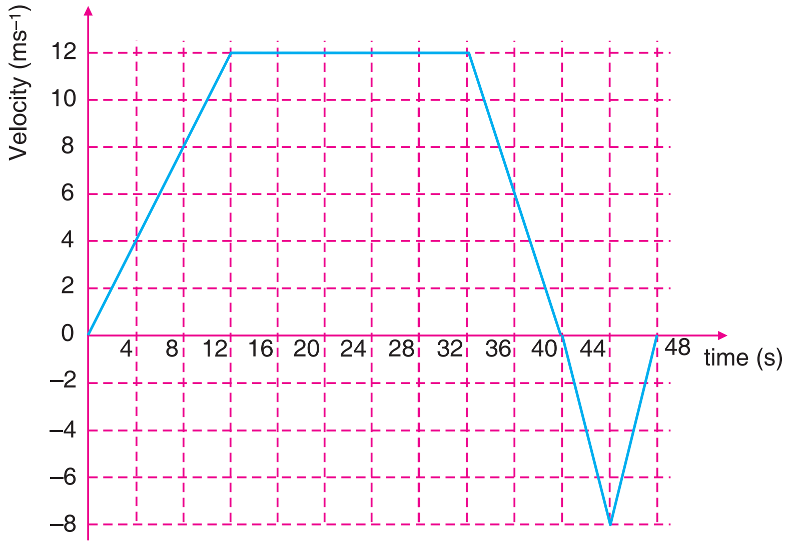


Fig. 9.33

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.

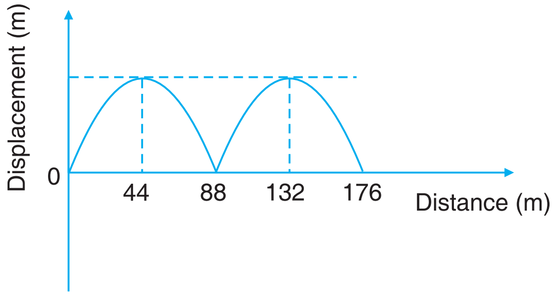


Fig. 9.34

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

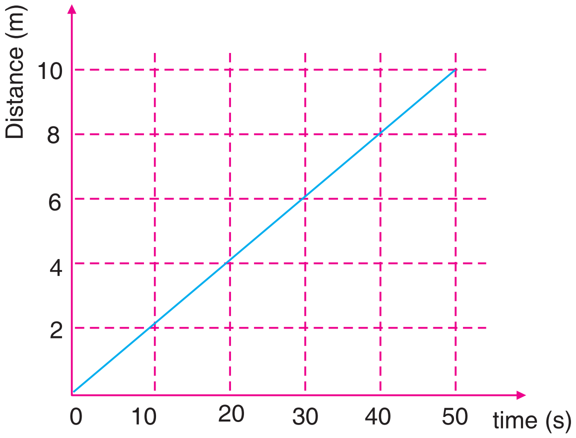


Fig. 9.35

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.

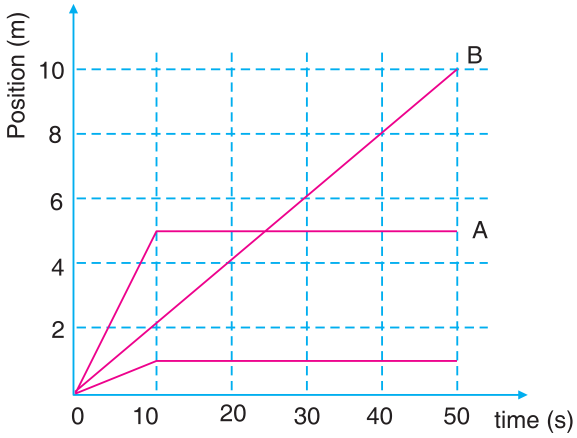


Fig. 9.36

4.

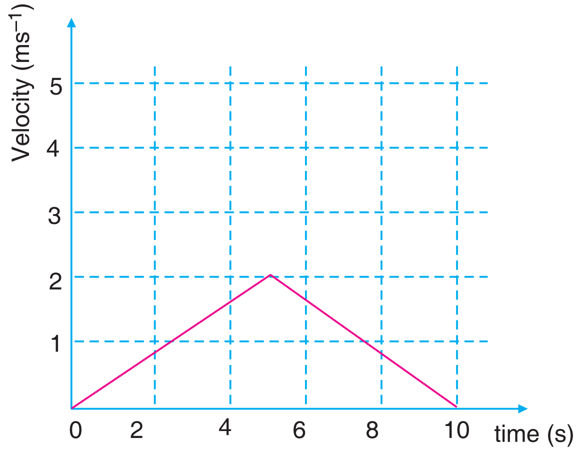


Fig. 9.37

(i) $a = 0.4$ ms^{-2}, (ii) $-a = 0.4$ ms^{-2}, (iii) 10 m

5.

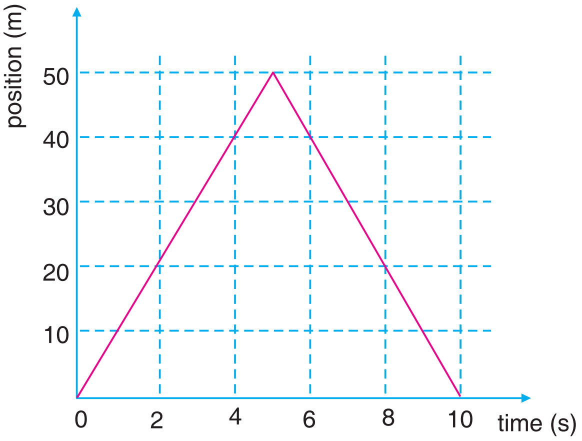


Fig. 9.38

9.4

1. (i) 19.6 m, (ii) 4 s
2. Zero and 9.8 ms^{-2}
3. 600 m
4. 7.5 ms^{-1}

9.5

1. (a)
2. (a)
3. (b)

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?

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.

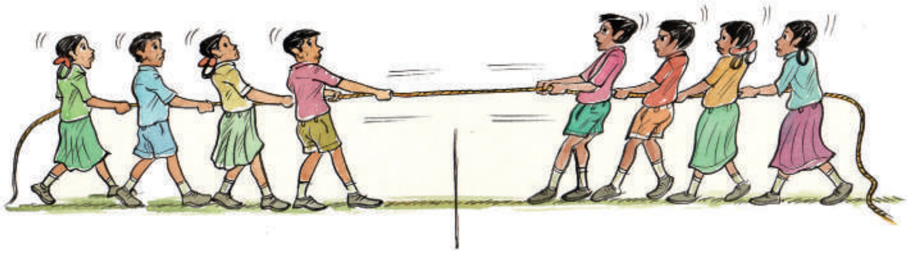
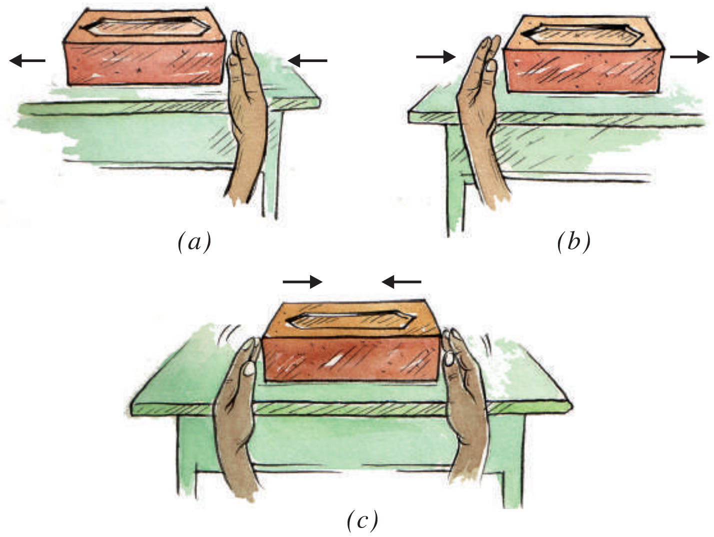


Fig. 10.2 *Tug of war*

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.

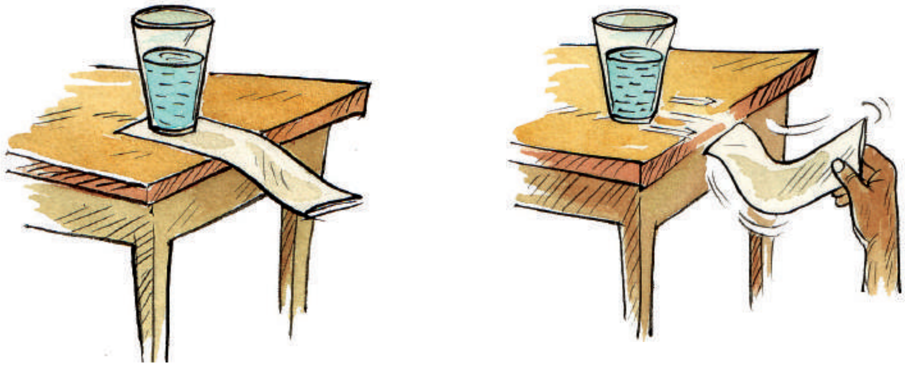


Fig. 10.4 *Glass remains in its position due to inertia*

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)?

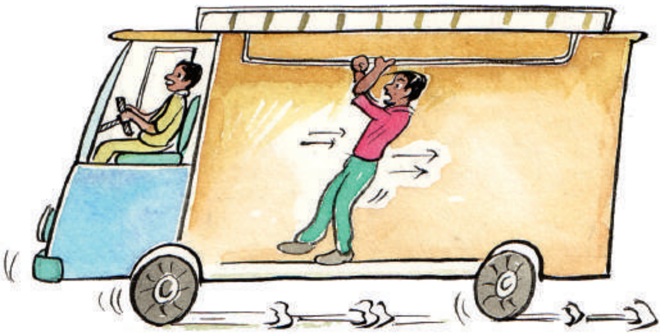


Fig. 10.5 *Passengers falling in the backward direction when the bus starts suddenly*

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

$$p = mv \qquad (10.1)$$

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.**

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.

Sir Isaac Newton
(1642-1727)

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, $m = \frac{1}{10}$ kg and $a = 10\ \text{ms}^{-2}$ (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, 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?

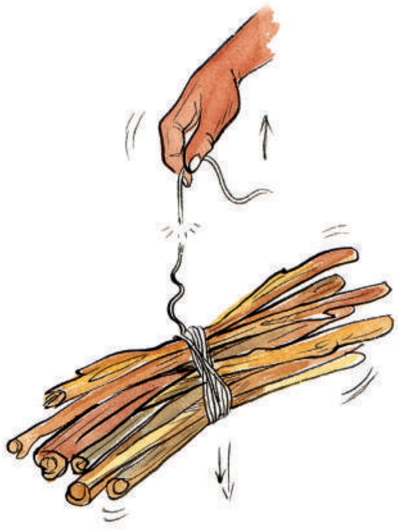


Fig. 10.8 *The string breaks when the bundle is lifted quickly.*

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 $m = 3\text{ kg}$ and $F = 15\text{ N}$

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.

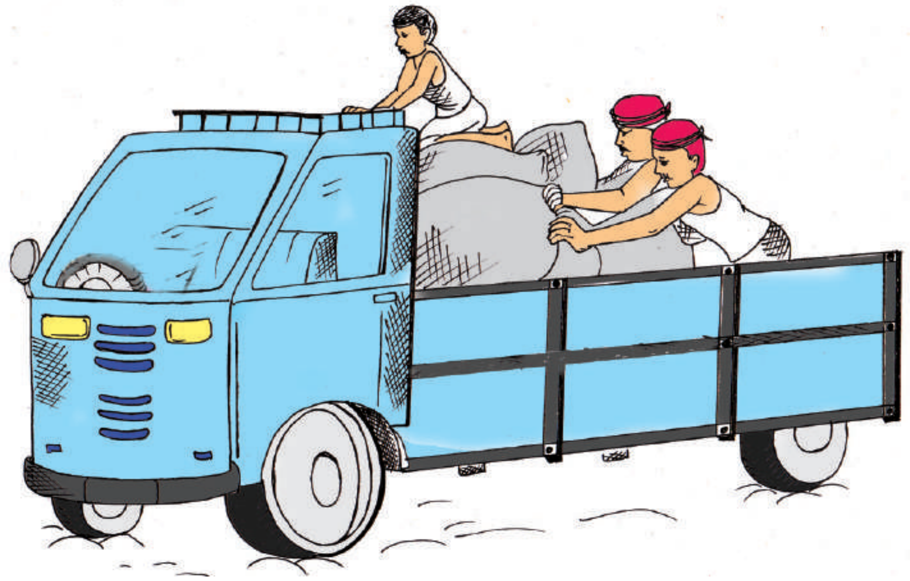


Fig. 10.11

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).

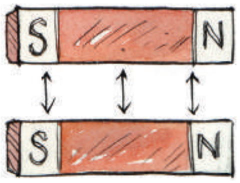


Fig. 10.12 *Repulsion between two magnets*

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).

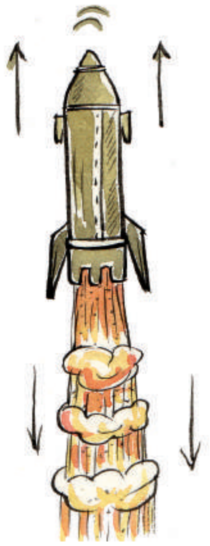


Fig. 10.14 *Working of jet planes and rockets*

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?

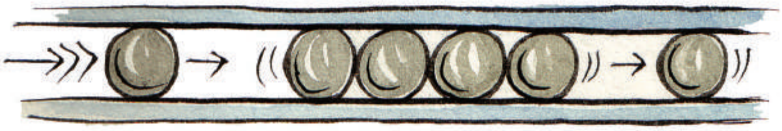


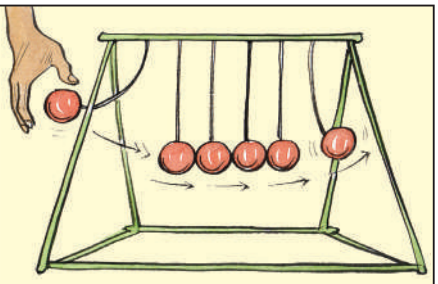
Fig. 10.15 *Arrangement to show the law of conservation of momentum*

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; $m = ?$
$V = -1$ ms^{-1}; $v = 250$ 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.

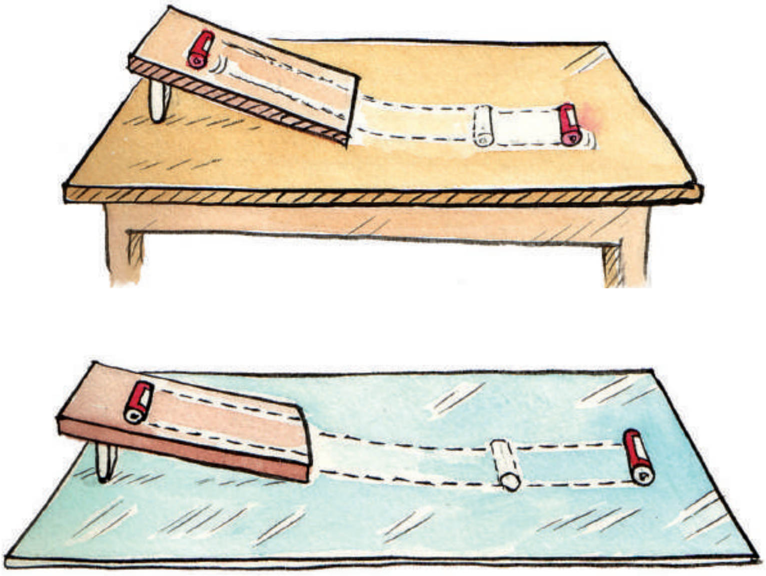


Fig. 10.16 *Pencil cell covers different distances on different type of surfaces*

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?

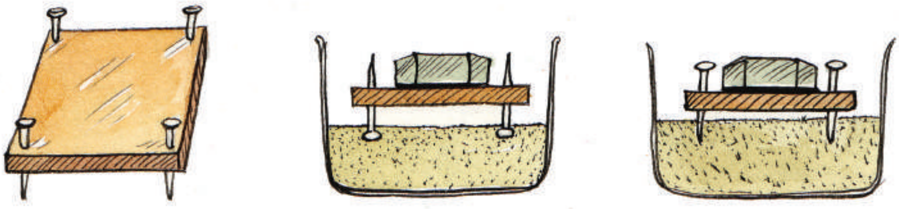
10.5 THRUST AND PRESSURE

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

$$\text{Pressure} = \frac{\text{thrust}}{\text{area}} \quad \text{...(10.5)}$$

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)

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?

