1. Laws of Motion

- Motion
- Acceleration
- Distance and displacement
- Newton's laws of motion and related equations.

Motion of an object

Can you tell?

In which of the following examples can you sense motion? How will you explain presence and absence of motion?

1. The flight of a bird
2. A stationary train
3. Leaves flying through air
4. A stone lying on a hill

We see the motion of several objects every day. Sometimes we cannot see the motion of an object directly, as in the case of a breeze. Can you list other examples of motion, besides those given here?

Think about it.

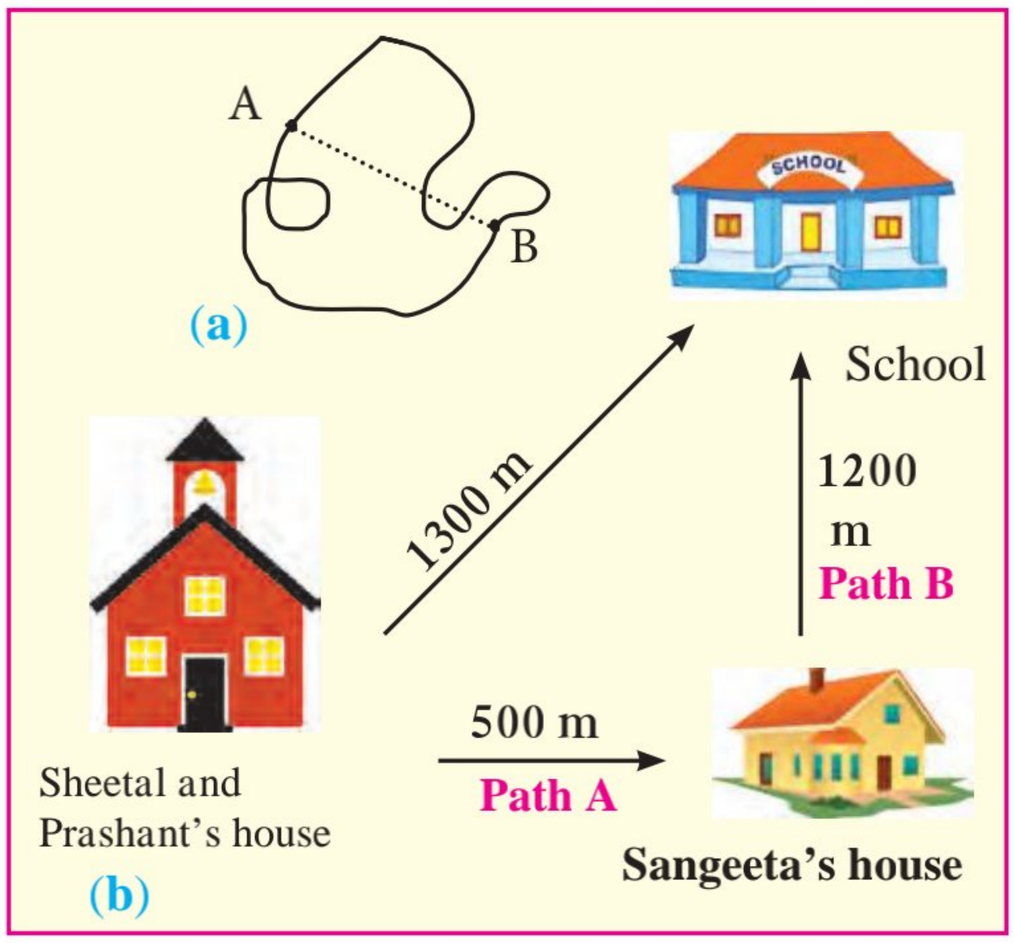
1. You are travelling in a bus. Is the person sitting next to you in motion?
2. What do you take into consideration to decide if an object is moving or not?

You have learnt that motion is a relative concept. If the position of an object is changing with respect to its surroundings, then it is said to be in motion. Otherwise, it is said to be at rest.

Displacement and distance

Let's try this

1. Measure the distance between points A and B in different ways as shown in figure 1.1(a)
2. Now measure the distance along the dotted line. Which distance is correct according to you and why?



1.1 Location of the school and houses

Think about it.

A. Sheetal first went to her friend Sangeeta's house on her way to school (see figure 1.1b).

B. Prashant went straight from home to school. Both are walking with the same speed. Who will take less time to reach the school and why?

In the above example, is there a difference between the actual distance and the distance travelled? What is it?

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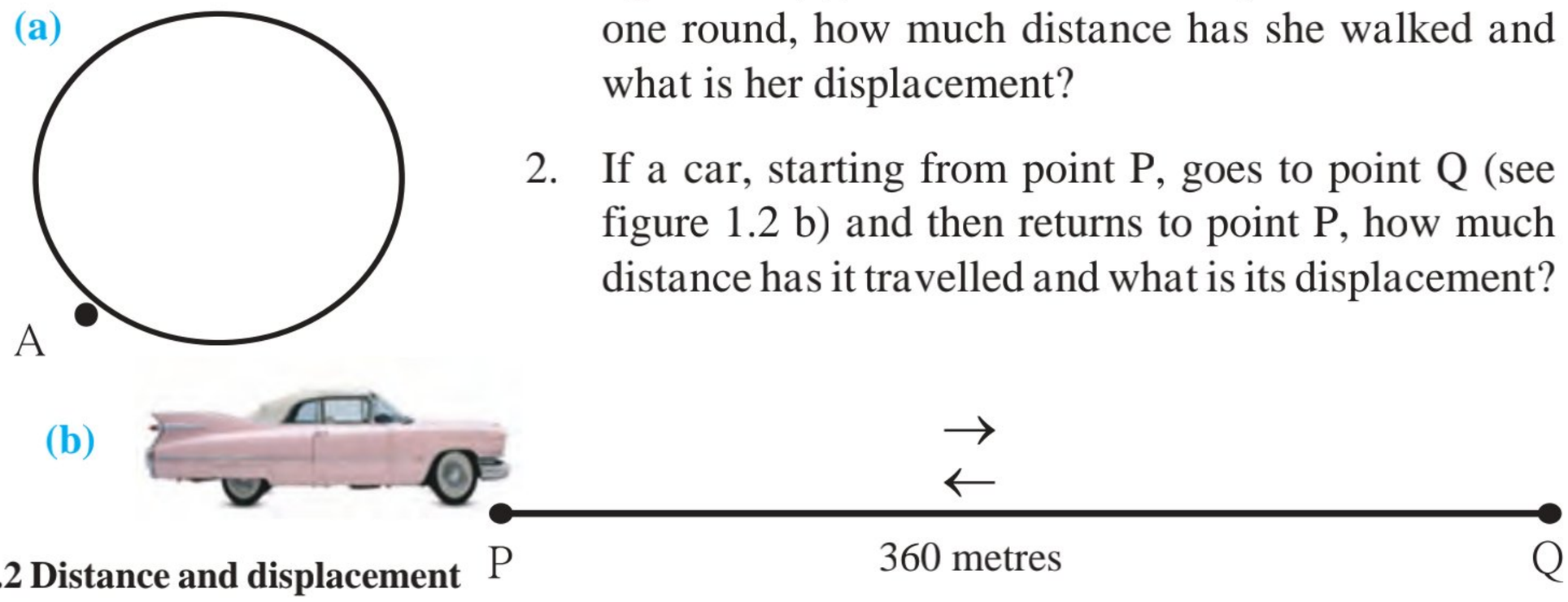
'Distance' is the length of the actual path travelled by an object in motion while going from one point to another, whereas displacement is the minimum distance between the starting and finishing points.

Use your brain power!

1. Every morning, Swaralee walks round the edge of a circular field having a radius of 100 m. As shown in figure 1.2 (a), if she starts from the point A and takes one round, how much distance has she walked and what is her displacement?

2. If a car, starting from point P, goes to point Q (see figure 1.2 b) and then returns to point P, how much distance has it travelled and what is its displacement?



1.2 Distance and displacement

Even if the displacement of an object is zero, the actual distance traversed by it may not be zero.

Speed and velocity

Can you recall?

1. What are vectors and scalars?
2. Which of the quantities distance, speed, velocity, time and displacement are scalars and which are vectors?

$$\text{Speed} = \frac{\text{Total distance travelled}}{\text{Time required}}$$

The distance travelled in a particular direction by an object in unit time is called its velocity. Here, unit time can be one second, one minute, one hour, etc. If large units are used, one year can also be used as a unit of time.

The displacement that occurs in unit time is called velocity.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

Always remember

1. The units of speed and velocity are the same. In the SI system, the unit is m/s while in the CGS system, it is cm/s.
2. Speed is related to distance while velocity is related to the displacement.
3. If the motion is along a straight line, the values of speed and velocity are the same, otherwise they can be different.

   Velocity is the displacement that occurs in unit time.

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In the first example (on page 1), the straight line distance between the houses of Sheetal and Sangeeta is 500 m and that between Sangeeta's house and school is 1200 m. Also, the straight line distance between Sheetal's house and school is 1300 m. Suppose Sheetal takes 5 minutes to reach Sangeeta's house and then 24 minutes to reach school from there, Then,

Sheetal's speed along path A $= \frac{\text{Distance}}{\text{Time}} = \frac{500 \text{ m}}{5 \text{ minute}} = 100 \text{ m/minute}$

Sheetal's speed along path B $= \frac{\text{Distance}}{\text{Time}} = \frac{1200 \text{ m}}{24 \text{ minute}} = 50 \text{ m/minute}$

Sheetal's average speed $= \frac{\text{Total distance}}{\text{Total time}} \quad \frac{1700 \text{ m}}{29 \text{ minute}} = 58\ 6 \text{ m/minute}$

Sheetal's velocity $= \frac{\text{Displacement}}{\text{Time}} = \frac{1300 \text{ m}}{29 \text{ minute}}$

Sheetal's velocity = 44.83 m/minute

Effect of speed and direction on velocity

Sachin is travelling on a motorbike. Explain what will happen in the following events during Sachin's ride (see figure 1.3).

1. What will be the effect on the velocity of the motorcycle if its speed increases or decreases, but its direction remains unchanged?
2. In case of a turning on the road, will the velocity and speed be same?

   If Sachin changes the direction of the motorcycle, keeping its speed constant, what will be the effect on the velocity?
3. If, on a turning, Sachin changes the direction as well as the speed of the motorcycle, what will be the effect on its velocity?

   It is clear from the above that velocity depends on speed as well as direction and that velocity changes by

   1. changing the speed while keeping the direction same
   2. changing the direction while keeping the speed same
   3. changing the speed as well as the direction.

1.3 Effect on velocity

Always remember

The first scientist to measure speed as the distance /time was Galileo. The speed of sound in dry air is 343.2 m/s while the speed of light is about 3×10^8 m/s. The speed of revolution of the earth around the sun is about 29770 m/s.

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Uniform and non-uniform linear motion

Amar, Akbar and Anthony are travelling in different cars with different velocities. The distances covered by them during different time intervals are given in the following table.

Time in the clock	Distance covered by Amar in km	Distance covered by Akbar in km	Distance covered by Anthony in km
5.00	0	0	0
5.30	20	18	14
6.00	40	36	28
6.30	60	42	42
7.00	80	70	56
7.30	100	95	70
8.00	120	120	84

Use your brain power !

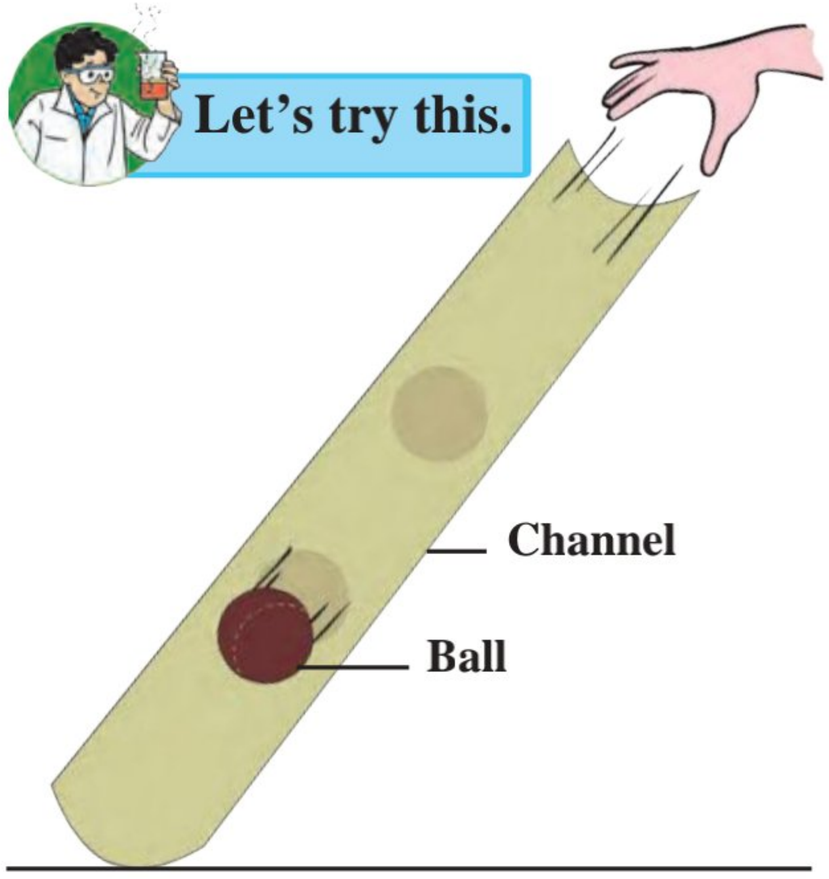
1. What is the time interval between the notings of distances made by Amar, Akbar and Anthony?
2. Who has covered equal distances in equal time intervals?
3. Are all the distances covered by Akbar in the fixed time intervals the same?
4. Considering the distances covered by Amar, Akbar and Anthony in fixed time intervals, what can you say about their speeds?

If an object covers equal distances in equal time intervals, it is said to be moving with uniform speed.

If an object covers unequal distances in equal time intervals, it is said to be moving with non-uniform speed. For example, the motion of a vehicle being driven through heavy traffic.

Acceleration

Let's try this.



1.4 Change in velocity

1. Take a 1m long plastic tube and cut it lengthwise into two halves.
2. Take one of the channel shaped pieces. Place one of its ends on the ground and hold the other at some height from the ground as shown in figure 1.4.
3. Take a small ball and release it from the upper end of the channel.
4. Observe the velocity of the ball as it rolls down along the channel.
5. Is its velocity the same at all points?
6. Observe how the velocity changes as it moves from the top, through the middle and to the bottom.

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You must have all played on a slide in a park. You know that while sliding down, the velocity is less at the top, it increases in the middle and becomes zero towards the end. The rate of change of velocity is called acceleration

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time.}}$$

If the initial velocity is 'u' and in time 't' it changes to the final velocity 'v',

$$\text{Acceleration} = a = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}} \quad \therefore a = \frac{(v-u)}{t}$$

Use your brain power!

1. When an object is at rest in the beginning of its motion, what is its initial velocity?
2. When an object comes to rest at the end of its motion, what is its final velocity?

If the velocity of an object changes during a certain time period, then it is said to have accelerated motion. An object in motion can have two types of acceleration.

1. If the velocity changes by equal amounts in equal time intervals, the object is said to be in uniform acceleration.
2. If the velocity changes by unequal amounts in equal time intervals, the object is say to be non-uniform acceleration.

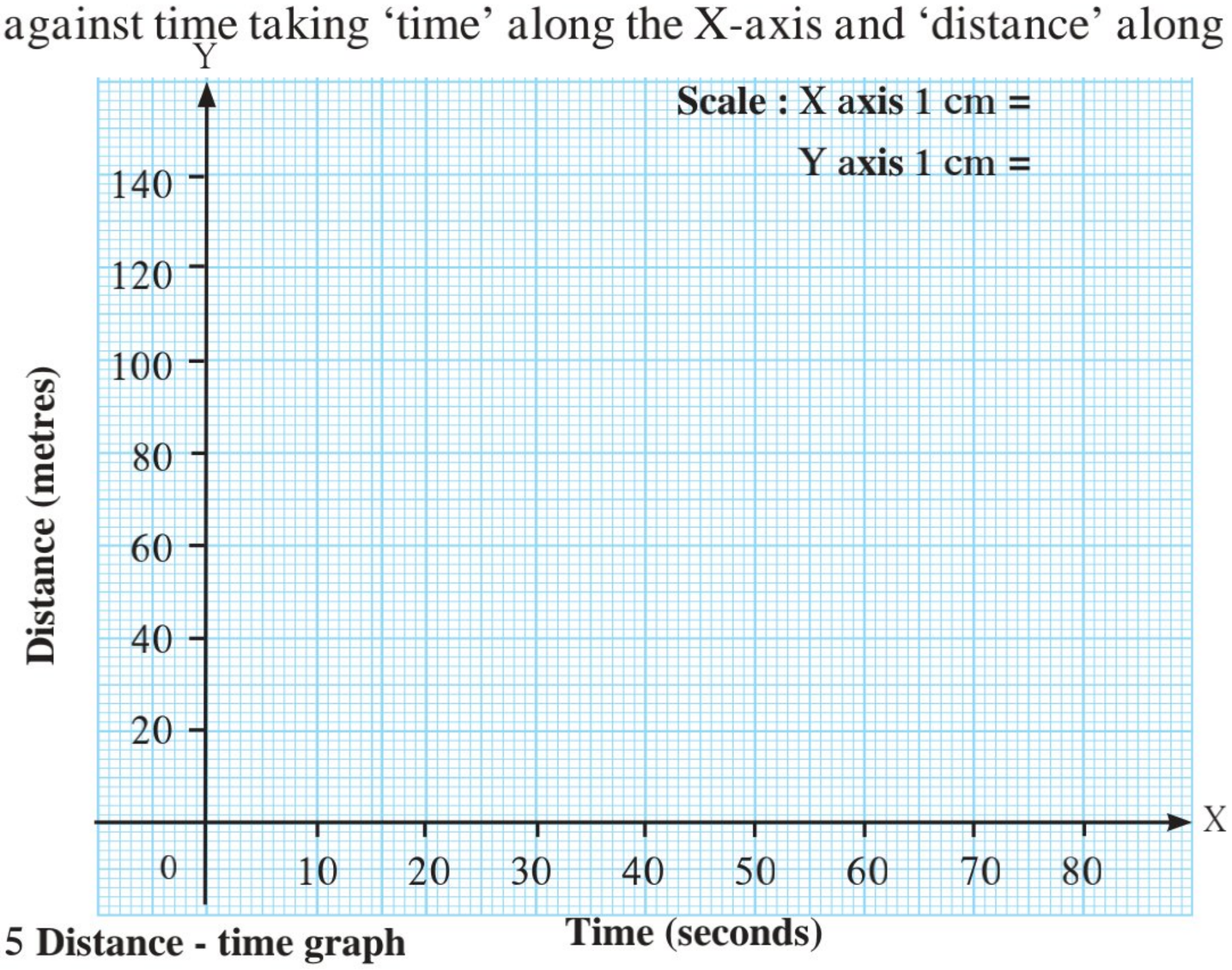
Positive, negative and zero acceleration

An object can have positive or negative acceleration. When the velocity of an object increases, the acceleration is positive. In this case, the acceleration is in the direction of velocity. When the velocity of an object decreases with time, it has negative acceleration. Negative acceleration is also called deceleration. Its direction is opposite to the direction of velocity. If the velocity of the object does not change with time, it has zero acceleration.

Distance-time graph for uniform motion

The following table shows the distances covered by a car in fixed time intervals. Draw a graph of distance against time taking 'time' along the X-axis and 'distance' along the Y-axis in figure 1.5.

Time (seconds)	Distance (metres)
0	0
10	15
20	30
30	45
40	60
50	75
60	90
70	105



1.5 Distance - time graph

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An object in uniform motion covers equal distances in equal time intervals. Thus, the graph between distance and time is a straight line.

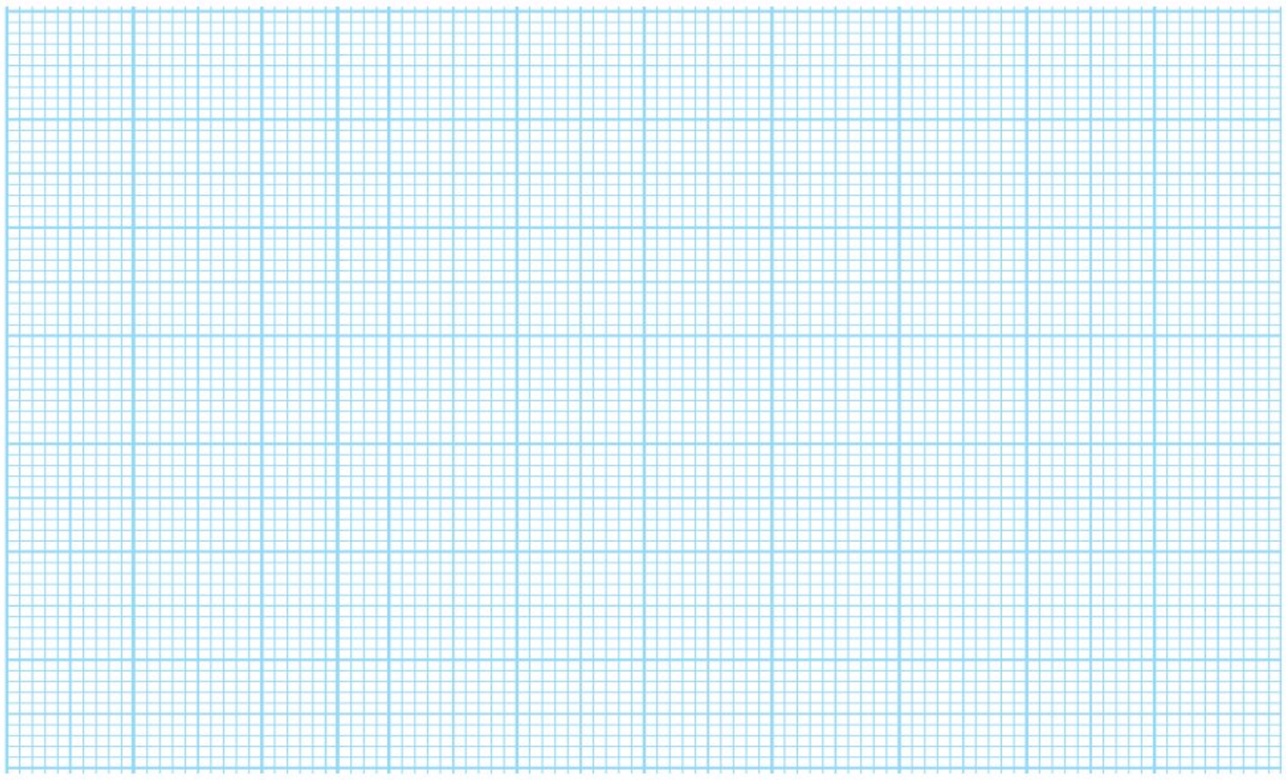
Use your brain power !

In the distance-time graph above, what does the slope of the straight line indicate?

Distance-time graph for non-uniform motion

The following table shows the distances covered by a bus in equal time intervals Draw a graph of distance against time taking the time along the X-axis and distance along the Y-axis in figure 1.6. Does the graph show a direct proportionality between distance and time?

Time (second)	Distance (metre)
0	0
5	7
10	12
15	20
20	30
25	41
30	50
35	58



1.6 Distance - time graph

Here, the distance changes non-uniformly with time. Thus, the bus is having non-uniform motion.

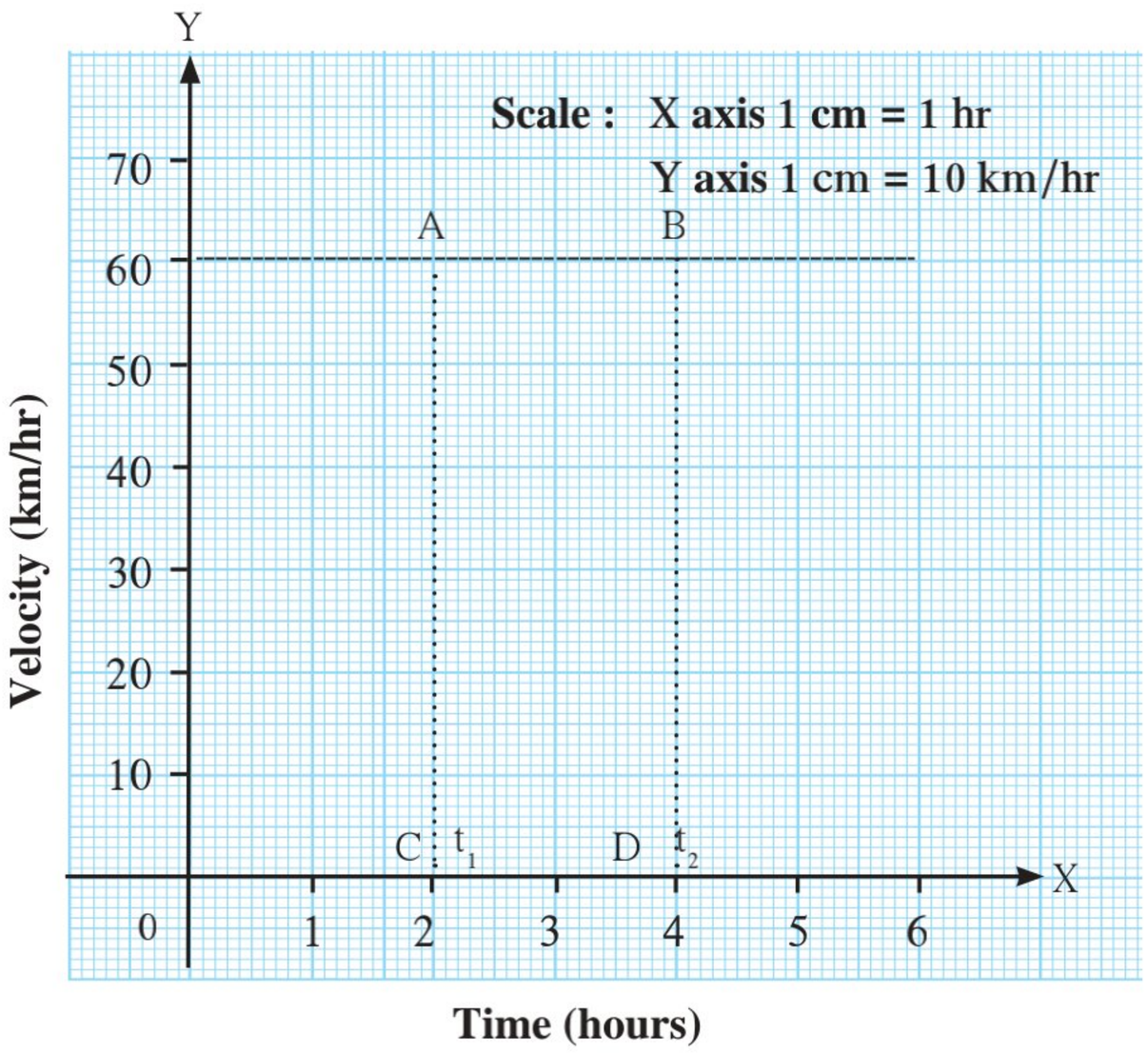
Use your brain power !

What difference do you see in the distance-time graphs for uniform and non-uniform motion?

Velocity-time graph for uniform velocity

A train is moving with a uniform velocity of 60 km/hour for 5 hours. The velocity-time graph for this uniform motion is shown in figure 1.7.

1. With the help of the graph, how will you determine the distance covered by the train between 2 and 4 hours?
2. Is there a relation between the distance covered by the train between 2 and 4 hours and the area of a particular quadrangle in the graph? What is the acceleration of the train?



1.7 Velocity - time graph

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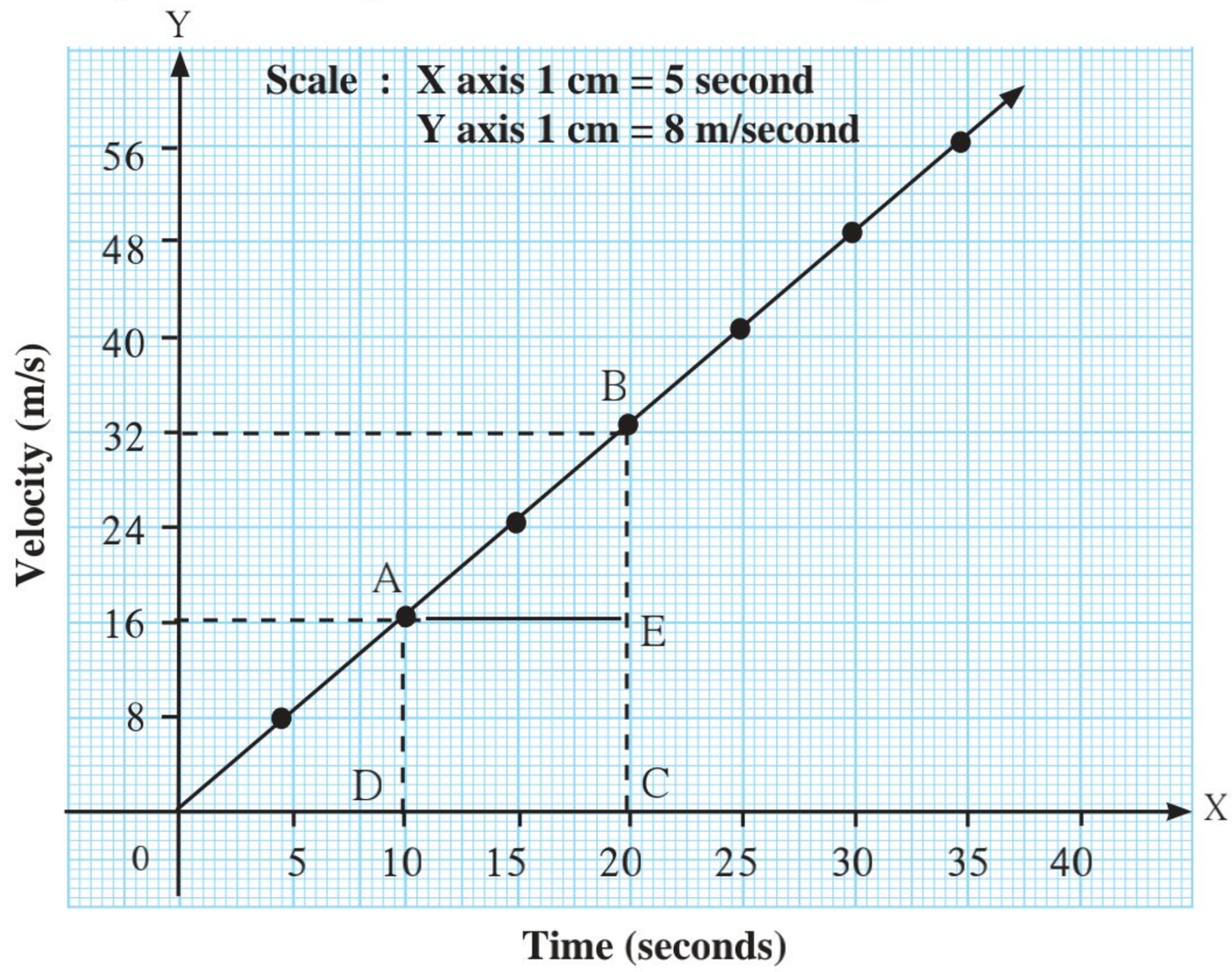
Velocity-time graph for uniform acceleration

The changes in the velocity of a car in specific time intervals are given in the following table.

Time (seconds)	Velocity (m/s)
0	0
5	8
10	16
15	24
20	32
25	40
30	48
35	56



1.8 Velocity - time graph

The velocity-time graph in figure 1.8 shows that,

1. The velocity changes by equal amounts in equal time intervals. Thus, this is uniformly accelerated motion. How much does the velocity change every 5 minutes?
2. For all uniformly accelerated motions, the velocity-time graph is a straight line.
3. For non-uniformly accelerated motions, the velocity-time graph may have any shape depending on how the acceleration changes with time.

From the graph in figure 1.8, we can determine the distance covered by the car between the 10th and the 20th seconds as we did in the case of the train in the previous example. The difference is that the velocity of the car is not constant (unlike that of the train) but is continuously changing because of uniform acceleration. In such a case, we have to use the average velocity of the car in the given time interval to determine the distance covered in that interval.

From the graph, the average velocity of the car = $\frac{32+16}{2}$ = 24 m/s

Multiplying this by the time interval, i.e. 10 seconds gives us the distance covered by the car. Distance covered = 24 m/s x 10 s = 240 m

Check that, similar to the example of the train, the distance covered is given by the area of quadrangle ABCD.

A (□ ABCD) = **A** (□ AECD) + **A** (△ ABE)

Equations of motion using graphical method

Newton studied motion of an object and gave a set of three equations of motion. These relate the displacement, velocity, acceleration and time of an object moving along a straight line.

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Suppose an object is in motion along a straight line with initial velocity 'u'. It attains a final velocity 'v' in time 't' due to acceleration 'a' its desplacement is 's'. The three equations of motion can be written as

$v = u + at$ This is the relation between velocity and time.

$s = ut + \frac{1}{2}at^2$ This is the relation between displacement and time.

$v^2 = u^2 + 2as$ This is the relation between displacement and velocity.

Let us try to obtain these equations by the graphical method.

Equation describing the relation between velocity and time

Figure 1.9 shows the change in velocity with time of a uniformly accelerated object. The object starts from the point D in the graph with velocity u. Its velocity keeps increasing and after time t, it reaches the point B on the graph.

The initial velocity of the object = u = OD

The final velocity of the object = v = OC

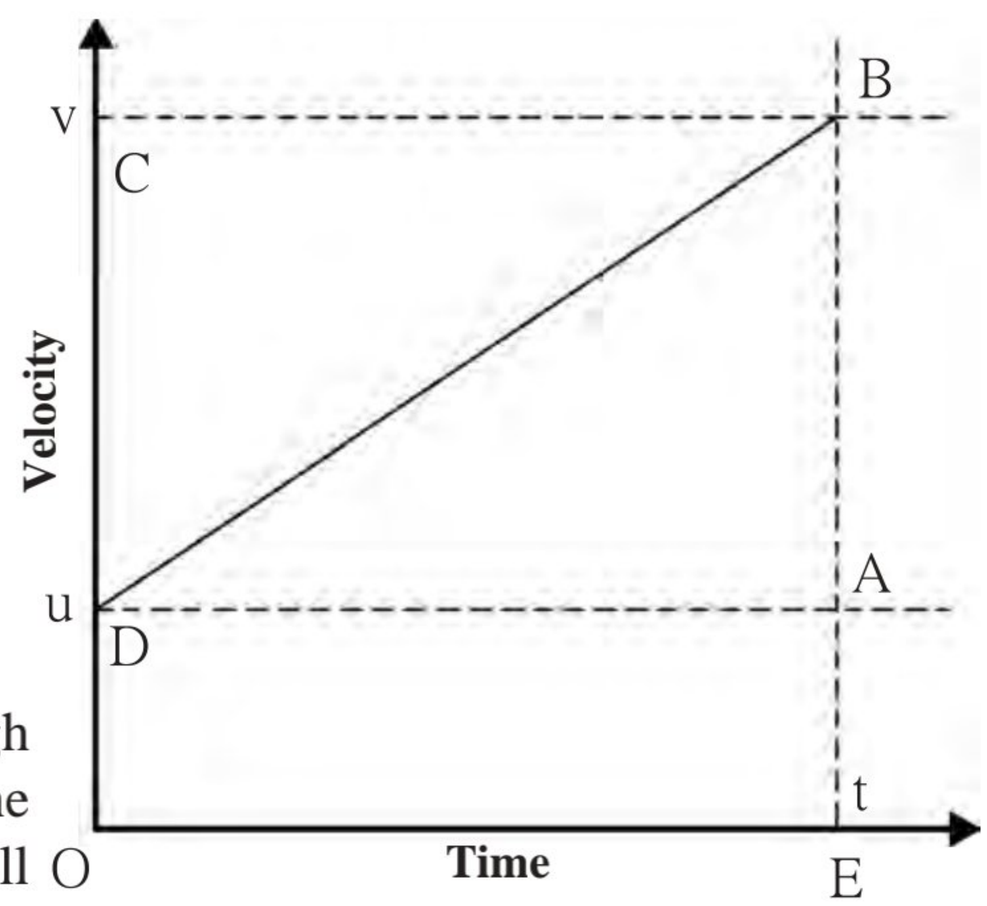
Time = t = OE

$$\text{Acceleration (a)} = \frac{\text{Change in velocity}}{\text{Time}}$$

$$= \frac{(\text{Final velocity} - \text{Initial velocity})}{\text{Time}}$$

$$= \frac{(OC - OD)}{t}$$

$\therefore$ CD = at ..... (i) (OC - OD = CD)



1.9 **Velocity - time graph**

Draw a line parallel to Y axis passing through B. This will cross the X axis in E. Draw a line parallel to X-axis passing through D. This will cross the line BE at A.

From the graph BE = AB + AE

$\therefore$ v = CD + OD .....(AB = CD and AE = OD)

$\therefore$ v = at + u (from i)

$\therefore$ v = u + at

This is the first equation of motion.

Equation describing the relation between displacement and time

Let us suppose that an object in uniform acceleration 'a' and it has covered the distance 's' within time 't'. From the graph in figure 1.9, the distance covered by the object during time 't' is given by the area of quadrangle DOEB.

$\therefore$ s = area of quadrangle DOEB

= area (rectangle DOEA) + area of triangle (DAB)

$\therefore$ $s = (AE \times OE) + (\frac{1}{2} \times [AB \times DA])$

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But, AE = u, OE = t and (OE = DA = t)
AB = at ---(AB = CD) --- from (i)

$\therefore\ s = u \times t + \frac{1}{2} \times at \times t$

$\therefore$ Newton's second equation of motion is $s = ut + \frac{1}{2} at^2$

Equation describing the relation between displacement and velocity

We have seen that from the graph in figure 1.9 we can determine the distance covered by the object in time t from the area of the quadrangle DOEB. DOEB is a trapezium. So we can use the formula for its area.

$\therefore$ s = area of trapezium DOEB

$\therefore\ s = \frac{1}{2} \times$ sum of lengths of parallel sides $\times$ distance between the parallel sides

$\therefore\ s = \frac{1}{2} \times (OD + BE) \times OE$ **But,** OD = u, BE = v **and** OE = t

$\therefore\ s = \frac{1}{2} \times (u + v) \times t$ ------ (ii)

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

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

$\therefore\ s = \frac{1}{2} \times (u + v) \times \frac{(v-u)}{a}$

$\therefore\ s = \frac{(v+u)(v-u)}{2a}$

$\therefore\ 2as = (v+u)(v-u) = v^2 - u^2$

$\therefore\ v^2 = u^2 + 2as$

this is Newton's third equation of motion

Always remember

The velocity of an accelerated object changes with time. Change in the velocity can be due to a change in direction or magnitude of the velocity or both.

Uniform circular motion

Let's try this

Observe the tip of the second hand of a clock. What can you say about its velocity and speed?

The speed of the tip is constant, but the direction of its displacement and therefore, its velocity is constantly changing. As the tip is moving along a circular path, its motion is called uniform circular motion. Can you give more examples of such motion?