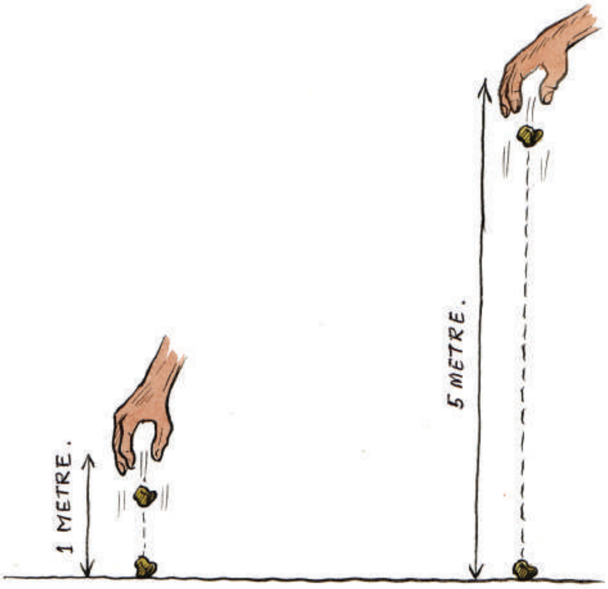


Fig. 11.1 *A stone falling from different heights*

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,

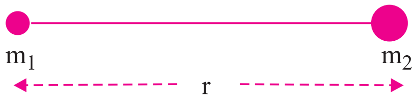


Fig. 11.2 *Newton's law of gravitation*

$$F \propto \frac{m_1 m_2}{r^2}$$

where m_1 and m_2 are the masses of the two particles separated by a distance r.

or $$F = G\frac{m_1 m_2}{r^2} \qquad \text{...(11.1)}$$

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^{2}kg^{-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,

$$F = \frac{6.67\times10^{-11}\times40\times40}{1\times1}$$

$$= 13340 \times 10^{-11} \text{ N}$$

$$= 113.34 \times 10^{-8} \text{ N}$$

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 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?

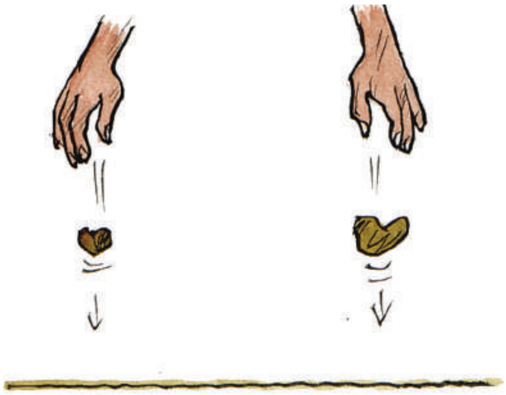
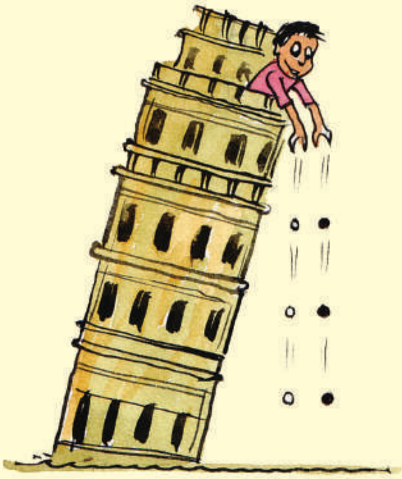


Fig. 11.3 *Dropping two stones of different masses together.*

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.

$$F = mg \tag{11.2}$$

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 $\times 10^{24}$ 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 $\times 10^{24}$ 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 = 3.84×10^8 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) $v^2 = u^2 = 2gs$

$$0 = u^2 + 2(-9.8 \text{ ms}^{-2}) \times 122.5 \text{ m}$$

For upward motion g is taken as negative.

$$\therefore \qquad -u^2 = -2 \times 9.8 \times 122.5 \text{ m}^2\text{s}^{-2}$$

$$u^2 = 2401 \text{ m}^2\text{s}^{-2}$$

$$u = 49 \text{ ms}^{-1}$$

Thus the velocity with which the ball was thrown upwards is 49 ms^{-1}.

(ii) From equation (11.5), $v = u + gt$

$$0 = 49 \text{ ms}^{-1} + (9.8 \text{ ms}^{-2}) \times t$$

Therefore, $t = \frac{49}{9.8}\text{s} = 5\text{s}$

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, $F = mg$ (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).

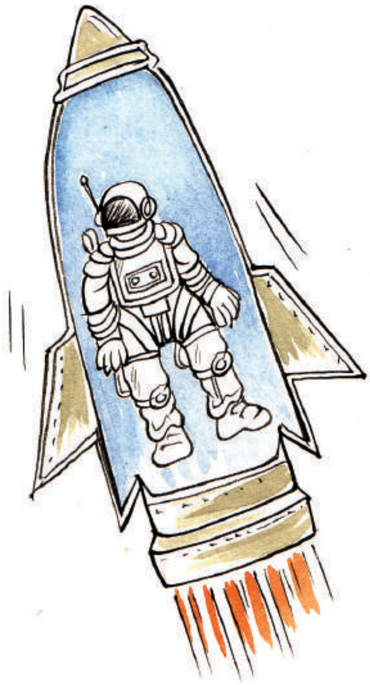


Fig. 11.6 *An astronaut in a spaceship*

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

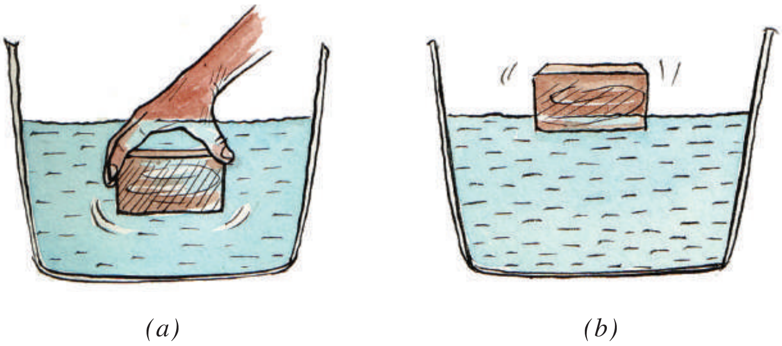
11.6.1 Buoyancy

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?

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.

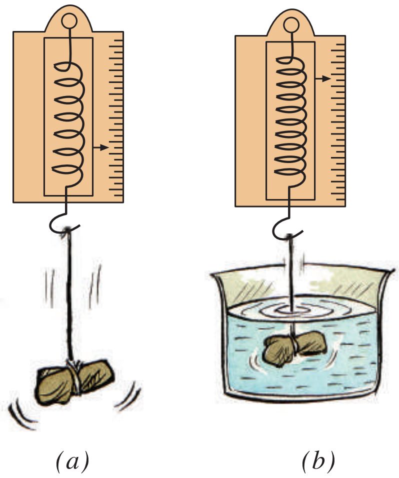


Fig. 11.8 *Reading of the spring balance decreases when the stone is immersed in water*

Archimedes' principle is stated as follows:

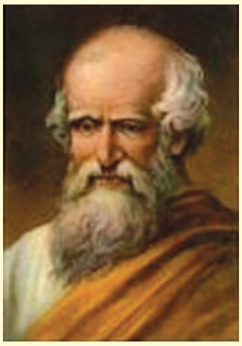
When a body is immersed fully or partially in a fluid, it experiences an upward force that is equal to the weight of the fluid displaced by it.

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.

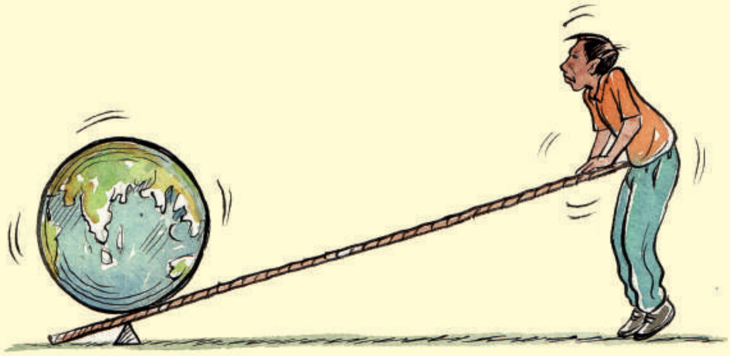
Do you know



Archimedes
(287 BC-212 BC)

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".

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:

    mass of the earth = 6×10^{24} kg
    mass of the sun = 2×10^{30} kg
    value of $G = 6.7 \times 10^{-11}$ Nm^{2}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

$$v = u + gt \qquad ...(1)$$

$$s = ut + \frac{1}{2}gt^2 \qquad ...(2)$$

$$v^2 = u^2 + 2gs \qquad ...(3)$$

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

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?

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.

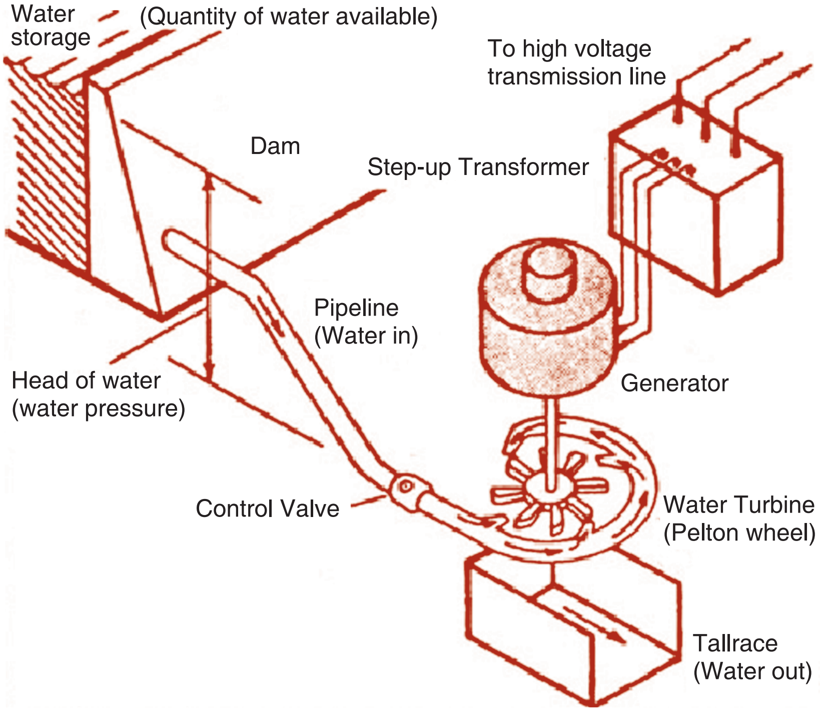


Fig. 12.7 *Generation of Hydroelectricity*

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.

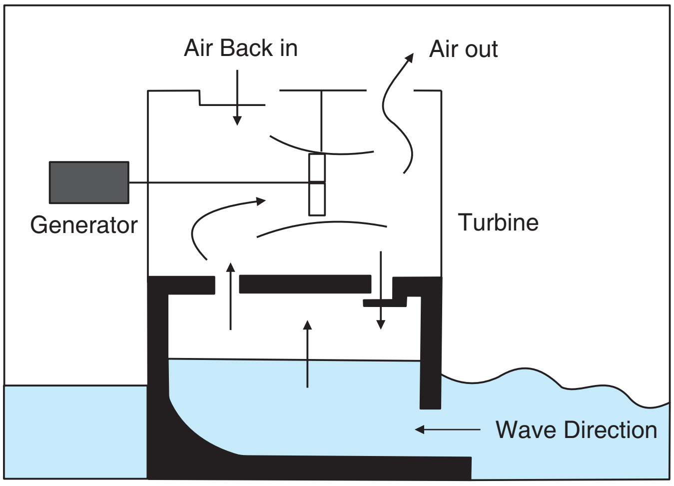


Fig. 12.8 *Generation of Ocean Energy*

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:

Notes

- 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.

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.

$$\text{work done } W = F \times PR \text{ and not } F \times PQ$$

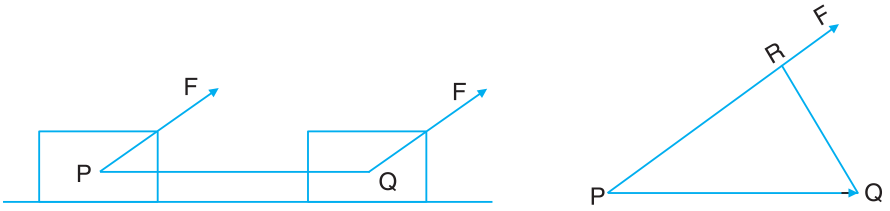


Fig. 13.2 *Work done when force and displacement are in different directions*

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.

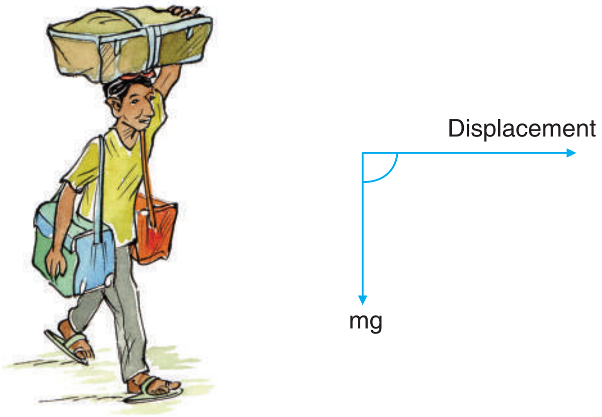


Fig. 13.3 *No work done against gravity when a person moves on a level road carrying a heavy load on his head*

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.

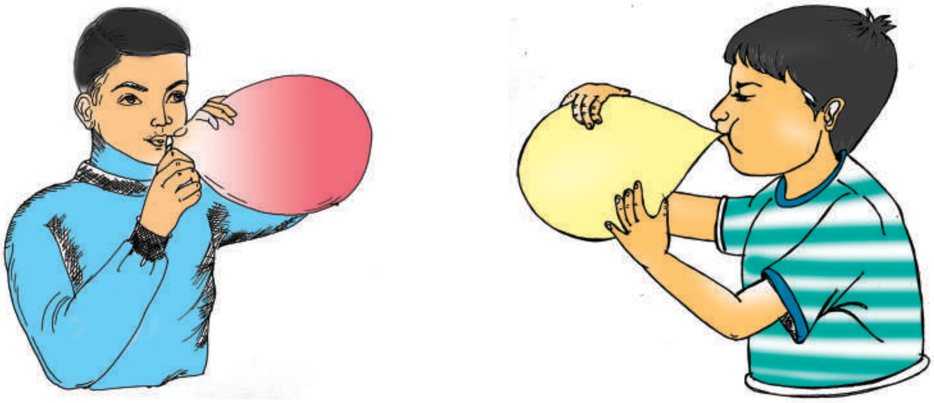


Fig. 13.4 *Alok and Kapil are inflating identical long balloons in different ways*

- 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.

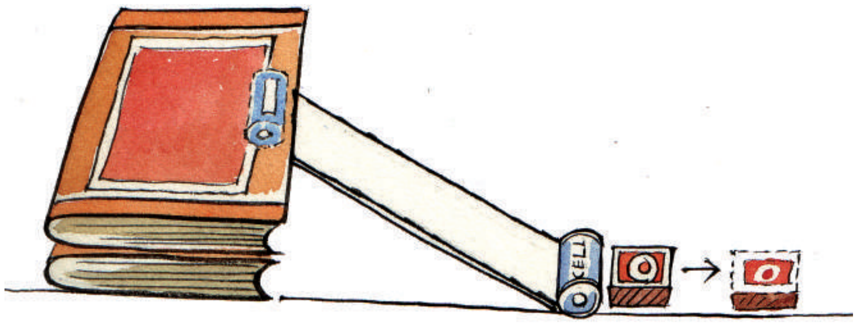


Fig. 13.6 *Experimental setup to demonstrate conversion of potential energy into kinetic energy*

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..............

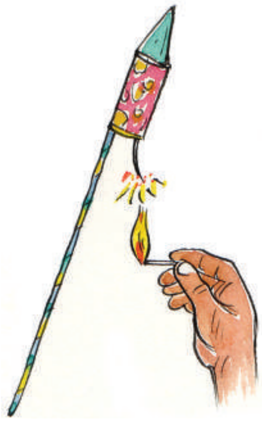
13.5 ENERGY TRANSFORMATIONS AND CONSERVATION

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.

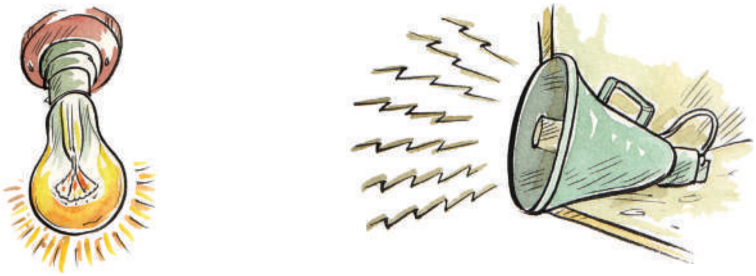
During transformation of energy from one form to another it remains constant. This is known as **Law of Conservation of Energy**.

(a) Photosynthesis (Solar energy → chemical energy of food)



(b) Bursting of fireworks (chemical energy → heat, light and sound energy)

Notes



(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

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

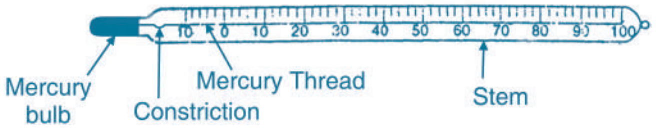
As discussed above temperature is a quantity which tells us how hot a body is? If a hot body is kept in contact with a colder body for some time, we will find that the hotter body does not remain that hot and the colder body becomes some what hotter. Thus heat is transferred from a hotter body (a body 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

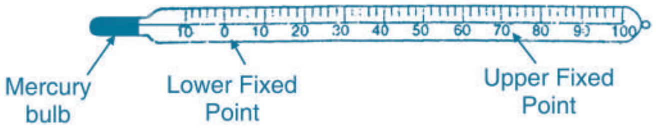
You might have noticed that whenever a patient is brought to a doctor, the doctor normally measures his body temperature. Do you know the device the doctor uses to measure his body temperature? What do they call it? They call it **thermometer**.

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

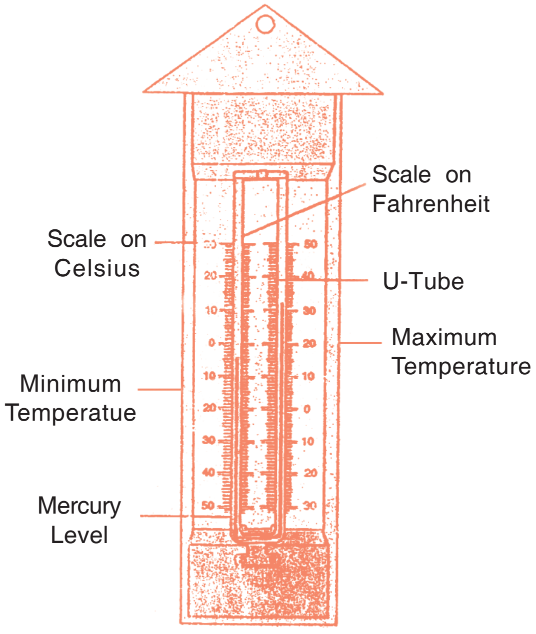
Clinical thermometer Fig. 14.1(a). The thermometer that we use for measuring temperature in science experiments is called **laboratory thermometer** Fig. 14.1(b) and the thermometer that the **meteorologists** use for determining the maximum and minimum temperature during a day is called as **maximum – 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).

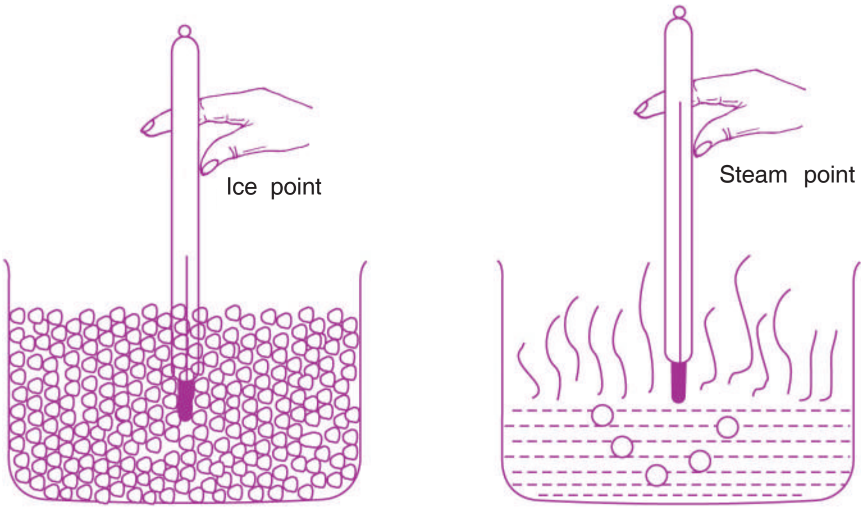


Fig. 14.2 *Calibration of a thermometer*

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).

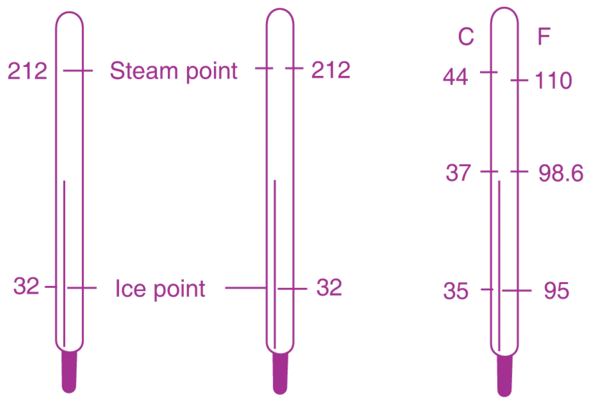


Fig. 14.3 *Different scales of temperature*

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 (× 10^3 J/kg)	Boiling Point (°C)	Latent heat of vaporization (× 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.

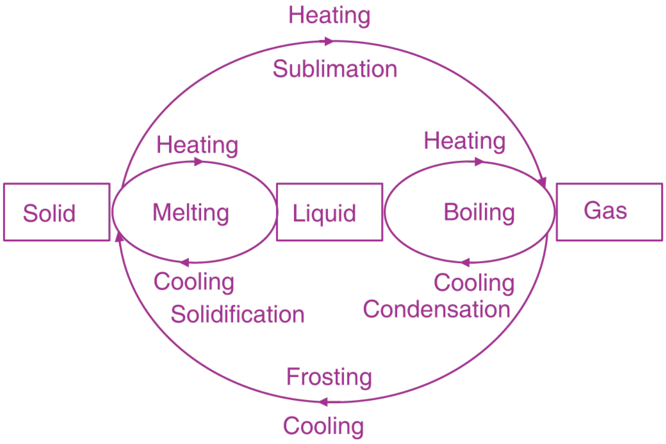


Fig. 14.4 *Change of state*

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.

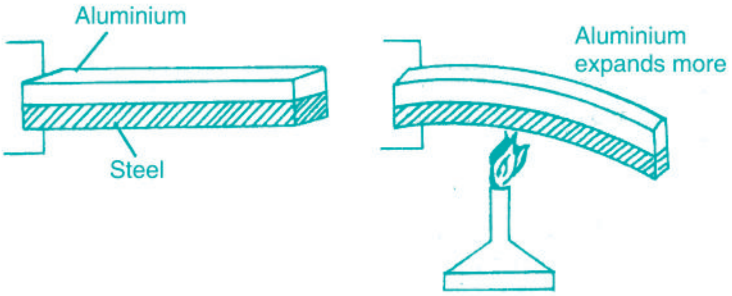


Fig. 14.6 *The bimetallic strip bends on heating*

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 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?

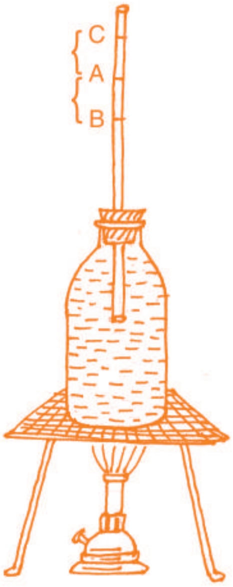


Fig. 14.7 *Expansion of Liquid*

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?

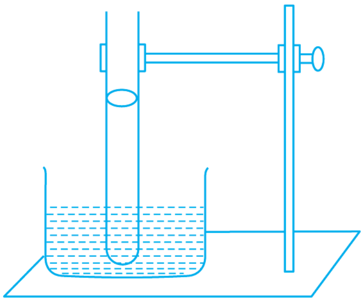


Fig. 14.8 *Expansion of gas*

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.

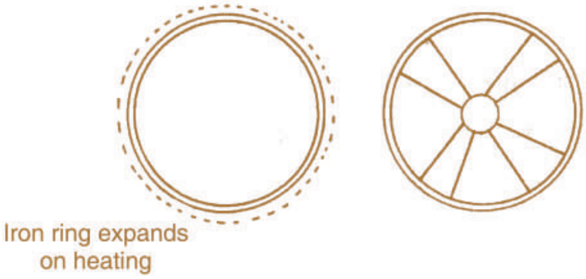


Fig. 14.10 *Fitting iron tyre on wooden wheel*

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.

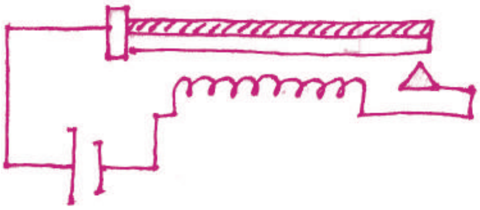


Fig. 14.11 *Principle of a thermostat*

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)].

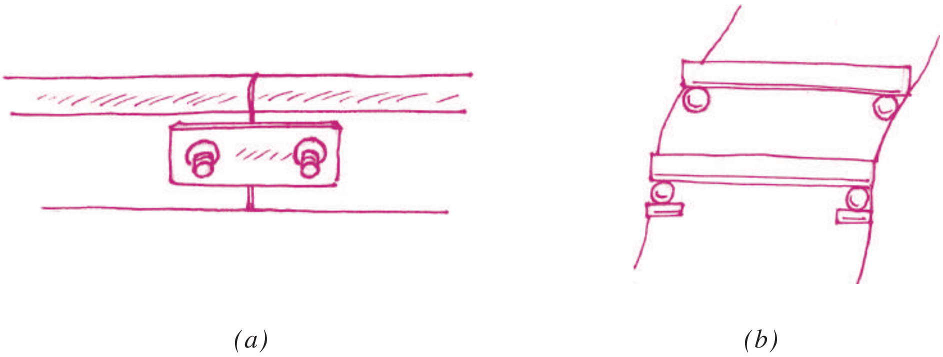

(a) *(b)*

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. $Q \propto m$

so, $Q \propto m\Delta\theta$

$$= ms\Delta\theta$$

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 2*r* 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

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.

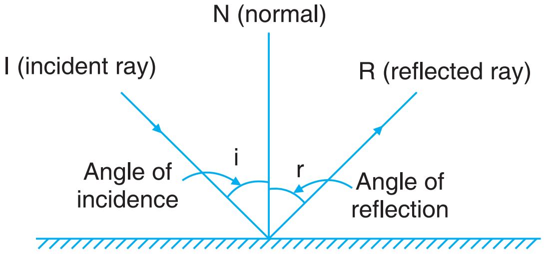


Fig. 15.1

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.

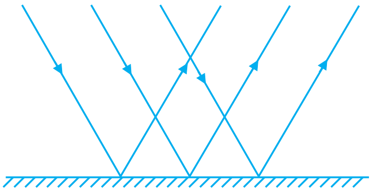


Fig. 15.2 *Regular reflection from a smooth plane surface*

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.

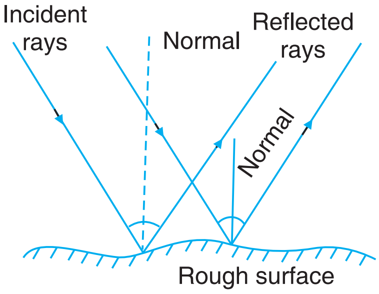


Fig. 15.3 *When surface is rough, parallel incident rays do not reflect parallel*

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.

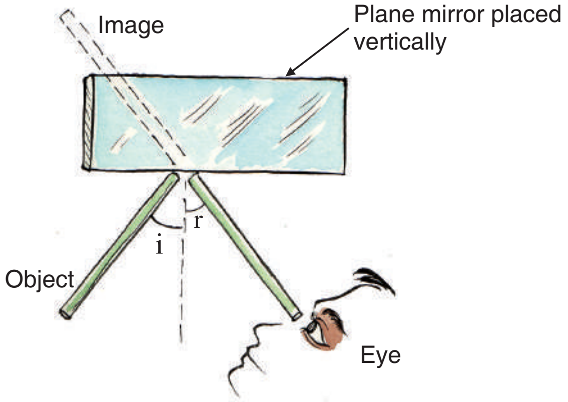


Fig. 15.4

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.

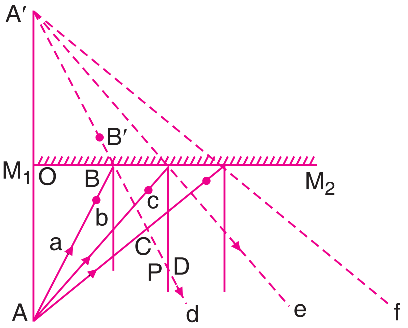


Fig. 15.5 *Image formation by a plane mirror*

(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., $OA = OA'$

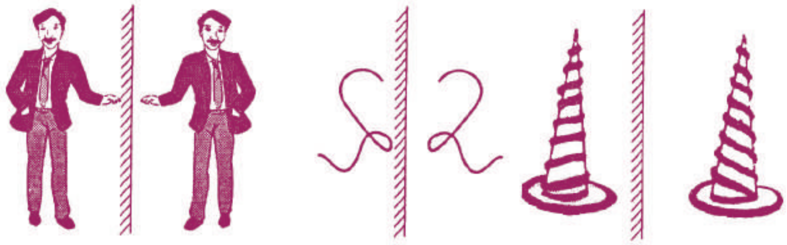
Hence, the image of a point in a plane mirror lies behind the mirror along the normal from the object, and is as for behind the mirror as the object is in front. It is an erect and virtual image of equal size.

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).



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

Fig. 15.6 *Lateral inversion in image formed by a plane mirror*

Similarly, if you read the sentence  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.

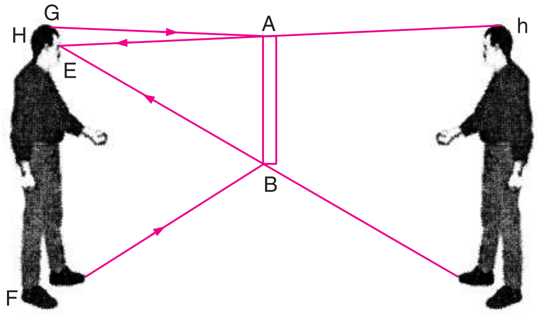


Fig. 15.7 *Size of plane mirror to see the full image*

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.

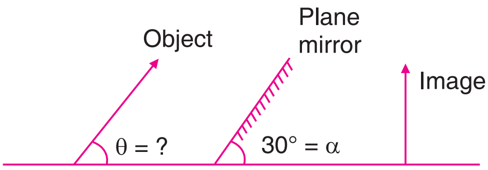


Fig. 15.8

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?

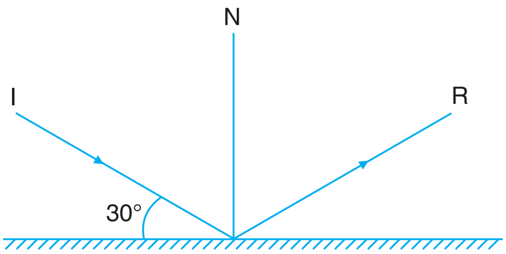


Fig. 15.9

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.

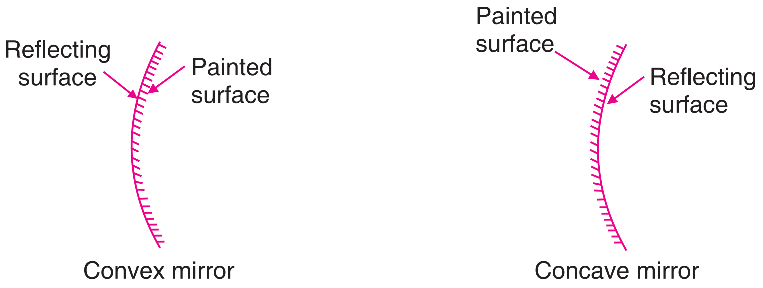


Fig. 15.10

To understand the reflection at spherical surface certain important terms are very useful. They are shown below in Fig. 15.11.