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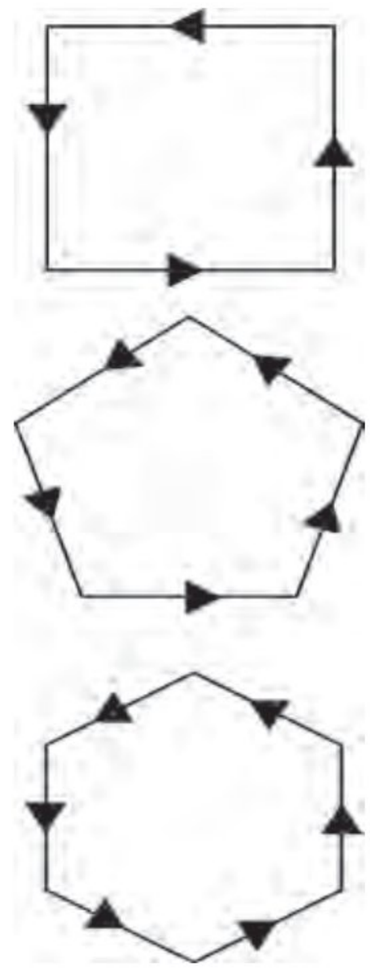
Try out and think about it

1. Draw a rectangular path as shown figure 1.10
2. Place the tip of your pencil on the middle of any side of the square path and trace the path.
3. Note how many times you have to change the direction while tracing the complete path.
4. Now repeat this action for a pentagonal, hexagonal, octagonal path and note the number of times you have to change direction.
5. If you increase the number of sides of the polygon and make it infinite, how many times will you have to change the direction? What will be the shape of the path?
   This shows that as we increase the number of sides, we have to keep changing direction more and more times. And when we increase the number of sides to infinity, the polygon becomes a circle.



1.10 Changes in direction

When an object is moving with a constant speed along a circular path, the change in velocity is only due to the change in direction. Hence, it is accelerated motion. When an object moves with constant speed along a circular path, the motion is called uniform circular motion, e.g. the motion of a stone in a sling or that of any point on a bicycle wheel when they are in uniform motion.

If an object, moving along a circular path of radius 'r', takes time 't' to come back to its starting position, its speed can be determined using the formula given below :

$$\text{Speed} = \frac{\text{Circumference}}{\text{Time}}$$

$$v = \frac{2\pi r}{t}$$ r =radius of the circle

Research

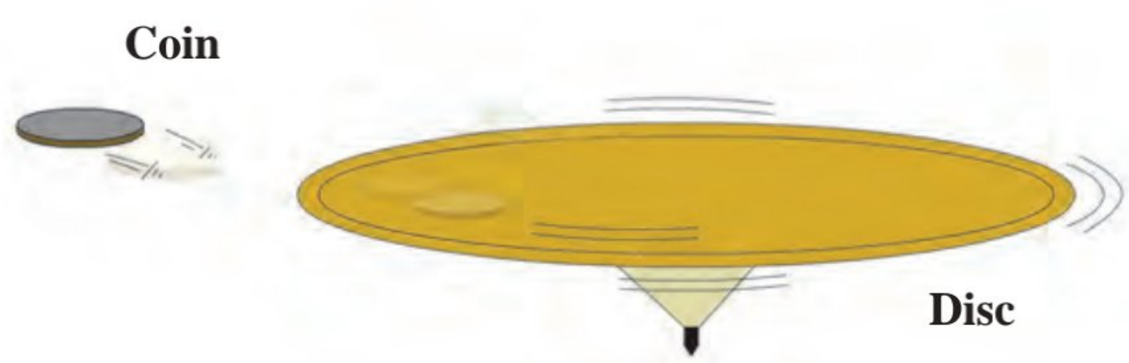
Find out more examples of circular motion in day to day life.

Determining the direction of velocity in uniform circular motion.

Let's try this

Take a circular disc and put a five rupee coin at a point along its edge.

Make it move around its axis by putting a pin through it. When the disc is moved at higher speed, the coin will be thrown off as shown in figure 1.11. Note the direction in which it is thrown off. Repeat the action placing the coin at different points along the edge of the circle and observe the direction in which the coin is thrown off.



1.11 The coin and the disc

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The coin will be thrown off in the direction of the tangent which is perpendicular to the radius of disc. Thus, the direction in which it gets thrown off depends on its position at the moment of getting thrown off. It means that, as the coin moves along a circular path the direction of its motion is changing at every point.

Solved examples

Example 1: An athlete is running on a circular track. He runs a distance of 400 m in 25 s before returning to his original position. What is his average speed and velocity?

Given : Total distance travelled = 400 m

Total displacement = 0, as he returns to his original position.

Total time = 25 seconds.

Average speed = ?, Average velocity = ?

$$\text{Average speed} = \frac{\text{Total distance covered}}{\text{Total time taken}} = \frac{400}{25} = 16 \text{ m/s}$$

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}} = \frac{0}{25} = 0 \text{ m/s}$$

Example 2: An aeroplane taxies on the runway for 30 s with an acceleration of 3 2 m/s^2 before taking off. How much distance would it have covered on the runway?

Given : a= 3 2 m/s^2, t = 30 s, u = o , s = ?

$$s = ut + \frac{1}{2}at^2 = 0 \times 30 + \frac{1}{2} \times 3\ 2 \times 30^2 = 1440 \text{ m}$$

Example 3: A kangaroo can jump 2.5 m vertically. What must be the initial velocity of the kangaroo?

Given :

a = 9 8 m/s^2

s = 2 5 m

v = 0

u = ?

$v^2 = u^2 + 2as$

$(0)^2 = u^2 + 2 \times (-9\ 8)\ (2\ 5)$ Negative sign is used as the acceleration is in the direction opposite to that of velocity.

$0 = u^2 - 49$

$u^2 = 49$

u = 7 m/s

Example 4 : A motorboat starts from rest and moves with uniform acceleration. If it attains the velocity of 15 m/s in 5 s, calculate the acceleration and the distance travelled in that time.

Given :

Initial velocity, u = 0,

final velocity, v = 15 m/s, time, t = 5 s.

Acceleration = a = ?

From the first equation of motion

$$a = \frac{v-u}{t} = \frac{15-0}{5} = 3 \text{ m/s}^2$$

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From the second equation of motion, the distance covered will be

$$s = ut + \frac{1}{2} at^2$$

$$s = 0 \times 5 + \frac{1}{2} 3 \times 5^2$$

$$= 0 + \frac{75}{2} = 37.5 \text{ m}$$

Newton's laws of motion

What could be the reason for the following?

1. A static object does not move without the application of a force.
2. The force which is sufficient to lift a book from a table is not sufficient to lift the table.
3. Fruits on a tree fall down when its branches are shaken.
4. An electric fan keeps on rotating for some time even after it is switched off.

If we look for reasons for the above, we realize that objects have some inertia. We have learnt that inertia is related to the mass of the object. Newton's first law of motion describes this very property and is therefore also called the law of inertia. All instances of inertia are examples of Newton's first law of Motion.

Newton's first law of motion

Let's try this

Fill a glass with sand. Keep a piece of cardboard on it. Keep a five rupee coin on the cardboard. Now strike the cardboard hard using your fingers. Observe what happens.

Balanced and unbalanced force

You must have played tug-of-war. So long as the forces applied by both the sides are equal, i.e. balanced, the centre of the rope is static in spite of the applied forces. On the other hand, when the applied forces become unequal, i.e. unbalanced, a net force gets applied in the direction of the greater force and the centre of the rope shifts in that direction.

'An object continues to remain at rest or in a state of uniform motion along a straight line unless an external unbalanced force acts on it.'

When an object is at rest or in uniform motion along a straight line, it does not mean that no force is acting on it. Actually there are a number of forces acting on it, but they cancel one another so that the net force is zero. Newton's first law explains the phenomenon of inertia, i.e. the inability of an object to change its state of motion on its own. It also explains the unbalanced forces which cause a change in the state of an object at rest or in uniform motion.

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Newton's second law of motion

Let's try this

A. 1. Ask your friend to drop one plastic and one rubber ball from the same height.
2. You catch the balls. Which ball was easier to catch and why?

B. 1. Ask your friend to throw a ball towards you at slow speed. Try to catch it.
2. Now ask your friend to throw the same ball at high speed towards you. Try to catch it. Which ball could you catch with greater ease? Why?

The effect of one object striking another object depends both on the mass of the former object and its velocity. This means that the effect of the force depends on a property related to both mass and velocity of the striking object. This property was termed 'momentum' by Newton.

Momentum has magnitude as well as direction. Its direction is the same as that of velocity. In SI system, the unit of momentum is kg m/s, while in CGS system, it is g cm/s.
If an unbalanced force applied on an object causes a change in the velocity of the object, then it also causes a change in its momentum. The force necessary to cause a change in the momentum of an object depends upon the rate of change of momentum.

Momentum (P) : Momentum is the product of mass and velocity of an object. P = m v. Momentum is a vector quantity.

'The rate of change of momentum is proportional to the applied force and the change of momentum occurs in the direction of the force.'

Suppose an object of mass m has an initial velocity u. When a force F is applied in the direction of its velocity for time t, its velocity becomes v.

$\therefore$ The initial momentum of the object = mu,
Its final momentum after time t = mv

$$\therefore \text{ Rate of change of momentum} = \frac{\text{Change in momentum}}{\text{Time}}$$

$$\therefore \text{ Rate of change of momentum} = \frac{mv - mu}{t} = \frac{m(v-u)}{t} = ma$$

According to Newton's second law of motion, the rate of change of momentum is proportional to the applied force.

$\therefore$ ma α F

$\therefore$ F = k ma (k = Constant of proportionality and its value is 1).

F = m $\times$ a

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Consider two objects having different masses which are initially at rest. The initial momentum for both is zero. Suppose a force 'F' acts for time 't' on both objects. The lighter object starts moving faster than the heavier object. However, from the above formula, we know that the rate of change of momentum i.e. 'F' in both objects is same and the total change in their momentum will also be same i.e. 'Ft'. Thus, if the same force is applied on different objects, the change in momentum is the same.

In SI system, the unit of force is newton.

Newton (N) : The force necessary to cause an acceleration of 1 m/s^2 in an object of mass 1 kg is called 1 newton.

$1\ N = 1\ kg \times 1\ m/s^2$

In CGS system the unit of force is a dyne.

Dyne: The force necessary to cause an acceleration of 1 cm/s^2 in an object of mass 1 gm is called 1 dyne.

$1\ dyne = 1\ g \times 1\ cm/s^2$

Use your brain power !

Why is there a thick bed of sand for a high jumper to fall on after his jump?

Newton's third law of motion

Let's try this

1. Take a plastic boat and make a hole at its rear end.
2. Inflate a balloon and fix it on the hole in the boat. Release the boat in water. What happens to the boat as the air in the balloon escapes slowly? Why?

We have learnt about force and its effect on an object through Newton's first and second laws of motion.

'However, in nature force cannot act alone.' Force is a reciprocal action between two objects. Forces are always applied in pairs. When one object applies a force on another object, the latter object also simultaneously applies a force on the former object. The forces between two objects are always equal and opposite. This idea is expressed in Newton's third law of motion. The force applied by the first object is called action force while the force applied by the second object on the first is called reaction force.

'Every action force has an equal and opposite reaction force which acts simultaneously.'

1. Action and reaction are terms that express force.
2. These forces act in pairs. One force cannot exist by itself.
3. Action and reaction forces act simultaneously.
4. Action and reaction forces act on different objects. They do not act on the same object and hence cannot cancel each other's effect.

Use your brain power !

1. While hitting a ball with a bat, the speed of the bat decreases.
2. A gun recoils i.e. moves backwards when a bullet is fired.
3. Mechanism of firing of a rocket.

How will you explain these with the help of Newton's third law of motion?

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Law of conservation of momentum

Suppose an object A has mass m_1 and its initial velocity is u_1. An object B has mass m_2 and initial velocity u_2.

According to the formula for momentum, the initial momentum of A is $m_1 u_1$ and that of B is $m_2 u_2$.

Suppose these two objects collide. Let the force on A due to B be F_1. This force will cause acceleration in A and its velocity will become v_1.

$\therefore$ Momentum of A after collision = $m_1 v_1$

According to Newton's third law of motion, A also exerts an equal force on B but in the opposite direction. This will cause a change in the momentum of B. If its velocity after collision is v_2,

The momentum of B after collision = $m_2 v_2$. If F_2 is the force that acts on object B,

$F_2 = -F_1$

$\therefore m_2 a_2 = - m_1 a_1$ ..... $\because F = ma$

$\therefore m_2 \times \frac{(v_2 - u_2)}{t} = - m_1 \times \frac{(v_1 - u_1)}{t}$ ..... $\because a = \frac{(v-u)}{t}$

$\therefore m_2 (v_2 - u_2) = - m_1 (v_1 - u_1)$

$\therefore m_2 v_2 - m_2 u_2 = - m_1 v_1 + m_1 u_1$

$\therefore (m_2 v_2 + m_1 v_1) = (m_1 u_1 + m_2 u_2)$

The magnitude of total final momentum = the magnitude of total initial momentum.

Thus, if no external force is acting on two objects, then their total initial momentum is equal to their total final momentum. This statement is true for any number of objects.

'When no external force acts on two interacting objects, their total momentum remains constant. It does not change.'

This is a corollary to Newton's third law of motion. The momentum is unchanged after the collision. The momentum gets redistributed between the colliding objects. The momentum of one of the objects decreases while that of the other increases. Thus, we can also state this corollary as follows.

'When two objects collide, the total momentum before collision is equal to the total momentum after collision.'

In order to understand this principle, let us consider the example of a bullet fired from a gun. When a bullet of mass m_1 is fired from a gun of mass m_2, its velocity becomes v_1, and its momentum becomes $m_1 v_1$. Before firing the bullet, both the gun and the bullet are at rest and hence the total initial momentum is zero. According to the above law, the total final momentum also has to be zero. Thus, the forward moving bullet causes the gun to move backward after firing. This backward motion of the gun is called its **recoil**. The velocity of recoil, v_2 , is such that,

$$m_1 v_1 + m_2 v_2 = 0 \text{ or } v_2 = - \frac{m_1}{m_2} \times v_1$$

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As the mass of the gun is much higher than the mass of the bullet, the velocity of the gun is much smaller than the velocity of the bullet. The magnitude of the momentum of the bullet and that of the gun are equal and their directions are opposite. Thus, the total momentum is constant. Total momentum is also constant during the launch of a rocket.

Solved examples

Example 1: The mass of a cannon is 500 kg and it recoils with a speed of 0.25 m/s. What is the momentum of the cannon?

Given : mass of the cannon = 500 kg, recoil speed = 0.25 m/s Momentum = ?

Momentum = m × v = 500 x 0.25 = 125 kg m/s

Example 2: 2 balls have masses of 50 gm and 100 gm and they are moving along the same line in the same direction with velocities of 3 m/s and 1.5 m/s respectively. They collide with each other and after the collision, the first ball moves with a velocity of 2.5 m/s. Calculate the velocity of the other ball after collision.

Given :

The mass of first ball = m_1 = 50 g = 0 05 kg, mass of the second ball = m_2 = 100 g = 0 1 kg

Initial velocity of the first ball = u_1 = 3 m/s, Initial velocity of the second ball = u_2 = 1.5 m/s

Final velocity of the first ball = v_1 = 2 5 m/s ,Final velocity of the second ball = v_2 = ?

According to the law of conservation of momentum, total initial momentum = Total final momentum.

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$(0\ 05 \times 3) + (0\ 1 \times 1\ 5) = (0\ 05 \times 2\ 5) + (0\ 1 \times v_2)$

$\therefore\ (0\ 15)+(0\ 15) = 0\ 125 + 0\ 1v_2$

$\therefore\ 0\ 3 = 0\ 125 + 0\ 1\ v_2$

$\therefore\ 0\ 1v_2 = 0\ 3 - 0\ 125 \quad \therefore v_2 = \frac{0\ 175}{0\ 1} = 1\ 75$ m/s

Exercises

1. Match the first column with appropriate entries in the second and third columns and remake the table.

S. No.	Column 1	Column 2	Column 3
1	Negative acceleration	The velocity of the object remains constant	A car, initially at rest reaches a velocity of 50 km/hr in 10 seconds
2	Positive acceleration	The velocity of the object decreases	A vehicle is moving with a velocity of 25 m/s
3	Zero acceleration	The velocity of the object increases	A vehicle moving with the velocity of 10 m/s, stops after 5 seconds.

2. Clarify the differences

A. Distance and displacement

B. Uniform and non-uniform motion.

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3. Complete the following table.

u (m/s)	a (m/s^2)	t (sec)	v = u + at (m/s)
2	4	3	-
-	5	2	20

u (m/s)	a (m/s^2)	t (sec)	$s = ut + \frac{1}{2} at^2$ (m)
5	12	3	-
7	-	4	92

u (m/s)	a (m/s^2)	s (m)	$v^2 = u^2 + 2as$ $(m/s)^2$
4	3	-	8
-	5	8.4	10

4. Complete the sentences and explain them.

a. The minimum distance between the start and finish points of the motion of an object is called the …….. of the object.

b. Deceleration is -------- acceleration

c. When an object is in uniform circular motion, its …… changes at every point.

d. During collision ..... remains constant.

e. The working of a rocket depends on Newton's …… law of motion.

5. Give scientific reasons.

a. When an object falls freely to the ground, its acceleration is uniform.

b. Even though the magnitudes of action force and reaction force are equal and their directions are opposite, their effects do not get cancelled.

c. It is easier to stop a tennis ball as compared to a cricket ball, when both are travelling with the same velocity.

d. The velocity of an object at rest is considered to be uniform.

6. Take 5 examples from your surroundings and give explanation based on Newtons laws of motion.

7. Solve the following examples.

a) An object moves 18 m in the first 3 s, 22 m in the next 3 s and 14 m in the last 3 s. What is its average speed? **(Ans: 6 m/s)**

b) An object of mass 16 kg is moving with an acceleration of 3 m/s^2 . Calculate the applied force. If the same force is applied on an object of mass 24 kg, how much will be the acceleration? **(Ans: 48 N, 2 m/s^2)**

c) A bullet having a mass of 10 g and moving with a speed of 1.5 m/s, penetrates a thick wooden plank of mass 90 g. The plank was initially at rest. The bullet gets embedded in the plank and both move together. Determine their velocity. **(Ans: 0.15 m/s)**

d) A person swims 100 m in the first 40 s, 80 m in the next 40 s and 45 m in the last 20 s. What is the average speed? **(Ans: 2.25 m/s^2)**

Project:

Obtain information about commonly used gadgets or devices which are based on the principles of Newton's laws of motion.

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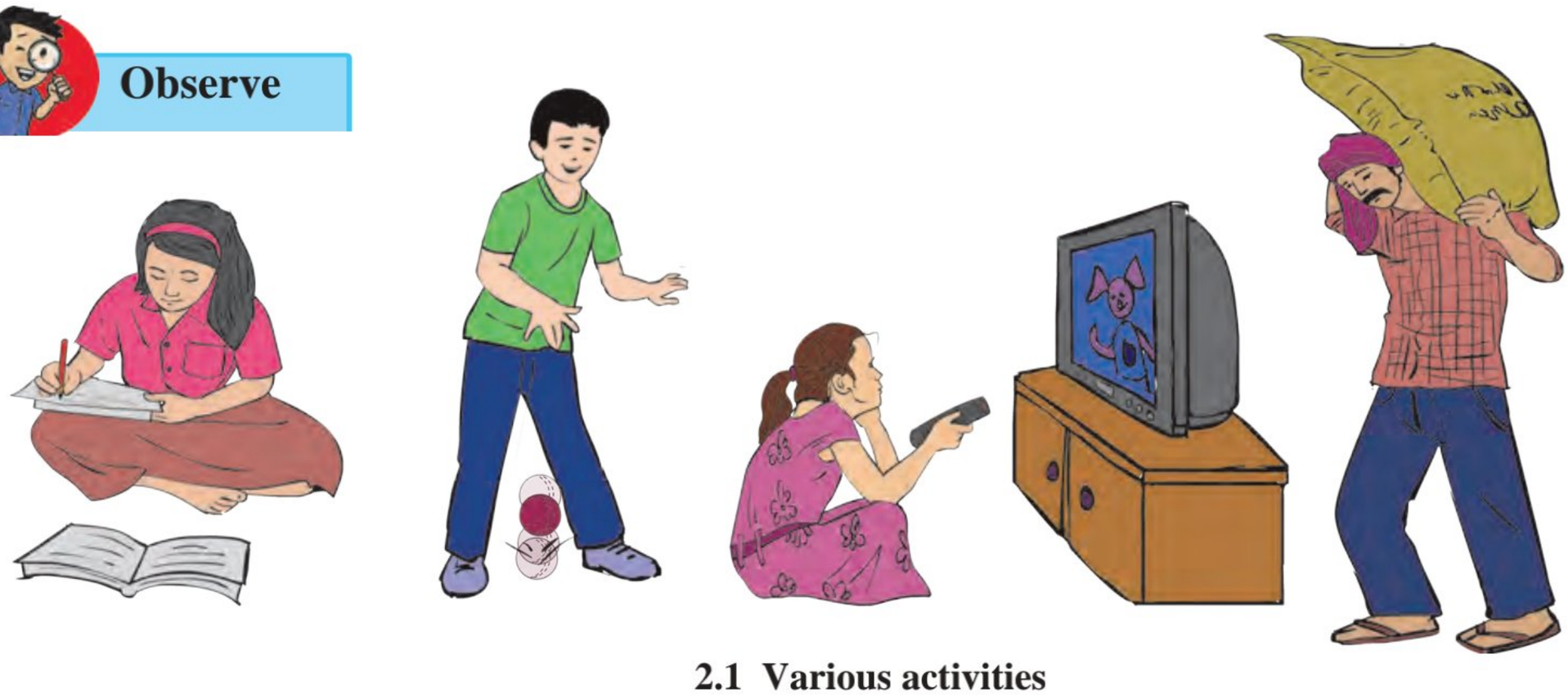
2. Work and Energy

- Work
- Energy
- Mechanical energy
- Law of conservation of energy
- Free fall

Observe



2.1 Various activities

Can you tell?

1. In which of the pictures above has work been done?
2. From scientific point of view, when do we say that no work was done?

Generally, any mental or physical activity is referred to as work. When we walk or run, the energy in our body is used to do the necessary work. We say that a girl who is studying is working or performing work. But that is mental work.

In physics, we deal with physical work. Work has a special meaning in physics.

'Work is said to be done when a force applied on an object causes displacement of the object.'

You have already learnt that the work done by a force acting on an object is the product of the magnitude of the force and the displacement of the object in the direction of the force. Thus, Work = force × displacement

Can you recall?

What are different types of forces and their examples?

Minakshee wants to displace a wooden block from point A to point B along the surface of a table as shown in figure 2.2A. She has used force F for the purpose. Has all the energy she spent been used to produce acceleration in the block? Which forces have been overcome using that energy?

Use your brain power !

You have learnt how to calculate the work done on an object when the displacement is in the direction of the applied force. But if the displacement is not in the direction of the applied force, how do we calculate the amount of work done?

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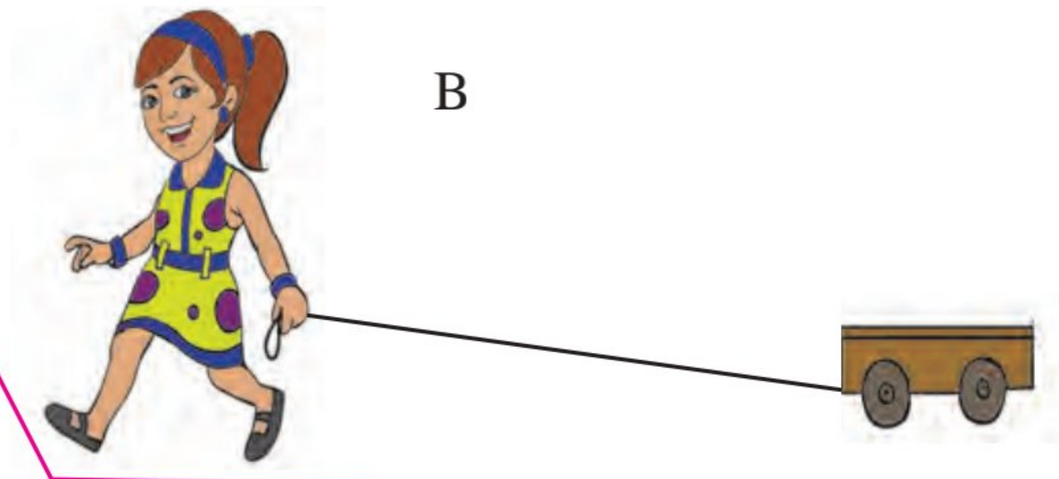
Observe and discuss.

A



B

C

2.2 Displacement of an object

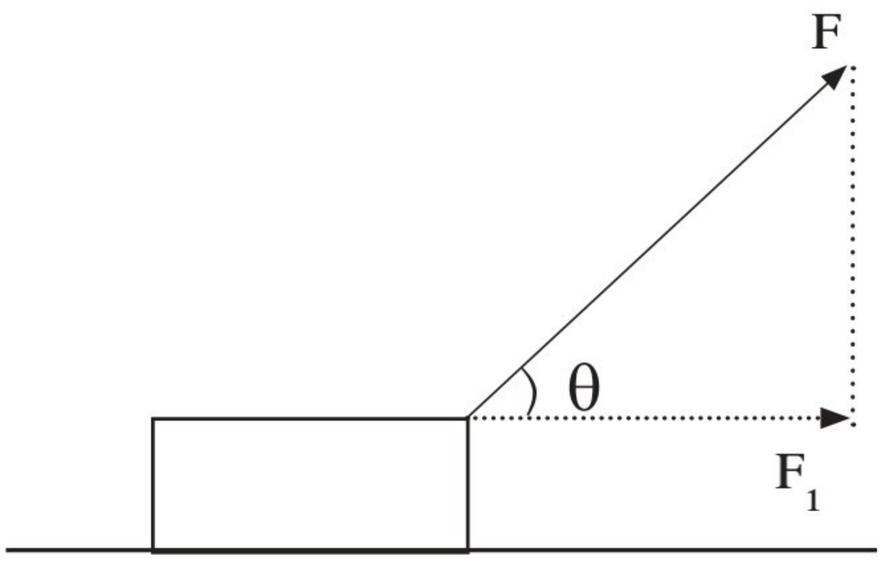
You must have seen the events depicted in the pictures B and C above. When a child pulls a toy with the help of a string, the direction of the force is different from that of displacement. Similarly, when a large vehicle tows a small one, the directions of force and the displacements are different. In both these cases, the direction of force makes an angle with the direction of displacement. Let us see how to calculate work done in such cases.

When a child pulls a toy cart, force is applied along the direction of the string while the cart is pulled along the horizontal surface. In this case, in order to calculate the amount of work done, we have to convert the applied force into the force acting along the direction of displacement.

Let F be the applied force and F_1 be its component in the direction of displacement. Let s be the displacement. The amount of work done is given by

$$W = F_1 \, s \qquad (1)$$

The force F is applied in the direction of the string i. e. at an angle with the horizontal. Let θ be the angle that the string makes with the horizontal. We can determine the component F_1, of this force F, which acts in the horizontal direction by means of trigonometry.



2.3 Force used for the displacement

(see figure2.3)

$\cos\theta$ = base / hypotenuse

$\cos\theta = F_1 / F$

$F_1 = F\cos\theta$

Thus, the work done by F_1 is

$W = F\cos\theta \, s$

$W = F s \cos\theta$

Enter your conclusions about the work done for the specific values of θ in the following table.

θ	cos θ	W = F s cos θ	Conclusion
0^0	1	W = F s	
90^0	0	0	
180^0	−1	W = −F s	

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Unit of work

Work = Force × Displacement

In SI system, the unit of force is newton (N) and the unit of displacement is metre (m). Thus, the unit of force is newton-metre. This is called joule.

1 Joule : If a force of 1 newton displaces an object through 1 metre in the direction of the force, the amount of work done on the object is 1 joule.

$\therefore$ 1 joule = 1 newton × 1 metre

1 J = 1 N × 1 m

In CGS system, the unit of force is dyne and that of displacement is centimeter (cm). Thus, the unit of work done is dyne-centimetre. This is called an erg.

1 erg : If a force of 1 dyne displaces an object through 1 centimetre in the direction of the force, the amount of work done is 1 erg.

1 erg = 1 dyne × 1 cm

Relationship between joule and erg

We know that, 1 newton = 10^5 dyne and 1 m = 10^2 cm

Work = force × displacement

1 joule = 1 newton × 1 m

1 joule = 10^5 dyne × 10^2 cm

= 10^7 dyne cm

1 joule = 10^7 erg

Positive, negative and zero work

Think before you answer

Discuss the directions of force and of displacement in each of the following cases.

1. Pushing a stalled vehicle
2. Catching the ball which your friend has thrown towards you.
3. Tying a stone to one end of a string and swinging it round and round by the other end of the string.
4. Walking up and down a staircase; climbing a tree.
5. Stopping a moving car by applying brakes.

You will notice that in some of the above examples, the direction of the force and displacement are the same. In some other cases, these directions are opposite to each other, while in some cases, they are perpendicular to each other. In these cases, the work done by the force is as follows.

1. When the force and the displacement are in the same direction ($\theta = 0^0$), the work done by the force is positive.
2. When the force and the displacement are in opposite directions ($\theta = 180^0$), the work done by the force is negative.
3. When the applied force does not cause any displacement or when the force and the displacement are perpendicular to each other ($\theta = 90^0$), the work done by the force is zero.

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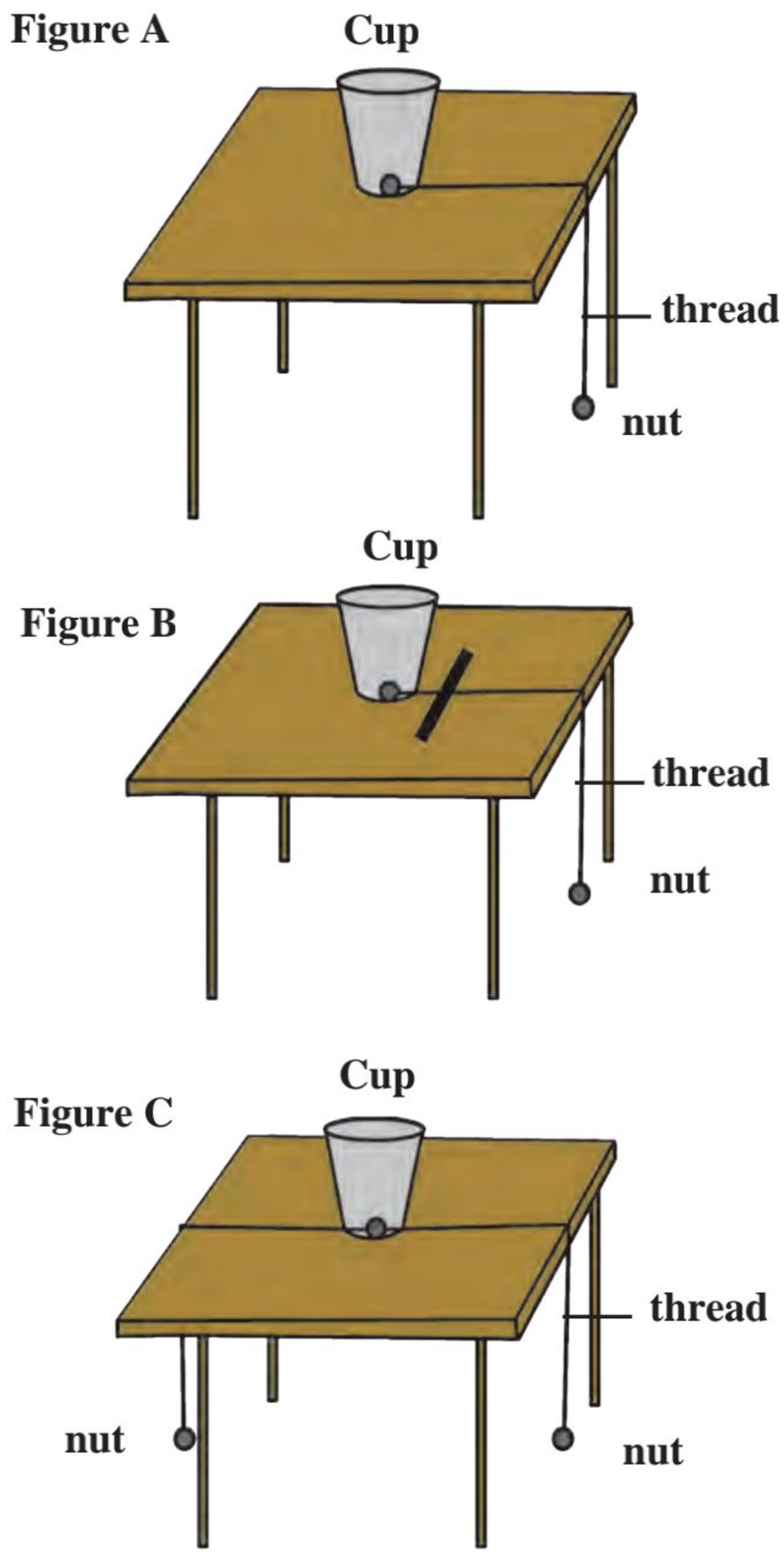
Try this

Take a plastic cup and make a hole in the centre of its bottom. Take a long thread, double it and pass it through the hole. Tie a thick enough knot at the end so that the knot will not pass through the hole, taking care that the two loose ends are below the bottom of the cup. Tie a nut each to the two ends as shown in figure 2.4. Now do the following.

As shown in figure 'A', put the cup on a table, keep one of the nuts in the cup and let the thread carrying the other nut hang down along the side of the table. What happens?

As shown in figure 'B', when the cup is sliding along the table, stop it by putting a ruler in its path.

As shown in figure 'C', keep the cup at the centre of the table and leave the two nuts hanging on opposite sides of the table.



2.4 Positive, negative and zero work

Questions:

1. Figure A - Why does the cup get pulled?
2. Figure B - What is the relation between the displacement of the cup and the force applied through the ruler?
3. In figure C - Why doesn't the cup get displaced?
4. What is the type of work done in figures A, B and C?

In the three actions above, what is the relationship between the applied force and the displacement?

Suppose an artificial satellite is moving around the earth in a circular orbit. As the gravitational force acting on the satellite (along the radius of the circle) and its displacement (along the tangent to the circle) are perpendicular to each other, the work done by the gravitational force is zero

Institutes at work

The National Physical Laboratory, New Delhi, was conceptualized in 1943. It functions under the Council of Scientific and Industrial Research. Its conducts basic research in the various branches of physics and helps various industries and institutes engaged in developmental work. Its main objective is to establish national standards of various physical quantities.

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Solved examples

Example 1: Calculate the work done to take an object of mass 20 kg to a height of 10 m.

($g = 9\ 8\ m/s^2$)

Given: $m = 20$ kg; $s = 10$ m

$g = 9\ 8\ m/s^2$

$\therefore F = m\ g$

$= 20 \times (-9\ 8)$

(The negative sign is taken because the displacement is opposite to the direction of the force.)

$F = -196$ N

$\therefore W = F\ s$

$= -196 \times 10$

$W = -1960$ J

(The negative sign appears because the direction of force is opposite to the direction of displacement so that the work done is negative.)

Example 2 : Pravin has applied a force of 100 N on an object, at an angle of 60^0 to the horizontal. The object gets displaced in the horizontal direction and 400 J work is done. What is the displacement of the object?

($\cos 60^0 = \frac{1}{2}$)

Given :

$\theta = 60^0$

$F = 100$ N

$W = 400$ J , $s = ?$

$W = F\ s \cos \theta$

$400 = 100 \times s \times \frac{1}{2}$

$\frac{400}{100} = \frac{1}{2} \times s$

$4 \times 2 = s$

$\therefore s = 8$ m

The object will be displaced through 8 m.

Energy

Why does it happen?

1. If a pot having a plant is kept in the dark, the plant languishes.
2. On increasing the volume of a music system or TV beyond a limit, the vessels in the house start vibrating.
3. Collecting sunlight on a paper with the help of a convex lens burns the paper.

The capacity of a body to perform work is called its energy. The units of work and energy are the same. The unit in SI system is **joule** while that in cgs system is **erg**.

You have learnt that energy exists in various forms like mechanical, heat, light, sound, electro-magnetic, chemical, nuclear and solar. In this chapter, we are going to study two forms of mechanical energy, namely, potential energy and kinetic energy.

Kinetic energy

What will happen in the following cases?

1. A fast cricket ball strikes the stumps.
2. The striker hits a coin on the carom board.
3. One marble strikes another in a game of marbles.

From the above examples we understand that when a moving object strikes a stationary object, the stationary object moves. Thus, the moving object has some energy, part or all of which it shares with the stationary object, thereby setting it in motion. 'The energy which an object has because of its motion is called its kinetic energy'. The work done by a force to displace a stationary object through a distance s is the kinetic energy gained by the object.

Kinetic energy = work done on the object

$\therefore K\ E = F \times s$

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Expression for kinetic energy :

Suppose a stationary object of mass m moves because of an applied force. Let u be its initial velocity (here u = 0). Let the applied force be F. This generates an acceleration a in the object, and, after time t, the velocity of the object becomes equal to v. The displacement during this time is s. The work done on the object, W = F . s

$W = F \times s$

According to Newton's second law of motion,

$F = ma$ -------- (1) Similarly, using Newton's second equation of motion

$s = ut + \frac{1}{2} at^2$ However, as initial velocity is zero, u = 0.

$s = 0 + \frac{1}{2} at^2$

$s = \frac{1}{2} at^2$ ------(2)

$\therefore W = ma \times \frac{1}{2} at^2$ ------ using equations (1) and (2)

$W = \frac{1}{2} m(at)^2$ -------(3)

Using Newton's first equation of motion .....

$v = u + at$

$\therefore v = 0 + at$

$\therefore v = at$

$\therefore v^2 = (at)^2$ ------(4)

$\therefore W = \frac{1}{2} mv^2$ ------- using equations (3) and (4)

The kinetic energy gained by an object is the amount of work done on the object.

$\therefore K E = W$

$\therefore K E = \frac{1}{2} mv^2$

Example : A stone having a mass of 250 gm is falling from a height. How much kinetic energy does it have at the moment when its velocity is 2 m/s?

Given : m = 250 g m = 0 25 kg

v = 2 m/s

$K E = \frac{1}{2} mv^2 = \frac{1}{2} \times 0\ 25 \times (2)^2 = 0\ 5\ J$

Use your brain power !

If the mass of a moving body is doubled, how many times will the kinetic energy increase?

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Potential energy

Try this

1. An arrow is released from a stretched bow.
2. Water kept at a height flows through a pipe into the tap below.
3. A compressed spring is released.

Which words describe the state of the object in the above examples? Where did the energy required to cause the motion of objects come from?

If the objects were not brought in those states, would they have moved?

'The energy stored in an object because of its specific state or position is called its potential energy.'

1.Hold a chalk at a height of 5 cm from the floor and release it.

2. Now stand up straight and then release the chalk.

3 Is there a difference in the results of the two activities? If so, why?

Expression for potential energy

To carry an object of mass 'm' to a height 'h' above the earth's surface, a force equal to 'mg' has to be used against the direction of the gravitational force. The amount of work done can be calculated as follows.

Work = force x displacement

$W = mg \times h$

$\therefore W = mgh$

$\therefore$ The amount of potential energy stored in the object because of its displacement P.E. = mgh (W = P.E.)

$\therefore$ Displacement to height h causes energy equal to mgh to be stored in the object.

Example : 500 kg water is stored in the overhead tank of a 10 m high building. Calculate the amount of potential energy stored in the water.

Given :

$h = 10$ m, $m = 500$ kg $g = 9\ 8$ m/s^2

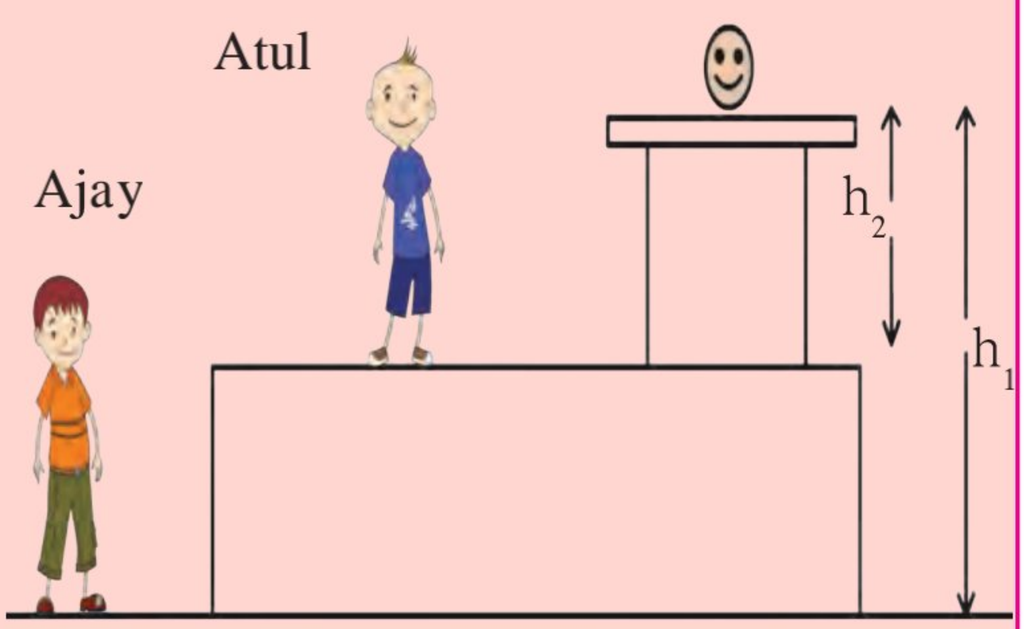
$\therefore$ P E = mgh

$= 10 \times 9\ 8 \times 500$

P E = 49000 J

Ajay and Atul have been asked to determine the potential energy of a ball of mass m kept on a table as shown in the figure. What answers will they get? Will they be different? What do you conclude from this?

Potential energy is relative. The heights of the ball with respect to Ajay and Atul are different. So the potential energy with respect to them will be different.



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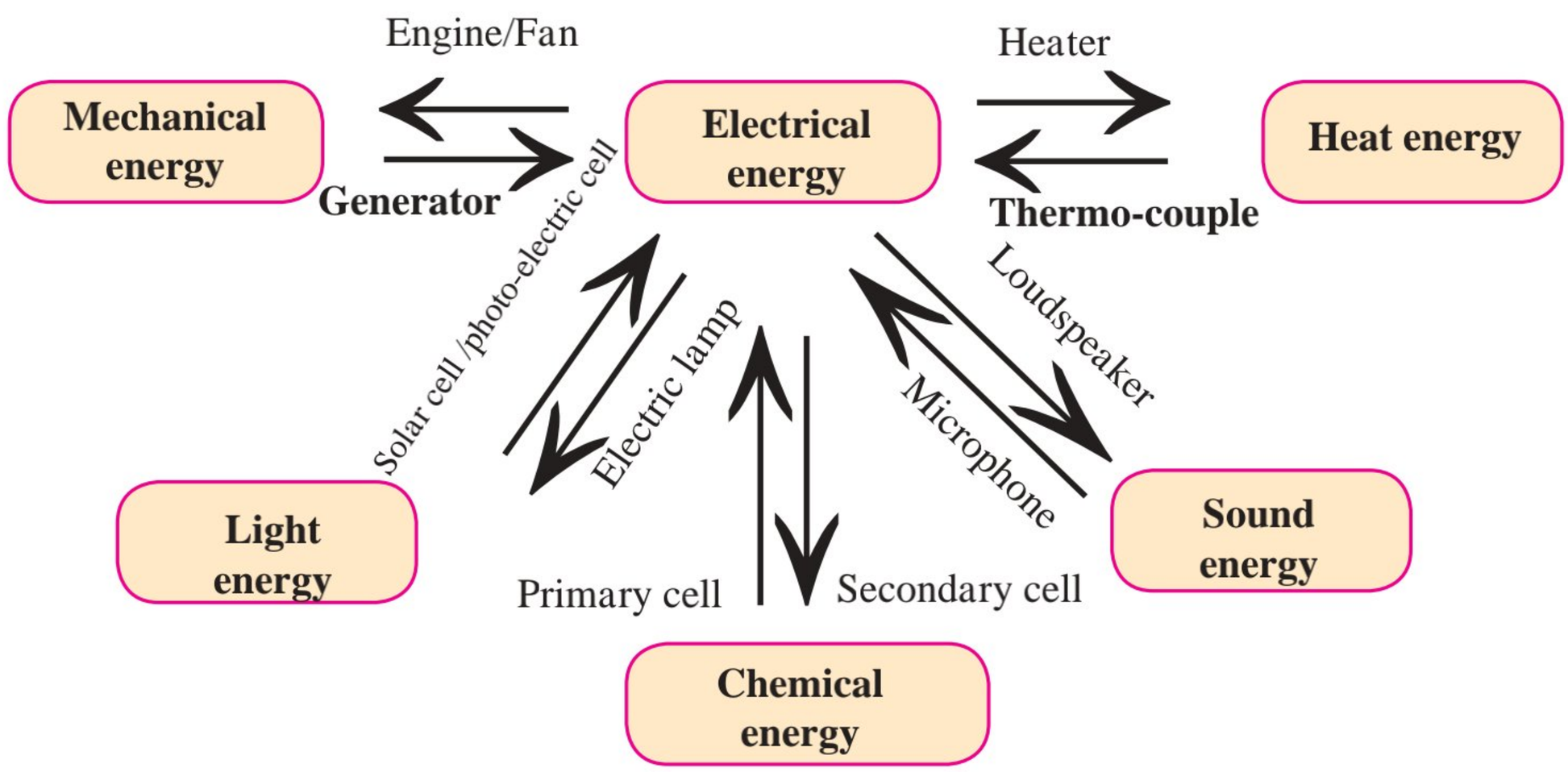
Transformation of energy

Can you tell?

Which are the different forms of energy? Which type of energy is used in each of the following processes?

1. A stretched piece of rubber 2. Fast moving car 3. The whistling of a cooker due to steam 4. The crackers exploded in Diwali 5. A fan running on electricity 6. Drawing out pieces of iron from garbage, using a magnet 7. Breaking of a glass window pane because of a loud noise.

Energy can be transformed from one type to another. For example, the exploding firecrackers convert the chemical energy stored in them into light, sound and heat energy.



2.5 Tranformation of energy

Observe the above diagram (figure 2.5) and discuss how tranformation of energy takes place, giving example of each.

Law of conservation of energy

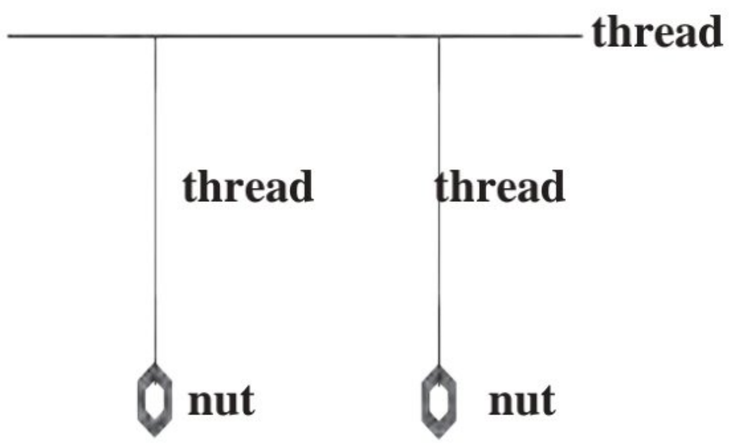
'Energy can neither be created nor destroyed. It can be converted from one form into another. Thus, the total amount of energy in the universe remains constant'.

Try this

Make two pendulums of the same length with the help of thread and two nuts. Tie another thread in the horizontal position.

Tie the two pendulums to this horizontal thread in such a way that they will not hit each other while swinging. Now swing one of the pendulums and observe. What do you see?

You will see that as the speed of oscillation of the pendulum slowly decreases, the second pendulum which was initially stationary, begins to swing. Thus, one pendulum transfers its energy to the other



2.6 Coupled oscillators

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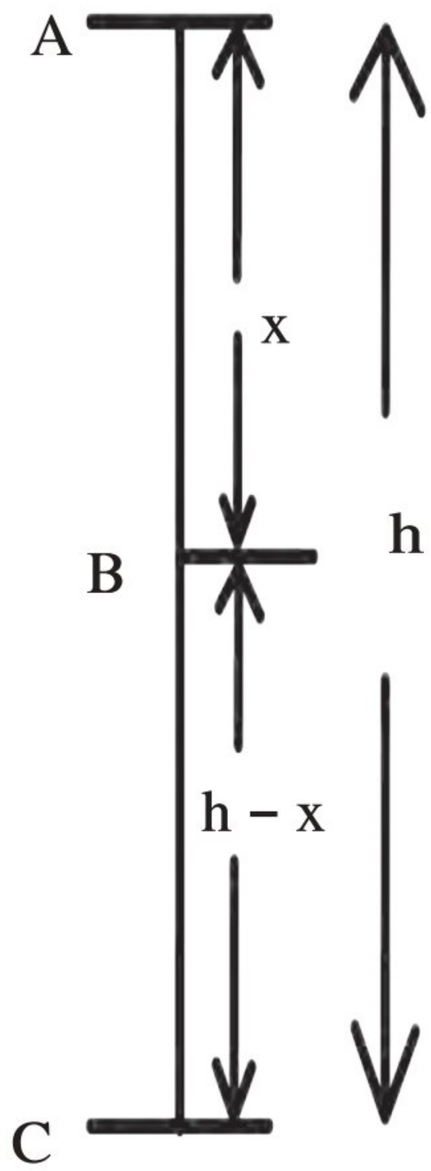
Free fall

If we release an object from a height, it gets pulled towards the earth because of the gravitational force. An object falling solely under the influence of gravitational force is said to be in free fall or to be falling freely. Let us look at the kinetic and potential energies of an object of mass m, falling freely from height h, when the object is at different heights

As shown in the figure, the point A is at a height h from the ground. Let the point B be at a distance x, vertically below A. Let the point C be on the ground directly below A and B. Let us calculate the energies of the object at A, B and C.



2.7 Free fall

1. When the object is stationary at A, its initial velocity is u = 0

$\therefore$ K E $= \frac{1}{2}$ mass x velocity^2

$= \frac{1}{2} mu^2$

K E = 0

P E = mgh

$\therefore$ Total energy = K E + P E

= 0 + mgh

Total Energy = mgh --- (1)

2 Let the velocity of the object be v_B when it reaches point B, having fallen through a distance x

u = 0, s = x, a = g

$v^2 = u^2 + 2as$

$v_B^2 = 0 + 2gx$

$v_B^2 = 2gx$

$\therefore$ K E $= \frac{1}{2} mv_B^2 = \frac{1}{2} m(2gx)$

K E = mgx

Height of the object when at B = h-x

$\therefore$ P E = mg (h−x)

P E = mgh − mgx

$\therefore$ Total Energy T E = K E + P E

= mgx + mgh − mgx

$\therefore$ T E = mgh -------(2)

3. Let the velocity of the object be v_C when it reaches the ground, near point C.

u = 0, s = h, a = g

$v^2 = u^2 + 2as$

$v_c^2 = 0 + 2gh$

$\therefore$ K E $= \frac{1}{2} mv_C^2 = \frac{1}{2} m(2gh)$

K E = mgh

The height of the object from the ground at point C is

h = 0

$\therefore$ P E = mgh = 0

$\therefore$ T E = K E + P E

T E = mgh ------(3)

From equations (1), (2) and (3) we see that the total energy of the object is the same at the three points A, B and C.

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Thus, every object has potential energy when it is at a height above the ground and it keeps getting converted to kinetic energy as the object falls towards the ground. On reaching the ground (point C), all the potential energy gets converted to kinetic energy. But at any point during the fall the total energy remains constant.

i.e., T.E. = P.E. + K.E.

T.E. at A = mgh + 0 = mgh

T.E. at B = mgx + mg (h - x) = mgh

T.E. at C = 0 + mgh = mgh

Power

Think before you answer

1. Can your father climb stairs as fast as you can?
2. Will you fill the overhead water tank with the help of a bucket or an electric motor?
3. Suppose Rajashree, Yash and Ranjeet have to reach the top of a small hill. Rajashree went by car, Yash went cycling while Ranjeet went walking. If all of them choose the same path, who will reach first and who will reach last?

In the above examples, the work done is the same in each example but the time taken to perform the work is different for each person or each method. The fast or slow rate of the work done is expressed in terms of power. 'Power is the rate at which work is done.'

If W amount of work is done in time t then,

$$\text{Power} = \frac{\text{Work}}{\text{Time}} \qquad P = \frac{W}{t}$$

In SI system the unit of work is J, so the unit of power is

J/s. This is called watt

1 watt = 1 joule / 1 second

In the industrial sector the unit used to measure power is called 'horse power.'

1 horse power = 746 watt.

The unit of energy for commercial use is kilo watt hour.

1000 joule work performed in 1 second is 1 kilowatt power.

1 kW h = 1 kW × 1hr

= 1000 W × 3600 s

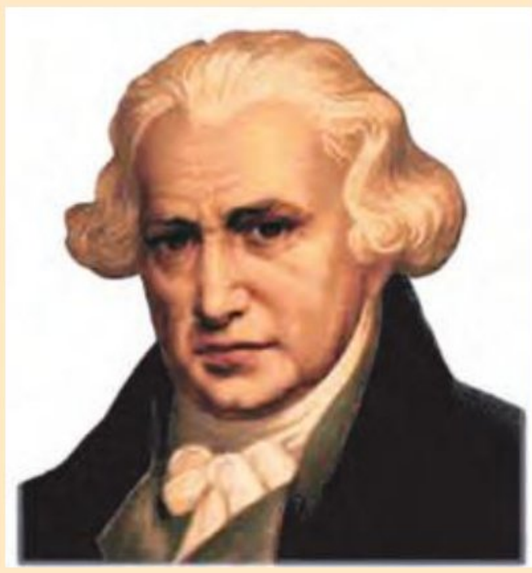
= 3600000 J

1 kW h = $3\ 6 \times 10^6$ J

Electricity used for domestic purposes is measured in units of kilowatt hour.

1 kW h = 1 unit

An introduction to scientists



The steam engine was invented in 1781 by the Scottish scientist James Watt (1736 – 1819). This invention brought about an industrial revolution. The unit of power is called Watt in his honour. James Watt was the first to use the term 'horse-power'.

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Solved problems

Example 1 : Swaralee takes 20 s to carry a bag weighing 20 kg to a height of 5 m. How much power has she used?

Given : m = 20 kg, h = 5 m, t = 40 s

∴ The force which has to be applied by Swaralee,

F = mg = 20 × 9 8

F = 196 N

Work done by Swaralee to carry the bag to a height of 5 m,

W = F s = 196 × 5 = 980 J

$$\therefore \text{ power} = (P) = \frac{\text{Work}}{t} = \frac{980}{40}$$

P = 24 5 W

Example 2 : A 25 W electric bulb is used for 10 hours every day. How much electricity does it consume each day?

Given :

P = 25, W = 0 025 kW

∴ Energy consumed = power × time

= 0 025 × 10

Energy = 0 25 kW hr

Exercises

1. Write detailed answers?

a. Explain the difference between potential energy and kinetic energy.

b. Derive the formula for the kinetic energy of an object of mass m, moving with velocity v.

c. Prove that the kinetic energy of a freely falling object on reaching the ground is nothing but the transformation of its initial potential energy.

d. Determine the amount of work done when an object is displaced at an angle of 30^0 with respect to the direction of the applied force.

e. If an object has 0 momentum, does it have kinetic energy? Explain your answer.

f. Why is the work done on an object moving with uniform circular motion zero?

2. Choose one or more correct alternatives.

a. For work to be performed, energy must be ….

(i) transferred from one place to another (ii) concentrated

(iii) transformed from one type to another (iv) destroyed

b. Joule is the unit of …

(i) force (ii) work (iii) power (iv) energy

c. Which of the forces involved in dragging a heavy object on a smooth, horizontal surface, have the same magnitude?

(i) the horizontal applied force (ii) gravitational force (iii) reaction force in vertical direction (iv) force of friction

d. Power is a measure of the .....

(i) the rapidity with which work is done (ii) amount of energy required to perform the work (iii) The slowness with which work is performed (iv) length of time

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e. While dragging or lifting an object, negative work is done by
(i) the applied force (ii) gravitational force (iii) frictional force (iv) reaction force

3. Rewrite the following sentences using proper alternative.

a. The potential energy of your body is least when you are .....
(i) sitting on a chair (ii) sitting on the ground (iii) sleeping on the ground (iv) standing on the ground

b. The total energy of an object falling freely towards the ground ...
(i) decreases (ii) remains unchanged (iii) increases (iv) increases in the beginning and then decreases

c. If we increase the velocity of a car moving on a flat surface to four times its original speed, its potential energy ....
(i) will be twice its original energy (ii) will not change (iii) will be 4 times its original energy (iv) will be 16 times its original energy.

d. The work done on an object does not depend on ....
(i) displacement (ii) applied force (iii) initial velocity of the object (iv) the angle between force and displacement.

4. Study the following activity and answer the questions.

1. Take two aluminium channels of different lengths.
2. Place the lower ends of the channels on the floor and hold their upper ends at the same height.
3. Now take two balls of the same size and weight and release them from the top end of the channels. They will roll down and cover the same distance.

Questions

1. At the moment of releasing the balls, which energy do the balls have?
2. As the balls roll down which energy is converted into which other form of energy?
3. Why do the balls cover the same distance on rolling down?
4. What is the form of the eventual total energy of the balls?
5. Which law related to energy does the above activity demonstrate ? Explain.

5. Solve the following examples.

a. An electric pump has 2 kW power. How much water will the pump lift every minute to a height of 10 m?
(Ans : 1224.5 kg)

b. If a 1200 W electric iron is used daily for 30 minutes, how much total electricity is consumed in the month of April? **(Ans :18 Unit)**

c. If the energy of a ball falling from a height of 10 metres is reduced by 40%, how high will it rebound?
(Ans : 6 m)

d. The velocity of a car increase from 54 km/hr to 72 km/hr. How much is the work done if the mass of the car is 1500 kg ?
(Ans. : 131250 J)

e. Ravi applied a force of 10 N and moved a book 30 cm in the direction of the force. How much was the work done by Ravi?
(Ans: 3 J)

Project :

Study the various instances of trasnformation of energy you see around you and discuss them in class.

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3. Current Electricity

- Potential and potential difference
- Conductors and insulators (bad conductors)
- Electrical resistance and Ohm's Law
- Connection of resistors and effective resistance

All around us

Electricity is of utmost importance in the modern world. We depend on it for almost everything in our day to day life. In order to avoid the inconvenience faced due to failure of power supply, hospitals, banks, offices and private institutions make alternative arrangements with the help of generators. Electricity is used for running electric furnaces, electric motors and several other instruments used in industries.

Domestic appliances like the fridge, electric oven, mixer, fans, washing machines, vacuum cleaner, rotimaker, etc. have helped us by saving time and labour. All these devices cannot be run without electricity.

Not only human beings but some animals also use electricity. For example, fishes such as eels use electricity to catch their prey and also for self-defence. The lightning that strikes the earth is an excellent example of natural flow of electricity. What if we could collect and store this electricity!

Can you recall?

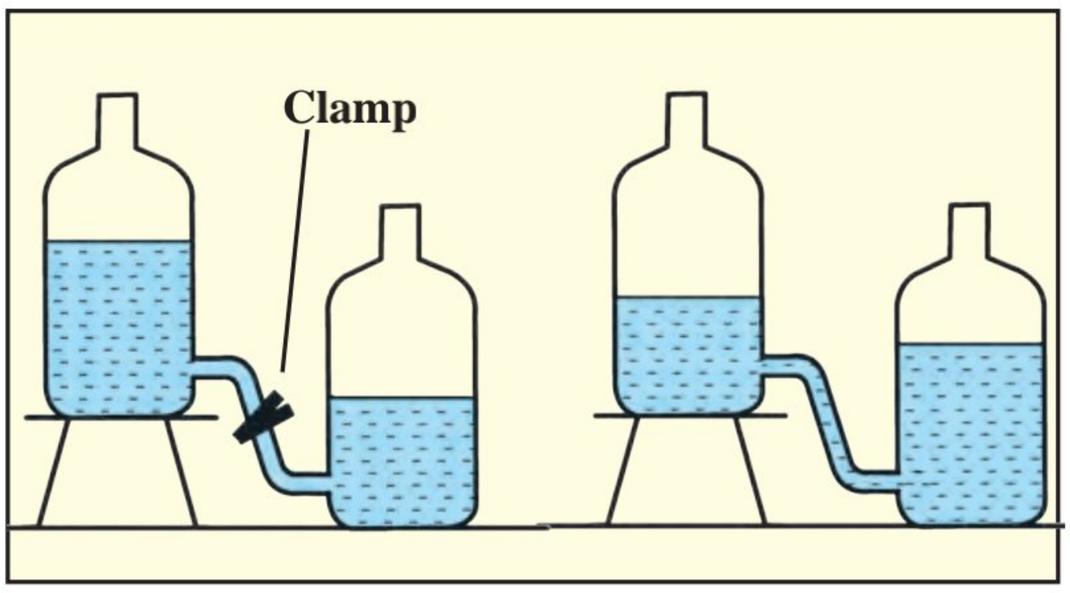
You must have seen a waterfall. Which way does the water flow?

For the generation of electricity, water is released from a dam at a higher level and because of gravity, it falls to a lower level. Thus, as we know, the direction of flow of water between two points depends on the level of the two points.

Potential and potential difference

Try this

Equipment : Two plastic bottles, rubber tube, clamp, water.
Procedure : Set up the experiment as shown in figure 3.1. Then remove the clamp from the rubber tube. Note your observations. Answer the following questions.



3.1 Level of water and direction of flow

1. What happens when the clamp is removed?
2. Does the water stop flowing? Why?
3. What will you do to keep the water flowing for a longer duration?

Just like water, the flow of electric charge between two points depends on a kind of electric level at those points. This level is called electric potential.

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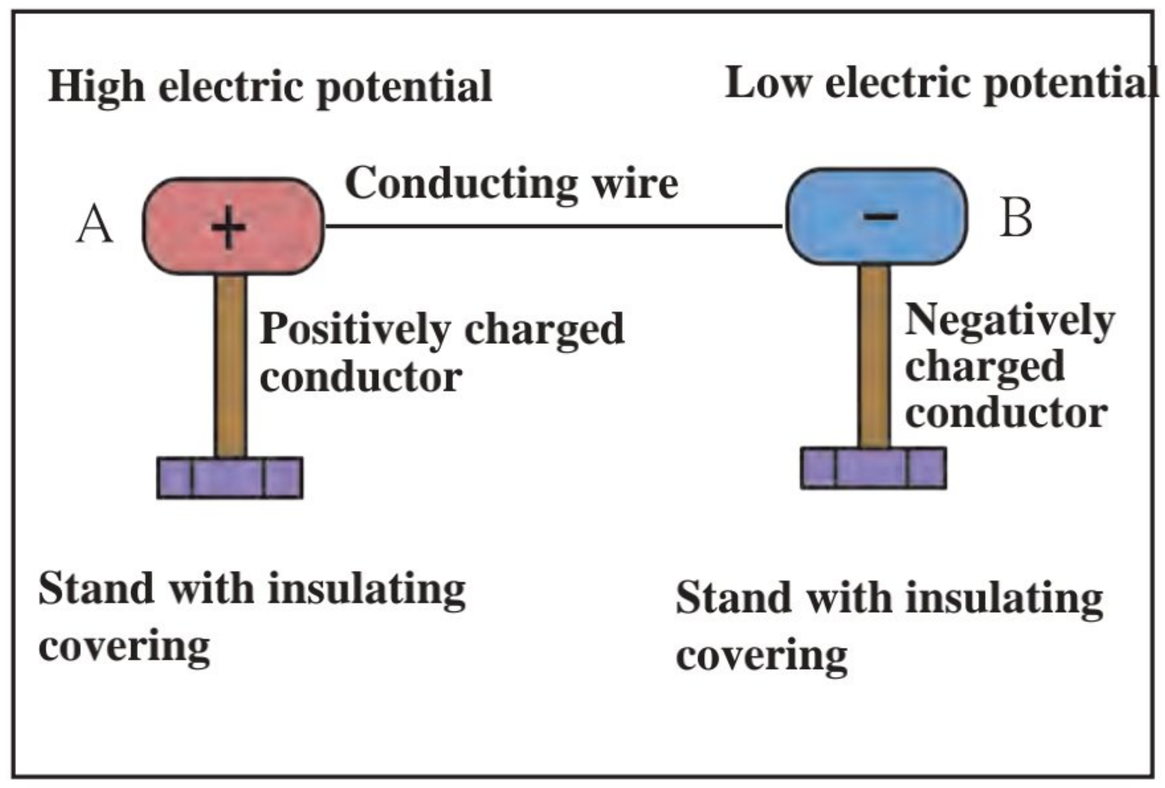
A positive charge flows from a point of higher potential to a point of lower potential. We have seen earlier that electricity flows due to the conduction of negatively charged electrons. Electrons flow from the point of lower potential to a point of higher potential. A lightning strike is the flow of electrons from point of lower (negative) potential on the clouds to the point of higher (zero) potential on the earth. We shall study the definition of electric potential in higher standards.

The difference between the values of potentials at two points A and B is called the potential difference between them.

In the figure 3.2, conductor A is at a higher potential than conductor B. When these two are connected by a conducting wire, a potential difference is created between its two ends and electrons will flow from B to A through the wire. This flow will continue until the two conductors, A and B have the same potential, i.e. until their potential difference becomes zero. Only then will the flow of electrons stop.



3.2 Potential difference and flow of electricity

Work has to be done against the electric field to take a positive charge from a point of lower potential to a point of higher potential.

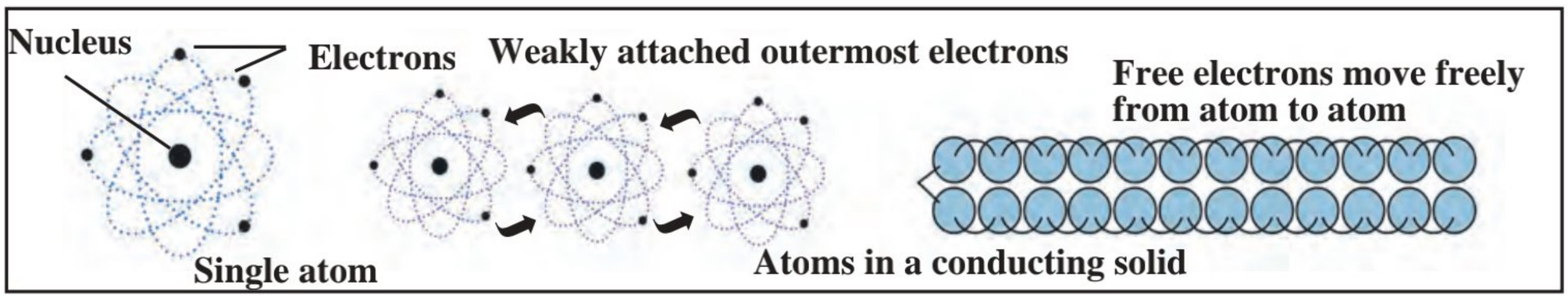
Potential difference of a cell

The difference in potential between the positive and negative terminals of a cell is the potential difference of that cell. This potential difference is caused by chemical reactions occurring inside the cell. The potential difference sets the electrons in motion and results in the flow of electricity through a conducting wire connected to the two ends of the cell.

The amount of work done to carry a unit positive charge from point A to point B is called the electric potential difference between the two points.

$$\text{Potential difference between two points} = \frac{\text{Work}}{\text{Total charge transferred}}, \quad V = \frac{W}{Q}$$

$$1\ V = \frac{1J}{1C}$$ The unit of potential difference in SI system is volt.



3.3 Free electrons

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Volta's simple electric cell

An introduction to scientists

The Italian scientist Alessandro Volta constructed the first electric cell. The unit of potential difference is named 'volt' in his honour.

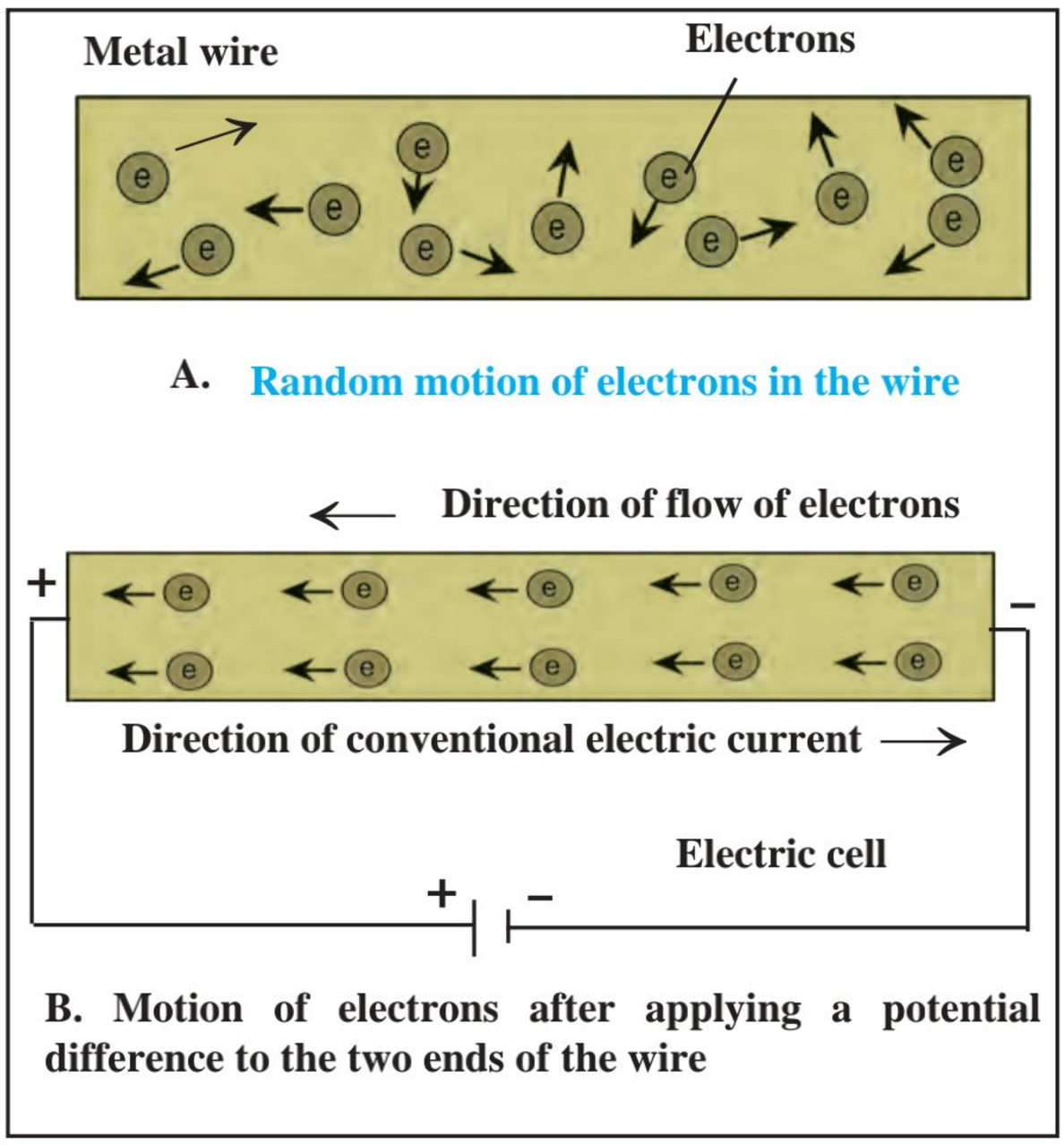
Do you know?

Very small values of potential difference are expressed in the following units.	Large values of potential difference are expressed in the following units.
1 1mV (millivolt) = 10^{-3} V	1 1kV (kilovolt) = 10^{3} V
2 1μV (microvolt) = 10^{-6} V	2 1MV (megavolt) = 10^{6} V

Free electrons : Every atom of a metallic conductor has one or more outermost electrons which are very weakly bound to the nucleus. These are called free electrons.
As shown in figure 3.3, these electrons can easily move from one part of a conductor to its other parts. The negative charge of the electrons also gets transferred as a result of this motion. The free electrons in a conductor are the carriers of negative charge.

Current flowing through a wire

As shown in the figure 3.4 A, if a conducting wire is not connected to a cell, its free electrons move randomly in all directions in the space between the atoms. When we connect the ends of the wire to the two terminals of a cell, electric force acts on the electrons. Being negatively charged, they start moving from the negative (lower potential) to the positive (higher potential) terminal of the cell, as shown in figure 3.4 B. Due to the flow of these electrons, current starts to flow through the wire. This motion of electrons is irregular but there is a definite, non-zero value to their average velocity.



3.4 Motion of free electrons

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Electric current

An electric current is the flow of electrons through a conductor. Quantitatively, current (I) is defined as the charge passing through a conductor in unit time.

If charge Q is flowing through cross-section of a conductor in time t then the

$$\text{current} = I = \frac{Q}{t}$$

The unit of charge in SI units is Coulomb (C). Current is expressed in Ampere (A). The charge of one electron is 1.6×10^{-19} C.

Even though, electrons move from negative end to positive end, conventionally, the direction of current flow is taken to be opposite of the direction of flow of electrons i.e. from the +ve end to the –ve end of a cell.

Ampere : One ampere current is said to flow in a conductor if one Coulomb charge flows through it every second.

$$1A = \frac{1C}{1s}$$

Do you know?

Very small values of current are expressed in the following units.

1. 1mA (mili ampere) = 10^{-3} A
2. 1μA (micro ampere) = 10^{-6} A

The French mathematician and scientist, Ampere, conducted a number of experiments on electricity. Today, we can measure the current flowing in a conductor only because of his extraordinary work. The unit of current is called ampere in recognition of his great work.

Example : A current of 0.4 A flows through a conductor for 5 minutes. How much charge would have passed through the conductor?

Given : I = 0 4 A

t = 5 min = 5 × 60 s =300 s

Formula Q = I × t

Q = 0 4 A × 300 s

Q = 120 C

∴ Charge passing through the conductor = 120 C

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Resistance and Ohm's Law

Ohm's law

The relationship between the current flowing through a wire (I) and the potential difference across its ends (V) can be obtained from the law that was given by the German scientist George Simon Ohm.

If the physical state of a conductor remains constant, the current (I) flowing through it is directly proportional to the potential difference (V) between its two ends.

$I \alpha V$

$I = kV$ (k = constant of proportionality)

$I \times \frac{1}{k} = V$ ($\frac{1}{k}$ = R = Resistance of the conductor)

$I \times R = V$ Hence $V = IR$ or $R = \frac{V}{I}$

This is known as Ohm's law.

Physical state of a conductor means its length, area of cross-section, temperature and the material it is made up of.

We can obtain the SI unit of resistance from the above formula, Potential difference and current are measured in Volts and Amperes respectively. The unit of resistance is called Ohm. It is indicated by the symbol Ω.

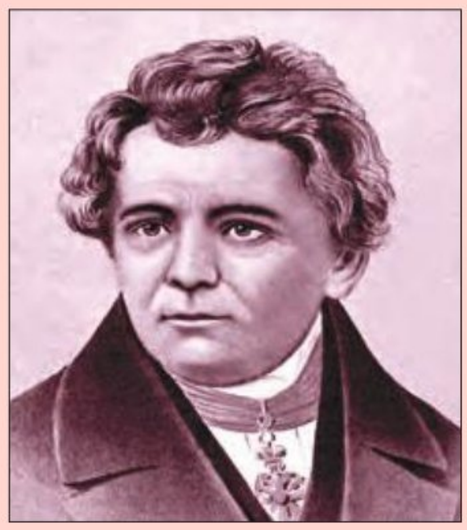
$$\therefore \quad \frac{1 \text{ Volt}}{1 \text{ Ampere}} = 1 \text{ Ohm } (\Omega)$$

Resistance of one Ohm : If one Ampere current flows through a conductor when one Volt potential difference is applied between its ends, then the resistance of the conductor is one Ohm.

Resistance and resistivity of a conductor

As shown in figure 3.4, there are a large number of free electrons in a conductor. They are constantly in random motion. When a potential difference is applied between the two ends of the conductor, these electrons start moving from the end at lower potential to the end at higher potential. This directional motion of the electrons causes the flow of current. Moving electrons strike the atoms and ions which lie along their path. Such collisions cause hindrance to the flow of electrons and oppose the current. This hindrance is called the resistance of the conductor.

Resistivity : At a given temperature, the resistance (R) of a conductor depends on its length (L), area of cross-section (A) and the material it is made of.



German physicist, George Simon Ohm established a law for measuring the resistance of a conductor. In his honour, the unit of resistance is called the Ohm.

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If the resistance of a conductor is R, then

$$R \alpha L$$

Also, $R \alpha \frac{1}{A}$

$$\therefore \quad R \alpha \frac{L}{A}$$

$$R = \rho \frac{L}{A}$$

Think about it

How will you prove that the unit of resistivity is Ω m ?