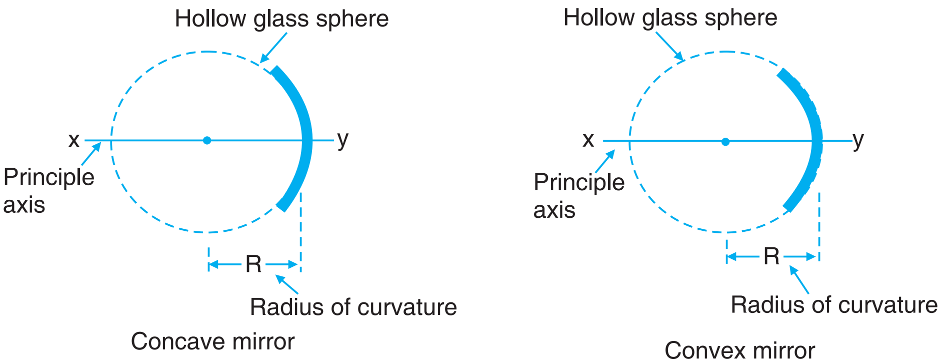


Fig. 15.11 *Some important terms of spherical mirrors*

(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,

$$MF = CF$$

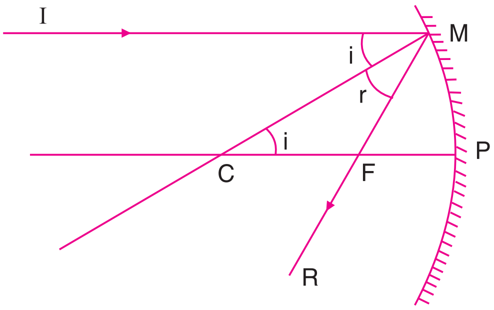


Fig. 15.12

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

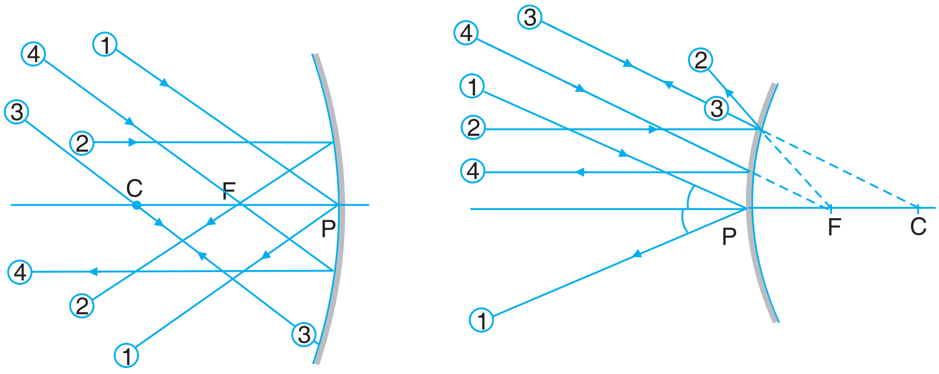
The ray diagram for image formation by mirrors can be drawn by taking any two of the following rays. The point where these two rays meet or appear to be coming from the point will be the image point which determines the position of image.

(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.

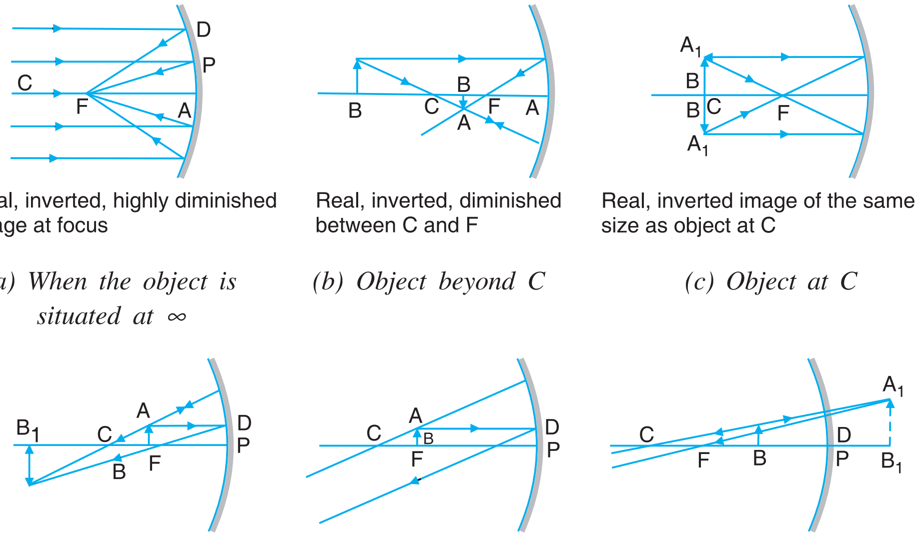


(a) (b)

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.



Real, inverted, highly diminished image at focus

(a) When the object is situated at ∞

Real, inverted, diminished between C and F

(b) Object beyond C

Real, inverted image of the same size as object at C

(c) Object at C

Real, inverted, enlarged image beyond C

(d) Object between C and F

Real, inverted, highly enlarged image at infinity

(e) Object at F

Virtual, erect, enlarged mage behind the mirror

(f) Object between F and P

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.

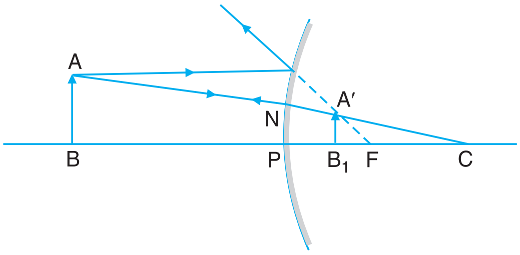


Fig. 15.15 *Image formation by a convex mirror*

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

$$\approx \left(\frac{360^\circ}{\theta} - 1\right), \text{ if } \left(\frac{360^\circ}{\theta}\right) \text{ is even integer}$$

$$\approx \frac{360^\circ}{\theta} \text{ if } \left(\frac{360^\circ}{\theta}\right) \text{ is odd integer}$$

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 $\theta = 120^\circ$ 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?

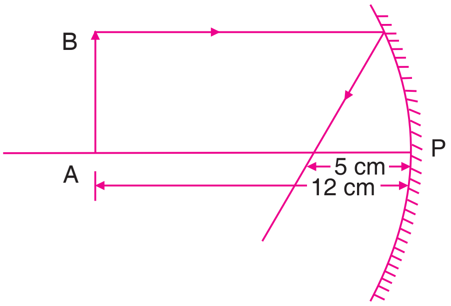


Fig. 15.16

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?

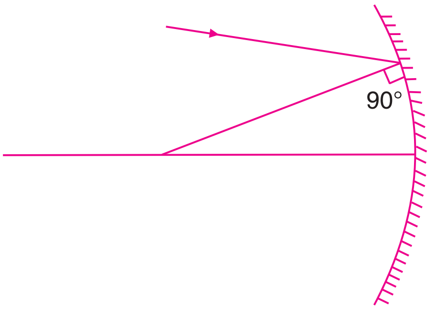


Fig. 15.17

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.

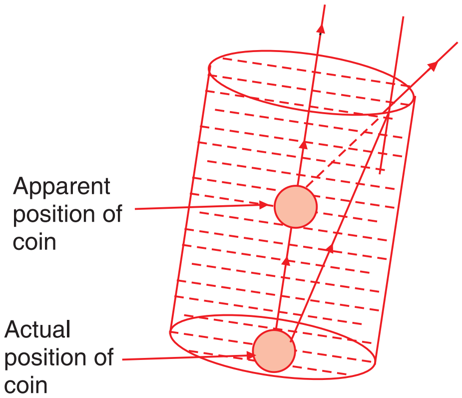


Fig. 15.18 *Coin placed in a tumbler filled with water*

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.

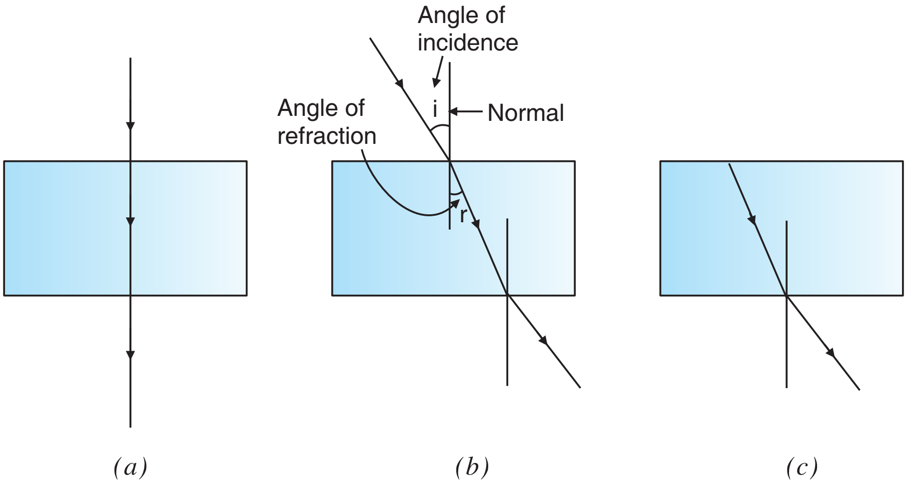


Fig. 15.19 *Refraction of light*

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.

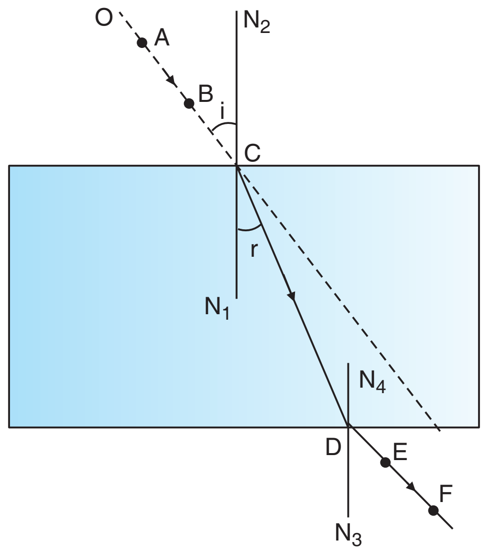


Fig. 15.20 *Refraction through a glass slab*

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.

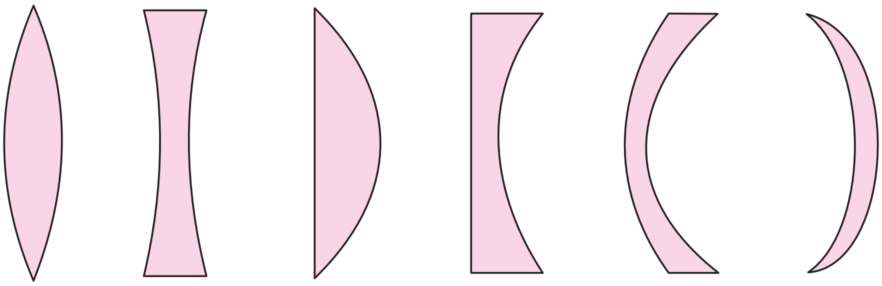
ACTIVITY 15.5

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.

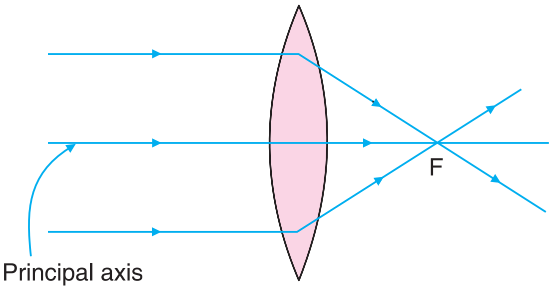


Fig. 15.23 *Converging action of a convex lens*

(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.

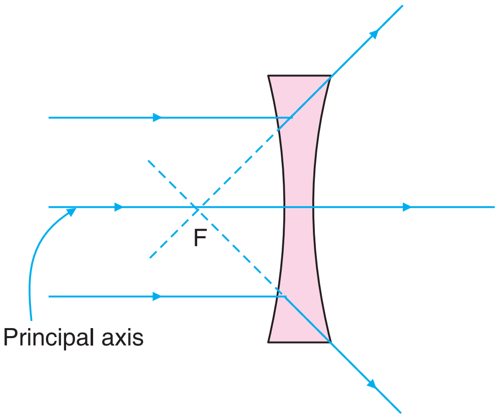


Fig. 15.24 *Diverging action of a concave lens*

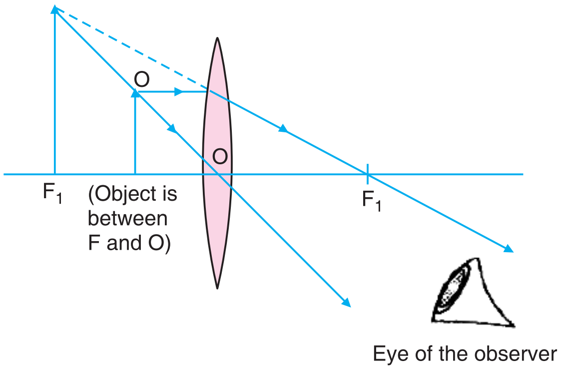
15.12 IMAGE FORMATION IN LENSES

In order to draw the image formed by any lens, only two rays are required. These two rays are:

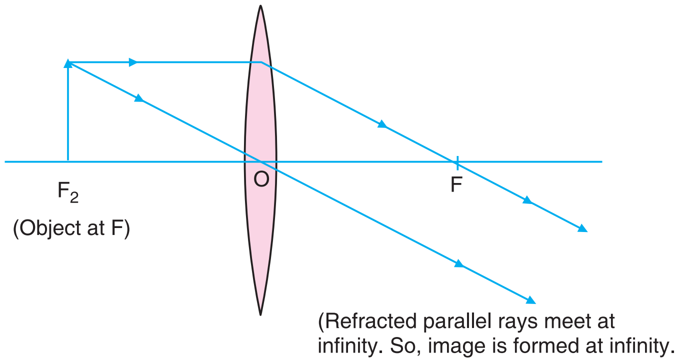
(i) A ray parallel to the principal axis of the lens converges after refraction at the principal focus of convex lens. It appears to diverge off in the case of concave lens.

(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.

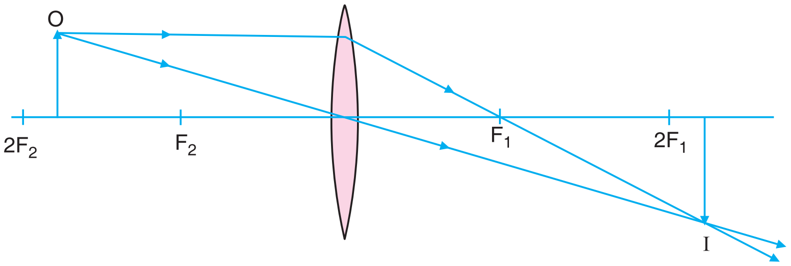


(a) Object is between focus and lens

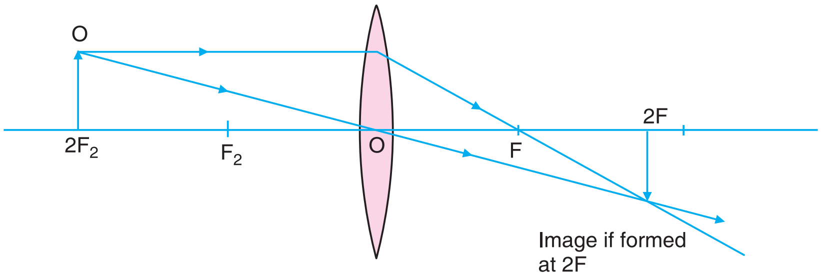


(Refracted parallel rays meet at infinity. So, image is formed at infinity.)

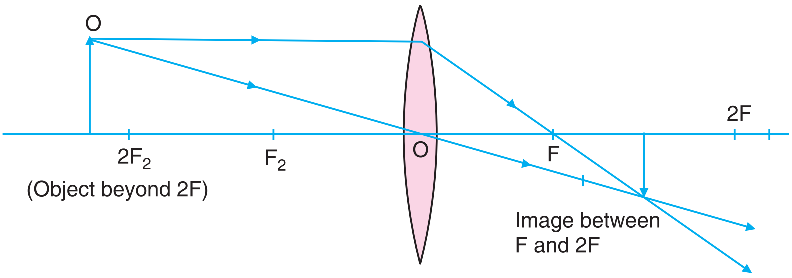
(b) Object at the first focus



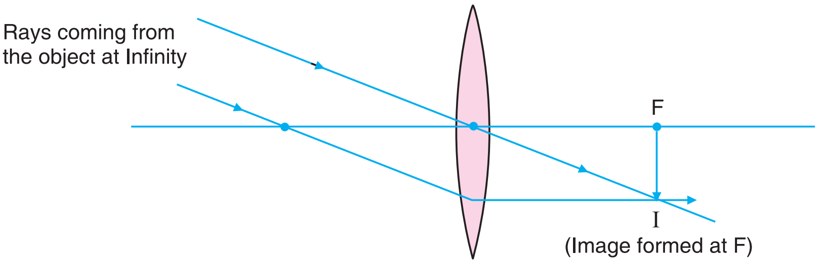
(c) Object is between F_2 and $2F_2$



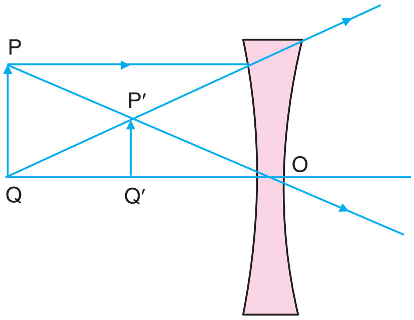
(d) Object is at $2F_2$



(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.