Resistivity of some materials

Copper – $1.7 \times 10^{-8}\ \Omega$ m

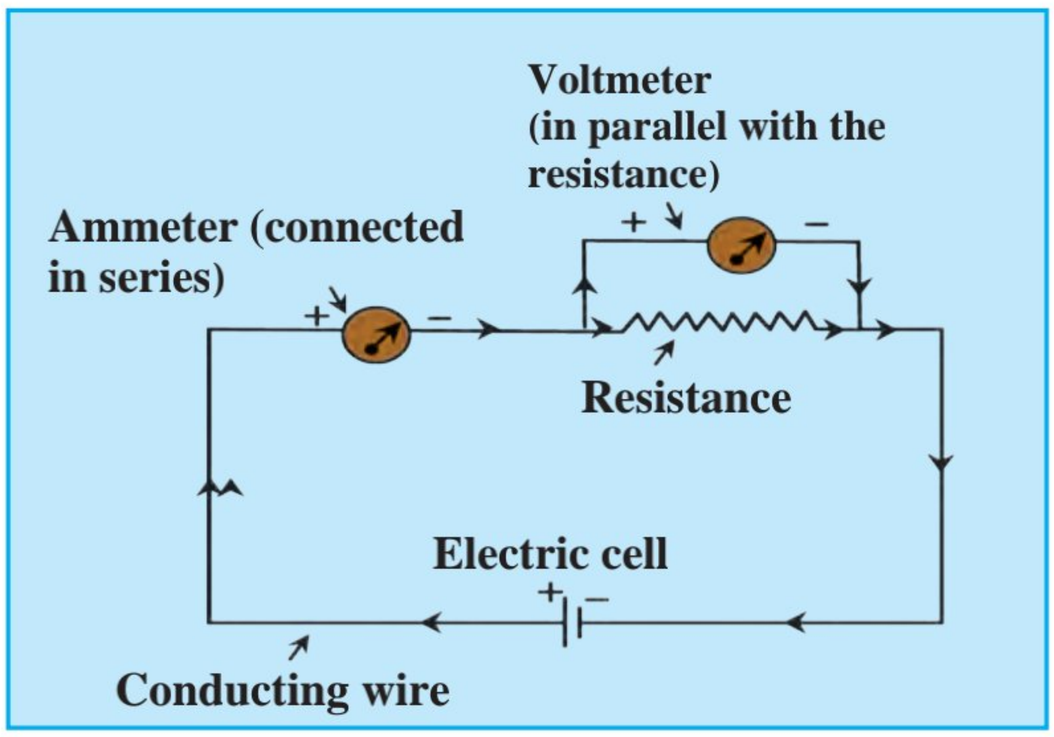
Nichrome – $1.1 \times 10^{-6}\ \Omega$ m

Diamond – 1.62×10^{13} to $1.62 \times 10^{18}\ \Omega$ m

ρ is the constant of proportionality and is called the resistivity of the material. The unit of resistivity in SI units is Ohm metre (Ωm). Resistivity is a specific property of a material and different materials have different resistivity

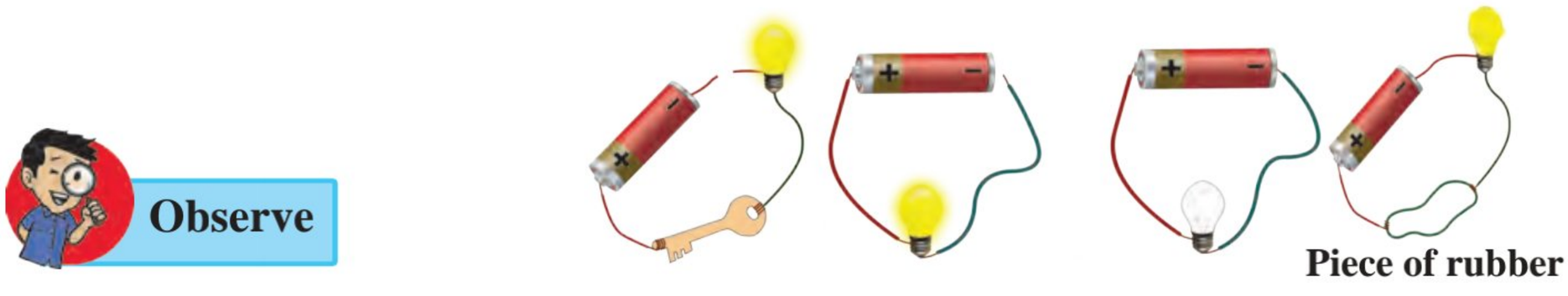
Electric circuit

A continuous path of an electric current through conducting wires connected to the two ends of a cell and other resistances is called an electric circuit. A circuit is depicted by a figure. This figure shows how different components are to be connected in the circuit, by using special symbols for each of the components. Such a figure is called an electric circuit diagram.

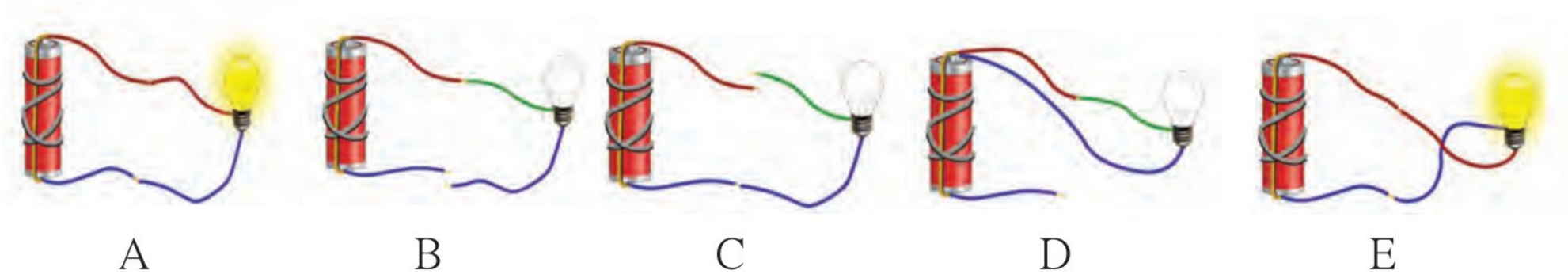


3.5 Electrical circuit

In the circuit in figure 3.5, an ammeter is used to measure current and a voltmeter to measure the potential difference between the two ends of a resistor. As the voltmeter has a very high resistance, only very small current flows through it.



1. Point out the mistakes in the figure above.
2. Why are the bulbs in Figures B, C and D below not lighting up ?



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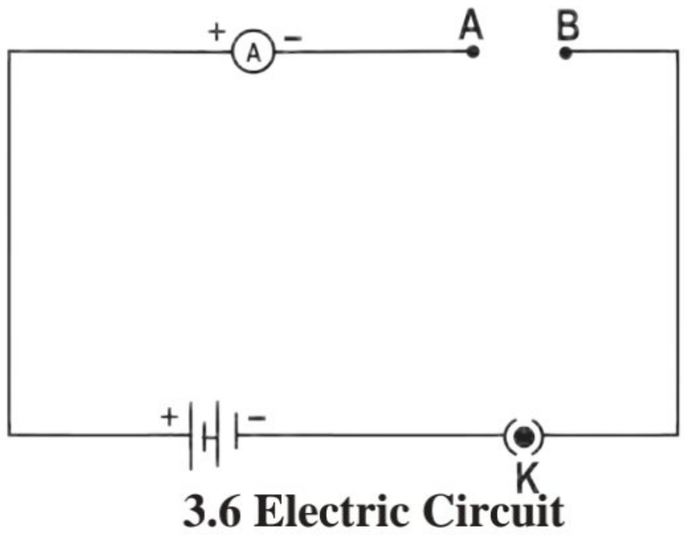
Symbols for components of an electric circuit and their uses

Component	Picture	Symbol	Use
Electric cell			To apply a potential difference between two ends of a conductor
Battery (collection of a number of cells)			To apply a larger potential difference between two ends of a conductor
Open tap key or plug key			To stop the flow of current flowing in a circuit by disconnecting two ends of a wire
Closed tap key or plug key			To start the flow of current in a circuit by connecting two ends of a wires.
Connecting (conducting) wires			To connect various components in the circuit.
Crossing wires			To show wires which cross but are not connected
Light bulb			To test the flow of electricity : Lighted : current is flowing; unlighted : current is not flowing
Resistance		R	To control the flow of current in the circuit
Variable resistance			To change the resistance as required and thereby control the current
Ammeter		A	To measure the current flowing in the circuit
Voltmeter		V	To measure the potential difference between two points in the circuit

Try this

Material: copper and aluminium wires, glass rod, rubber

Method : Make connections as shown in figure 3.6. First connect a copper wire between points A and B and measure the current in the circuit. Then, in place of the copper wire, connect aluminium wire, glass rod, rubber, etc, one at a time and measure the current each time. Compare the values of the current in different cases.



3.6 Electric Circuit

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Conductors and insulators

We have learnt about the resistance to an electric current. We can divide substances into conductors and insulators (bad conductors).

Conductors : Those substances which have very low resistance are called conductors. Current can flow easily through such materials.

Insulators : Those substances which have extremely high resistance and through which current cannot flow are called insulators.

1. Why are some substances conductors while others are insulators?
2. Why can our body conduct electricity?

Make a list of conductors and insulators you see around you.

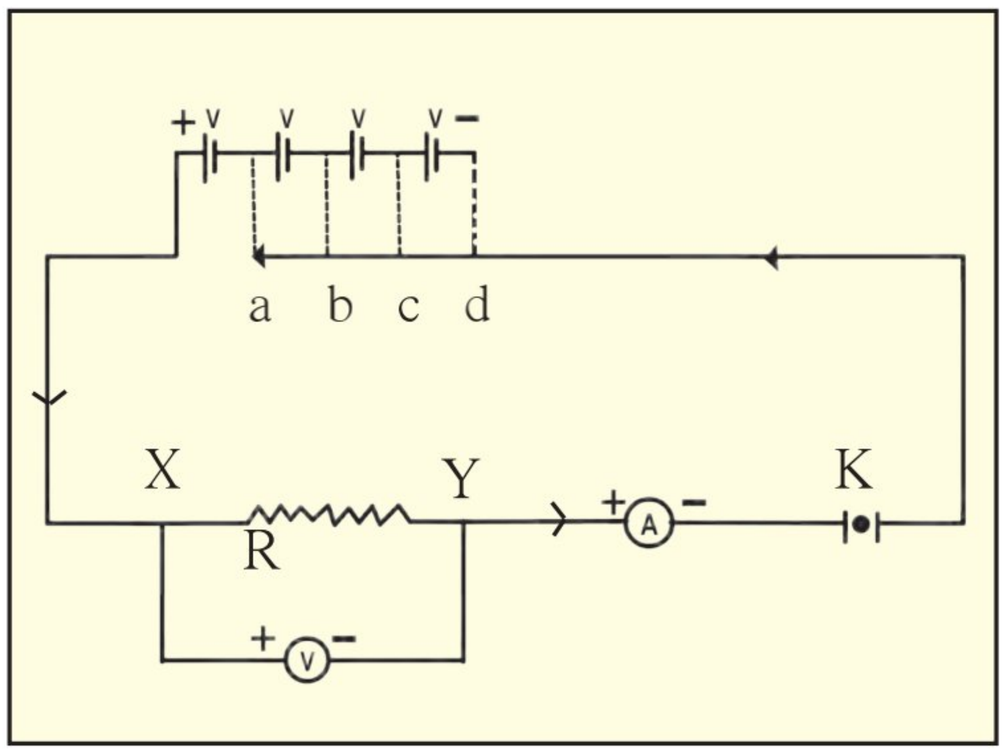
Experimental proof of Ohm's law :

Try this

Material : 4 cells of 1.5 V each, ammeter, voltmeter, conducting wires, nichrome wire, plug key.

Procedure :

1. Set up the circuit as shown in figure 3.7.
2. Use the nichrome wire XY as the resistance.
3. Connect one of the 4 cells as shown in figure 3.7 (a.) Take readings of ammeter and voltmeter and enter them in the table below.
4. Now add the rest of the cells one by one as shown in figures 3.7 (b, c and d). Enter the readings in the table for each case.
5. Determine the values of $\frac{V}{I}$ for each case.
6. Draw a graph between current and potential difference and study it.



3.7 Verification of Ohm's Law

Observation chart

No.	Number of cells used	Current (I) (mA)	Current (I) (A)	Potential difference (Volts)	V / I = R in (Ω)
1 2 3 4					

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Solved examples : Ohm's law and resistivity

Example 1 : The resistance of the filament in a light bulb is 1000 Ω. If the bulb is fed by a current from a source of potential difference 230 V, how much current will flow through it?

Given : $R = 1000\ \Omega$

$V = 230\ V$

Formula $I = \frac{V}{R}$

$\therefore I = \frac{230\ V}{1000\ \Omega} = 0\ 23\ A$

∴ The current flowing through the filament of the bulb = 0.23 A.

Example 2 : The length of a conducting wire is 50 cm and its radius is 0.5 mm. If its resistance is 30 Ω, what is the resistivity of its material?

Given : $L = 50\ cm = 50 \times 10^{-2}\ m$

$r = 0\ 5\ mm = 0\ 5 \times 10^{-3} m$

$= 5 \times 10^{-4}\ m$ and $R = 30\ \Omega$

Resistivity $\rho = \frac{RA}{L}$

and $A = \pi r^2$

$$\therefore \rho = R\ \frac{\pi r^2}{L}$$

$$= \frac{30 \times 3.14 \times (5 \times 10^{-4})^2}{50 \times 10^{-2}}$$

$$= \frac{30 \times 3.14 \times 25 \times 10^{-8}}{50 \times 10^{-2}}$$

$= 47\ 1 \times 10^{-6}\ \Omega\ m$

$= 4\ 71 \times 10^{-5}\ \Omega\ m$

∴ Resistivity of the wire $4.71 \times 10^{-5}\ \Omega\ m$

Example 3 : A current of 0.24 A flows through a conductor when a potential difference of 24 V is applied between its two ends. What is its resistance?

Given : $V = 24\ V, I = 0\ 24\ A$

Formula $R = \frac{V}{I}$

$\therefore I = \frac{24\ V}{0.24\ A}$

$R = 100\ \Omega$

The resistance of the conductor is 100 Ω

Example 4 : Determine the current that will flow when a potential difference of 33 V is applied between two ends of an appliance having a resistance of 110 Ω. If the same current is to flow through an appliance having a resistance of 500 Ω, how much potential difference should be applied across its two ends?

Given : $V = 33\ V$ and $R = 110\ \Omega$

In the first case,

$$I = \frac{V}{R} = \frac{33}{110}$$

$\therefore I = 0\ 3\ A$

Current flowing through the appliance = 0.3 A

In the second case,

$I = 0\ 3\ A, R = 500\ \Omega$

$V = IR = 0\ 3 \times 500\ V = 150\ V$

The required potential difference between its two ends = 150 V

Using ICT

Using the internet find out about the different softwares used to solve mathematical problems and use them to solve problems given in this and other chapters.

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Example 5 : Determine the resistance of a copper wire having a length of 1 km and diameter of 0.5 mm

Given : ρ = Resistivity of copper = $1\ 7 \times 10^{-8}\ \Omega$ m

Converting all measures into metres.

$L = 1$ km $= 1000$ m $= 10^3$ m

$d = 0\ 5$ mm $= 0\ 5 \times 10^{-3}$ m

If r is the radius of the wire then, its area of cross-section

$A = \pi r^2$

$$\therefore\ A = \pi \times \left(\frac{d}{2}\right)^2$$

$$= \frac{\pi}{4}(0\ 5 \times 10^{-3})^2\ m^2 = 0\ 2 \times 10^{-6}\ m^2$$

$$R = \rho \frac{L}{A} = \frac{1.7 \times 10^{-8}\ \Omega\ m \times (10^3 m)}{0.2 \times 10^{-6} m^2} = 85\ \Omega$$

System of resistors and effective resistance

A resistor is a two ended component having a given amount of resistance between its two ends. In several electrical devices, a number of resistors are connected together in different ways. Ohm's law is applicable to all such connected resistors.

Resistors in series

Study figure 3.8.

You can see that the ends of the three resistors are connected so that they follow one after the other in a single line. These resistors are said to be connected in 'series.' In such an arrangement, the same current flows through each resistor. The value of current is I and the potential difference between C and D is V.

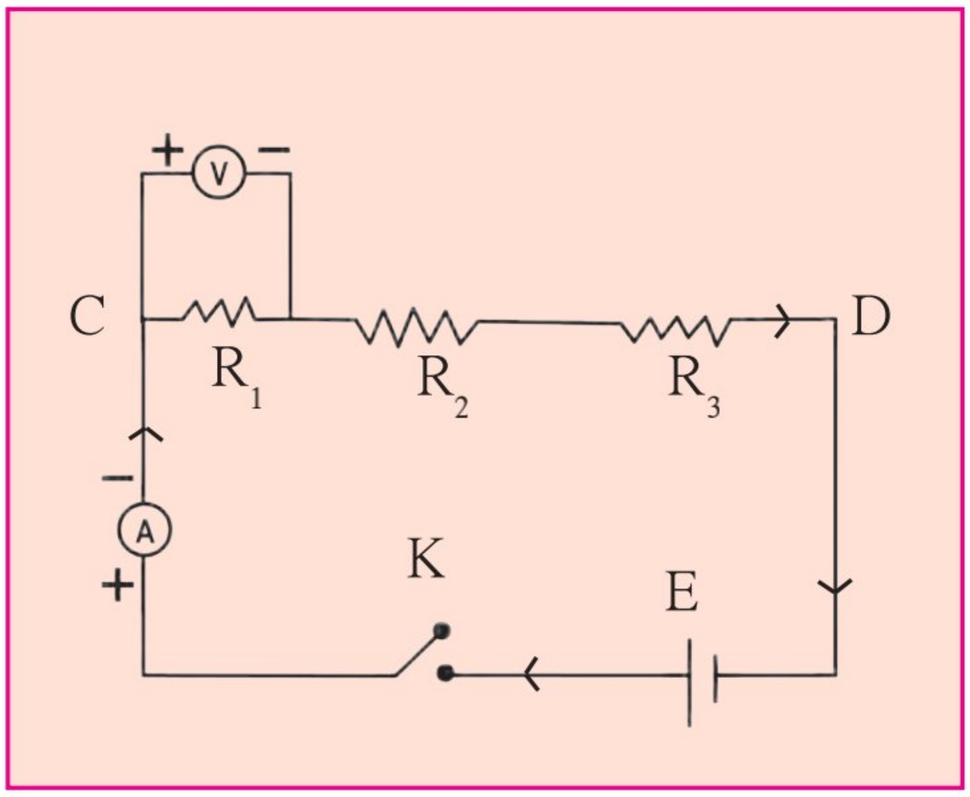
The three resistors, R_1, R_2 and R_3 are connected in series in the circuit. Let the voltages across them be V_1, V_2 and V_3 respectively. Then,

$$V = V_1 + V_2 + V_3 \text{--------}(1)$$

If R_S (S for series) is the effective resistance between C and D, then, according to Ohm's law,

$$V = I R_S$$

$V_1 = I R_1$, $V_2 = I R_2$ and $V_3 = I R_3$ Substituting all these in equation (1) we get,



3.8 Resistors in series

$$I R_S = I R_1 + I R_2 + I R_3$$

$$R_S = R_1 + R_2 + R_3$$

If n resistors are connected in series then,

$$R_s = R_1 + R_2 + R_3 + \text{-------} + R_n$$

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If resistors are connected in series,

1. The same current flows through each resistor.
2. The effective resistance of the resistors is equal to the sum of their individual resistances.
3. The potential difference between the two extremes of the arrangement is equal to the sum of the potential differences across individual resistors.
4. The effective resistance is larger than each of the individual resistances.
5. This arrangement is used to increase the resistance in a circuit.

Do you know?

When resistors are connected in series, they are connected one after another. If any one of them does not function, the circuit breaks and there is no flow of electricity. If two bulbs are connected in series, they will both give less light than if they had been connected individually. If three bulbs are connected in series, their light output will decrease further.

Think about it : What is the reason behind this?

Solved examples for resistors in series

Example 1 : Three resistors having resistances of 15 Ω, 3 Ω and 4 Ω are connected in series. What is the effective resistance in the circuit?

Given : $R_1 = 15\ \Omega$, $R_2 = 3\ \Omega$, $R_3 = 4\ \Omega$

Effective resistance $R_s = R_1 + R_2 + R_3 = 15 + 3 + 4 = 22\ \Omega$

$\therefore$ The effective resistance in the circuit $= 22\ \Omega$

Example 2 : Two resistors having resistances of 16 Ω and 14 Ω are connected in series. If a potential difference of 18 V is applied across them, calculate the current flowing through the circuit and the potential difference across each individual resistor.

Given : $R_1 = 16\ \Omega$ and $R_2 = 14\ \Omega$

$R_s = 14\ \Omega + 16\ \Omega = 30\ \Omega$

Let the current flowing through the circuit be I and the potential differences across 16 Ω and 14 Ω be V_1 and V_2 respectively.

$V = I R \qquad V = V_1 + V_2 = 18\ V$

$$I = \frac{V}{R} = \frac{18\ V}{30\ \Omega}$$

$\therefore I = 0\ 6\ A$

$V_1 = I R_1$

$V_1 = 0\ 6 \times 16 = 9\ 6\ V$

$V_2 = I R_2 = 0\ 6 \times 14 = 8\ 4\ V$

$\therefore$ The current flowing in the circuit is 0.6 A and the potential differences across the resistances 16 Ω and 14 Ω are 9.6 V and 8.4 V respectively.

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Do you know?

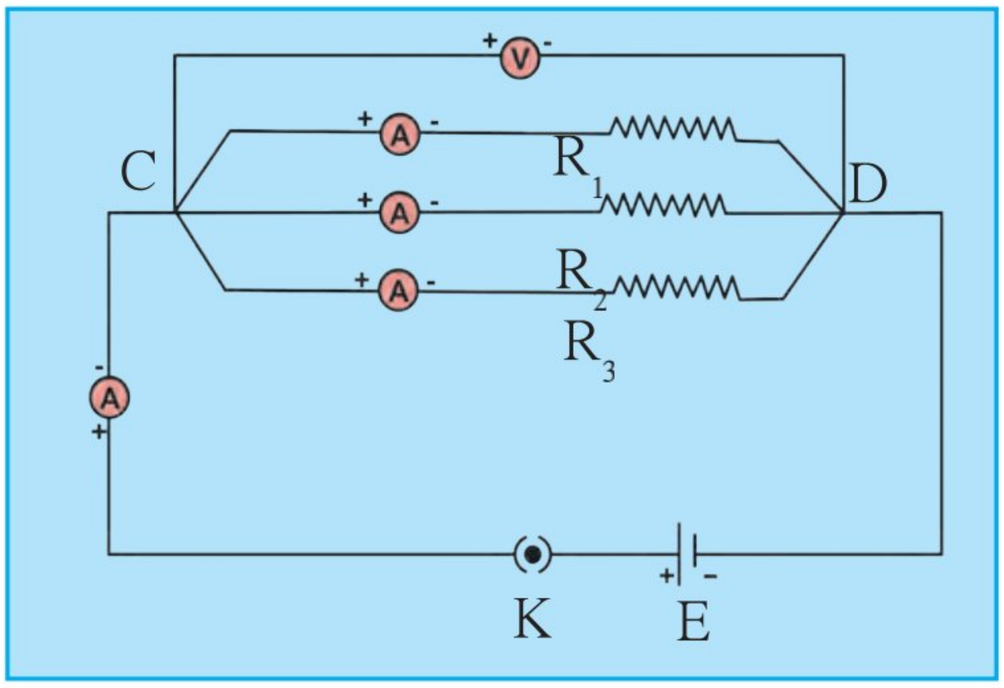
The resistance of some conductors becomes nearly zero if their temperature is decreased upto a certain value close to 0 K. Such conductors are called super conductors.

Some conductors do not obey Ohm's law. Such conductors are called non-ohmic conductors.

Resistors in parallel

Resistors are said to be connected in parallel when their ends are connected at both sides as shown in figure 3.9. The figure shows three resistors R_1, R_2 and R_3 connected in parallel between points C and D. V is the potential difference between C and D. Let I_1, I_2 and I_3 be the currents flowing through R_1, R_2, and R_3 respectively.

Then, the total current flowing through the circuit is



3.9 Resistors in parallel

$$I = I_1 + I_2 + I_3 \text{-------}(1)$$

Let R_p (p for parallel) be the effective resistance between C and D. According to Ohm's law,

$$I = \frac{V}{R_P} \quad \text{Similarly } I_1 = \frac{V}{R_1}, \; I_2 = \frac{V}{R_2}, \; I_3 = \frac{V}{R_3}$$

Substituting these in equation (1)

$$\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\therefore \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

If n resistors are connected in parallel,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \quad + \frac{1}{R_n}$$

Even if any one of the several bulbs connected in parallel becomes non-functional because of some damage to its filament, the circuit does not break as the current flows through the other paths, and the rest of the bulbs light up.

When several bulbs are connected in parallel, they emit the same amount of light as when they are connected individually in the circuit, while bulbs connected in series emit less light than when connected individually.

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If a number of resistors are connected in parallel,

1. The inverse of the effective resistance is equal to the sum of the inverses of individual resistances.
2. The current flowing through an individual resistor is proportional to the inverse of its resistance and the total current flowing through the circuit is the sum of the currents flowing through individual resistors.
3. The potential difference across all resistors is the same.
4. The effective resistance of resistors connected in parallel is less than the least resistance of individual resistors.
5. This arrangement is used to reduce the resistance in a circuit.

Solved examples of resistors in parallel

Example 1: Resistors having resistances of 15 Ω, 20 Ω and 10 Ω are connected in parallel. What is the effective resistance in the circuit?

Given : $R_1 = 15\ \Omega$, $R_2 = 20\ \Omega$ and $R_3 = 10\ \Omega$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_P} = \frac{1}{15} + \frac{1}{20} + \frac{1}{10} = \frac{4+3+6}{60} = \frac{13}{60}$$

$$R_P = \frac{60}{13} = 4\ 615\ \Omega$$

∴ Effective resistance in the circuit = 4 615 Ω, less than the least of the three, 10 Ω.

Example 2 : Three resistors having resistances of 5 Ω, 10 Ω and 30 Ω are connected in parallel and a potential difference of 12 V is applied across them. Obtain the current flowing through the circuit and through individual resistors. What is the effective resistance in the circuit?

Given : $R_1 = 5\ \Omega$, $R_2 = 10\ \Omega$ and $R_3 = 30\ \Omega$, $V = 12$ V

$$I_1 = \frac{V}{R_1} = \frac{12}{5} = 2\ 4\ A$$

$$I_2 = \frac{V}{R_2} = \frac{12}{10} = 1\ 2\ A$$

$$I_3 = \frac{V}{R_3} = \frac{12}{30} = 0\ 4\ A$$

$$I = I_1 + I_2 + I_3 = 2\ 4 + 1\ 2 + 0\ 4 = 4\ 0\ A$$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{5} + \frac{1}{10} + \frac{1}{30} = \frac{6+3+1}{30} = \frac{10}{30} = \frac{1}{3}$$

Effective resistance in the circuit = 3 Ω and the current flowing through the resistances 5 Ω, 10 Ω and 30 Ω is 2.4 A, 1.2 A and 0.4 A respectively. The total current flowing through the circuit is 4 A.

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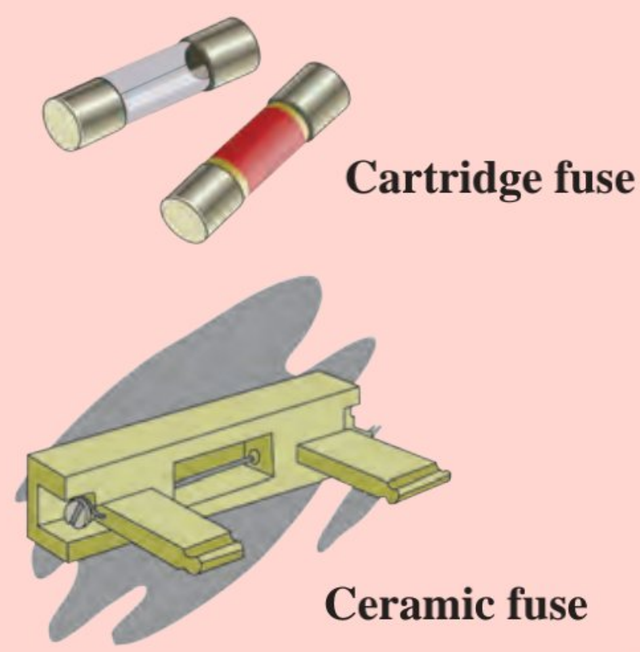
Domestic electrical connections

The electricity in our homes is brought through the main conducting cable either from the electric pole or from underground cables. Usually, there are three wires in the cable. One is called the live wire which brings in the current. It has a red or brown insulation. The other wire is called neutral wire through which the current returns. It is blue or black. In India, the voltage difference between the live and neutral wires is about 220V. Both these wires are connected to the electric meter through a fuse. Through a main switch, they are connected to all the conducting wires inside the home so as to provide electricity to every room. In each separate circuit, various electrical appliances are connected between the live and neutral wires. The different appliances are connected in parallel and the potential difference across every appliance is the same. The third wire is called the earth wire and is of yellow or green colour. This is connected to a metal plate buried deep underground near the house and is for safety purposes.

Fuse wire : Fuse wire is used to protect domestic appliances. It is made of a mixture of substances and has a specific melting point. It is connected in series to the electric appliances. If for some reason, the current in the circuit increases excessively, the fuse wire gets heated up and melts. The circuit gets broken and the flow of current stops, thus protecting the appliance. This wire is fitted in a groove in a body of porcelain - like non-conducting material. For domestic use, fuse wires with upper limits of 1 A, 2 A, 3 A, 4 A, 5 A and 10 A are used.



Precautions to be taken while using electricity

1. Electric switches and sockets should be fitted at a height at which small children cannot reach and put pins or nails inside. Plug wires should not be pulled while removing a plug from its socket.
2. Before cleaning an electrical appliance it should be switched off and its plug removed from the socket.
3. One's hands should be dry while handling an electrical appliance, and, as far as possible, one should use footwear with rubber soles. As rubber is an insulator, it prevents the current from flowing through our body, thereby protecting it.
4. If a person gets an electric shock, you should not touch that person. You should switch off the main switch and if the switch is too far or you do not know where it is located, then you should remove the plug from the socket if possible. If not, then you should use a wooden pole to push the person away from the electric wire.

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Exercises

1. The accompanying figure shows some electrical appliances connected in a circuit in a house. Answer the following questions.

A. By which method are the appliances connected?

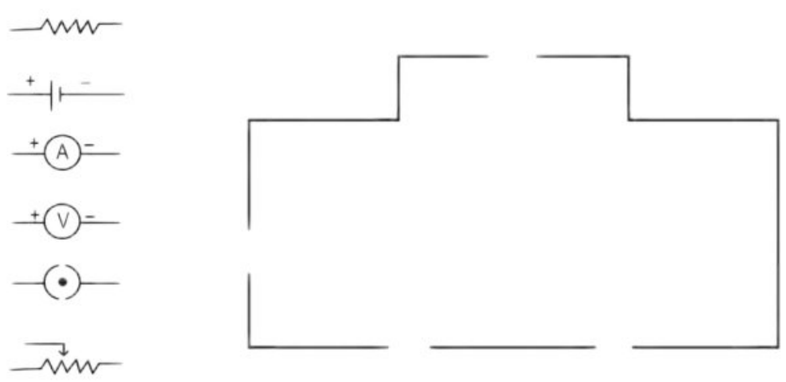
B. What must be the potential difference across individual appliances?

C. Will the current passing through each appliance be the same? Justify your answer.

D. Why are the domestic appliances connected in this way?

E. If the T.V. stops working, will the other appliances also stop working? Explain your answer.

2. The following figure shows the symbols for components used in the accompanying electrical circuit. Place them at proper places and complete the circuit.



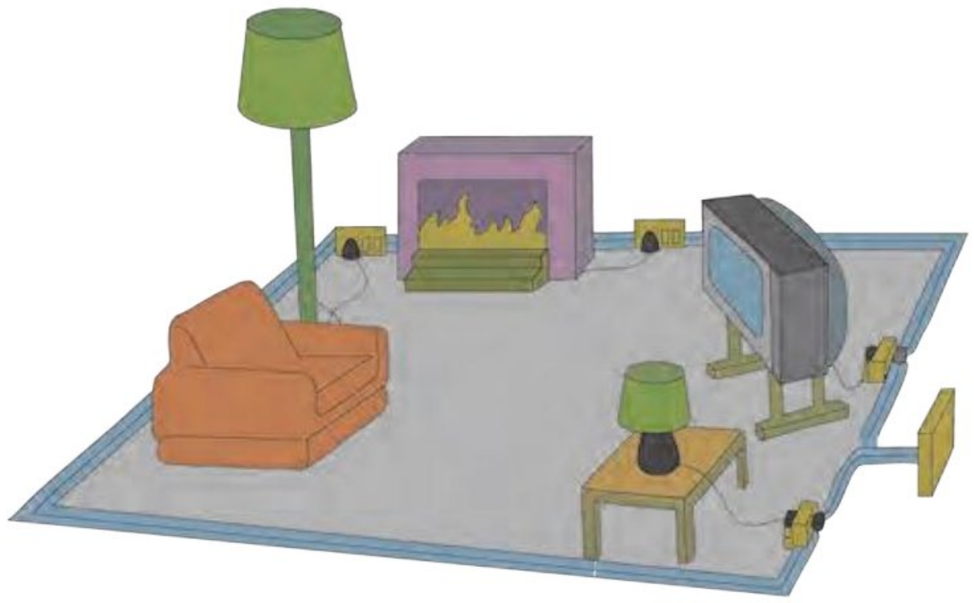
Which law can you prove with the help of the above circuit?

3. Umesh has two bulbs having resistances of 15 Ω and 30 Ω. He wants to connect them in a circuit, but if he connects them one at a time the filament gets burnt. Answer the following.

A. Which method should he use to connect the bulbs?

B. What are the characteristics of this way of connecting the bulbs depending on the answer of A above?

C. What will be the effective resistance in the above circuit?



4. The following table shows current in Amperes and potential difference in Volts.

a. Find the average resistance.

b. What will be the nature of the graph between the current and potential difference? (Do not draw a graph.)

c. Which law will the graph prove? Explain the law.

V (Volts)	I (Amp)
4	9
5	11.25
6	13.5

5. Match the pairs

'A' Group	'B' Group
1. Free electrons	a. V/ R
2. Current	b. Increases the resistance in the circuit
3. Resistivity	c. Weakly attached
4. Resistances in series	d. VA/LI

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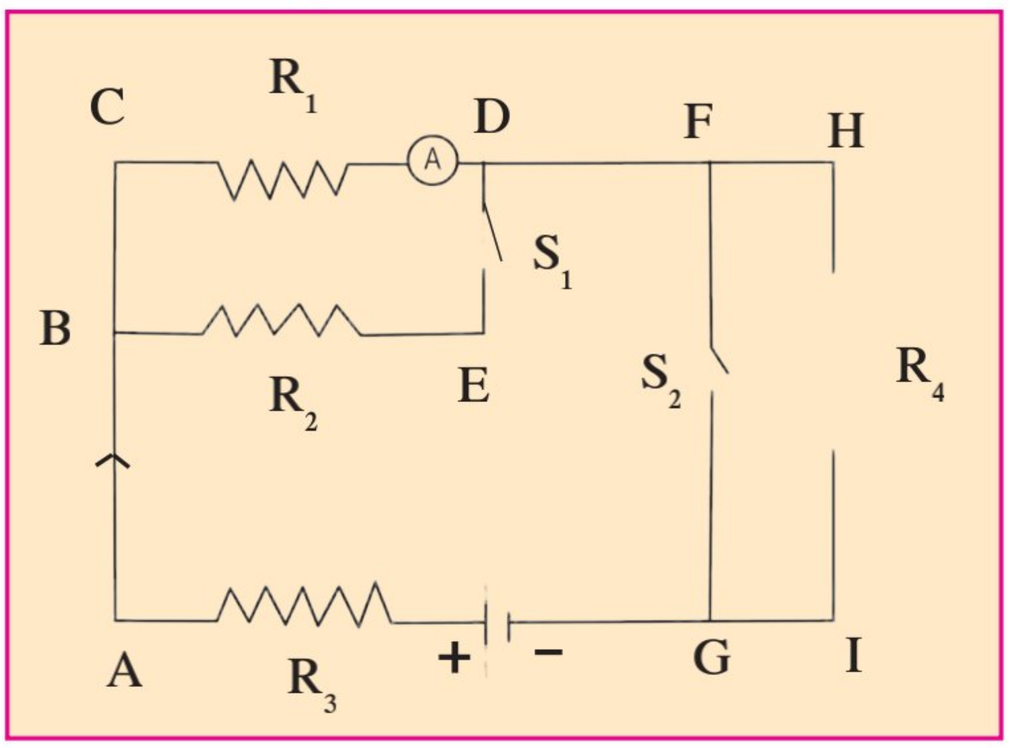
6. **The resistance of a conductor of length x is r. If its area of cross-section is a, what is its resistivity? What is its unit?**

7. **Resistances R_1, R_2, R_3 and R_4 are connected as shown in the figure. S1 and S2 are two keys. Discuss the current flowing in the circuit in the following cases.**



a. Both S_1 and S_2 are closed
b. Both S_1 and S_2 are open
c. S_1 is closed but S_2 is open.

8. **Three resistances x_1, x_2 and x_3 are connected in a circuit in different ways. x is the effective resistance. The properties observed for these different ways of connecting x_1, x_2 and x_3 are given below. Write the way in which they are connected in each case. (I-current, V-potential difference, x-effective resistance)**

a Current I flows through x_1, x_2 and x_3

b x is larger than x_1, x_2 and x_3

c x is smaller than x_1, x_2 and x_3

d The potential difference across x_1, x_2 and x_3 is the same

e $x = x_1 + x_2 + x_3$

f $x = \dfrac{1}{\dfrac{1}{x_1} + \dfrac{1}{x_2} + \dfrac{1}{x_3}}$

9. **Solve the following problems.**

A. The resistance of a 1m long nichrome wire is 6 Ω. If we reduce the length of the wire to 70 cm. what will its resistance be?

(Answer : 4.2 Ω)

B. When two resistors are connected in series, their effective resistance is 80 Ω. When they are connected in parallel, their effective resistance is 20 Ω. What are the values of the two resistances?

(Answer : 40 Ω , 40 Ω)

C. If a charge of 420 C flows through a conducting wire in 5 minutes what is the value of the current?

(Answer : 1.4 A)

Project :

Ask an electrician to explain to you the electrical wiring in your house and other related important points. Take care to understand them well, and explain them to others also.

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4. Measurement of Matter

- Laws of chemical combination
- Atom - shape, mass, valency
- Molecular mass and the concept of mole
- Radicals

Can you recall?

1. What is the Dalton's atomic theory ?
2. How are the compounds formed ?
3. What are the molecular formulae of salt, slaked lime, water, lime, limestone ?

In the previous standard we have learnt that compounds are formed by chemical combination of elements. We have also learnt that an important principle of Dalton's atomic theory is that molecules of a compound are formed by joining atoms of different elements.

Laws of chemical combination

The composition of a substance changes during a chemical change. The fundamental experiments is this regard were performed by scientists in the 18th and 19th century. While doing this, they measured accurately, the substances used and formed. The scientists Dalton, Thomson and Rutherford studied the structure of substances and the atom and thus discovered the laws of chemical combination. Scientists could then write the molecular formulae of various compounds on the basis of Dalton's atomic theory and the laws of chemical combination. Here we shall verify the laws of chemical combination by means of known molecular formulae.

Try this

Apparatus : Conical flask, test tubes, balance, etc.
Chemicals : Calcium chloride ($CaCl_2$), sodium sulphate (Na_2SO_4), calcium oxide (CaO), Water (H_2O)

Activity 1

- Take 56 g calcium oxide in a large conical flask and put 18 g water in it.
- Observe what happens.
- Measure the mass of the substance formed.
- What similarity do you find? Write your inference.

Activity 2

- Take a solution of calcium chloride in a conical flask and a solution of sodium sulphate in a test tube.
- Tie a thread to the test tube and insert it in the conical flask.
- Seal the conical flask with an airtight rubber cork.
- Weigh the conical flask using a balance.
- Now tilt the conical flask so that the solution in the test tube gets poured in the conical flask.
- Now weigh the conical flask again.