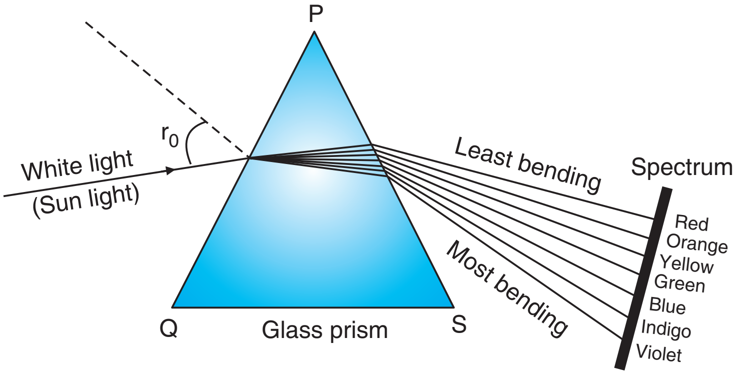


Fig. 15.26 *Dispersion of light*

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.

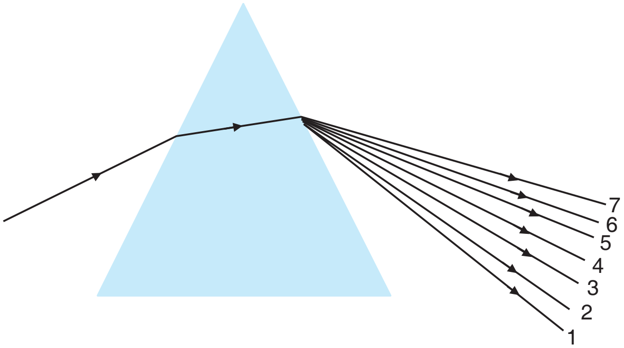


Fig. 15.27

3. How do r and δ change for same angle of incidence i if the prism shown in Fig. is immersed in water

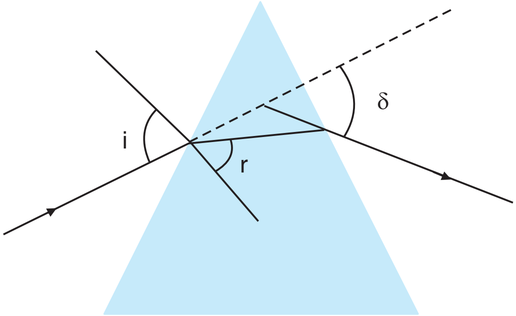


Fig. 15.28

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.**

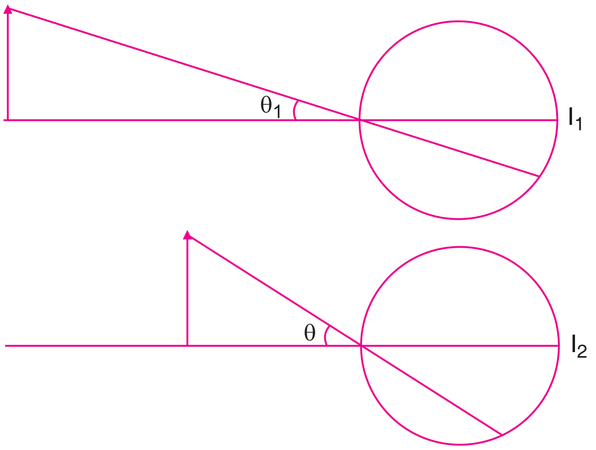
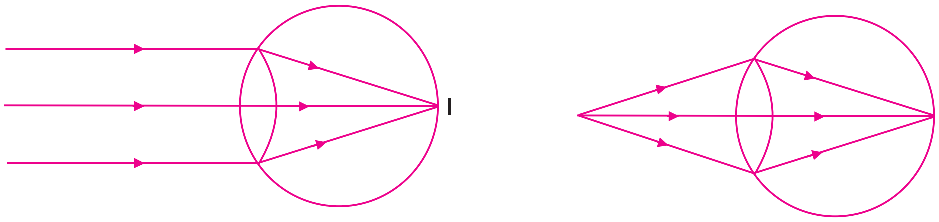


Fig. 15.29 *Image formation in eye*

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).

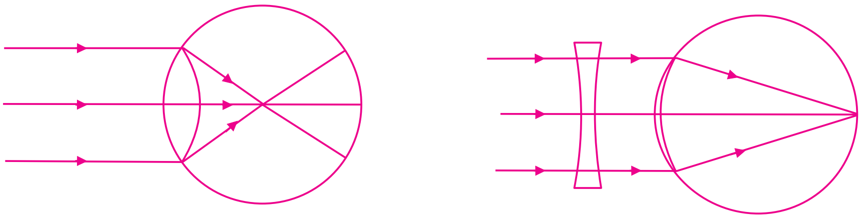


Relaxed eye *Maximum strained eye*

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.

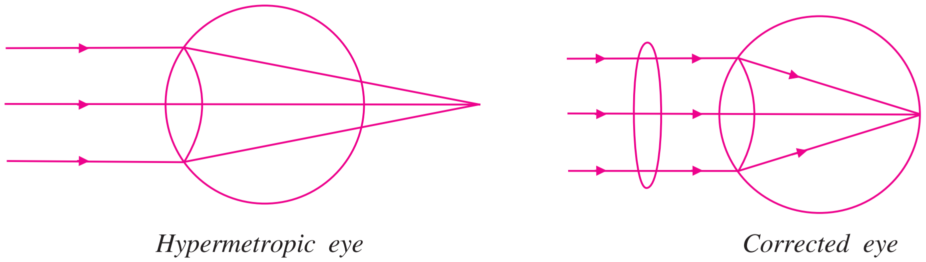


Fig. 15.32

(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?

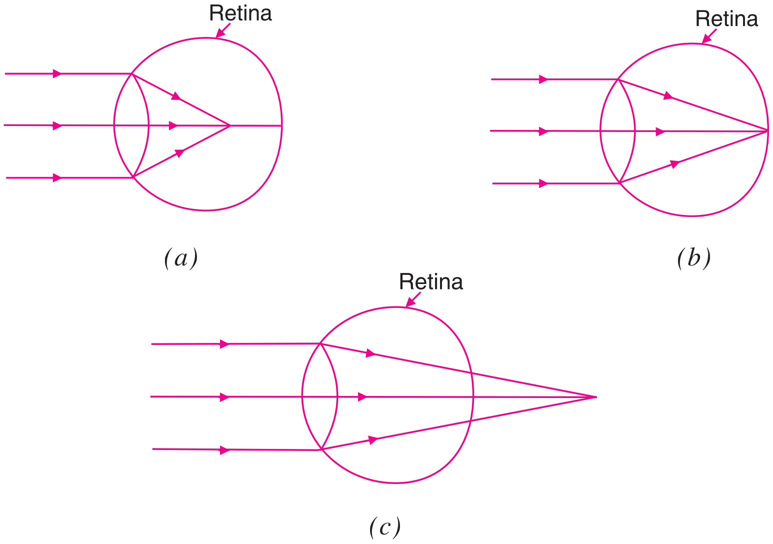


Fig. 15.33

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 $P=\dfrac{1}{f\,(m)}$. 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

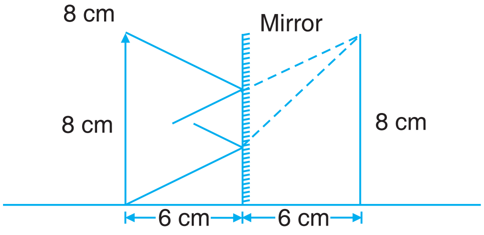
2. (i) Real image can be taken on screen while virtual can not.

   (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.

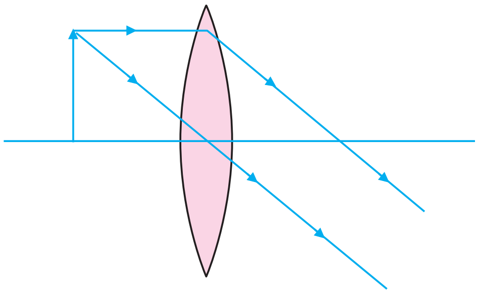
Position of object	Position of image
(i) at F	(i) at infinity
(ii) between F and $2F$	(ii) beyond $2F$
(iii) beyond $2F$	(iii) between F and $2F$
(iv) between F and $2F$	(iv) beyond $2F$
(v) beyond $2F$	(v) between F and $2F$

10. (i) in vehicle for rear view (ii) as safety viewers at dangerous corners
11. No, not always

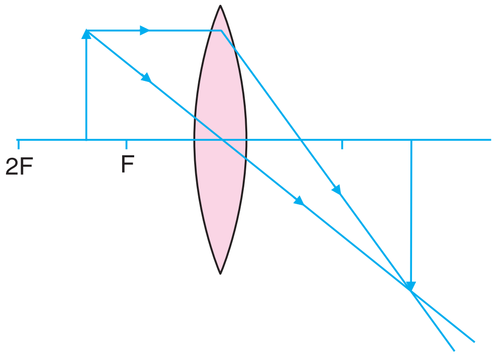
12. Object must be placed either between focal point and pole for virtual image or between F and $2F$ for real image.

15.3

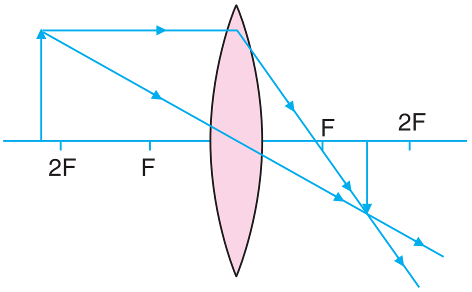
1. Concave lens
2. (i)



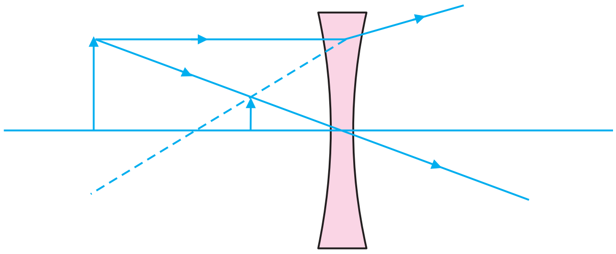
(ii)



(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

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.

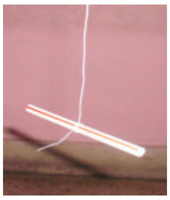
It was realized that metal can be charged by rubbing but only if it is held in a handle of glass or amber. The metals cannot be charged if it is held directly in the hand. This is because electric charges move along the metal and pass through the human body (conductor) to the earth.

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.

Attractive force

Repulsive force

Repulsive force

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 $q_1 = q_2 = 1$C, $r = 1$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

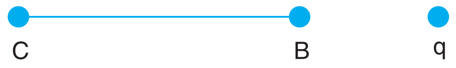


Fig. 16.2 *charge q coming from infinity to B or C*

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?

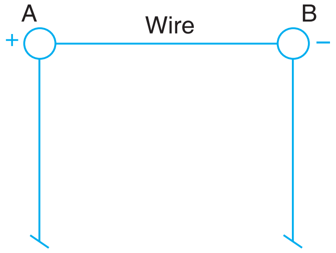


Fig 16.4 *Two metallic spheres mounted on stands*

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.

$$1 \text{ mA} = 10^{-3}\text{A}$$

$$1 \text{ µA} = 10^{-6} \text{ A}$$

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.

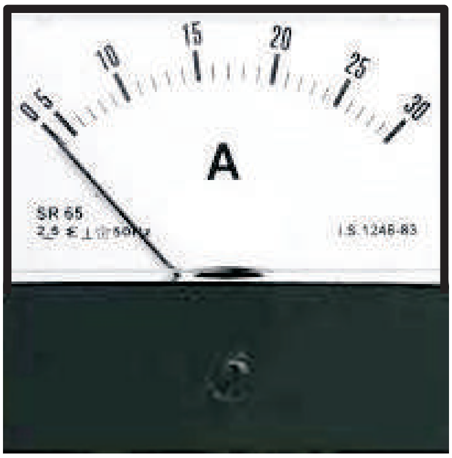
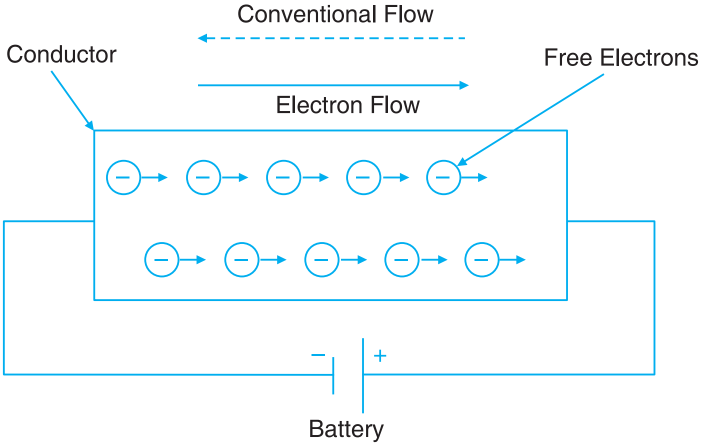


Fig. 16.5 *Ammeter*

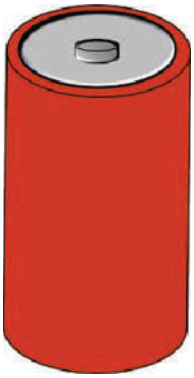
Do you know

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.

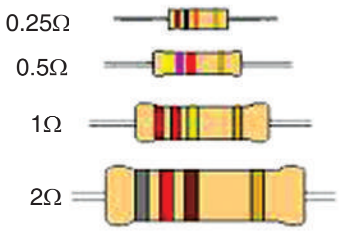
Conductors are the materials which allow the electric current to flow through them quite freely e.g. metals like silver, copper, aluminum.

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).

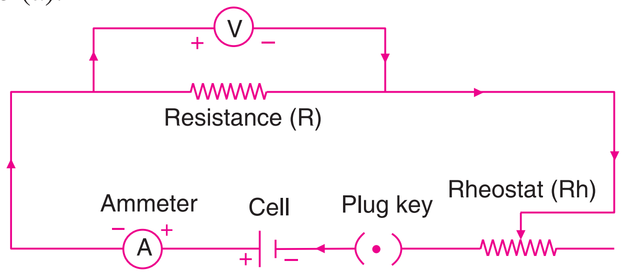


Fig. 16.6 *(a) Circuit diagram to study relationship between voltage and current*

(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).

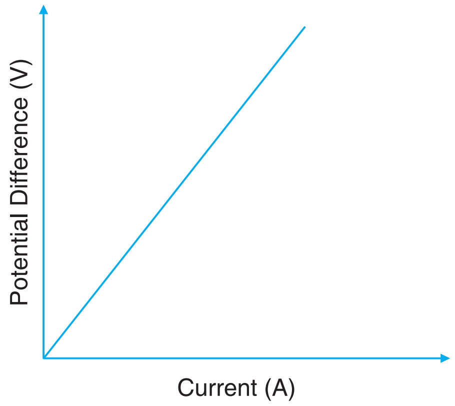


Fig. 16.6 *(b) variation of voltage with current*

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)

$$1 \text{ k}\Omega = 10^3 \ \Omega$$

$$1\text{M}\Omega = 10^6 \ \Omega$$

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.

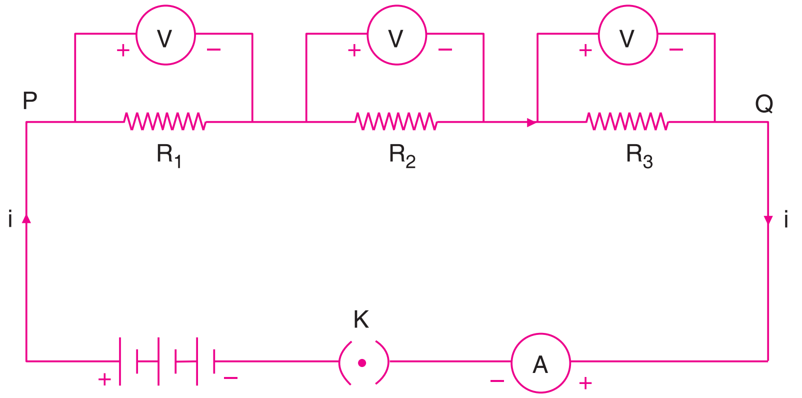


Fig. 16.7 *Resistors in series*

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

$$= iR_1 + iR_2 + iR_3$$

$$= i(R_1 + R_2 + R_3) \quad (16.1)$$

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

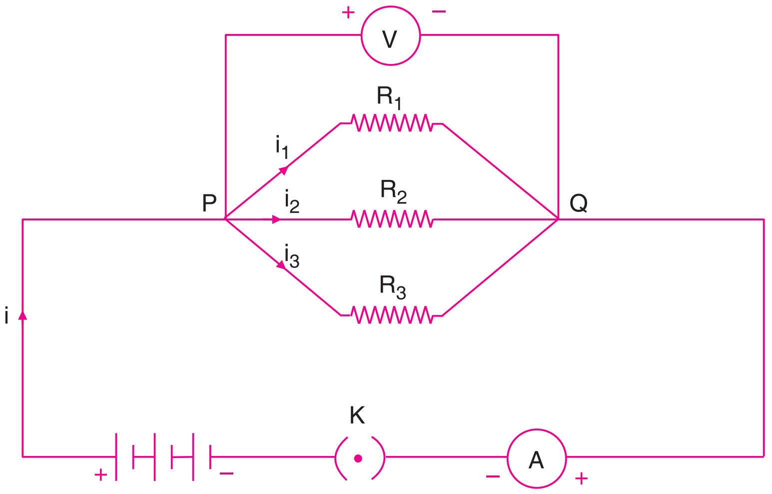


Fig. 16.8 *Resistors in parallel*

$$i = i_1 + i_2 + i_3 \tag{16.3}$$

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.