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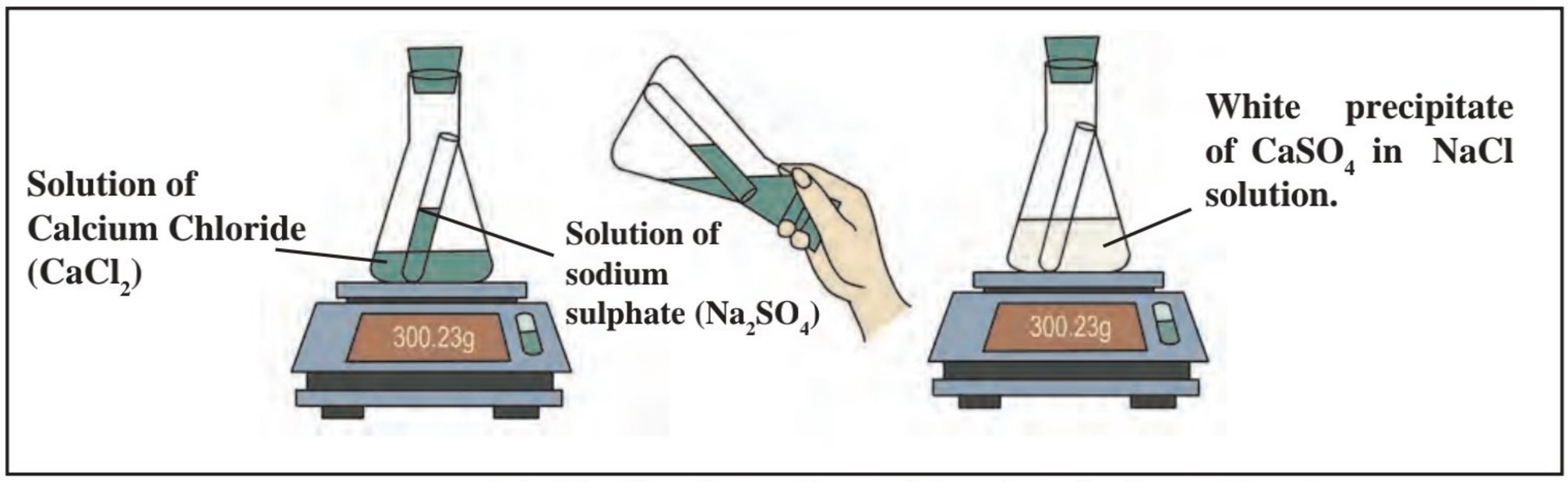

4.1 Verification of law of the chemical combination

Law of conservation of matter

In the above activities, the mass of the original matter and the mass of the matter newly formed as a result of the chemical change are equal. In 1785, the French Scientist Antoine Lavoisier inferred from his research that 'there is no rise or drop in the weight of the matter during a chemical reaction.' In a chemical reaction the total weight of the **reactants** is same as the total weight of the **products** formed due to the chemical reactions and this is called the law of conservation of matter.

Law of constant proportion

In 1794 the French scientist J. L. Proust stated the law of constant proportions as "The proportion by weight of the constituent elements in the various samples of a compound is fixed," e.g., the proportion by weight of hydrogen and oxygen in water is 1:8. This means that 9 g water is formed by chemical combination of 1 g hydrogen and 8 g oxygen. Similarly, the proportion by weight of carbon and oxygen in carbon dioxide is 3:8. For example, in 44 g of carbondioxide there is 12 g of carbon and 32 g oxygen so that the proportion by weight of carbon and oxygen is 3:8.

Proust

Lavoisier

An introduction to scientists

Antoine Lavoisier (1743-94)

French scientist, father of modern chemistry, substantial contribution in the fields of chemistry, biology and economics.

- Nomenclature of oxygen and hydrogen.
- Showed that matter combines with oxygen during combustion.
- Was the first to use accurate weighing techniques to weigh reactants and products in a chemical reaction.
- Discovered that water is made up of hydrogen and oxygen.
- Assigned systematic names to the compounds, e.g. sulphuric acid, sulphate, sulphite.
- Author of the first book on modern chemistry.
- Studied the elements such as oxygen, hydrogen, nitrogen, phosphorus, mercury, zinc and sulphur.
- First writer of the law of conservation of mass, in a chemical reaction.

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Verification of the law of constant proportion

Many compounds can be made by different methods. For example, two samples of the compound copper oxide, CuO, were obtained, one by decomposition of copper carbonate, $CuCO_3$, and another by decomposition of copper nitrate, $Cu(NO_3)_2$. From each of these samples, a mass of 8g of copper oxide was taken and each was treated independently with hydrogen gas. Both gave 6.4 g copper and 1.8 g water. Let us see how this is a verification of the law of constant proportion.

The reaction of copper oxide with hydrogen yielded two known substances, namely, the compound water and the element copper. It is known that, in the compound water, H_2O, the elements H and O are in the proportion 1:8 by weight. This means that in 9g water there are 8g of the element oxygen. Therefore, 1.8g water contains (8x1.8/9 = 1.6)g oxygen. This oxygen has come from 8g copper oxide. It means that 8g of both the samples of copper oxide contained 6.4g copper and 1.6g oxygen; and the proportion by weight of copper and oxygen in it is 6.4:1.6, that is, 4:1. Thus, the experiment showed that the proportion by weight of the constituent elements in different samples of a compound is constant.

Now let us see what the expected proportion by weight of the constituent elements of copper oxide would be from its known molecular formula CuO. To find out this, we need to use the known atomic masses of the elements. The atomic masses of Cu and O are 63.5 and 16 respectively. This means that the proportion by weight of the constituent elements Cu and O in the compound CuO is 63.5 : 16 which is 3.968:1, or approximately 4:1.

The experimental value of proportion by weight of the constituent elements matched with the expected proportion calculated from the molecular formula. Thus, the law of constant proportion is verified.

Atom : size, mass and valency

Can you recall?

1. From which experiments was it discovered that atoms have an internal structure? When?
2. What are the two parts of an atom? What are they made up of?

We have learnt that at the centre of an atom is the nucleus and that there are moving electrons in the extra-nuclear part. The electrons are negatively charged elementary particles while the elementary particles that make up the nucleus are positively charged protons and electrically neutral neutrons. Look at the image of an atom obtained with a field ion microscope.

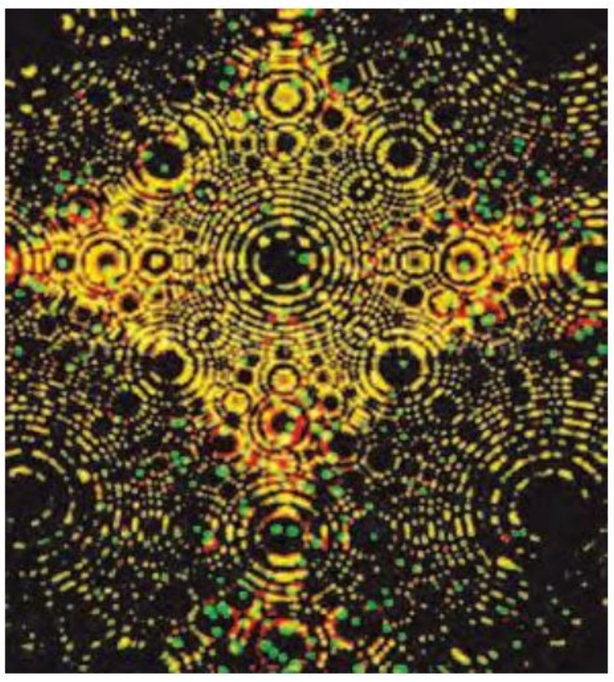
The size of an atom is determined by its radius. The atomic radius of an isolated atom is the distance between the nucleus of an atom and its outermost orbit. Atomic radius is expressed in nanometres..

$$\frac{1}{10^9}\ m = 1nm$$

$$1m = 10^9\ nm.$$

Approximate size of atom

Atomic radius (in metres)	Example
10^{-10}	Hydrogen atom
10^{-9}	Water molecule
10^{-8}	Haemoglobin molecule



4.2 Field ion microscope image of iridium atoms (every spot in this image is an atom)

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Atoms are very very tiny. Modern instruments like the electron microscope, field ion microscope, scanning tunneling microscope have the capacity to show enlarged images of the atom.

The atomic size depends on the number of electron orbits in the atom. The greater the number of orbits the larger the size. For example, an atom of K is bigger than an atom of Na. If two atoms have the same outermost orbit, then the atom having the larger number of electrons in the outermost orbit is smaller than the one having fewer electrons in the same outermost orbit. For example an atom of Mg is smaller than an atom of Na.

The mass of an atom

The mass of an atom is concentrated in its nucleus and it is due to the protons (p) and neutrons (n) in it. The number (p+n) in the atomic nucleus is called the **atomic mass number**. Protons and neutrons are together called **nucleons**.

An atom is very very tiny. Then how do we determine its mass? Scientists too, struggled with this question. It was not possible for scientists of the 19th century to measure atomic mass accurately. Therefore, the concept of 'relative mass of an atom' was put forth. A reference atom was required for expressing the relative mass of an atom. The hydrogen atom being the lightest was initially chosen as the reference atom. The relative mass of a hydrogen atom which has only one proton in its nucleus was accepted as one (1). Therefore, the magnitude of the relative atomic masses of various atoms became equal to their atomic mass number (p+n).

Let us see how to express the relative mass of a nitrogen atom, having accepted the relative atomic mass of hydrogen as 1.

The mass of one nitrogen atom is fourteen (14) times that of a hydrogen atom. Therefore, the relative mass of a nitrogen atom is 14. This is how the relative atomic masses of various elements were determined. On this scale, the relative atomic masses of many elements came out to be fractional. Therefore, in the course of time, different atoms were chosen as reference atoms. Finally in 1961, the carbon atom was selected as the reference atom. In this scale, the relative mass a carbon atom was accepted as 12. The relative atomic mass of one hydrogen atom compared to the carbon atom becomes 12 x 1/12, that is 1. The mass of one proton and of one neutron on the scale of relative atomic masses is approximately one.

Research

The relative atomic masses of some elements in the chart below are given. You have to find the relative atomic masses of the others.

Element	Atomic mass	Element	Atomic mass	Element	Atomic mass
Hydrogen	1	Oxygen	-	Phosphorus	-
Helium	4	Fluorine	19	Sulphur	32
Lithium	7	Neon	20	Chlorine	35.5
Beryllium	9	Sodium	-	Argon	-
Boron	11	Magnesium	24	Potassium	-
Carbon	12	Aluminium	-	Calcium	40
Nitrogen	14	Silicon	28		

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Today, we have highly accurate methods for measuring the mass of an atom directly. Hence, instead of relative mass, Unified Mass has now been accepted as the unit of atomic mass. It is called Dalton. Its symbol is 'u'. $1u = 1\ 66053904 \times 10^{-27}$ kg

Chemical symbols of elements

Can you tell?

1. How is an element indicated in Chemistry?
2. Write down the symbols of the elements you know.
3. Write down the symbols for the following elements : antimony, iron, gold, silver, mercury, lead, sodium.

Dalton used certain signs represent elements. For example ⊙ for hydrogen, © for copper. Today we use the symbols determined by IUPAC (International Union of Pure and Applied Chemistry). These are offical names and symbols and are used all over the world. The current method of choosing chemical symbols is based on the method invented by Berzelius. According to this method the symbol of an element is either the first letter or the first and second/another specific letter in its name. Of the two letters, the first is a capital letter and the second is small.

Molecules of elements and compounds

Atoms of some elements such as helium, neon have independent existence. It means that these elements are in a mono-atomic molecular state. Sometimes, two or more atoms of an element combine to form molecules of that element. Such elements are in a poly-atomic molecular state. For example, the elements oxygen, nitrogen are in a diatomic molecular state as O_2, N_2 respectively. When atoms of different elements combine with each other, the molecules of compounds are formed. In other words, compounds are formed by chemical attraction between different elements.

Make a list and discuss

Make a list of elements in the mono-atomic and in the diatomic molecular state.

Molecular mass and the concept of mole

Molecular mass

The molecular mass of a substance is the sum of the atomic masses of all the atoms in a single molecule of that subtance. Like atomic mass, molecular mass is also expressed in the unit Dalton (u).

How to deduce the molecular mass of H_2O ?

Molecule	Constituent elements	Atomic mass u	Number of atoms in the molecule	Atomic mass × number of atoms	Mass of the constituents u
H_2O	Hydrogen	1	2	1 × 2	2
	Oxygen	16	1	16 × 1	16
Molecular mass = sum of constituent atomic masses (Molecular mass of H_2O) = (Atomic mass of H) × 2 + (Atomic mass of O) × 1					Molecular Mass 18

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Use your brain power !

Following are atomic masses of a few elements in Daltons and the molecular formulae of some compounds. Deduce the molecular masses of those compounds.

Atomic masses → H(1), O(16), N(14), C(12), K(39), S(32) Ca(40), Na(23), Cl(35 5), Mg(24), Al(27)

Molecular formulae → $NaCl$, $MgCl_2$, KNO_3, H_2O_2, $AlCl_3$, $Ca(OH)_2$, MgO, H_2SO_4, HNO_3, $NaOH$

Mole

Try this

1. Weigh single grains of *tur dal, masoor dal* and *chana dal* on a balance. What was your experience?
2. Weigh 10g of *tur dal, masoor dal* and *chana dal* each and count the number of *dal* grains of each kind in the weighed portions. Is the number the same in each portion, or different?
3. Draw a line sketch on a paper. Paint it by placing/pasting the dal grains in the sequence Tur, Masoor and Bengal gram. You will need equal number of *dal*-grains of the three kinds. Count that number and therefrom deduce the number of grams of *tur dal, masoor dal* and *chana dal* required for painting the picture. Also find out how many dozens of the respective dal-grains were required.
4. What inference will you draw about the weights of an equal number of its different *dal* grains and the number of its *dal* grains in equal weights of different *dals*?

Think about it

How much of wheat, jowar and bajra seed is required for sowing one acre of land? Can these weights be correlated to the number of grains of the respective cereals they contain?

Can you tell?

1. Is it possible to weigh one molecule using a weighing balance?
2. Will the number of molecules be the same in equal weights of different substances?
3. If we want equal numbers of molecules of different substances, will it work to take equal weights those substances?

When elements and compounds take part in chemical reactions, it is their atoms and molecules that react with each other, and therefore it is necessary to know the numbers of their atoms and molecules. However, while carrying out a chemical reaction it, is convenient to measure out quantities that can be handled instead of counting the numbers of atoms and molecules. The concept of 'mole' is useful for this purpose.

A mole is that quantity of a substance whose mass in grams is equal in magnitude to the molecular mass of that substance in Daltons. Thus, the molecular mass of oxygen is 32u, and therefore 32g oxygen is 1mole of oxygen. The molecular mass of water is 18u. Therefore, 18g of water make 1 mole of water.

1 mole of a compound is the mass of that subtance in grams equal in magnitude to its molecular mass. The SI unit is mol.

$$\text{Number of moles of a substances (n)} = \frac{\text{Mass of subtance in grams}}{\text{Molecular mass of substance}}$$

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Avogadro's number

The number of molecules in one mole of any substance is constant. The Italian scientist Avogadro did pioneering work in this context. Therefore this number is called Avogadro's number and is denoted by the symbol N_A. Later scientists demonstrated experimentally that the value of Avogadro's number is 6.022×10^{23}. A mole of any substance stands for 6.022×10^{23} molecules. Just as a dozen has 12 items, a century has 100 or a gross has 144, a mole means 6.022×10^{23}. For example, a mole of water, that is, 18g of water contains 6.022×10^{23} molecules of water.

How many molecules are there in 66 g of CO_2 ?

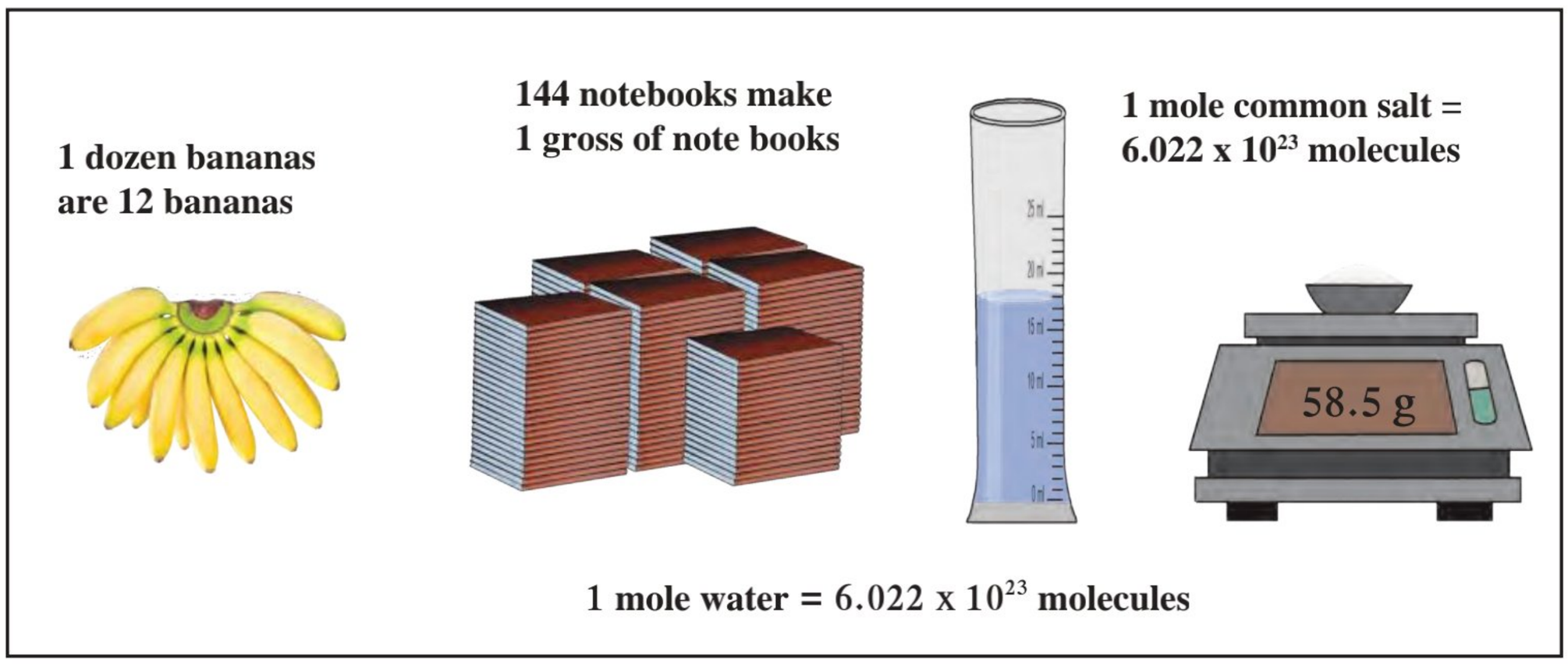
Method : molecular mass of CO_2 is 44.

$$\text{Number of moles in the given } CO_2 \text{ (n)} = \frac{\text{Mass of } CO_2 \text{ in grams}}{\text{Molecular mass of } CO_2} = \frac{66}{44}$$

$\therefore$ n = 1.5 mol

$\therefore$ 1 mol of CO_2 contains 6.022×10^{23} molecules.

$\therefore$ 1.5 mol CO_2 contains $1.5 \times 6.022 \times 10^{23}$ molecules = 9.033×10^{23} molecules



4.3 One mole (Avogadro's number)

Use your brain power !

1. How many molecules of water are there in 36g water?
2. How many molecules of H_2SO_4 are there in a 49g sample ?

Always remember

1. The number of molecules in a given quantity of a substance is determined by its molecular mass.
2. The number of molecules in equal masses of different substances is different.
3. One mole quantities of different substances have different masses measured in grams.

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Valency

Can you recall?

1. Determine the valencies of H, Cl, O and Na from the molecular formulae H_2, HCl, H_2O and NaCl.
2. What is the type of chemical bond in NaCl and $MgCl_2$?

The capacity of an element to combine is called its valency. The valency of an element is indicated by a specific number. It is the number of chemical bonds formed by one atom of that element with other atoms. In the 18th and 19th century, the laws of chemical combination were used to find out the valencies of elements. In 20th century, the relationship of the valency of an element with its electronic configuration was recognised.

Sodium atom (Na) Electron configuration (2,8,1) $\xrightarrow{-1e^-}$ Sodium ion Na^+ (2,8)

Chlorine atom (Cl) Electron configuration (2,8,7) $\xrightarrow{+1e^-}$ Chloride ion Cl^- (2,8,8)

$Na^+ + Cl^- \longrightarrow$ NaCl (sodium chloride)

A sodium atom gives away $1e^-$ and a cation of sodium is formed, hence, the valency of sodium is one. A chlorine atom takes up $1e^-$ and forms an anion of chlorine (chloride), and thus, the valency of chlorine is one. After the give and take of electrons is over, the electronic configuration of both the resulting ions has a complete octet. Due to the attraction between the unit but opposite charges on the two ions, one chemical bond is formed between Na^+ and Cl^- and the compound NaCl is formed.

Thus, a sodium atom has the capacity to give away $1e^-$ while a chlorine atom has the capacity to take up $1e^-$. This means that the valency of both the elements sodium and chlorine is one. From this the electronic definition of valency is as follows : "The number of electrons that an atom of an element gives away or takes up while forming an ionic bond, is called the valency of that element."

Science capsule

Positively charged ions are called **cations** while negatively charged ions are called **anions**. For example, $MgCl_2$ contains Mg^{++} and Cl^- as cation and anion respectively. The electrons present in the outermost orbit of an atom are called valence electrons.

Use your brain power !

How will the compounds, $MgCl_2$ and CaO be formed their elements?

The number of electrons that are given away or taken up is always a whole number. Therefore, valency is always a whole number.

The National Chemical Laboratory (NCL), a unit of the CSIR, was established in 1950. Its objectives are to conduct research in the various branches of chemistry, to aid industry and to develop new technology with a view to making profitable use of the country's natural resources. The Laboratory conducts research in fields such as biotechnology, nonotechnology and polymer science.

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Complete the following chart.

Element	Atomic number	Electron configu-ration	Valence elec-trons	Valen-cy
Hydrogen	1	1	1	1
Helium	2	2	2	0
Lithium	……	2,1	…..	……
Beryllium	4	…….	…….	2
Boron	5	2,3	……	…….
Carbon	…….	2,4	4	…….
Nitrogen	7	……..	……..	3
Oxygen	…..	2,6	6	……..
Fluorine	9	……	7	…….
Neon	0	…….	……	……..
Sodium	……	2,8,1	1	1
Magnesium	12	……	2	……
Aluminium	13	2,8,3	……	……
Silicon	14	……	4	…….

Variable valency

Under different conditions the atoms of some elements give away or take up different numbers of electrons. In such cases those elements exhibit more than one valency. This property of elements is called variable valency.

Some elements that exhibit variable valency

Element	Symbol	Valency	Ion	Nomenclature
Copper	Cu	1 and 2	Cu^{+} Cu^{2+}	Cuprous Cupric
Mercury	Hg	1 and 2	Hg^{+} Hg^{2+}	Mercurous Mercuric
Iron	Fe	2 and 3	Fe^{2+} Fe^{3+}	Ferrous Ferric

Always remember

Iron (Fe) exhibits the variable valencies 2 and 3. Therefore iron forms two compounds with chlorine $FeCl_2$ and $FeCl_3$.

Research

1. Find out some more elements which have variable valency.
2. Find out the compounds of the above elements which have variable valency.

Radicals

Complete the table

Write down the cations and anions obtained from the compounds in the following chart.

Base	Cation	Anion	Acid	Cation	Anion
NaOH			HCl		
KOH			HBr		
$Ca(OH)_2$			HNO_3		

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Compounds with ionic bonds have two constituents. These are a cation (positively charged ion) and anion (negatively charged ion).They take part independently in chemical reactions, and are therefore, called radicals. It is seen from the above chart that different bases such as NaOH, KOH are formed when various cationic radicals are paired with the anionic radical, hydroxide. Hence the cationic radicals are also called basic radicals. Different bases are distinguished from each other by the basic radicals in them. On the other hand, different acids, such as HCl, HBr are formed when various anionic radicals are paired with the cationic radical H^+. Therefore, the anionic radicals are called acidic radicals. The difference in the composition of various acids becomes clear by the acidic radicals in them.

Can you tell?

Which are the basic radicals and which are the acidic radicals among the following?

Ag^+, Cu^{2+}, Cl^-, I^-, SO_4^{2-}, Fe^{3+}, Ca^{2+}, NO_3^-, S^{2-}, NH_4^+, K^+, MnO_4^-, Na^+

Generally, basic radicals are formed by removal of electrons from the atoms of metals, such as Na^+, Cu^{2+}. But there are some exceptions, such as NH_4^+. Similarly, the acidic radicals are formed by adding electrons to the atoms of non-metals, such as Cl^-, S^{2-}. But there are some exceptions like MnO_4^-

Use your brain power !

Classify the following radicals into two types. While doing this use a criterion other than the criteria used above.

Ag^+, Mg^{2+}, Cl^-, SO_4^{2-}, Fe^{2+}, ClO_3^-, NH_4^+, Br^-, NO_3^-

Monoatomic radicals such as Na^+, Cu^+, Cl^- are called simple radicals. When a radical is a group of atoms carrying charge, such as SO_4^{2-}, NH_4^+, it is called composite radical. The magnitude of charge on any radical is its valency.

Chemical formulae of compounds : recapitulation.

The characteristics of a compound formed by ionic bonds is that its molecule has two parts. These are a cation and an anion, that is, a basic radical and an acidic radical. These two parts are oppositely charged. The force of attraction between them constitutes the ionic bond. The name of an ionic compound has two words. The first word is the name of the cation and the second is the name of the anion. For example, while writing the formula of a compound such as sodium chloride the symbol of the cation is written on the left and adjoined to it on the right is the symbol of the anion. The charges are not shown though the number of the ions is written as a subscript on the right of the symbol of the ion. This number is obtained easily by the method of cross multiplication of the valencies. The steps for writing a chemical formula are shown on the next page.

Using ICT

To study 'Measurement of Matter' further and for additional information, visit the websites given alongside.

Prepare a spreadsheet showing the atomic mass of elements, molecular masses, electronic configurations and valencies.

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Step 1 : To write the symbols of the radicals. (Basic radical on the left.)

Na SO_4

Step 2 : To write the valency below the respective radical.

Na SO_4

1 2

Step 3 : To cross-multiply as shown by the arrows the number of the radicals.

Na SO_4

1 2

Step 4 : To write down the chemical formula of the compound.

Na_2SO_4

In order to write the chemical formulae of compounds, it is necessary to know the valency of the various radicals. The names and symbols along with the charge of common radicals are given in the chart below.

Ions/Radicals

Basic Radicals				Acidic Radicals			
H^+	Hydrogen	Al^{3+}	Aluminium	H^-	Hydride	MnO_4^-	Permanganate
Na^+	Sodium	Cr^{3+}	Chromium	F^-	Fluoride	ClO_3^-	Chlorate
K^+	Potassium	Fe^{3+}	Ferric	Cl^-	Chloride	BrO_3^-	Bromate
Ag^+	Silver	Au^{3+}	Gold	Br^-	Bromide	IO_3^-	Iodate
Cu^+	Cuprous	Sn^{4+}	Stannic	I^-	Iodide	CO_3^{2-}	Carbonate
Hg^+	Mercurous	NH_4^+	Ammonium	O^{2-}	Oxide	SO_4^{2-}	Sulphate
Cu^{2+}	Cupric/Copper			S^{2-}	Sulphide	SO_3^{2-}	Sulphite
Mg^{2+}	Magnesium			N^{3-}	Nitride	CrO_4^{2-}	Chromate
Ca^{2+}	Calcium					$Cr_2O_7^{2-}$	Dichromate
Ni^{2+}	Nickel			OH^-	Hydroxide	PO_4^{3-}	Phosphate
Co^{2+}	Cobalt			NO_3^-	Nitrate		
Hg^{2+}	Mercuric			NO_2^-	Nitrite		
Mn^{2+}	Manganese			HCO_3^-	Bicarbonate		
Fe^{2+}	Ferrous (Iron II)			HSO_4^-	Bisulphate		
Sn^{2+}	Stannous			HSO_3^-	Bisulphite		
Pt^{2+}	Platinum						

Books are my friends

Essentials of Chemistry, The Encylopedia of Chemistry, Science and Technology Dictionary.

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Use your brain power !

Using the chart of ions/radicals and the cross-multiplication method, write the chemical formulae of the following compounds : Calcium carbonate, Sodium bicarbonate, Silver chloride, Calcium hydroxide, Magnesium oxide, Ammonium phosphate, Cuprous bromide, Copper sulphate, Potassium nitrate, Sodium dichromate

Exercises

1. Give examples.

a. Positive radicals
b. Basic radicals
c. Composite radicals
d. Metals with variable valency
e. Bivalent acidic radicals
f. Trivalent basic radicals

2. Write symbols of the following elements and the radicals obtained from them, and indicate the charge on the radicals.

Mercury, potassium, nitrogen, copper, sulphur, carbon, chlorine, oxygen

3. Write the steps in deducing the chemical formulae of the following compounds.

Sodium sulphate, potassium nitrate, ferric phosphate, calcium oxide, aluminium hydroxide

4. Write answers to the following questions and explain your answers.

a. Explain how the element sodium is monovalent.
b. M is a bivalent metal. Write down the steps to find the chemical formulae of its compounds formed with the radicals, sulphate and phosphate
c. Explain the need for a reference atom for atomic mass. Give some information about two reference atoms.
d. What is meant by Unified Atomic Mass.'
e. Explain with examples what is meant by a 'mole' of a substance.

5. Write the names of the following compounds and deduce their molecular masses.

Na_2SO_4, K_2CO_3, CO_2, $MgCl_2$, NaOH, $AlPO_4$, $NaHCO_3$

6. Two samples 'm' and 'n' of slaked lime were obtained from two different reactions. The details about their composition are as follows:

'sample m' mass : 7g
Mass of constituent oxygen : 2g
Mass of constituent calcium : 5g
'sample n' mass : 1.4g
Mass of constituent oxygen : 0.4g
Mass of constituent calcium : 1.0g

Which law of chemical combination does this prove? Explain.

7. Deduce the number of molecules of the following compounds in the given quantities.

32g oxygen, 90g water, 8.8g carbon di oxide, 7.1g chlorine.

8. If 0.2 mol of the following substances are required how many grams of those substances should be taken?

Sodium chloride, magnesium oxide, calcium carbonate

Project :

Prepare models of various radicals using cardboard, small circular magnets and araldite. From these make molecules of various compounds.

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5. Acids, Bases and Salts

- Arrhenius theory of acids and bases
- Concentration of an acid or a base
- pH of a solution
- pH of an acid and a base
- Salts

Can you recall?

How are the following substances classified into three groups with the help of litmus? Lemon, tamarind, baking soda, buttermilk, vinegar, orange, milk, lime, tomato, milk of magnesia, water, alum.

We have earlier seen that some foodstuffs are sour to taste while some others are bitter and slippery or soapy to touch. When these substances are studied scientifically, it is found that they contain acidic and basic substances respectively. We have also learnt an easy and safe method of using an indicator like litmus to identify acids and bases.

How are acids and alkalies identified with the help of litmus paper?

We shall now learn more about acids and bases. But let us first review what the molecules of compounds are made up of?

Fill in the columns in the part a of the following table.

A				B
Name of the compound	**Molecular formula**	**Basic radical**	**Acidic radical**	**Type of the compound**
Hydrochloric acid	HCl	H^+	Cl^-	Acid
	HNO_3			
	HBr			
	H_2SO_4			
	H_3BO_3			
	$NaOH$			
	KOH			
	$Ca(OH)_2$			
	NH_4OH			
	$NaCl$			
	$Ca(NO_3)_2$			
	K_2SO_4			
	$CaCl_2$			
	$(NH_4)_2SO_4$			

Some compounds are seen to have H^+ as the basic radical in their molecules. These are all acids. Some compounds are seen to have OH^- as the acidic radical in their molecule. All these compounds are bases. Those ionic compounds which have a basic radical other than H^+ and an acidic radical other than OH^- are called salts.

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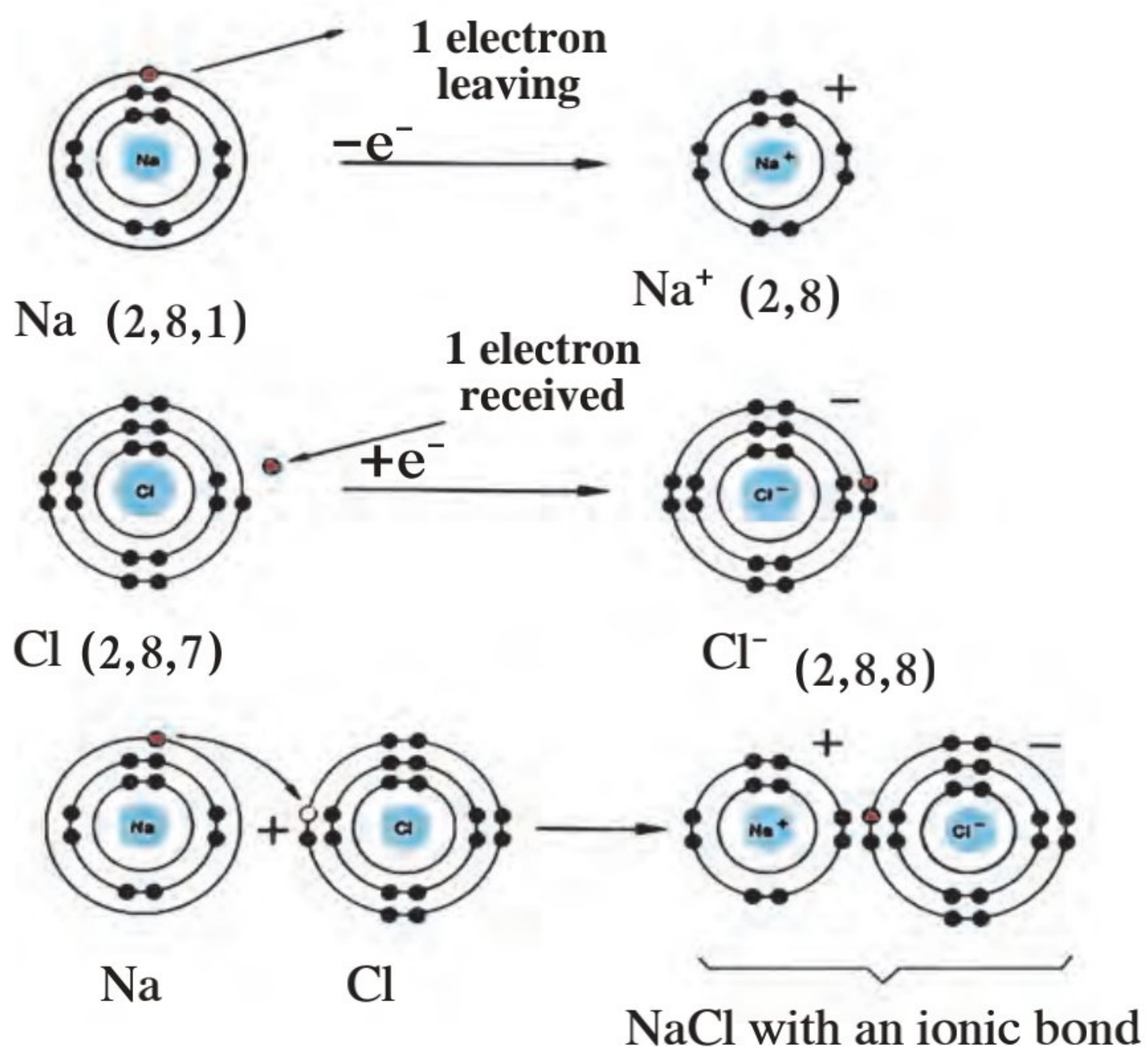
Now complete part B of the above table. It will be clear that there are three types of ionic compounds and these are acids, bases and salts.

Ionic compounds : recapitulation

The molecule of an ionic compound has two constituents, namely, cation (postive ion/ basic radical) and anion (negative ion /acidic radical). There is a force of attraction between these ions as they are oppositely charged, and that is called the ionic bond. The force of attraction between one positive charge on a cation and one negative charge on an anion makes one ionic bond.



5.1 Formation of the compound NaCl
Electron configuration

While studying static electricity we have learnt that there is a natural tendency of any body to change from an electrically charged state into an electrically neutral state. Why, then, is an electrically charged ion formed from an electrically balanced, that is, neutral atom? The explanation lies in the electronic configuration of atoms. Let us see once again how the sodium and chlorine atoms form the Na^+ and Cl^- and as a result, how the NaCl salt is fomed. Figure 5.1 shows how this takes place.

The outermost shell of the sodium and the chlorine atoms is not a complete octet. However outermost shell in both the Na^+ and Cl^- ions is a complete octet.

An electronic configuration with a complete octet indicates a stable state. Further, an ionic bond is formed between the oppositely charged Na^+ and Cl^- ions and therefore an ionic compound NaCl having very high stability is formed.

Dissociation of ionic compounds

On mixing the substances as shown here, what are the resulting mixtures formed by mixing the following subtances called?

Can you recall?

1. Water and salt
2. Water and sugar
3. Water and sand
4. Water and sawdust

On dissolving in water, an ionic compound forms an aqueous solution. In the solid state, the oppositely charged ions in the ionic compound are sitting side by side. When an ionic compound begins to dissolve in water, the water molecules push themselves in between the ions of the compound and separate them from each other. That is to say, an ionic compound dissociates while forming an aqueous solution. (See figure 5.2)

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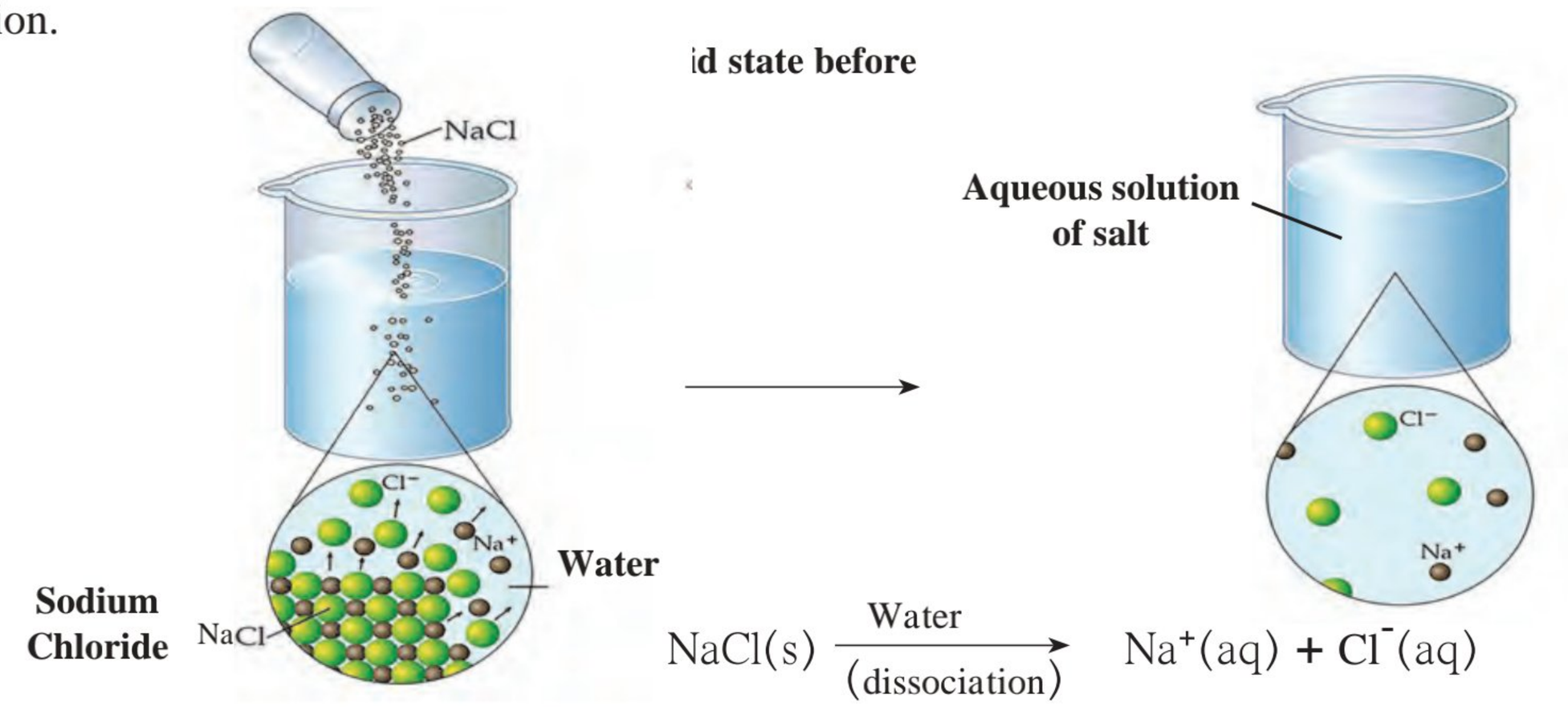
Each of the dissociated ions in the aqueous solution is surrounded by water molecules. This state is indicated by writing (aq), meaning aqueous, on the right of the symbol of the ion.