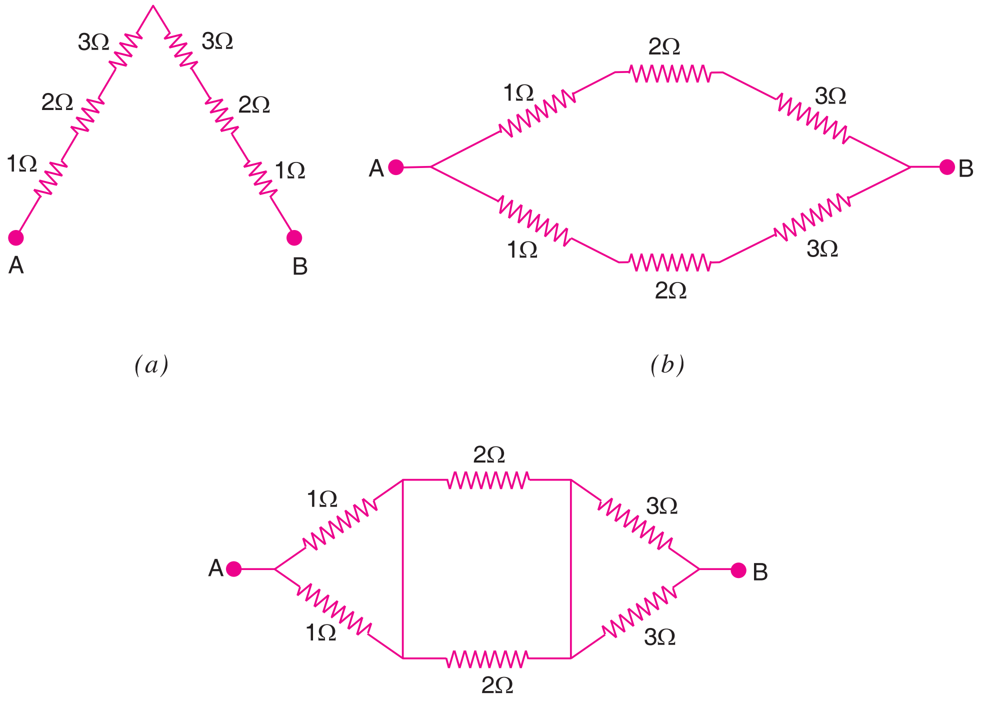
Solution: Given $i = 0.5A$ $\quad t = \frac{1}{5}$ of an hour $= \frac{1}{5} \times 60$ min $= 12$ min

$$Q = it = 12 \times 60 \text{ s} = 720 \text{ s}$$

$$= (0.5\text{A}) \times 720 \text{ s} = 720 \text{ s}$$

$$= 360 \text{ C}$$

Example 16.4: Find the equivalent resistance of the following combination of resistors.



(a) (b)

(c)

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?

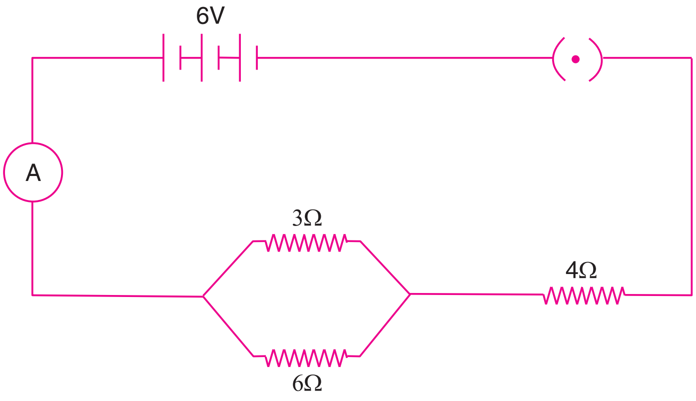


Fig. 16.10

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 $V = iR$

$$\therefore \qquad W = (iR)it$$

$$W = i^2Rt.$$

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.

$$\text{Electric power } P = \frac{\text{Work done } (W)}{\text{Time taken } (t)} = \frac{Vit}{t} = Vi$$

$$\therefore \qquad P = Vi$$

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.

$$1 \text{ kilowatt (kW)} = 1000 \text{ W}$$

$$1 \text{ megawatt (MW)} = 10^6 \text{ W}$$

$$1 \text{ gigawatt (GW)} = 10^9 \text{ W}$$

For electric power another bigger unit horse power (hp) is also used.

$$1 \text{ (hp)} = 746 \text{ W}$$

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.

$$1 \text{ kilowatt hour (kW h)} = 1 \text{ kilowatt} \times 1 \text{ hour}$$

$$= 1000 \text{ watt} \times 3600 \text{ second}$$

$$= 1000 \text{ joule/second} \times 3600 \text{ second}$$

$$= 36 \times 10^5 \text{ joule}$$

$$1 \text{ kW h} = 3.6 \times 10^6 \text{ J}$$

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.

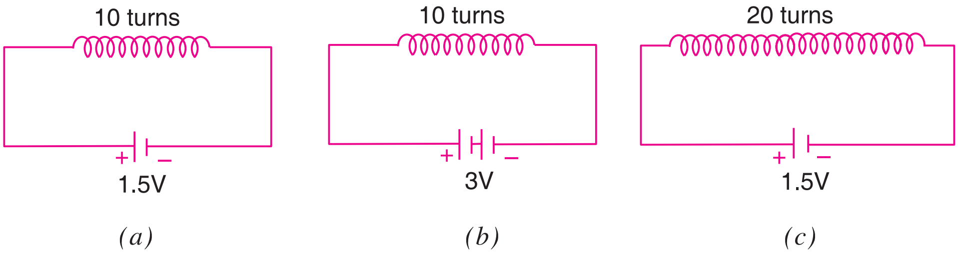
(i) Attach connecting wires to the free ends of the 10-turn coil permanently.

(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.



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

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

$$1 \times 4.18 \times 10^3 \times 30 = 2000 \times t$$

$$t = \frac{125.4 \times 10^3}{2 \times 10^3} = 62.7\,\text{s}$$

Example 16.8: How many kilowatt hour of energy will be consumed by a 2 hp motor in 10 hours?

Solution:

$$P = 2 \text{ hp} = 2 \times 746 \text{ W}$$

$$= 1.492 \text{ kW}$$

$$Q = Pt = 1.492 \text{ kW} \times 10 \text{ h} = 14.92 \text{ kW h}$$

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 $V = 250\ \text{V}$ $R = 1000\ \text{W}$ $t = 10\ \text{s}$

$$Q = \frac{V^2 t}{R} = \frac{250 \times 250 \times 10}{1000} = 625\,\text{J}$$

Example 16.10: Compute the heat generated while transferring 96 kC of charge in one hour through a potential difference of 50V.

Solution: Given: $V = 50\text{V}$ $t = 1\ \text{h}$ $q = 96000\ \text{C}$

$$\begin{aligned} W &= qV \\ &= 96000\ \text{C} \times 50\ \text{V} \\ W &= 4800000\ \text{J} \\ &= 4.8 \times 10^6\ \text{J} \\ &= 4.8\ \text{MJ}. \end{aligned}$$

Example 16.11: An electric iron of resistance 25 Ω takes a current of 5A. Calculate the heat developed in 1 minute.

Solution: Given: $R = 25\ \Omega$ $i = 5\text{A}$ $t = 1\ \text{min}\ (= 60\ \text{s})$

Heat developed $H = i^2 R t$

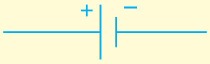
$$\begin{aligned} &= (5\ A)^2 \times 25\ \Omega \times 60\ \text{s} \\ &= 37500\ \text{J} = 3.75 \times 10^4\ \text{J} \end{aligned}$$

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

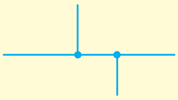


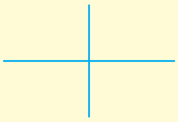
Single electric cell

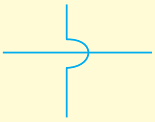

Battery

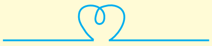

An open plug key or switch


A closed plug key or switch

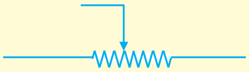

Wires joined

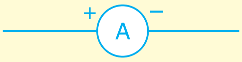

Wires crossed


Wires crossing without contact

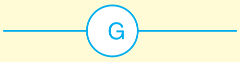

An electric bulb


A resistor

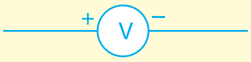

A Rheostat



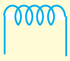
An ammeter

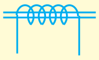


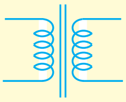
A galvanometer

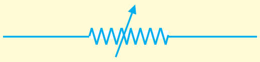


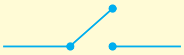
A voltmeter


Electromagnet


Electromagnet with iron core

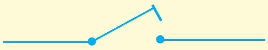

Transformer

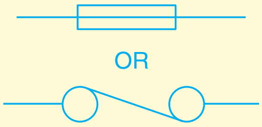

Variable resistance


Open switch


Closed switch

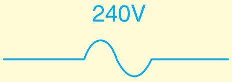

Inductor


Tapping key

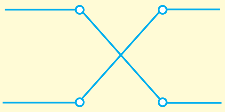


Electric fuse


Capacitor



a.c. supply


Reversing key

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 $[R_1 + (R_2 R_3/R_2 + R_3)]$

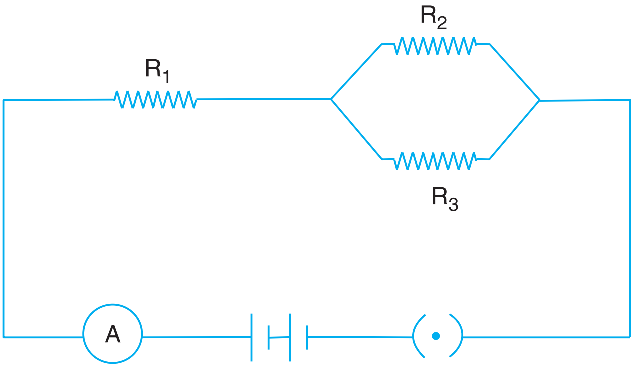


Fig. 16.12

(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.

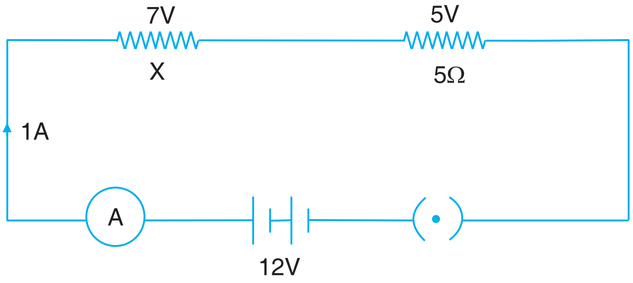


Fig. 16.13

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.

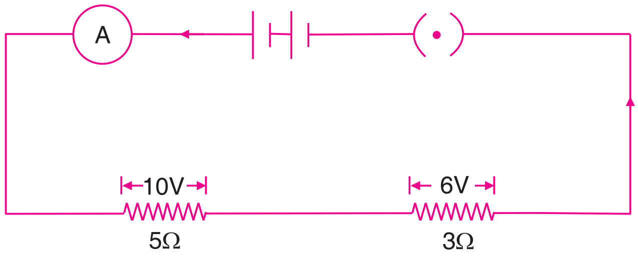


Fig. 16.14

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.

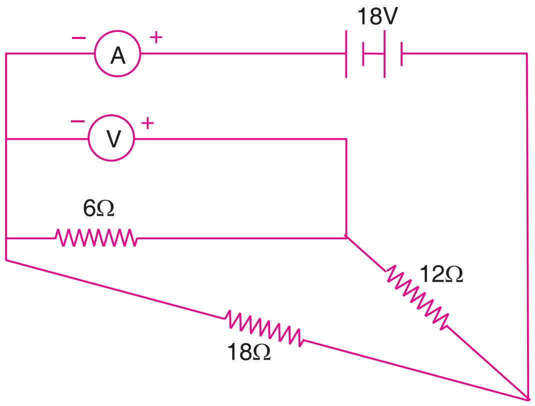


Fig. 16.15

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.

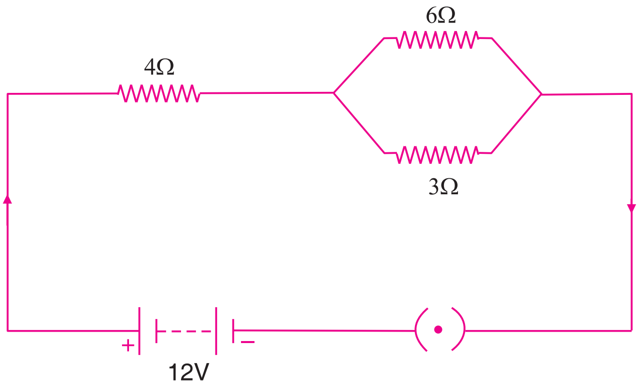


Fig. 16.16

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. $N = \frac{Q}{|e|} = \frac{10\times10^{-6}}{1.6\times10^{-19}} = 6.25\times10^{13}$ electrons

3. $F = k\frac{q_1 q_2}{r^2} \Rightarrow F = k\frac{2q_1 \times 2q_2}{(r/2)^2} = 8\text{F}$

4. $F' = 1/4\ \text{F}$

5. (i) $V = \frac{U}{q} = \frac{10}{10^{-6}} = 10^7\ \text{V}$

   (ii) $U = \frac{KQq}{r} \quad Q \quad \frac{Ur}{Kq} \quad \frac{10\times0.5}{9\times10^9\times10^{-6}} \quad \frac{5}{9} \quad 10^{-3}\text{C}$

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 kW h = 3.6×10^6 J

6. (i) Electric heater (ii) Electric kettle

Notes

16.4

1. $R = \frac{V^2}{P}$, 40W lamp has higher resistance.

2. $I = \frac{P}{V} = \frac{100\text{ W}}{220\text{ V}} = \frac{5}{11}\text{A}.$

3. $Q = Pt = 60\text{W} \times 4\text{h} \times 30 = 7200\text{ W h} = 7.2\text{ kW h}$

4. $Q = Pt = \frac{746}{4}\text{W}\times 3600\text{s} = 671400\text{J}.$

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

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

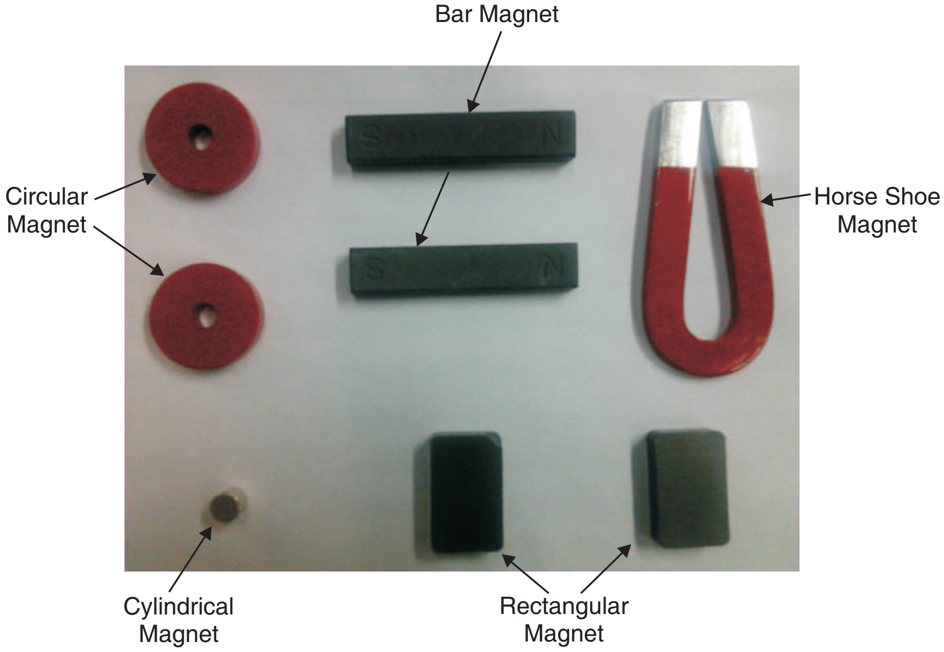


Fig. 17.2 *Magnets of different shapes*

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.