5.2 Dissociation of salt in aqueous solution

Arrhenius theory of acids and bases

The Swedish scientist Arrhenius put forth a theory of Acids and Bases in the year 1887. This theory gives definitions of acids and bases as follows :

Acid : An acid is a substance which on dissolving in water gives rise to H^+ ion as the only cation. For example, HCl, H_2SO_4, H_2CO_3.

$$HCl\,(g) \xrightarrow[\text{(dissociation)}]{\text{water}} H^+(aq) + Cl^-(aq)$$

$$H_2SO_4\,(l) \xrightarrow[\text{(dissociation)}]{\text{water}} H^+(aq) + HSO_4^-(aq)$$

$$HSO_4^-(aq) \xrightarrow{\text{(dissociation)}} H^+(aq) + SO_4^{2-}(aq)$$

Use your brain power !

1. What are the names of the following compounds? NH_3, Na_2O, CaO.
2. When the above compounds are mixed with water they combine with water. Complete the following table by writing the ions formed by their combination with water.
3. Into which type will you classify the above compounds- acid, base or salt ?

$NH_3\,(g) + H_2O(l)$	$\longrightarrow$	$NH_4^+\,(aq) + OH^-(aq)$
$Na_2O(s)$ + ...	$\longrightarrow$	$2\,Na^+(aq)$ + ...
$CaO(s) + H_2O(l)$	$\longrightarrow$	..... + ...

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Base : A base is a substance which on dissolving in water gives rise to the OH^- ion as the only anion. For example, NaOH, $Ca(OH)_2$

$$NaOH\ (s) \xrightarrow[\text{(dissociation)}]{\text{water}} Na^+(aq) + OH^-(aq)$$

$$Ca(OH)_2\ (s) \xrightarrow[\text{(dissociation)}]{\text{water}} Ca^{2+}(aq) + 2OH^-(aq)$$

Classification of acids and bases

1. Strong and weak acids, bases and alkali

1. Acids and bases are classified into strong and weak types on the basis of the extent to which they dissociate in their aqueous solutions.

Strong acid : On dissolving in water, a strong acid dissociates almost completely and the resulting aqueous solution contains mainly H^+ ions and the concerned acidic radical. For example, HCl, HBr, HNO_3, H_2SO_4.

Weak acid : On dissolving in water a weak acid does not dissociate completely, and the resulting aqueous solution contains H^+ ion and the concerned acidic radical in small proportion along with large proportion of the undissociated molecules of the acid. For example, H_2CO_3, CH_3COOH (Acetic Acid).

Strong base : On dissolving in water, a strong base dissociates almost completely and the resulting aqueous solution contains mainly OH^- ions and the concerned basic radicals. For example, NaOH, KOH, $Ca(OH)_2$, Na_2O.

Weak base : On dissolving in water a weak base does not dissociate completely, and the resulting aqueous solution contains a small proportion of OH^- ions and the concerned basic radical along with a large proportion of undissociated molecules of the base. For example, NH_4OH.

Alkali : The bases which are highly soluble in water are called alkali. For example, NaOH, KOH, NH_3. Here, NaOH and KOH are strong alkalies while NH_3 is a weak alkali.

2. Basicity and acidity

Complete the following table.

Acid : Number of H^+ obtained from one molecule.						
HCl	HNO_3	H_2SO_4	H_2CO_3	H_3BO_3	H_3PO_4	CH_3COOH
Base : Number of OH^- ions obtained from one molecule						
NaOH	KOH	$Ca(OH)_2$	$Ba(OH)_2$	$Al(OH)_3$	$Fe(OH)_3$	NH_4OH

Acids and bases are also classified according to their basicity and acidity respectively.

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Basicity of acids : The number of H^+ ions obtainable by the dissociation of one molecule of an acid is called its basicity.

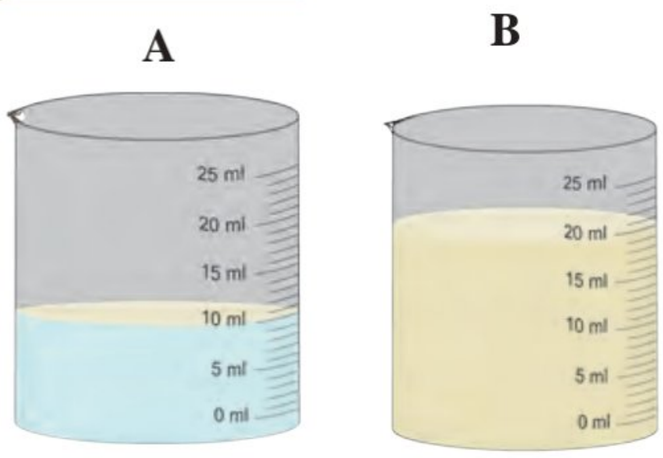
Acidity of bases : The numbers of OH^- ions obtainable by the dissociation of one molecule of a base is called its acidity.

Use your brain power !

1. On the basis of the above table give examples of monobasic, dibasic and tribasic acids.
2. On the basis of the above table give the three types of bases their examples.

Concentration of acid and base

Try this



5.3 Solution of lemon juice

Cut a lemon into two equal parts. Take the juice of each part into two separate beakers. Pour 10ml of drinking water in one beaker and 20ml in the second. Stir the solutions in both the beakers and taste them. Is there any difference in the tastes of the solutions in the two beakers? What is that difference?

In the above activity, the sour taste of the solutions is because of the solute, lemon juice, in them. The quantity of the lemon juice is the same in both the solutions. Yet their taste is different. The solution in the first beaker is more sour than the one in the second. Why is it so?

Although the quantity of the solute is the same in both the solutions, the quantity of the solvent is different. Ratio of the quantity of the solute to the quantity of the resulting solution is different. This ratio is larger for the soultion in the first beaker and, therefore, that solution tastes more sour. On the other hand, the proportion of the lemon juice in the total solution in the second beaker is smaller and the taste is less sour.

The taste of foodstuff depends upon the nature of the taste-giving ingredient and its proportion in the foodstuff. Similarly, all the properties of a solution depend on the nature of the solute and solvent and also on the proportion of the solute in the solution. The Proportion of a solute in a solution is called the concentration of the solute in the solution. When the concentration of a solute in its solution is high, it is a concentrated solution, while the solution is called a dilute solution when the concentration of the solute is low.

Several units are used to express the concentration of a solution. Two of these units are used more frequently. The first unit is the mass of solute in grams dissolved in one litre of the solution. (grams per litre, g/L). The second unit is the number of moles of the solute dissolved in one litre of the solution. This is also called the molarity (M) of the solution. The molarity of a solute is indicated by writing its molecular formula inside a square bracket. For example [NaCl] = 1 means the molarity of this solution of common salt is 1M (1 Molar).

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Complete the following table of the concentration of various aqueous solutions.

Solute			Quantity of solute		Volume of solution	Concentration of the solution	
A	B	C	D	$E = \frac{D}{C}$	F	$G = \frac{D}{F}$	$H = \frac{E}{F}$
Name	Molecular formula	Molecular mass (u)	Gram (g)	Mole (mol)	Litre (L)	Gram/litre (g/L)	Molarity (M) mole/litre (mol/L)
Sodium Chloride	NaCl	58.5 u	117 g	2 mol	2 L	58.5 g/L	1 M
.....	HCl	.....	3.65 g	.....	1 L	.....	.....
.....	NaOH	.....	.....	1.5 mol	2 L	.....	.....

The pH of solution

We have seen that acids and bases dissociate to a smaller or larger extent on dissolving in water forming H^+ and OH^- ions respectively. H^+ and OH^- ions are found in different proportions in all natural aqueous solutions, and that determines the properties of those solutions.

For example, the proportion of H^+ and OH^- ions divides soil into the acidic, neutral and basic types of soil. It is necessary for blood, cell sap, etc. to have H^+ and OH^- ions in certain definite proportions for their proper functioning. Fermentation carried out with the help of micro-organisms, other biochemical processes and also many chemical processes require the proportion of H^+ and OH^- ions to be maintained within certain limits. Pure water, also, undergoes dissociation to a very small extent and gives rise to H^+ and OH^- ions in equal proportion.

$$H_2O \xrightarrow{\text{dissociation}} H^+ + OH^-$$

Due to this property of water to undergo dissociation, there exist both H^+ and OH^- ions in any aqueous solution. However, their concentration may be different.

pH of some common aqueous solutions

	Solution	pH
Strong acids	1M HCl	0.0
↑	Gastric juice	1.0
	Lemon juice	2.5
	Vinegar	3.0
	Tomato juice	4.1
	Black coffee	5.0
	Acid rain	5.6
Weak acids	Urine	6.0
Neutral	Rain, milk	6.5
Weak bases	Pure water, sugar solution	7.0
↓	Blood	7.4
	Solution of baking soda	8.5
	Toothpaste	9.5
	Milk of magnesia	10.5
	Limewater	11.0
Strong bases	1 M NaOH	14.0

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The concentration of H^+ ions formed by dissociation of water at 25^0C is 1 x 10^{-7} mol/L. At the same temperature, the concentration of H^+ ions in 1M solution of HCl is 1 x 10^0 mol/L. While in a 1M NaOH solution, the concentration of H^+ ions is 1 x 10^{-14} mol/L. Thus, we see that in common aqueous solutions, the range of H^+ ion concentration is very wide from 10^0 to 10^{-14} mol/L. In 1909, the Danish scientist Sorensen introduced a convenient new scale of expressing H^+ ion concentration which is found to be very useful in chemical and biochemical processes. It is the pH scale (pH : power of hydrogen) The pH scale extends from 0 to 14. According to this scale pure water has a pH of 7 meaning pure water has $[H^+]$ = 1 x 10^{-7} mol/L. pH 7 indicates a neutral solution. This pH is the midpoint of the scale. The pH of an acidic solution is less than 7 and that of a basic solution is greater than 7. The table (See page no. 63) gives the pH values of some common solutions.

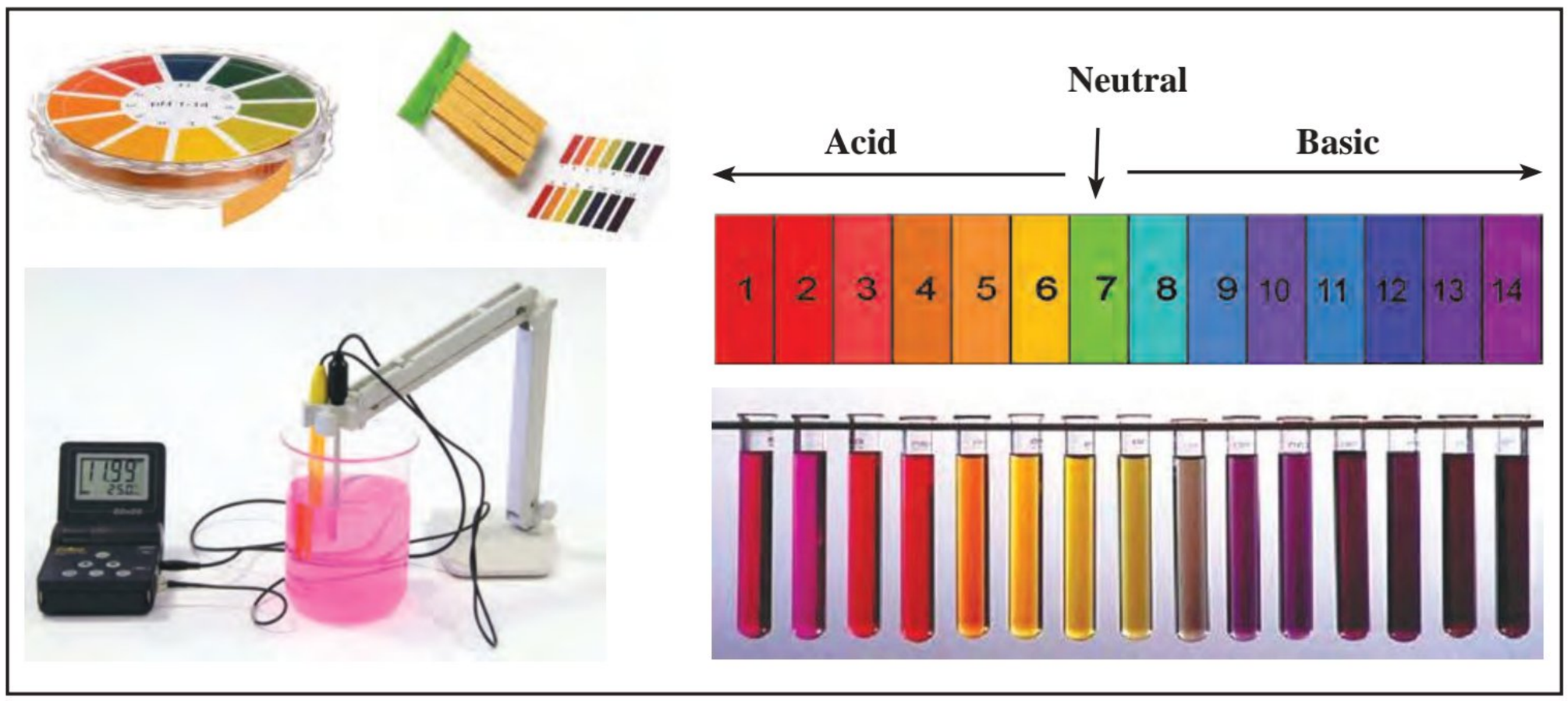
By which other method could we find out the pH of a solution?

Universal indicators

Can you recall?

What are the colours of the following natural and synthetic indicators in acidic and basic solutions?
Litmus, turmeric, *jamun*, methyl orange, phenolphthalein?

We know that some natural and synthetic dyes show two different colours in acidic and basic solutions, and such dyes are used as acid-base indicators. In the pH scale, the pH of solutions varies from 0 to 14 in accordance with the strength of the acid or base. To show these variations in pH, a universal indicator is used. A universal indicator shows different colours at different values of pH.



5.4 Measurement of pH : universal indicator and pH meter

A universal indicator is made by mixing several synthetic indicators in specific proportions. The pH of a solution can be determined by means of a universal indicator solution or the pH paper made from it. However, the most accurate method of measuring the pH of a solution is to use an electrical instrument called pH meter. In this method, pH is measured by dipping electrodes into the solution.

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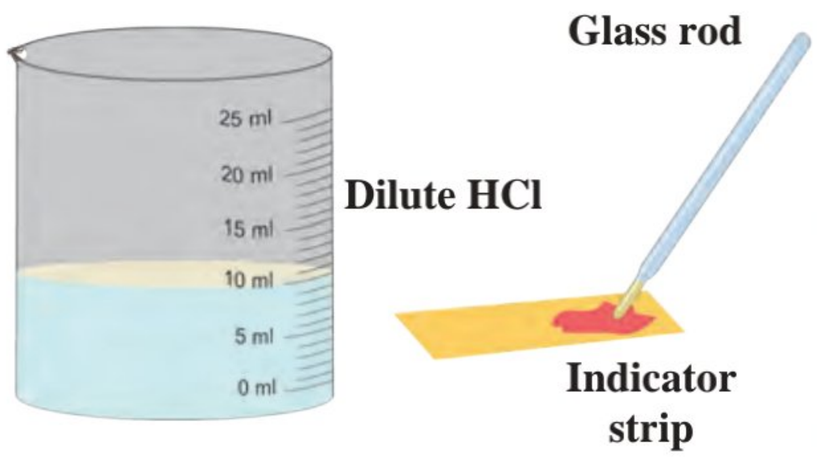
Try this



5.5 Neutralization

Reactivity of acids and bases

1. Neutralization

Do this : Take 10ml dilute HCl in a beaker. Use a glass rod to put a drop of this solution on a pH paper and record the pH of the solution. Add to it a few drops of dilute NaOH solution by means of a dropper and stir the solution with the glass rod. Measure the pH of the resulting solution by putting a drop of this solution on another pH paper. In this manner, go on adding dilute NaOH drop by drop and recording the pH. What do you find? Stop adding NaOH when a green colour appears on the pH paper, that is when the pH of the solution becomes 7.

The neutralization reaction : Why does the pH increase as NaOH solution is added drop by drop to the HCl solution? The answer lies in the process of dissociation. Both HCl and NaOH dissociate in their aqueous solutions. Addition of NaOH solution to HCl solution is like adding a large concentration of OH^- ions to a large concentration of H^+ ions. However water dissociates into H^+ and OH^- ions to a very small extent. Therefore, on mixing, the excess OH^- ions combine with the excess H^+ ions to form H_2O molecules which mix with the solvent water. This change can be represented by the ionic equation shown as follows.

$$H^+ + Cl^- + Na^+ + OH^- \longrightarrow Na^+ + Cl^- + H_2O$$

It can be seen from the above equation that the Na^+ and Cl^- ions are on both the sides. Therefore the net ionic reaction is $H^+ + OH^- \longrightarrow H_2O$

As the NaOH solution is added drop by drop to the HCl solution, the concentration of H^+ goes on decreasing due to combination with added OH^- ions, and that is how the pH goes on increasing.

When enough NaOH is added to HCl, the resulting aqueous solution contains only Na^+ and Cl^- ions, that is, NaCl, a salt, and the solvent water. The only source of H^+ and OH^- ions in this solution is dissociation of water. Therefore, this reaction is called the neutralization reaction. The neutralization reaction is also represented by the following simple equation.

$$\underset{\text{Acid}}{HCl} + \underset{\text{base}}{NaOH} \longrightarrow \underset{\text{Salt}}{NaCl} + H_2O$$

Complete the following table of neutralization reactions and also write down the names of the acids, bases and salts in it.

Acid + base	⟶	Salt + Water
HNO_3 + ...	⟶	$KNO_3 + H_2O$
.....+ 2 NH_4OH	⟶	$(NH_4)_2SO_4$ + ...
.....+ KOH	⟶	KBr +

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Always remember

In the neutralization reaction, an acid reacts with a base to form a salt and water.

Use your brain power !

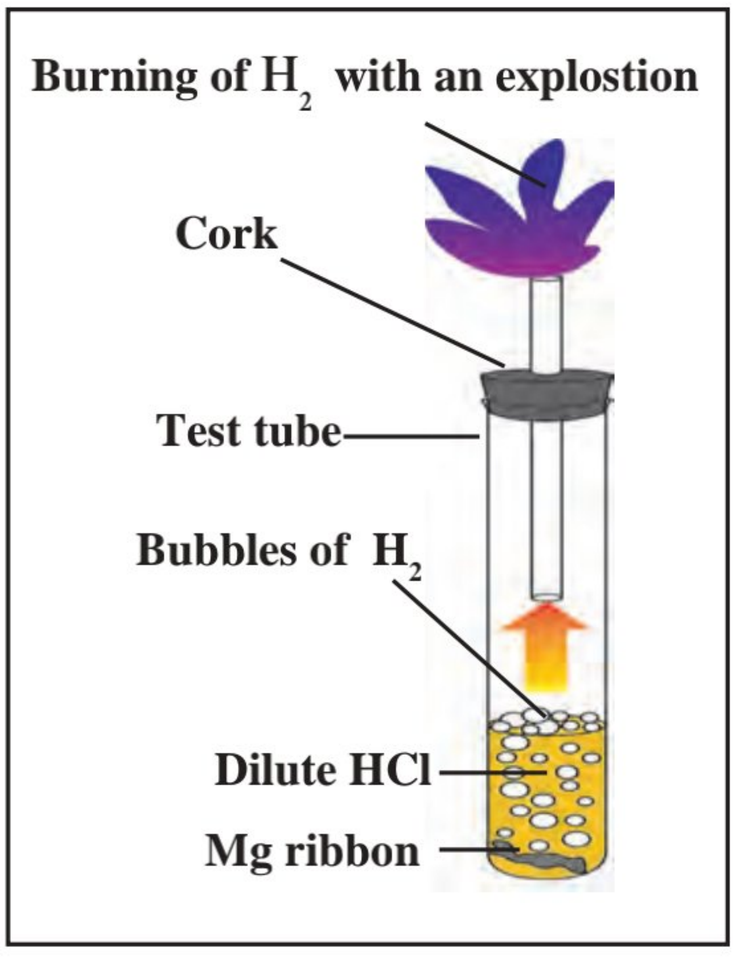
What would be the definition of an acid and a base with reference to the neutralization reaction ?

2. Reaction of acids with metals

The reaction of acids with metals is determined by the strength and the concentration of the acid and also by the reactivity of the metal and the temperature. It is easy to bring about the reaction of a dilute solution of strong acids with moderately reactive metals at normal temperature.

Try this

Activity : Take a big test tube. Choose a rubber stopper in which a gas tube can be fitted. Take a few pieces of magnesuim ribbon in the test tube and add some dilute HCl to it. Take a lighted candle near the end of the gas tube and observe. What did you observe ?



5.6 Reaction of a dilute solution of a strong acid with a metal

Magnesium metal reacts with dilute hydrochloric acid and an inflammable gas, hydrogen, is formed. During this reaction, the reactive metal displaces hydrogen from the acid to release hydrogen gas. At the same time, the metal is converted into basic radical which combines with the acidic radical from the acid to form the salt.

Complete the following reactions.

Metal + Dilute acid $\longrightarrow$ Salt + Water

$Mg(s) + 2HCl\ (aq) \longrightarrow MgCl_2\ (aq) + H_2\ (g)$

Zn (s) + ... (aq) $\longrightarrow$ $ZnSO_4$ (aq) + ...

.....(s) + ... (aq) $\longrightarrow$ $Cu\ (NO_3)_2\ (aq) + H_2\ (g)$

3. Reaction of acids with oxides of metals

Try this

Take some water in a test tube and add a little red oxide (the primer used before painting iron articles) to it. Now add a small quantity of dilute HCl to it, shake the test tube and observe.

1. Does the red oxide dissolve in water?
2. What change takes place in the particles of red oxide on adding dilute HCl ?

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The chemical formula of red oxide is Fe_2O_3. The water-insoluble red oxide reacts with HCl to produce a water soluble salt $FeCl_3$. This gives a yellowish colour to the water. The following chemical equation can be written for this chemical change.

$$Fe_2O_3\,(s) + 6HCl\,(aq) \longrightarrow 2FeCl_3\,(aq) + 3H_2O\,(l)$$

Complete the following.

Metal oxide + dilute acid	$\longrightarrow$	**Salt + Water**
$CaO\,(s) + 2\,HCl\,(aq)$	$\longrightarrow$	+
$MgO\,(s) +$	$\longrightarrow$	$MgCl_2\,(aq) + H_2O\,(l)$
$ZnO\,(s) + 2\,HCl\,(aq)$	$\longrightarrow$	+
$Al_2O_3\,(s) + 6\,HF(l)$	$\longrightarrow$	+

1. What type of compound is a metal oxide, with reference to neutralization reaction?
2. Explain the statement 'Metal oxides are basic in nature.'

4. Reaction of bases with oxides of non-metals

Try this

Bases react with oxides of non-metals to form a salt and water. Hence, oxides of non-metals are said to be acidic in nature. Sometimes the oxides of non-metals themselves are said to be examples of acids.

Complete the following reactions.

Oxide of non-metal + base	$\longrightarrow$	**salt + water**
$CO_2\,(g) + 2\,NaOH\,(aq)$	$\longrightarrow$	$Na_2CO_3\,(aq) + H_2O\,(l)$
$+ 2\,KOH\,(aq)$	$\longrightarrow$	$K_2CO_3\,(aq) + H_2O\,(l)$
$SO_3\,(g) +$	$\longrightarrow$	$Na_2SO_4\,(aq) + H_2O\,(l)$

Zinc oxide reacts with sodium hydroxide to form sodium zincate (Na_2ZnO_2) and water. Similarly, aluminium oxide reacts with sodium hydroxide to form sodium aluminate ($NaAlO_2$) and water.

Use your brain power !

1. Write down chemical equations for both these reactions.
2. Can we call Al_2O_3 and ZnO acidic oxides on the basis of these reactions?
3. Define 'amphoteric oxides' and give two examples.

5. Reaction of acids with carbonates and bicarbonates of metals

Try this

Activity : Fit a bent tube in a rubber cork. Take some lime water in a test tube and keep it handy. Take some baking soda in another test tube and add some lemon juice to it. Immediately fit the bent tube over it. Insert its other end into the lime water. Note down your observations of both the test tubes. Repeat the procedure using washing soda, vinegar and dilute HCl properly. What do you see ?

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In this activity, when limewater comes in contact with the gas released in the form of an effervescence, it turns milky. This is a chemical test for carbon dioxide gas. When lime water turns milky, we infer that the effervescence is of carbon dioxide gas. This gas is produced on reaction of acids with carbonate and bicarbonate salts of metals. A precipitate of $CaCO_3$ is produced on its reaction with the limewater $Ca(OH)_2$. This reaction can be represented by the following chemical equation.

$$Ca(OH)_2\,(aq) + CO_2\,(g) \longrightarrow CaCO_3\,(s) + H_2O(l)$$

Salts

Types of salts : acidic, basic and neutral salts

Try this

Activity : Prepare 10 ml aqueous solutions from 1gm each of sodium chloride, ammonium chloride and sodium bicarbonate. Measure pH of each solution by means of pH paper. Are the values the same for all three ? Classify the salts based on the pH values.

We have seen that salts are formed by the reaction between acids and bases. Though this reaction is called a neutralization reaction, the resulting salts are not always neutral. A neutral salt is formed by neutralization of a strong acid by a strong base. The aqueous solution of a neutral salt has pH equal to 7.

An acidic salt is formed by the neutralization reaction between a strong acid and a weak base. The pH of the aqueous solution of an acidic salt is less than 7. On the contrarary, a basic salt is formed by a neutralization reaction between a weak acid and a strong base. The pH of an aqueous solution of such a basic salt is greater than 7.

Classify the following salts into the types acidic, basic and neutral. Sodium sulphate, potassium chloride, ammonium nitrate, sodium carbonate, sodium acetate, sodium chloride.

Complete the reactions in the following table.

Carbonate salt of metal + dilute acid $\longrightarrow$ Another salt of metal + Carbon dioxide		
Na_2CO_3 (s) + 2 HCl (aq)	$\longrightarrow$	2 NaCl (aq) + CO_2 (g)
Na_2CO_3 (s) + ...	$\longrightarrow$	Na_2SO_4 (aq) + CO_2 (g)
$CaCO_3$ (s) + 2 HNO_3 (aq)	$\longrightarrow$	..... + ...
K_2CO_3 (s) + H_2SO_4 (aq)	$\longrightarrow$	..... + ...

Bicarbonate salt of metal + dilute acid $\longrightarrow$ Another salt of metal + carbon dioxide + water		
1. $NaHCO_3$ (s) + HCl (aq)	$\longrightarrow$	NaCl (aq) + CO_2 (g) + H_2O (*l*)
2. $KHCO_3$ (s) + HNO_3 (aq)	$\longrightarrow$	..... + ... + ...
3. $NaHCO_3$ (s) + ...	$\longrightarrow$	CH_3COONa (aq)+ ..... + ...

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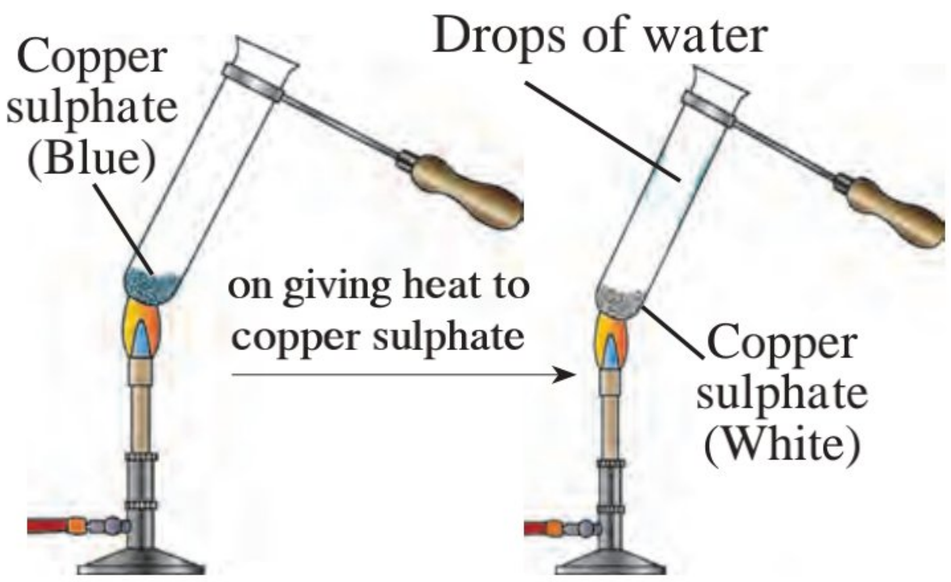
Water of crystallisaton

Try this



5.7 Properties of water of crystalisation

Activity : Take some crystals of blue vitriol in two test tubes.
Add some water in one test tube and shake it. What did you see?
What is the colour of the solution formed?
Heat the other test tube on low flame of a burner. What did you see?
What change did occur in the colour of blue vitriol?
What did you see in the upper part of the test tube?

When the second test tube cools down add some water in it and shake. What is the colour of the resulting solution? What inference can be drawn from this observation?

$$\underset{\text{(Blue)}}{CuSO_4\ 5H_2O} \xrightarrow{\text{Heat}} \underset{\text{(White)}}{CuSO_4} + 5H_2O$$

On heating, the crystalline structure of blue vitriol broke down to form a colourless powder and water came out. This water was part of the crystal structure of blue vitriol. It is called water of crystallization. On adding water to the white powder a solution was formed which had the same colour as the solution in the first test tube. From this we come to know that no chemical change has occurred in the crystals of blue vitriol due to heating. Losing water on heating blue vitriol, breaking down of the crystal structure, losing blue colour and regaining blue colour on adding water are all physical changes.

Repeat the above activity for Ferrous sulphate, sodium carbonate and write chemical equations.

Try this

Apparatus : Evaporating dish, Bunsen burner, tripod stand, wire gauze, etc.
Chemicals : Alum.

Procedure : Taka a small stone of alum in the evaporating dish. Keep the dish on the tripod stand and heat it with the help of burner.
What did you seen in the dish? What is meant by puffed alum?

Ionic compounds are crystalline in nature. These crystals are formed as a result of definite arrangement of ions. In the crystals of some compounds water molecules are also included in this arrangement. That is the water of crystallization. The water of crystallization is present in a definite proportion of the chemical formula of the compound. It is indicated in the chemical formula as shown below.

1 Crystalline blue vitriol– $CuSO_4\ 5H_2O$
2 Crystalline ferrous sulphate (Green vitriol) – $FeSO_4\ 7H_2O$
3 Crystalline washing soda –$Na_2CO_3.10H_2O$
4.Crystalline alum -$K_2SO_4.Al_2(SO_4)_3.24\ H_2O$

1. Crystalline substances contain water of crystallization.
2. The molecules of water of crystallization are part of the internal arrangement of the crystal.
3. On heating or just by keeping, the water of crystallization is lost and the crystalline shape of that part is lost.

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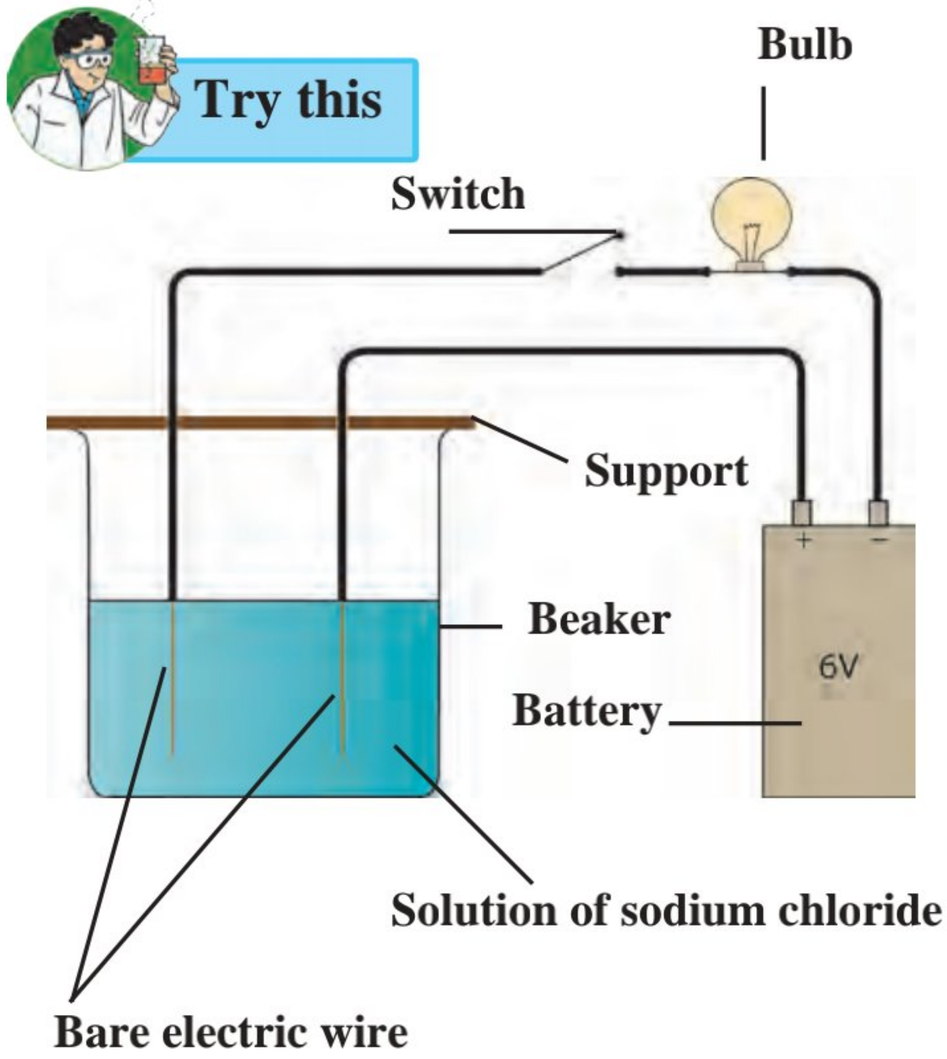
Ionic compounds and electrical conductivity



5.8 Testing the electrical conductivity of a solution

Activity : Prepare a solution of 1g sodium chloride in 50ml water. Take two electrical wires. Connect one wire to the positive terminal of a 6V battery. While connecting the other wire to the negative terminal of the battery, include one switch and one holder with an electric bulb. Remove the insulating cladding from 3cm portion of the other free ends of the two wires. Take the salt solution in a 100ml capacity beaker and immerse the uncovered ends of the two wires in it keeping the wire erect with the help of a support. Switch on the current. Note whether the bulb glows. Repeat the same procedure using solutions of 1g copper sulphate, 1g glucose, 1g urea, 5ml dilute H_2SO_4 and 5ml dilute NaOH each in 50ml water. Record your observations in a table. **(Do not forget to clean the beaker and uncovered part of the wires with water, every time you change the solution.)**

Use your brain power !

1. With which solutions did the bulb glow?
2. Which solutions are electrical conductors?

The bulb glows only when electric current passes through it. And this can happen only when the electric circuit is complete. In the above activity, the circuit is found to be complete when the aqueous solutions of NaCl, $CuSO_4$, H_2SO_4 and NaOH are used. It means that these solutions are conductors of electricity.

Electrons conduct electricity through electrical wires; and ions conduct electricity through a liquid or a solution. Electrons leave the battery at the negative terminal, complete the electric circuit and enter the battery at the positive terminal. When there is a liquid or a solution in the circuit, two rods, wires or plates are immersed in it. These are called electrodes. Electrodes are usually made of a conducting solid. The electrode connected to the negative terminal of a battery by means of a conducting wire is called a **cathode** and the electrode connected to the positive terminal of a battery is called an **anode**.

Why does the electric circuit get completed on immersing the electrodes in certain liquids or solutions? In order to understand this phenomenon, let us look more closely at the solutions in the above activity, which were found to be electrical conductors.

Dissociation of ions and electrical conductivity

In the above activity it was found that the aqueous solutions of the compounds NaCl, $CuSO_4$, H_2SO_4 and NaOH are electricity conductors. Out of these NaCl and $CuSO_4$ are salts, H_2SO_4 is a strong acid and NaOH is a strong base. We have seen that salts, strong acids and strong bases dissociate almost completely in their aqueous solutions. Therefore, the aqueous solutions of all these three contain large numbers of cations and anions.