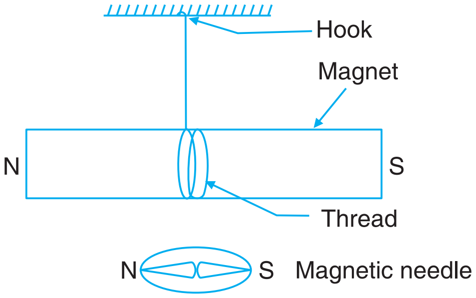


Fig. 17.3 (i)

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.

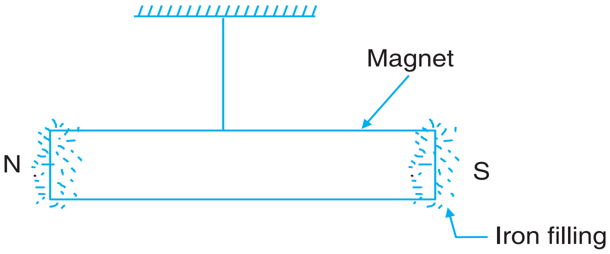


Fig. 17.3 (ii)

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.

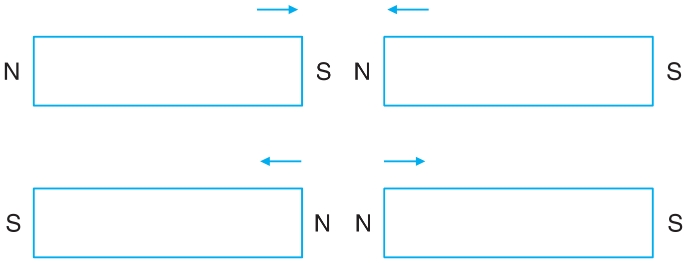


Fig. 17.3 (iii)

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.

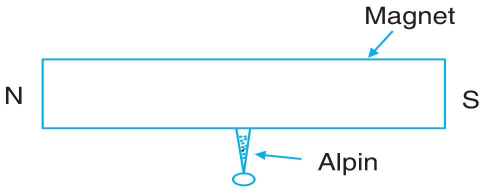


Fig. 17.3 (iv)

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.

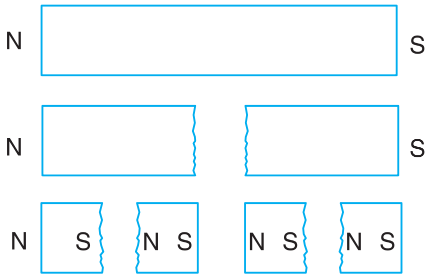


Fig. 17.3 (v)

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.

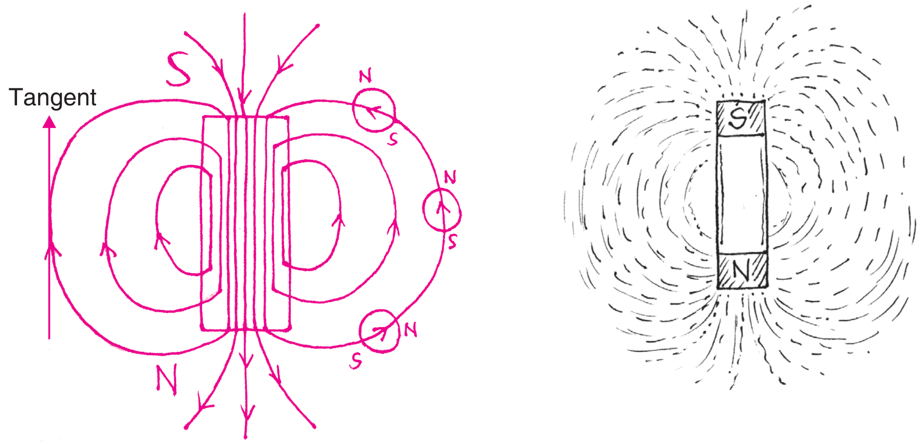


Fig. 17.4 (i)

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.

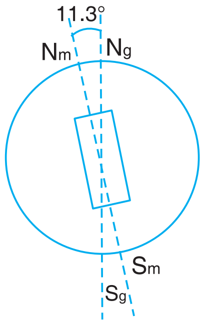


Fig. 17.4 (ii)

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'.

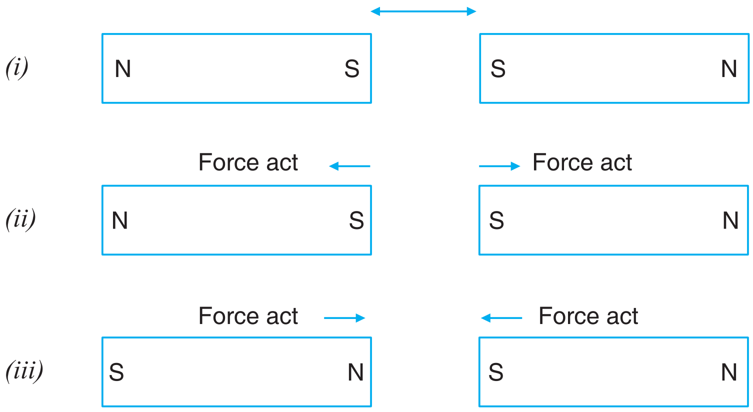


Fig. 17.5

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

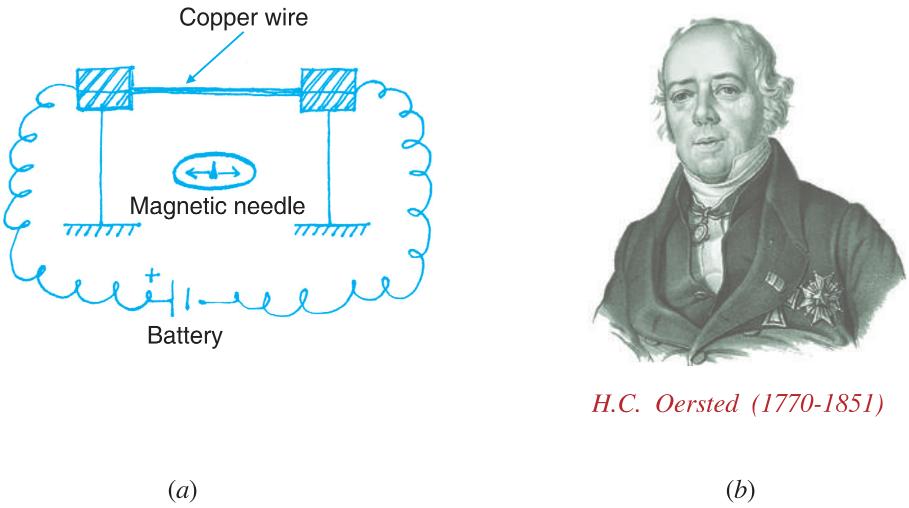
   (iii) North-south (iv) North-east
5. Do magnetic field exist throughout space?
6. The north pole, magnetic needle points towards earth's

   (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*) (*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.

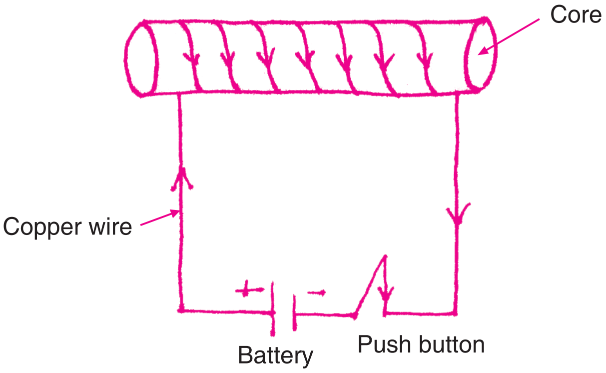


Fig. 17.7 *Solenoid*

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.

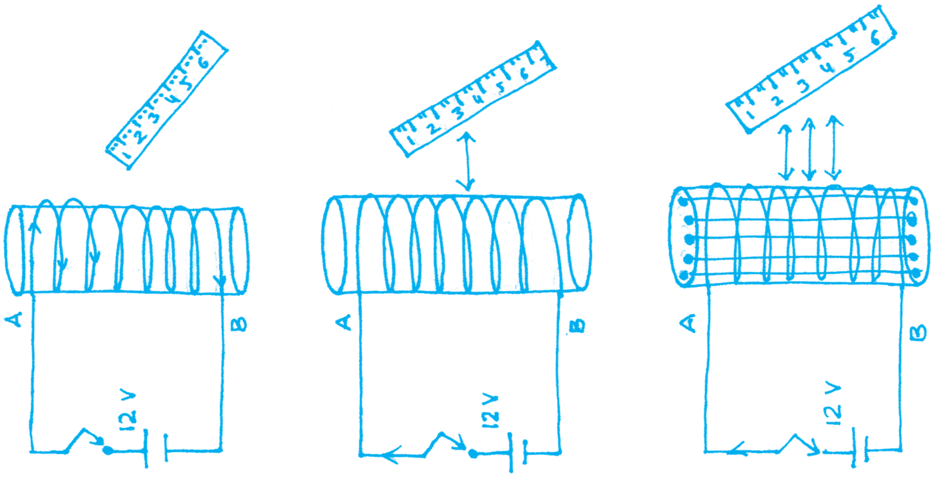
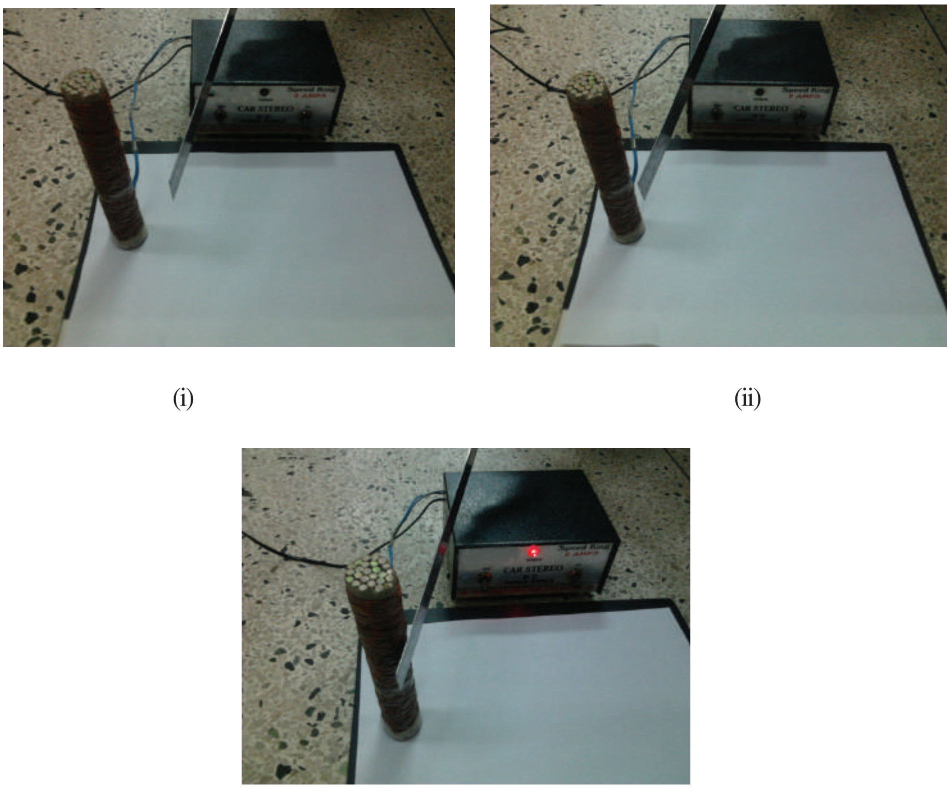


Fig. 17.8 (a)



(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'.

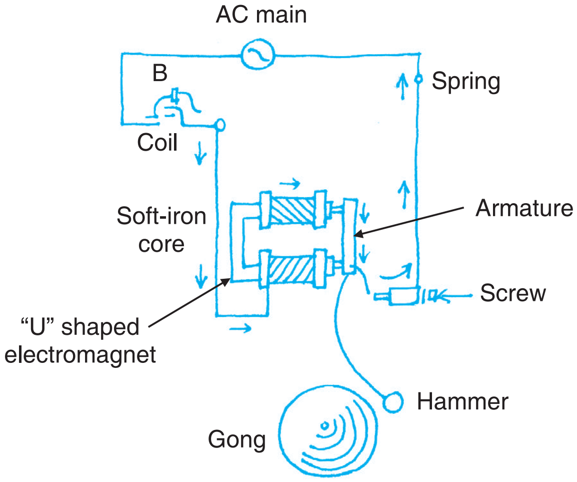


Fig. 17.9 *Electric bell*

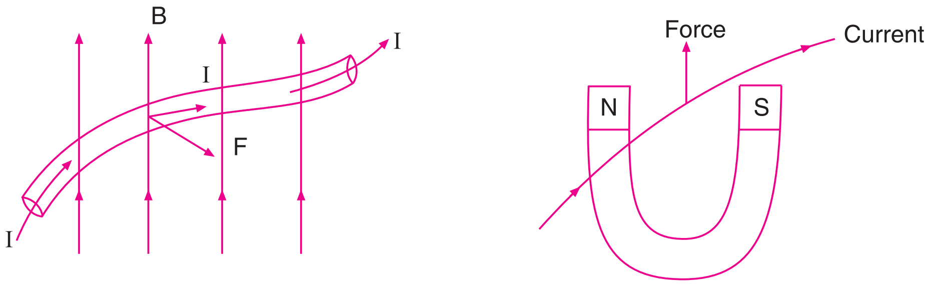
The poles of the electromagnet are connected to a power supply (battery or main). Between this a push button (B) is attached as shown in Fig. 17.9. When the push button is pressed, current starts flowing in the coil of the electromagnet and its soft iron 'core' gets magnetized. This magnetized core pulls 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.

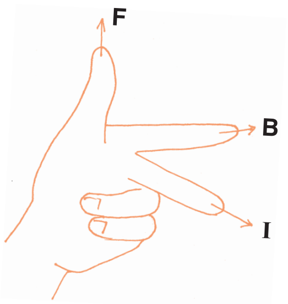


Fig. 17.11 Flemings left hand rule

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

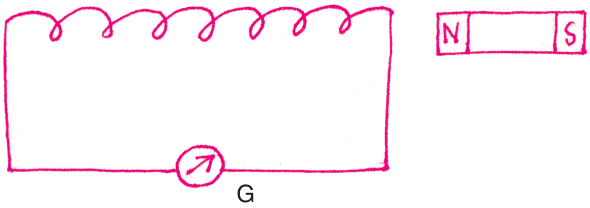
4. Why does an iron core increase the magnetic field of a coil of wire
    (i) The iron atom line up to add the magnetic field
    (ii) Iron attract things includes magnetic fields
    (iii) The iron core actually decrease the field, allowing it to be turned off
5. List the factors affecting the strength of an electromagnet?
6. What is the role of solenoids in making electromagnet?

17.6 ELECTROMAGNETIC INDUCTION

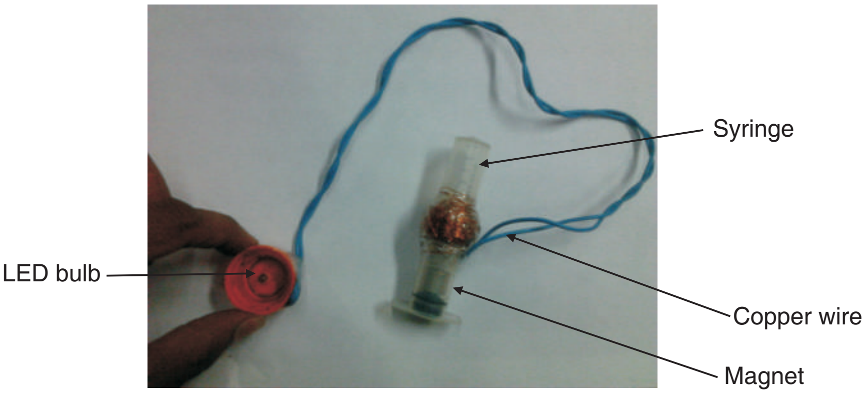
Previously in this lesson, we have seen that magnetic field is created when current flows through a solenoid (a cylindrical core of insulated copper wires). Do you think that the reverse should also be possible? That means conversion of electricity from magnetism. Michael Faraday, a great scientist also 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.

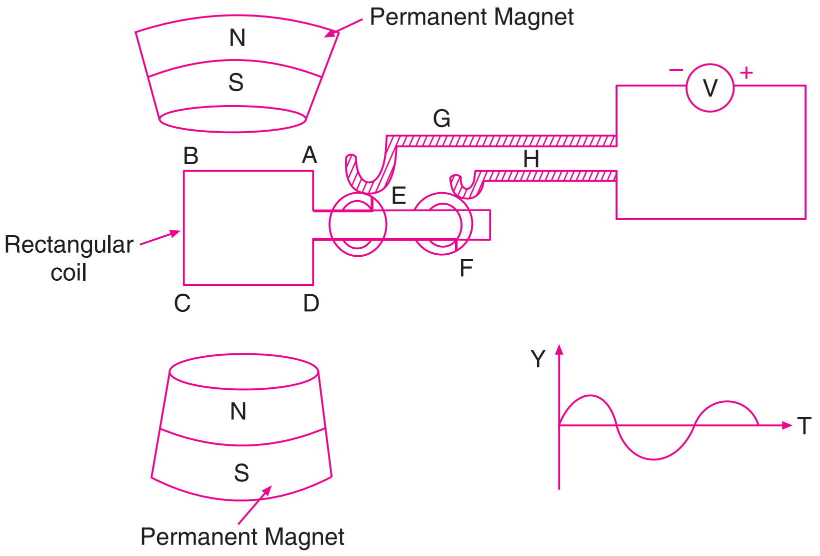


Fig. 17.13 *A.C. Generator*

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.

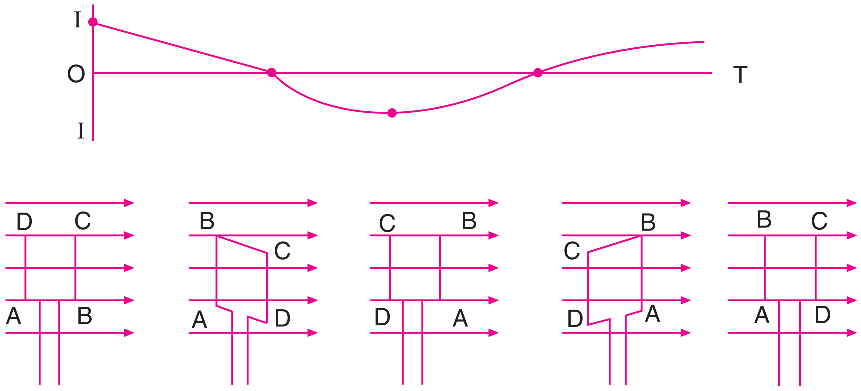


Fig. 17.14

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.

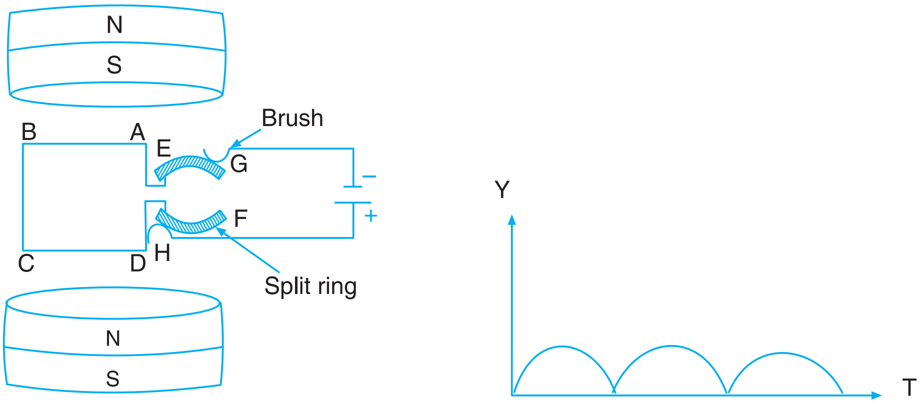


Fig. 17.15 *D.C. Generator*

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.

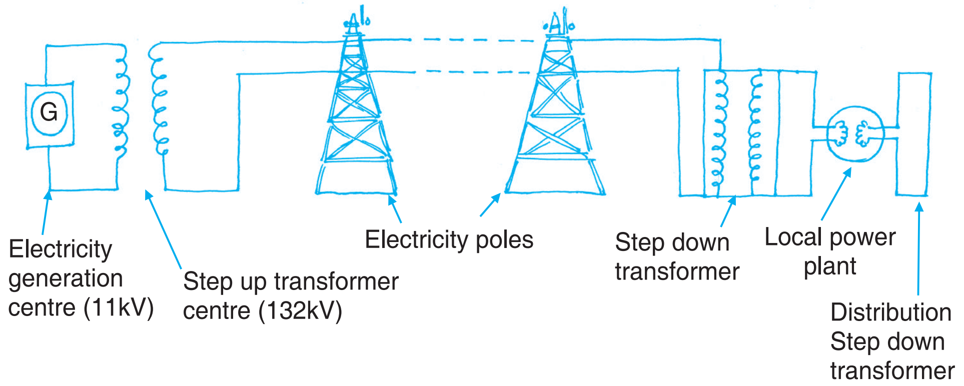


Fig. 17.16 *Distribution of electrical energy*

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.

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.

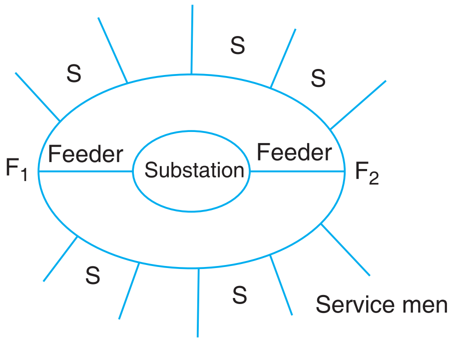


Fig. 17.17 *Ring System*

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.

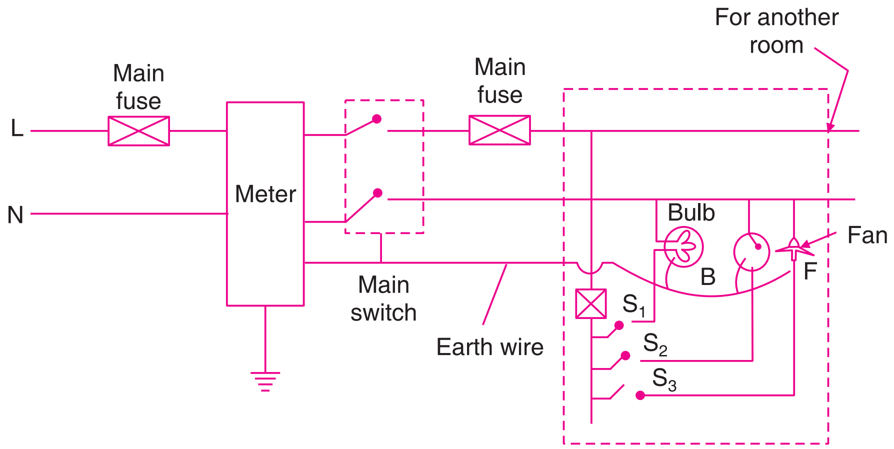


Fig. 17.18 *Household circuit (one bulb, one fan and one plug point)*

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

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.

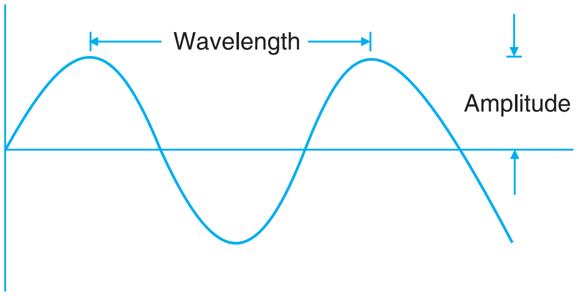


Fig.18.1 *A representation of wave*

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.

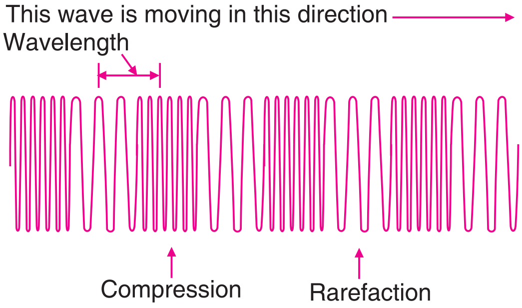


Fig. 18.2 *Formation of rarefactions and compressions in air and indication of wavelength*

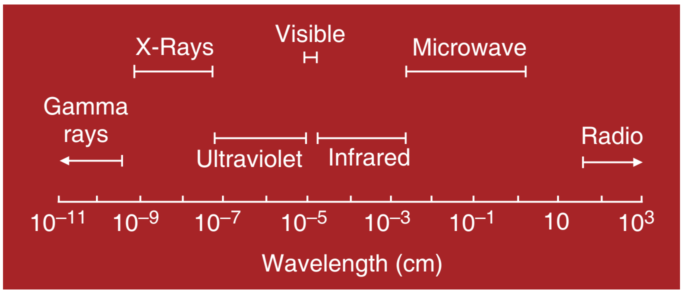
While transverse waves form only in fluids (air and liquid), the longitudinal waves can form in all the three media viz. solid, liquid and gas. One way to visualize a longitudinal wave is to take a spring, fix it between two ends and then pull or press it on one end along the length. Compressions and 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.

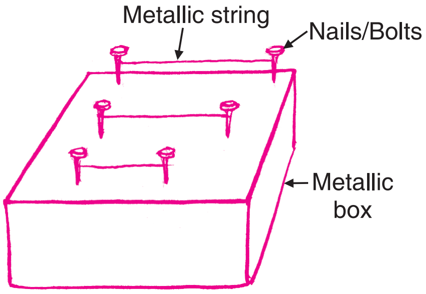


Fig.18.4. *A musical string instrument (which you can make using a metallic box and metallic strings)*

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

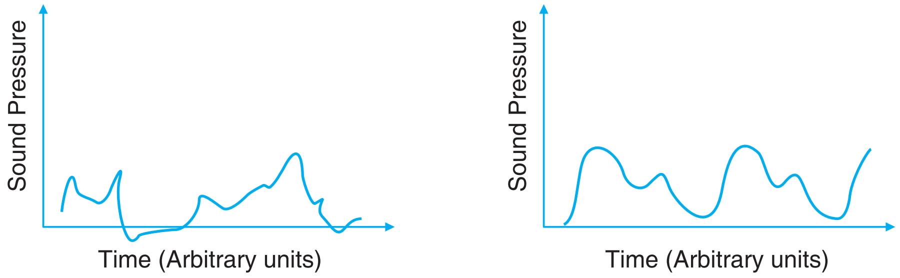
You can do a simple experiment to understand the relation between the pitch of a sound and the wave length. This will help us to understand difference in sounds from a dhol and tabla as well as from a small and a long string. The smaller one will produce a higher frequency.

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.



Noise

Music

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.

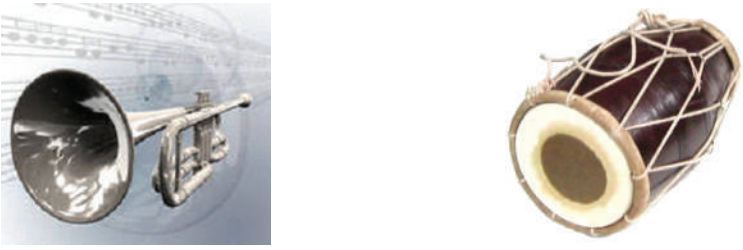
In India we see many musical instruments. Flute (Baansuri), Sitar, Sarod, Tabla, drum ghatam (pitcher), and even some Western instruments like guitar, piano and harmonium are quite popular. Some are string instruments where sound is produced by plucking a string and setting it to vibrate such as Tanpura, 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.

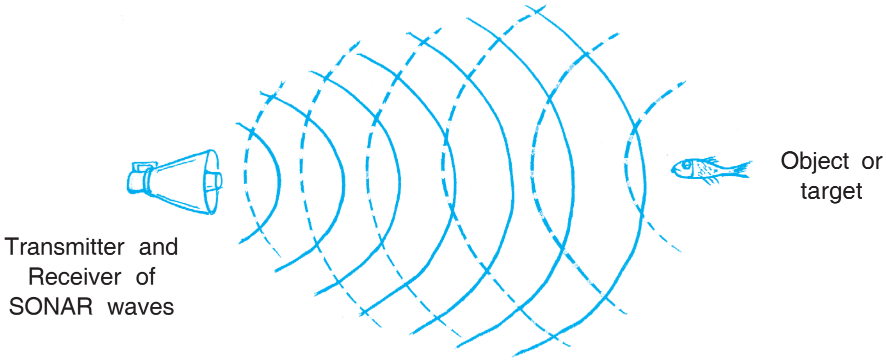


Fig. 18.7 *Working of SONAR: The continuous lines are used for transmitted SONAR waves and the dashed lines are used for reflected SONAR waves.*

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)

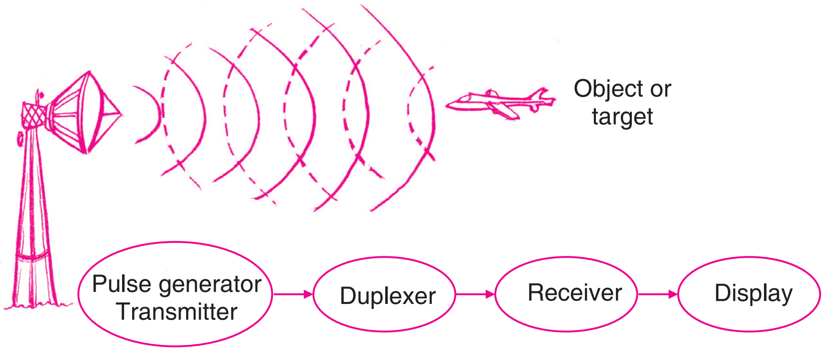


Fig. 18.8 *A simple sketch of components of RADAR*

Notes

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.

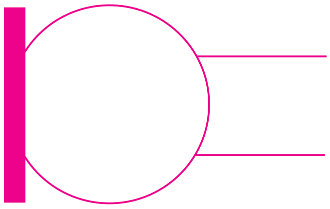


Fig. 18.9 *Symbol of a microphone*

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).

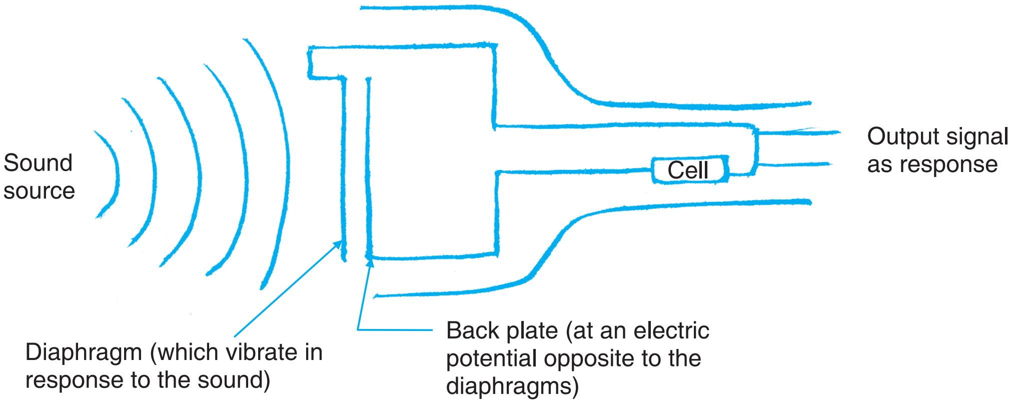


Fig. 18.10 (a) *Structure of a condenser (capacitor) microphone*

Fig. 18.10 (b) *Condenser 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.

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:

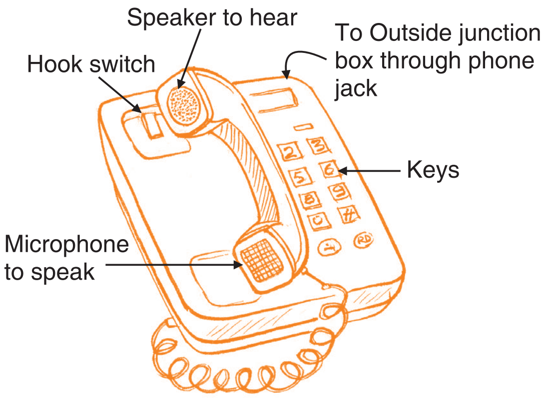


Fig. 18.11 (a) *The basic structure of a wired phone set (In actual phone there is a provision so that your voice does not reach and disturb you)*

(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

Fig. 18.11 (b) *Mobile*

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.

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

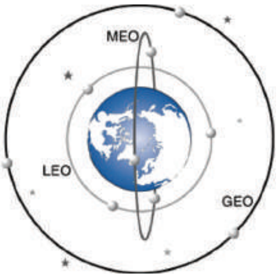


Fig. 18.12 *A satellite moves in Low (LEO), Geostationary orbit (GEO) or in an orbit. LEO goes over the poles in each revolution (Polar orbit) which is used for mapping Earth. This is useful in weather studies because it allows looking at clouds etc. at the same time every day. The geostationary and 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.