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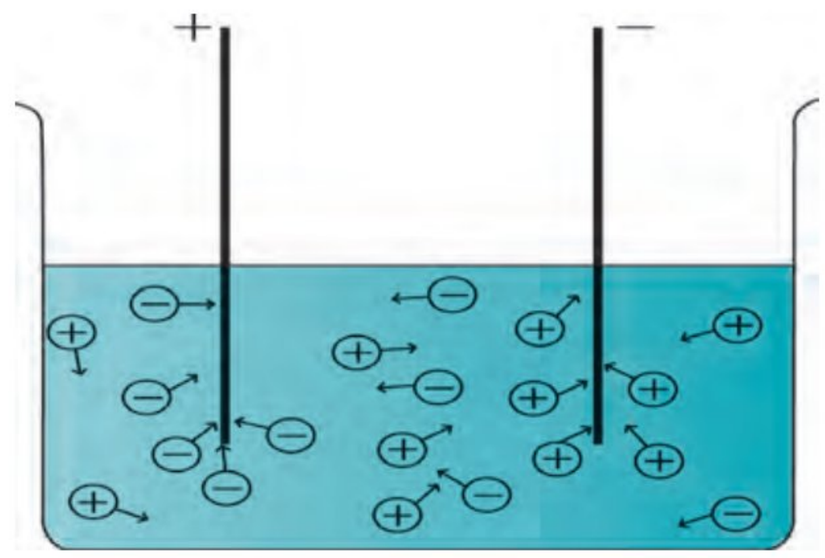
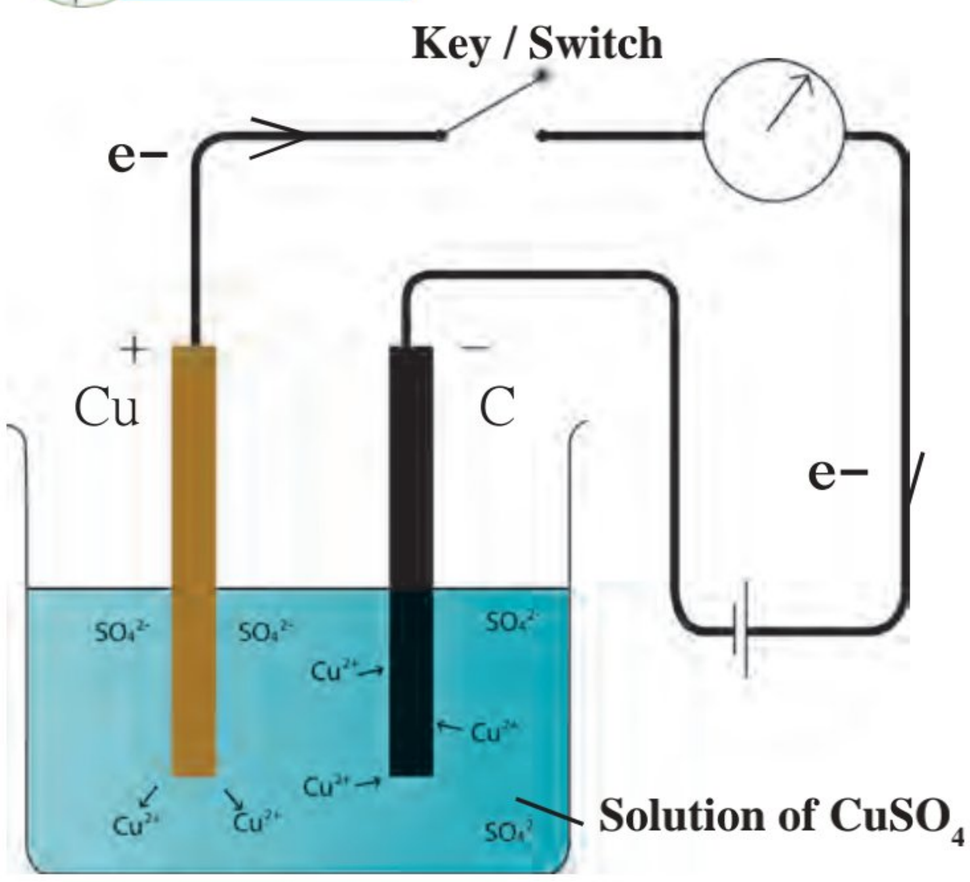
A characteristic of the liquid state is the mobility of its particles. Due to this mobility, the positively charged cations in the solution are attracted towards the negative electrode or cathode and move towards the cathode; on the other hand, the negatively charged anions move in the direction of the anode. The movement of ions in the solution towards the respective electrodes amounts to the conduction of electricity through the solution. From this, you will understand that those liquids or solutions which contain a large number of dissociated ions conduct electricity.



5.9 Dissociation of ions

Try this



5.10 Electrolysis

Electrolysis

Procedure : Take a solution of 1g copper sulphate in 50ml water in a 100ml capacity beaker. Use a thick plate of copper as anode and a carbon rod as cathode. Arrange the apparatus as shown in the figure and pass an electric current though the circuit for some time. Do you see any changes ?

In the above activity copper appears to have deposited on the portion of the cathode immersed in the solution. How did this happen? When an electric current started flowing through the circuit, the cations, that is, Cu^{++} ions in the solution got attracted towards the cathode. Cu atoms are formed when electrons coming out from the cathode combine with the Cu^{++} ions. A deposit of the copper appeared on the cathode. Even though the Cu^{++} ions in the solution were used up in this manner, the colour of the solution remained the same. Because, while electric current was on, electrons were removed from the Cu atoms of the anode and sent to the battery through the electric wire. The Cu^{++} ions formed in this manner, entered the solution. In this way decomposition of the solute in the solution took place due to the electric current. This is called electrolysis. There are two parts in the electrolysis process. These are the cathode reaction and the anode reaction. The two parts of the electrolysis process that take place in the above activity are shown below.

Cathode reaction $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$

Anode reaction $Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$

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Always remember

1. It is necessary for the liquid/solution to have a large number of dissociated ions for electrolysis to take place. Therefore, substances which undergo dissociation to great extent in the liquid state or a solution are called electrolytes. Salts, strong acids and strong bases are electrolytes. Their solutions have high electrical conductivity. In other words electrolytes are good conductors of electricity in their liquid or solution state.
2. An assembly that consists of a container electrolyte and the electrodes dipped in it, is called an electrolytic cell.

Use your brain power !

1 In the above activity, if electric current passesd through the electrolytic cell for a long time, what change would be seen at the anode?
2. Would water be a good conductor of electricity?

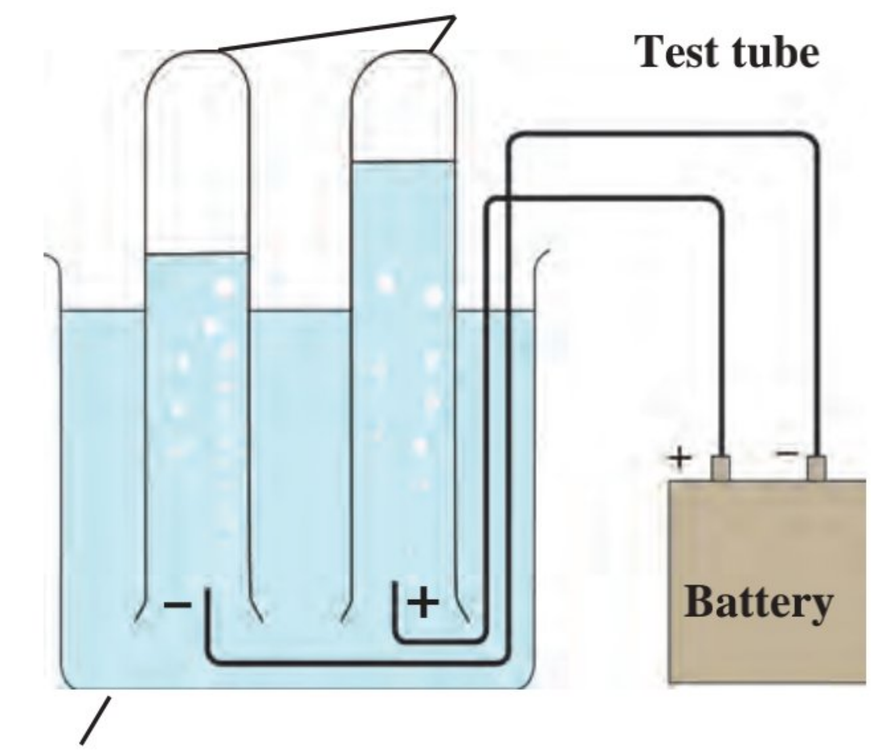
Website for more information

www.chemicalformula.org

If pure water is used in an electrolytic cell, current does not flow even on putting on the switch. From this we learn that pure water is a bad conductor of electricity. And we have already seen the reason behind this. The concentration of H^+ and OH^- ions formed by dissociation of water is very low, only 1×10^{-7} mol/L for each ion. However, the electrical conductivity of water increases on mixing a small amount of salt or a strong acid/base in it due to their dissociation and electrolysis of water takes place.

Electrolysis of water

Try this



5.11 Electrolysis of water

Activity : Dissolve 2g salt in 500ml pure water. Take 250 ml of this solution in a 500ml capacity beaker. Connect two electrical wires to the positive and negative terminals of a power supply. Remove the insulating cladding from about 2cm portions at the other ends of the wires. These are the two electrodes. Fill two test tubes upto the brim with the prepared dilute salt solution. Invert them on the electrodes without allowing any air to enter. Start the electric current under 6V potential difference form the power supply. Observe what happens in the test tubes after some time.

1. Did you see the gas bubbles forming near the electrodes in the test tubes?
2. Are these gases heavier or lighter than water?
3. Are the volumes of the gases collected over the solution in the two test tubes the same or different?

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It is found in the above activity that the volume of the gas formed near the cathode is double that of the gas formed near the anode. Scientists have shown that hydrogen gas is formed near the cathode and oxygen gas near the anode. From this, it is clear that electrolysis of water has taken place and its constituent elements have been released. The concerned electrode reactions are as follows.

Cathode reaction $2H_2O\ (l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$

Anode reaction $2H_2O\ (l) \longrightarrow O_2\ (g) + 4H^+(aq) + 4e^-$

1. Test the solutions in the two test tubes with litmus paper, what do you see ?
2. Repeat the activity by using dilute H_2SO_4 as well as dilute NaOH as the electrolyte.

Research There are many applications of electrolysis of electrolytes. Collect information about them.

Exercises

1. Identify the odd one out and justify.

(a) Chloride, nitrate, hydride, ammonium

(b) Hydrogen chloride, sodium hydroxide, calcium oxide, ammonia

(c) Acetic acid, carbonic acid, hydrochloric acid, nitric acid

(d) Ammonium chloride, sodium chloride, potassium nitrate, sodium sulphate

(e) Sodium nitrate, sodium carbonate, sodium sulphate, sodium chloride

(f) Calcium oxide, magnesium oxide, zinc oxide, sodium oxide.

(g) Crystalline blue vitriol, crystalline common salt, crystalline ferrous sulphate, crystalline sodium carbonate.

(h) Sodium chloride, potassium hydroxide, acetic acid, sodium acetate.

2. Write down the changes that will be seen in each instance and explain the reason behind it.

(a) 50ml water is added to 50ml solution of copper sulphate.

(b) Two drops of the indicator phenlphthalein were added to 10ml solution of sodium hydroxide.

(c) Two or three filings of copper were added to 10ml dilute nitric acid and stirred.

(d) A litmus paper was dropped into 2ml dilute HCl. Then 2ml concentrated NaOH was added to it and stirred.

(e) Magnesium oxide was added to dilute HCl and magnesium oxide was a added to dilute NaOH.

(f) Zinc oxide was added to dilute HCl and zinc oxide was added to dilute NaOH.

(g) Dilute HCl was added to limestone.

(h) Pieces of blue vitriol were heated in a test tube. On cooling, water was added to it.

(i) Dilute H_2SO_4 was taken in an electrolytic cell and electric current was passed through it.

3. Classify the following oxides into three types and name the types.

CaO, MgO, CO_2, SO_3, Na_2O, ZnO, Al_2O_3, Fe_2O_3

4. Explain by drawing a figure of the electronic configuration.

a. Formation of sodium chloride from

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sodium and chlorine.

b. Formation of a magnesium chloride from magnesium and chlorine.

5. Show the dissociation of the following compounds on dissolving in water, with the help of chemical equation and write whether the proportion of dissociation is small or large.

Hydrochloric acid, Sodium chloride, Potassium hydroxide, Ammonia, Acetic acid, Magnesium chloride, Copper sulphate.

6. Write down the concentration of each of the following solutions in g/L and mol/L.

a. 7.3g HCl in 100ml solution
b. 2g NaOH in 50ml solution
c. 3g CH_3COOH in 100ml solution
d. 4.9g H_2SO_4 in 200ml solution

7. Obtain a sample of rainwater. Add to it a few drops of universal indicator. Meausre its pH. Describe the nature of the sample of rainwater and explain the effect if it has on the living world.

8. Answer the following questions.

a. Classify the acids according to their basicity and give one example of each type.
b. What is meant by neutralization? Give two examples from everyday life of the neutralization reaction.
c. Explain what is meant by electrolysis of water. Write the electrode reactions and explain them.

9. Give reason for the following.

a. Hydronium ions are always in the form H_3O^+
b. Buttermilk spoils if kept in a copper or brass container.

10. Write the chemical equations for the following activities.

(a) NaOH solution was added to HCl solution.
(b) Zinc dust was added to dilute H_2SO_4.
(c) Dilute nitric acid was added to calcium oxide.
(e) Carbon dioxide gas was passed through KOH solution.
(f) Dilute HCl was poured on baking soda.

11. State the differences.

a. Acids and bases
b. Cation and anion
c. Negative electrode and positive electrode.

12. Classify aqueous solutions of the following substances according to their pH into three groups : 7, more than 7, less than 7.

Common salt, sodium acetate, hydrochloric acid, carbon dioxide, potassium bromide, calcium hydoxide, ammonium chloride, vinegar, sodium carbonate, ammonia, sulphur dioxide.

Project :

Collect information about electroplating. Make a list of articles in day-to-day life, where this technique is used.

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11. Reflection of Light

➢ **Mirrors and types of mirrors** ➢ **Spherical mirrors and images formed by them** ➢ **Magnification due to spherical mirrors**

Can you recall?

1. What is light?
2. What is meant by reflection of light? Which are the different types of reflection?

Light is an agent which gives us information about what is happening in our surroundings. We can enjoy various wonders of nature like the sunrise, sunset and rainbow only because there is light. It is only because of light that we can see the lush green vegetation, colourful flowers, deep blue skies in the day, stars shining in the dark night sky in the beautiful world around us. We can see the man-made objects in our surroundings as well. Light is actually electromagnetic radiation which causes the sensation of vision.

Light reflects differently from the various surfaces around us. We have already learnt that the reflection from smooth, flat surfaces is regular reflection while rough surfaces reflect light irregularly.

Mirror and types of mirrors

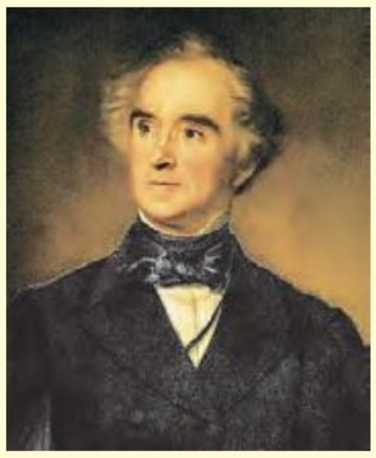
Can you tell? What is a mirror?

We need polished surfaces for reflecting light. This is because polished surfaces absorb less light and so maximum light gets reflected.

In scientific language, a surface which reflects light and creates clear images is called a mirror. A mirror is a reflecting surface.

We use various types of mirrors in our daily life. Mirrors are of two types: plane mirrors and spherical mirrors.

An introduction to scientists



The German scientist Justus von Liebig coated the plane surface of a piece of ordinary glass with silver metal and made the first mirror. Such a mirror is called a silvered glass mirror.

Plane mirror – Plane mirrors are used in various activities in our day to day life. A mirror is made by coating the back surface of a flat and smooth glass piece with a thin, reflecting film of aluminium or silver. To protect this reflecting film and to make that side opaque, another coat of a substance like lead oxide is given over it.

10.1 Plane mirror

Can you recall? What are the laws of reflection of light?

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We see a clear image of ourselves when we stand in front of a mirror in our house. To understand how an image is formed in a mirror let us first consider an image formed by a point source. Light rays travel in all directions from such a source. Several of these rays fall on the mirror, get reflected and reach our eyes. Due to reflection, they appear to be coming from a point behind the mirror. That point is the image of the point source.

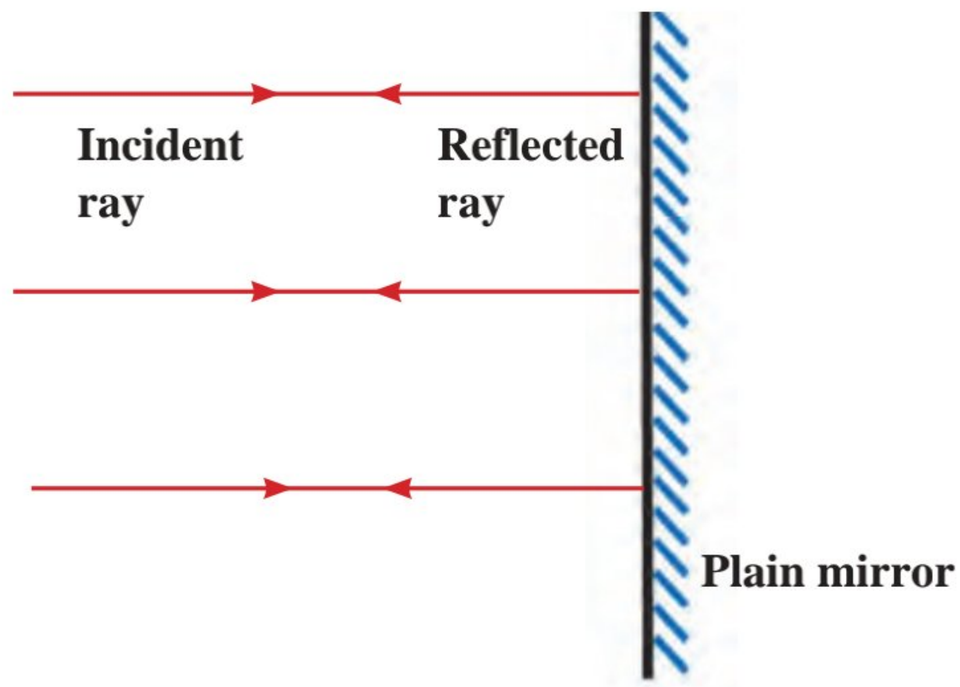
As figure 11.2 A shows, light rays falling perpendicularly on the mirror are reflected back in the perpendicular direction.

Figure 11.2 B shows a point source O in front of the plane mirror M_1M_2. Incident rays OR_1 and OR_2 get reflected according to the laws of reflection along paths R_1S_1 and R_2S_2 respectively. When these reflected rays are extended behind the mirror, they meet at O_1. When seen from E, the rays appear to be coming from O_1. Other rays starting from O also get reflected and appear to be coming from O_1. Thus, point O_1 is the image of point O.

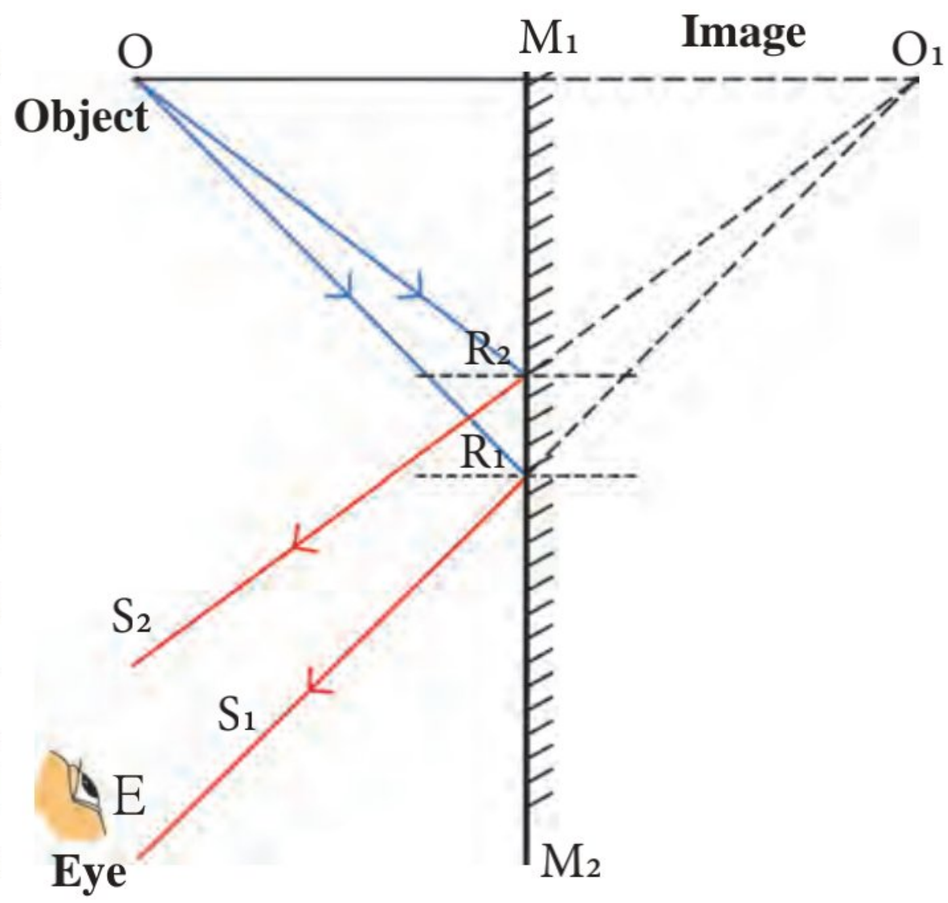
The reflected rays do not actually meet. Hence, such an image is called a virtual image. The perpendicular distance of the image from the mirror is equal to the perpendicular distance of the source from the mirror.

If we use an extended source instead of a point source, an image is formed of every point of the source, thereby forming an extended image of the whole source. As shown in figure 11.2 C, an extended source PQ is kept in front of the mirror M_1M_2. The images of P and Q are formed at P_1 and Q_1 respectively. Similarly, images of all points between P and Q are formed between P_1 and Q_1 resulting in the image P_1Q_1 of the entire extended source.

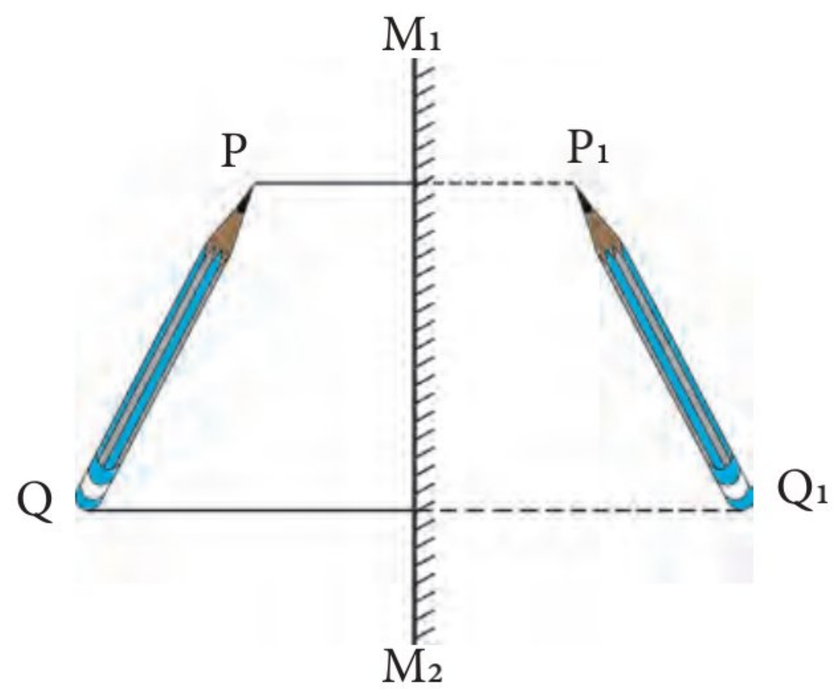
The image formed by a plane mirror is of the same size as the source.



A. Rays falling on a mirror normal to its surface



B. Image of a point source formed by a mirror



C. Image of an extended source formed by a mirror

11.2 Formation of images by a mirror

Can you tell?

1. If we hold a page of a book in front of a mirror, we see laterally inverted letters in the mirror. Why does it happen?
2. Which letters of the English alphabet form images that look the same as the original letters?

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The image of a word appears laterally inverted in the mirror. The image of every point on the word is formed behind the mirror at the same distance from the mirror as the point itself. This is called lateral inversion.

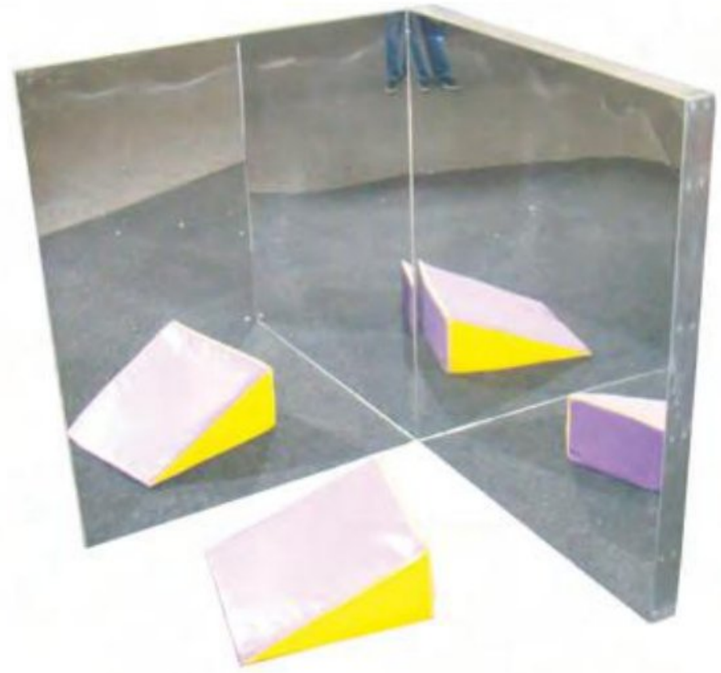
Use your brain power !

When a person stands in front a plane mirror, how is the image formed? What is the nature of the image?

Try this

Place two plane mirrors at an angle of 90^0 to each other. Place a small object between them. Images will be formed in both mirrors. How many images do you see?

Now change the angle between the mirrors as given in the following table and count the number of images each time. How is this number related to the measure of the angle? Discuss this relationship.



11.3 Mirrors at right angles to each other

Angle	Number of images
120°	
90°	
60°	
45°	
30°	

$$n = \frac{360^0}{A} - 1$$

n = number of images, A = angle between the mirrors

1. Check if the number of images that you obtained for different values of angles is consistent with the above formula.
2. If we keep the mirrors parallel to each other, how many images will we see?

Statement: In order to see the full image of a person standing in front of a mirror, the minimum height of the mirror must be half the height of the person.

Proof : In figure 11.4, the point at the top of the head, the eyes and a point at the feet of a person are indicated by H, E and F respectively. R and S are midpoints of HE and EF respectively. The mirror PQ is at a height of NQ from the ground and is perpendicular to it. PQ is the minimum height of the mirror in order to obtain the full image of the person. For this, RP and QS must be perpendicular to the mirror. Find out why, by studying the figure 11.4.

Minimum height of the mirror

PQ = RS

$$= RE + ES = \frac{HE}{2} + \frac{EF}{2} = \frac{HF}{2} = \text{Half of the person's height}$$

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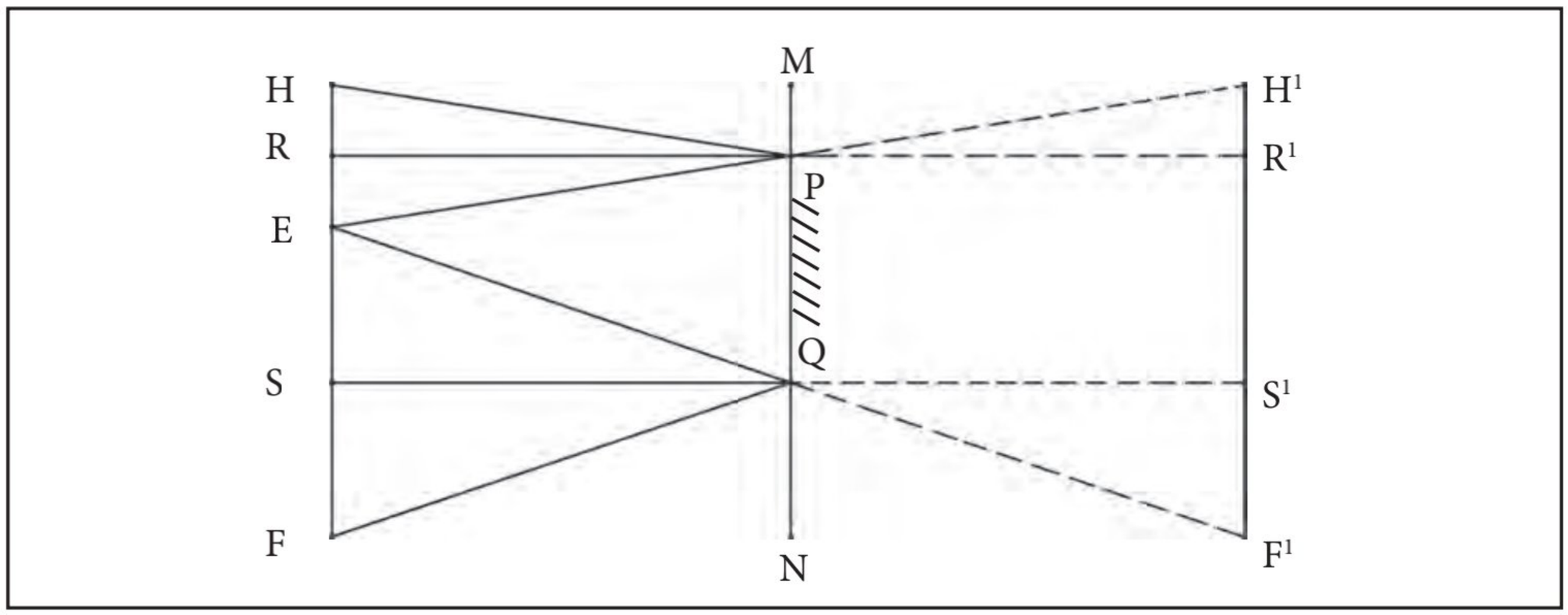


11.4 A plane mirror and the full image of a person

Spherical mirrors

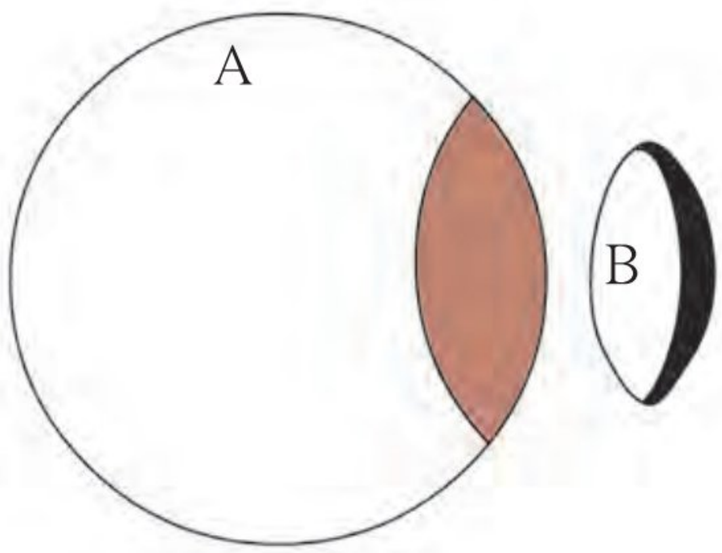
Observe and discuss.

11.5 Laughing Chamber

You must have seen the mirrors displayed in the Laughing Chamber in a fair. Your face appears distorted in these mirrors. Why does this happen? These mirrors are different from the mirrors we have at home. They are curved. The images formed by curved mirrors are different from those formed by plane mirrors. Because of this we do not see the familiar images in these mirrors.

The rear view mirrors in cars, which enable drivers to see the vehicles coming from behind, are curved mirrors.

Try this



11. 6 Creation of spherical mirrors

If we cut a rubber ball into two parts as shown in figure 11.6, we can see that each of the two parts has two types of surfaces.

Generally, spherical mirrors are parts of a hollow glass sphere like the part B in the figure. The inner or outer surface of this part is coated with a shiny substance to produce a spherical mirror. Reflection of light takes place either from its outer or inner surface. Thus, there are two types of spherical mirrors as described below.

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A. Concave mirror

If the inner surface of the spherical mirror is the reflecting surface, then it is called a concave mirror.

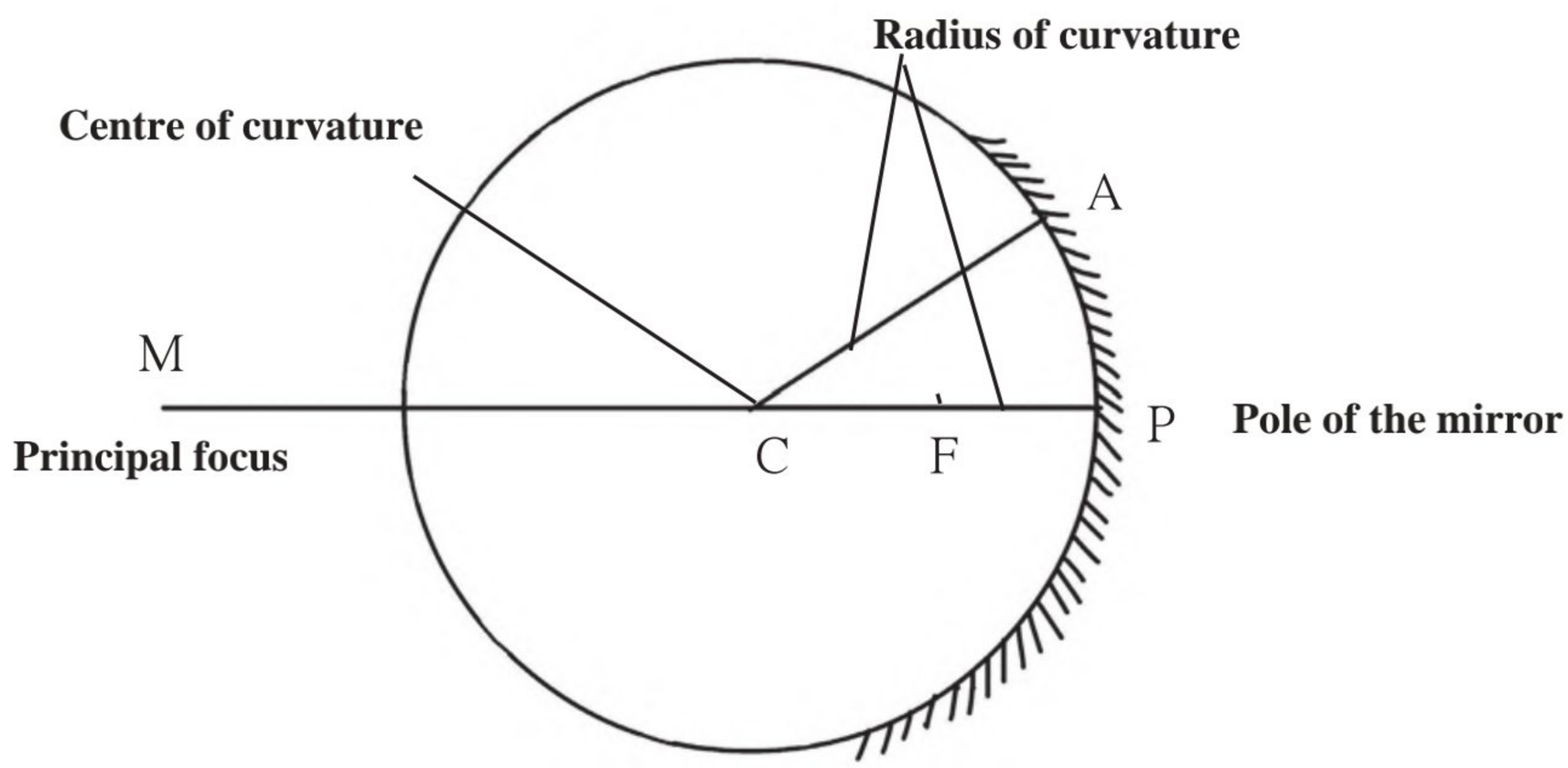
B. Convex mirror

If the outer surface of the spherical mirror is the reflecting surface then it is called a convex mirror.

Terms related to spherical mirrors

Pole : The centre of the mirror surface is called its pole. P is the pole of the mirror in figure 11.7.

Centre of curvature : The centre of the sphere of which the mirror is a part, is called the centre of curvature of the mirror. C is the centre of curvature of the mirror in the figure.



11.7 Terms related to spherical mirrors

Radius of curvature : The radius of the sphere of which the mirror is a part, is called the radius of curvature of the mirror. The length CP or CA in the figure is the radius of curvature of the mirror.

Principal axis : The straight line passing through the pole and centre of curvature of the mirror is called its principal axis. PM is the principal axis of the mirror in the figure.

Principal focus : Incident rays which are parallel to the principal axis of a concave mirror, after reflection from the mirror, meet at a particular point in front of the mirror on the principal axis. This point (F) is called the principal focus of the concave mirror. In the case of a convex mirror, incident rays parallel to the principal axis, after reflection, appear to come from a particular point behind the mirror lying along the principal axis. This point is called the principal focus of the convex mirror.

Focal length : The distance (f) between the pole and the principal focus of the mirror is called the focal length. This distance is half of the radius of curvature of the mirror.

Use your brain power !

What is the difference between the principal focus of the concave and convex mirrors?

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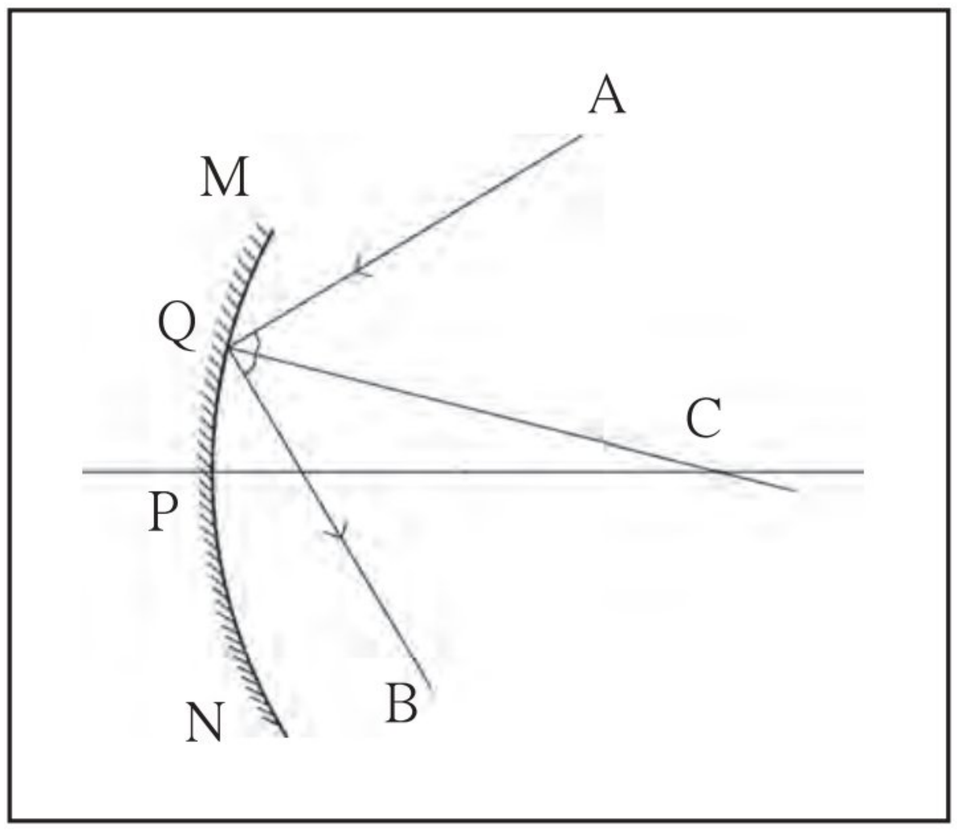
Drawing the reflected rays

Try this



11.8 **Drawing the reflected rays.**

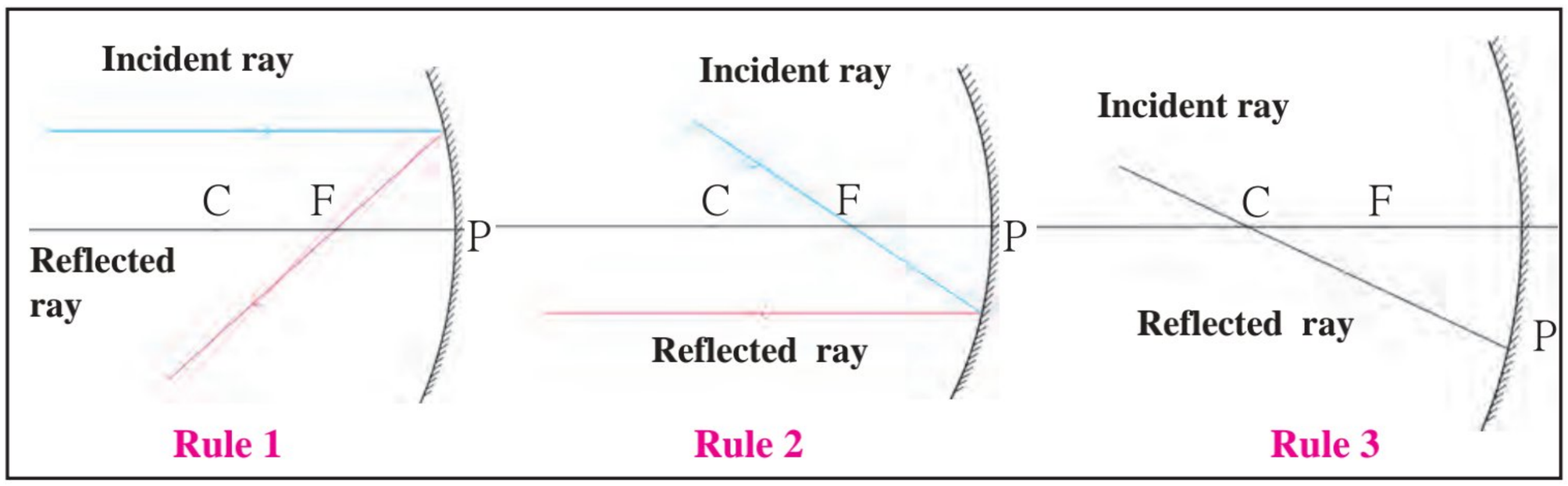
How do we determine the direction that an incident ray will take after reflection from a spherical mirror? In figure 11.8, MN is a spherical mirror and ray AQ is incident on it. CQ is a radius and therefore is perpendicular to the mirror at Q. Thus, angle AQC is the angle of incidence. According to the laws of reflection, angle of incidence and angle of reflection are of the same measure. Thus, while drawing the reflected ray QB, angle CQB must be equal to the angle AQC.

We can study the images produced by spherical mirrors by drawing ray diagrams. A ray diagram is the depiction of the path taken by light rays. To draw a ray diagram, we use the following rules, which are based on the laws of reflection of light. (See figure 11.9).

Rule 1 : If an incident ray is parallel to the principal axis then the reflected ray passes through the principal focus.

Rule 2 : If an incident ray passes through the principal focus of the mirror, the reflected ray is parallel to the principal axis.

Rule 3 : If an incident ray passes through the centre of curvature of the mirror, the reflected ray traces the same path back.



11.9 Rules for drawing ray diagrams

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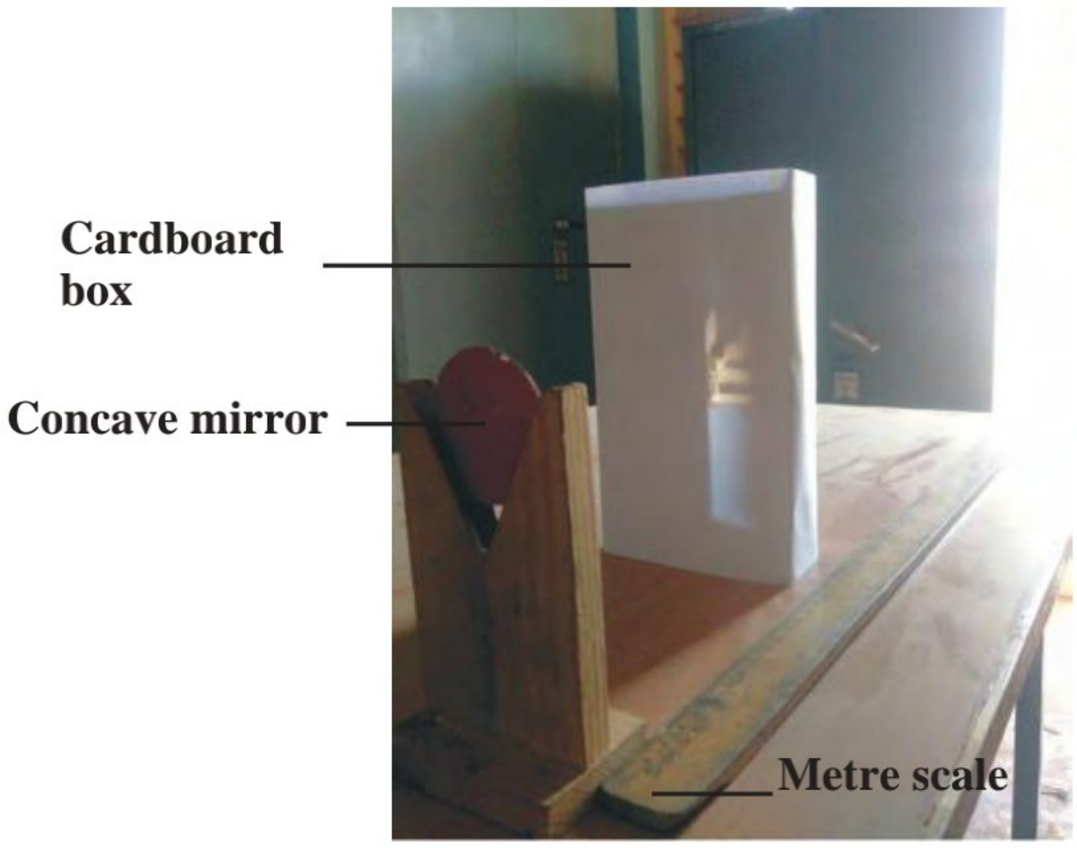
Images formed by a concave mirror

Try this

Material : Candle or glass lamp, two cardboard boxes, large cardboard sheet, white paper, concave mirror, metre ruler, wooden block.

Action : Take the cardboard box, large enough to hold the candle or lamp. Cut off one side and place the candle inside. Cut out an arrow shaped slit from one side, so that we get an arrow shaped light source. Make a screen of size 20 cm x30 cm by sticking a white paper on the cardboard sheet and set it up vertically with the help of the wooden block. Fix the mirror vertically on the other cardboard box by making a slit on its top surface.



11.10 Images formed by a plane mirror

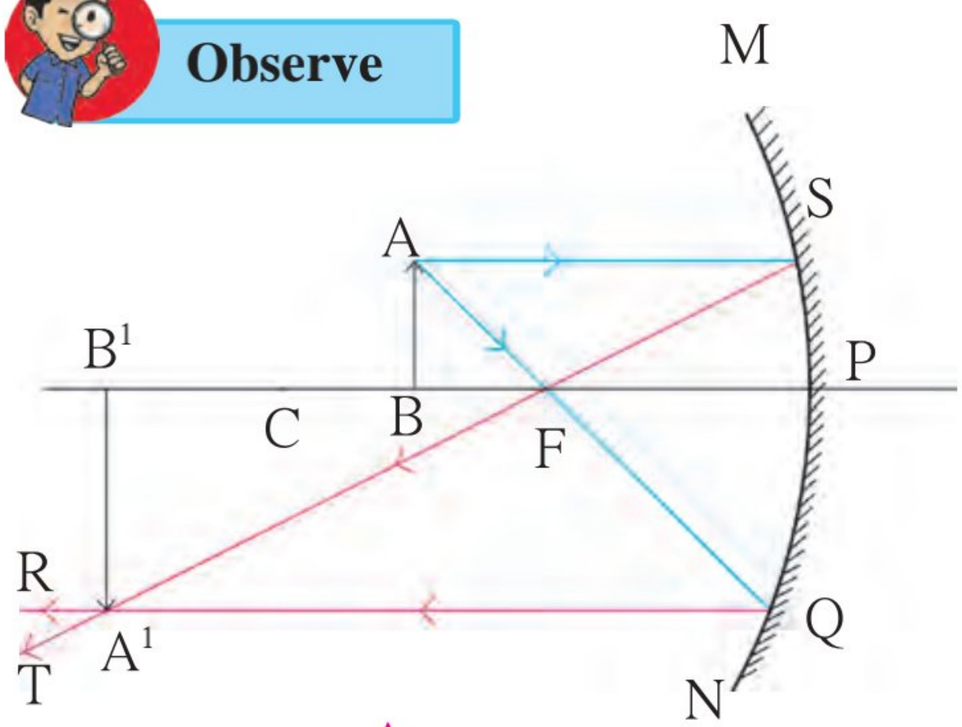
Place the screen near a window and place the mirror in front of it such that the image of the sun or some far away object forms clearly on the screen. Measure the distance between the screen and the mirror in this situation. This is the focal length of the mirror.

Set up the experiment as shown in figure 11.10, in a dark room. Place the mirror near the 0 mark on the metre scale. Place the screen in front of it and place the light source in between the two so that the distance between the mirror and the source is a little more than the focal length of the mirror.

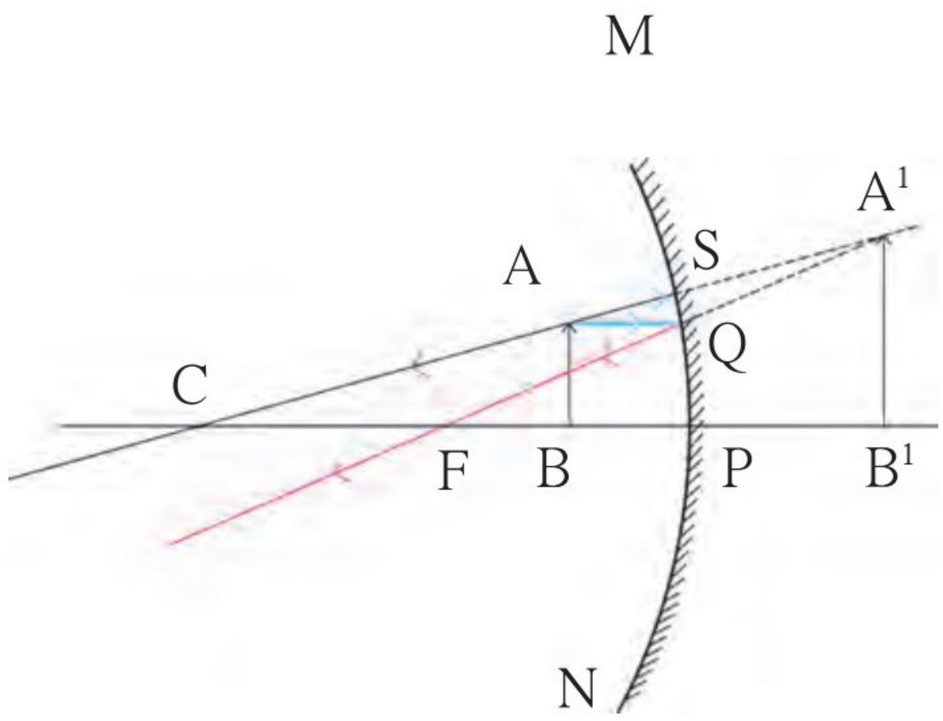
Obtain a clear image of the source on the screen by moving the screen along the metre scale and perpendicular to it. The image will be inverted and larger than the source. As the image is obtained on the screen, it is a real image.

Now move the source away from the mirror so that the distance between the two is greater than twice the focal length of the mirror. Get a clear image on the screen by moving it towards the mirror. The image is inverted, smaller than the object and real.

Observe



A.



B.

11.11 Images obtained in a concave mirror

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As shown in figure 11.11 A, an object AB is placed between the focus and the centre of curvature of the concave mirror MN. The incident ray AQ, starting from A, and going through the focus F, becomes parallel to the principal axis after reflection and returns along QR. The incident ray AS, parallel to the axis, after reflection passes through the focus and returns along the path ST. It cuts the reflected ray QR at point A^1. Thus, the image of A is formed at A^1. The point B is situated on the principal axis and so its image will also be on the axis and will be directly above A^1. Thus the image of B is at B^1. The images of points between A^1 and B^1 will be formed between points A^1 and B^1. Thus, the image of object AB is A^1B^1.

From this we see that when the object is placed between the focus and the centre of curvature of the mirror, the image is formed beyond the centre of curvature. This image is larger than the object and is inverted. As the reflected rays actually cross each other, the image is a real image and can be obtained on a screen.

In figure 11.11 B, an object AB is placed between the pole and focus of the mirror. The incident ray AQ is parallel to the principal axis and the incident ray AS is in the direction joining A with the centre of curvature. The figure shows how these rays get reflected and form the image A^1B^1 of the object. This image is behind the mirror, erect and larger than the object. As the reflected rays do not actually meet but appear to come together behind the mirror, the image is a virtual image.

The position and type of the image produced by a concave mirror when an object is placed at different distances from it are given in the following table.

Images formed by concave mirrors

No.	Position of the object	Position of the image	Nature of image	Size of the image
1	Between pole and focus	Behind the mirror	Erect, virtual	Magnified
2	At the focus	At infinity	Inverted, real	Very large
3	Between focus and centre of curvature	Beyond the centre of curvature	Inverted, real	Magnified
4	At the centre of curvature	At the centre of curvature	Inverted, real	Same as the object
5	Beyond the centre of curvature	Between the centre of curvature and focus	Inverted, real	Diminished
6	At a very large (infinite) distance	At focus	Inverted, real	Point image

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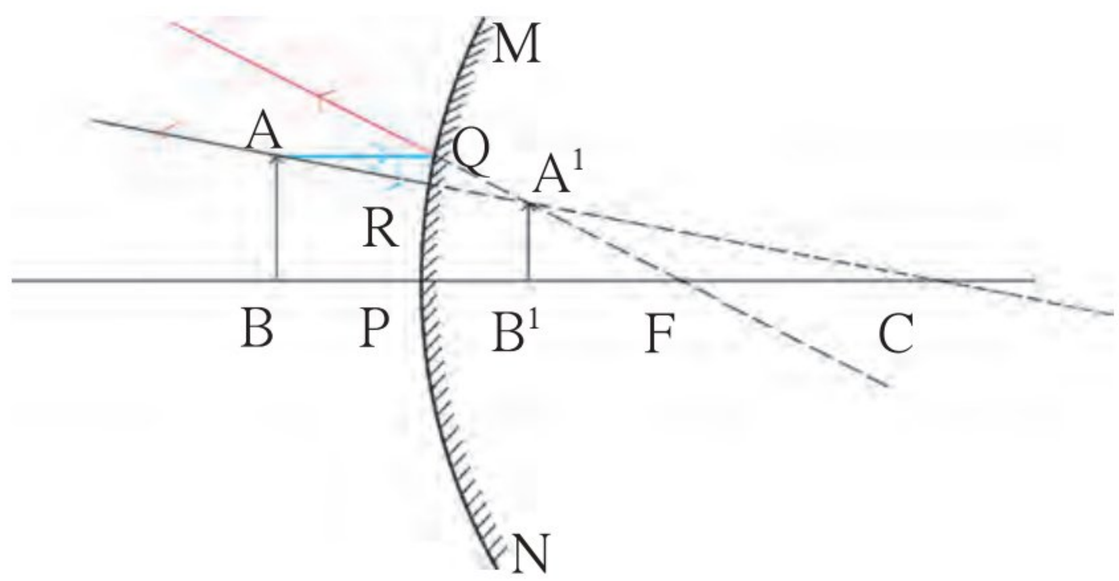
Try this

Draw ray diagrams and determine the position and type of images formed by a concave mirror when the object is placed at (1) Focus (2) Centre of curvature (3) Beyond the centre of curvature and (4) At an infinite distance. Tally your answers with the information given in the table.

Image formed by a convex mirror

Figure 11.12 shows an object AB kept in front of a convex mirror MN. Incident rays AQ, starting from A and travelling parallel to the axis and AR going towards the centre of curvature are shown. How these get reflected and form the image A^1B^1 can be understood from the figure. It is clear that the image is smaller than the object, behind the mirror and erect. As the reflected rays do not actually cross one another, the image is a virtual image.

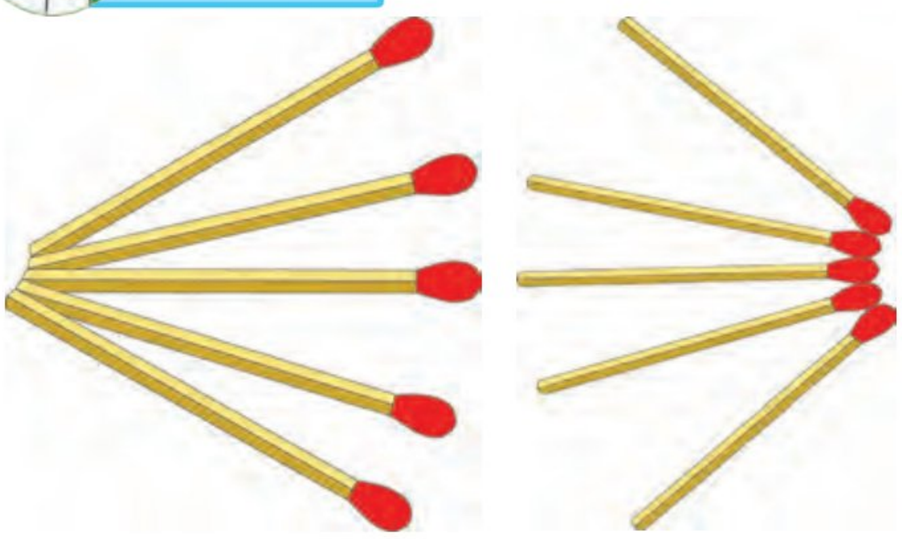
The nature of the image formed by a convex mirror does not depend on the distance of the object from the mirror. These images are always virtual, smaller than the object and situated behind the mirror.



11.12 Image formed in a convex mirror

Divergence and convergence of light

Try this



11.13 Divergence and convergence

A. Take 5 sticks from a matchbox. Arrange them so that their heads come together at a point. In this arrangement, the heads of the matchsticks are said to have converged.

B. Now arrange the sticks so that their uncoated ends are together at a point. The heads are spread apart. In this arrangement, the heads are diverging from the point.

A concave mirror is also called a focusing mirror. This is because, as shown in figure 11.14 A, parallel rays get focused after reflection in this mirror. The size of the image produced by these mirrors can be larger or smaller than the object, depending upon the distance of the object from the mirror.

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A convex mirror is also called a dispersing mirror. This is because, as shown in figure 11.14 B, parallel incident rays get dispersed after reflection in this mirror. The size of the images produced by these mirrors is always smaller than the size of the objects.

How will you find out if a mirror is concave or convex?

The special mirror which is used for shaving is a concave mirror. When held close to the face, it gives vertical and larger image of the face. If the same mirror is taken farther away from the face, the image gets smaller and smaller.

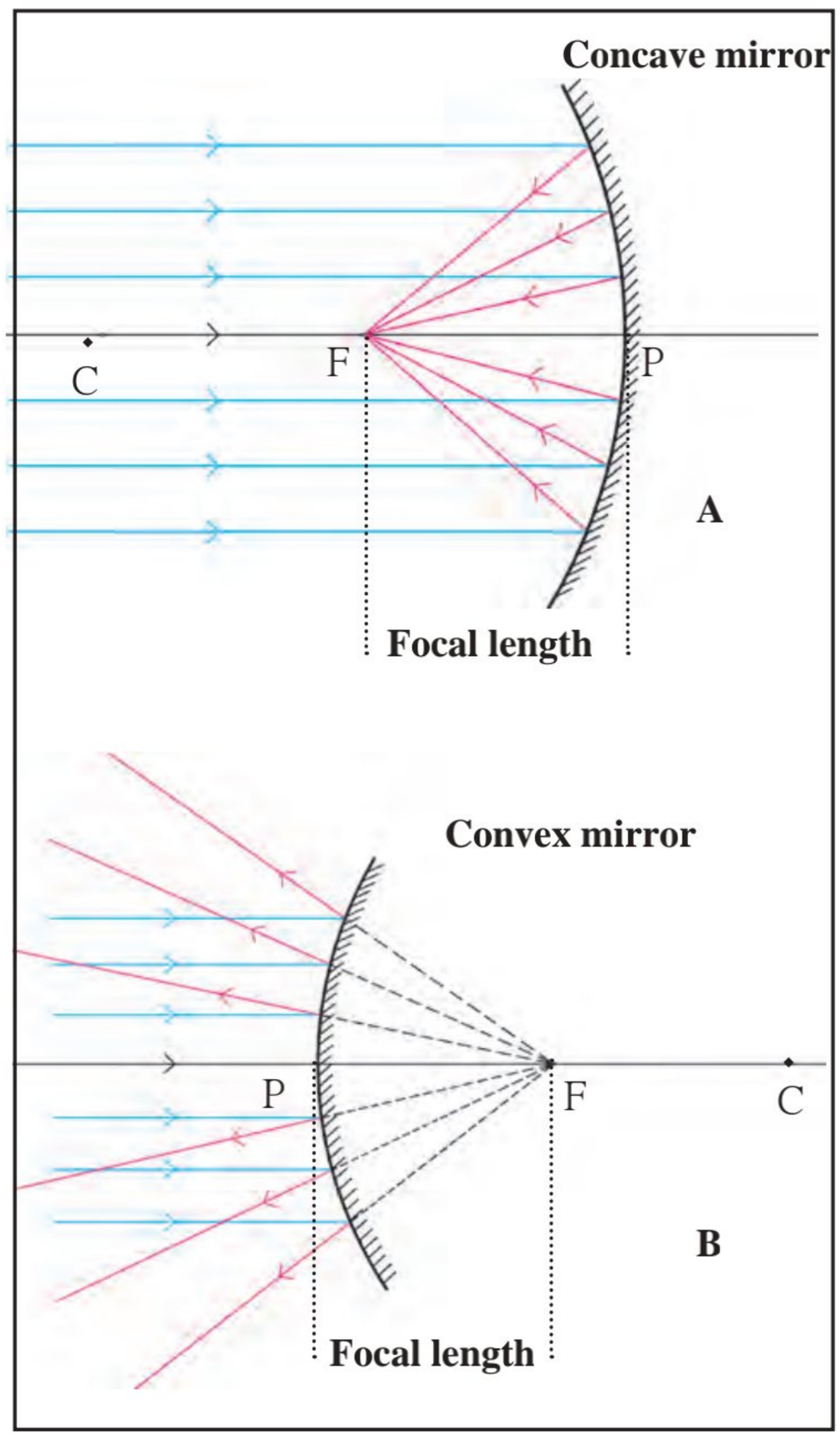
The mirrors used in cars and motorcycles are convex mirrors. In these mirrors the image of a face is erect and smaller and it remains erect but becomes smaller and smaller when the mirror is taken away from the face. As a result we can see the images of the surroundings also in the mirror. Thus, we can determine the nature of the mirror by studying the images produced by them.

When the light rays coming from an object enter our eyes, we can see the object because, while passing through the lenses in our eyes, the rays converge, and the image of the object forms on the retina of our eye. This image, formed by the light rays actually converging at a point, is a real image. A real image can be obtained on a screen.

The image produced by a plane mirror is a virtual image. This image is produced at a point from which the reflected light rays appear to diverge (figure 11.2 B). This image cannot be obtained on a screen as the rays do not actually meet there.

When light rays collect at a point after reflection from a spherical mirror, they are said to converge there. When we want to bring light rays together at a point, a converging light beam is used. Doctors use such a beam to converge light on a tooth, ear, nose, etc. Equipment using solar energy also use converging light.

When light rays starting from a point spread out after reflection by a spherical mirror, light is said to have diverged. When we want light rays to spread out from a source, a divergent beam is used, as for example, in street lamps.



11.14 Concave and convex mirror

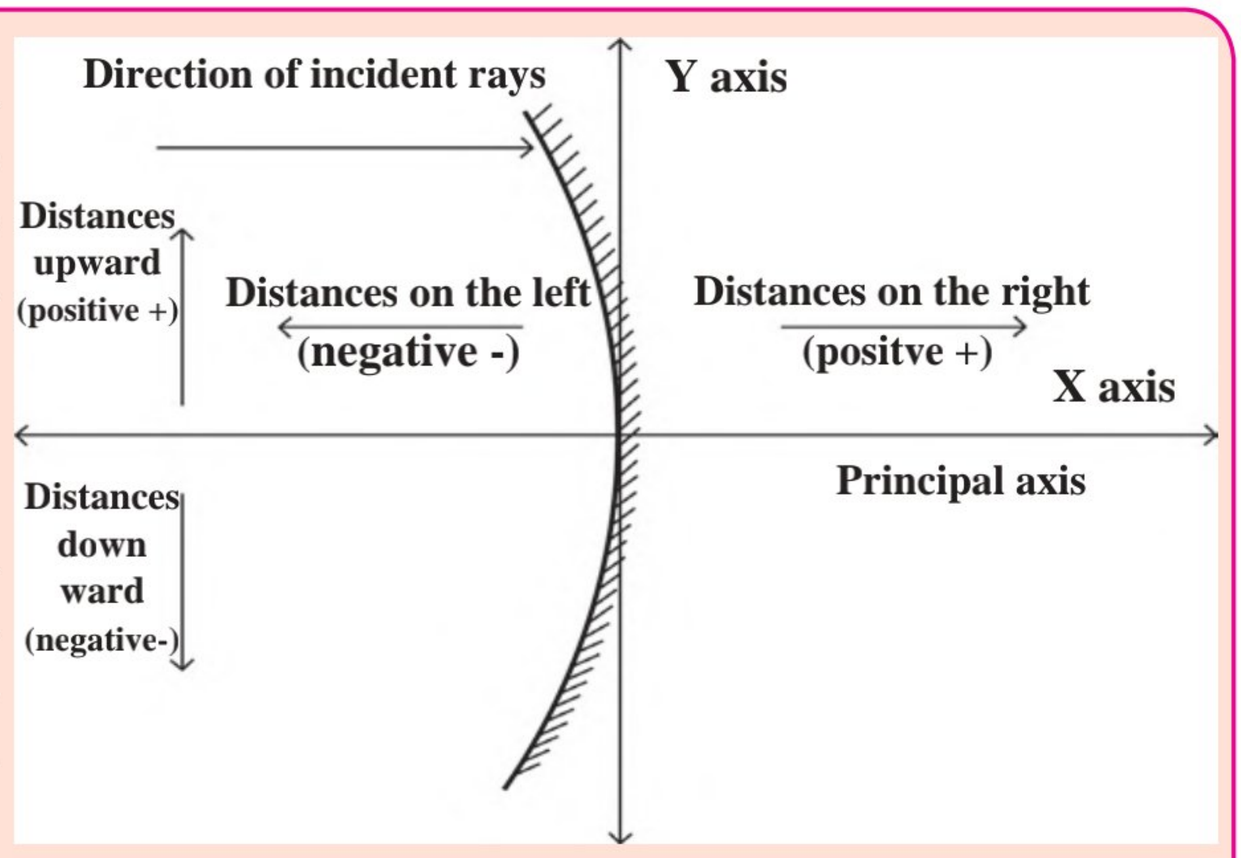
Uses of concave mirrors

1. Barber shop, dental hospital – If the object is placed between the pole and focus of the mirror, an erect, virtual and magnified image is obtained
2. Torch and head lamps of vehicles- The source of light is kept at the focus of the mirror. Thus, a parallel beam of light is obtained.
3. Flood lights- The source of light is placed a little beyond the centre of curvature of the mirror. This gives a bright beam of light.
4. Various equipment using solar energy - Sun rays reflected by a concave mirror come together in the focal plane.

Uses of convex mirrors

1. Mirrors on the sides of cars are convex mirrors
2. Big convex mirrors are fitted in shops.

According to the Cartesian sign convention, the pole of the mirror is taken as the origin. The principal axis is taken as the X- axis of the frame of reference. The sign conventions are as follows.



11.15 Cartesian sign conventions

1. The object is always kept on the left of the mirror. All distances parallel to the principal axis are measured from the pole of the mirror.
2. All distances measured towards the right of the pole are taken to be positive, while those measured towards the left are taken to be negative.
3. Distances measured vertically upwards from the principal axis are taken to be positive.
4. Distances measured vertically downwards from the principal axis are taken to be negative.
5. The focal length of a concave mirror is negative while that of a convex mirror is positive.

Mirror formula

We get the correct values of distances by using the Cartesian sign convention. The object distance (u) is the distance of the object from the pole, while the image distance (v) is the distance of the image from the pole. The relationship between the object distance, image distance and the focal length (f) is called the mirror formula.

The mirror formula is expressed as follows :

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

This formula is valid for all spherical mirrors, for all positions of objects, under all circumstances.

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Magnification due to spherical mirrors

The magnification due to a spherical mirror is given by the ratio of the height of the image (h_2) to the height of the object (h_1). This tells us how large the image is as compared to the object.

Magnifiction M $= \dfrac{\text{Height of the image}}{\text{Height of the object}} = \dfrac{h_2}{h_1}$. From this it can be shown that $\mathbf{M = -\dfrac{v}{u}}$

As the object is always kept above the principal axis, its height is always taken to be positive. For virtual images, the height is positive while for real images, it is negative. As the object is kept on the left of the mirror, its distance (u) is always negative.

Try this Determine the sign of magnification in each of the 6 cases in the table on page 122 using both formulae and verify that they are the same.

Solved examples

Example : Rajashree wants to get an inverted image of height 5 cm of an object kept at a distance of 30 cm from a concave mirror. The focal length of the mirror is 10 cm. At what distance from the mirror should she place the screen ? What will be the type of the image, and what is the height of the object?

Given :

Focal length $= f = -10$ cm, object distance $= u = -30$ cm ,
height of the image $= h_2 = -5$ cm
Image distance $= v = ?$, height of object $= h_1 = ?$

According to the mirror formula

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$$

$$\frac{1}{v} = \frac{1}{-10} - \frac{1}{-30}$$

$$\frac{1}{v} = \frac{-3+1}{30}$$

$$\frac{1}{v} = \frac{-2}{30}$$

$$\frac{1}{v} = \frac{1}{-15} \text{ cm}$$

$$v = -15$$

Magnification

$$M = \frac{h_2}{h_1} = -\frac{v}{u}$$

$$h_1 = -\frac{uh_2}{v}$$

$$h_1 = -\frac{(-30)(-5)}{-15}$$

$$h_1 = (-2)(-5)$$

$$h_1 = 10 \text{ cm}$$

The height of the object is 10 cm. Thus, the image will be real and diminshed.

Rajashree has to place the screen 15 cm to the left of the mirror.

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Always remember

The image in front of the mirror which can be obtained on a screen is called a real image. For any position of the object, a convex mirror always produces an erect diminished image (which is smaller than the object) and is situated behind the mirror. The image which is behind the mirror and thus cannot be obtained on a screen is called a virtual image. The magnification of such an image is less than 1.

Exercises

1. Answer the following questions.

a. Explain the difference between a plane mirror, a concave mirror and a convex mirror with respect to the type and size of the images produced.

b. Describe the positions of the source of light with respect to a concave mirror in 1.Torch light
2. Projector lamp 3. Floodlight

c. Why are concave mirrors used in solar devices?

d. Why are the mirrors fitted on the outside of cars convex?

e. Why does obtaining the image of the sun on a paper with the help of a concave mirror burn the paper?

f. If a spherical mirror breaks, what type of mirrors are the individual pieces?

2. What sign conventions are used for reflection from a spherical mirror?

3. Draw ray diagrams for the cases of images obtained in concave mirrors as described in the table on page 122.

4. Which type of mirrors are used in the following?

Periscope, floodlights, shaving mirror, kaleidoscope, street lights, head lamps of a car.

5. Solve the following examples

a. An object of height 7 cm is kept at a distance of 25 cm in front of a concave mirror. The focal length of the mirror is 15 cm. At what distance from the mirror should a screen be kept so as to get a clear image? What will be the size and nature of the image? **(Answer: 37.5 cm and 10.5 cm. Image is real)**

b. A convex mirror has a focal length of 18 cm. The image of an object kept in front of the mirror is half the height of the object. What is the distance of the object from the mirror? **(Answer: 18 cm)**

c. A 10 cm long stick is kept in front of a concave mirror having focal length of 10 cm in such a way that the end of the stick closest to the pole is at a distance of 20 cm. What will be the length of the image? **(Answer: 10 cm)**

6. Three mirrors are created from a single sphere. Which of the following - pole, centre of curvature, radius of curvature, principal axis - will be common to them and which will not be common?

Project :

Make a kaleidoscope and make a presentation in the class about how it works.

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12. Study of Sound

- **Sound waves**
- **Velocity of sound**
- **Reflection of sound**
- **The human ear, audible sound, infra sound and ultrasound**

Can you recall?

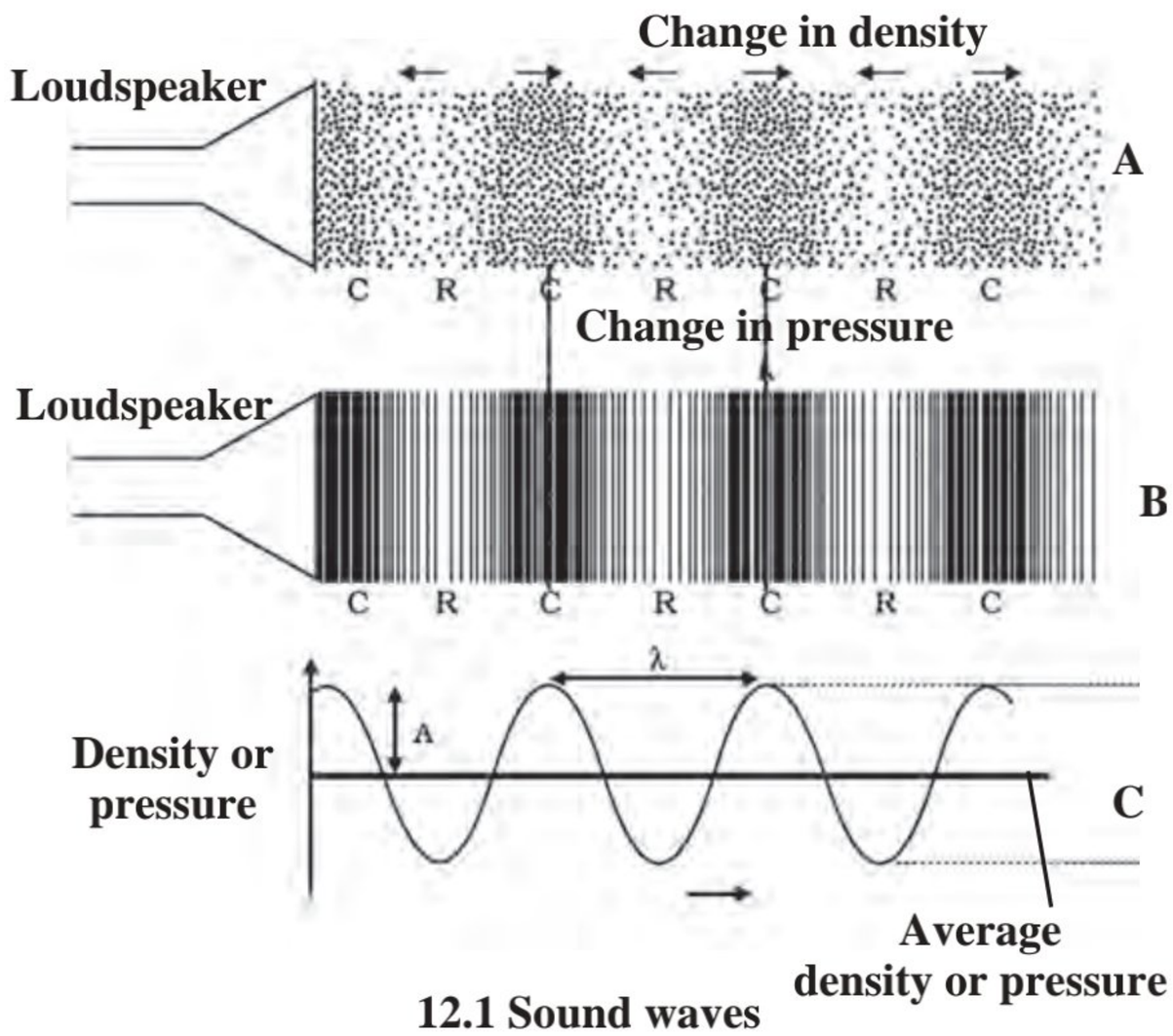
1. How does the velocity of sound depend on its frequency?
2. How is the direction of the oscillation of the particles of the medium related to the direction of propagation of the sound-wave?

Sound is a form of energy which creates the sensation of hearing in our ears. This energy is in the form of waves. A medium is necessary for the propagation of sound waves. Sound waves give rise to a chain of compression (place of higher density) and rarefaction (place of lower density) in the medium. The particles of the medium oscillate about their central or mean positions, in a direction parallel to the propagation of the wave. Such waves are called **longitudinal waves**. On the other hand, in the waves created by dropping a stone in still water, the particles of water oscillate up and down. These oscillations are perpendicular to the direction of propagation of the wave, such waves are called **transverse waves**.

Observe and discuss.

A sound wave can be shown in the form a graph. At any moment during the propagation of a sound wave we would find alternate bands of compression and rarefaction of the medium i.e. bands of greater and lesser density.

Figure 12.1 A shows the changes in density while figure B shows the changes in pressure. The changes in density or pressure are shown in the form of a graph in figure C.



12.1 Sound waves

The wavelength of sound waves is indicated by the Greek letter *lambda* (λ), while its frequency is indicated by *nu* (υ). The amplitude, which is the maximum value of pressure or density, is indicated by A. The time taken for one oscillation of pressure or density at a point in the medium is called the time period and is indicated by T.

The value of frequency determines the pitch (high or low) of the sound while the value of the amplitude determines its strength or loudness.

Research

1. How are the frequencies of notes ***sa, re ga ma, pa, dha, ni*** related to each other?
2. What is the main difference between the frequencies of the voice of a man and that of a woman?

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Velocity of sound

Try this

1. Take your friend to a place where there are iron pipes e.g. the school verandah, a staircase or a fence.
2. Stand near one end of the pipe and ask the friend to stand 20 to 25 feet away from you near the pipe.
3. Ask the friend to gently tap the pipe with a stone. Press your ear to the pipe and listen to the sound coming through the pipe.
4. The same sound coming through the air can also be heard. But which sound reaches you first?

From the above activity you can see that you hear the sound through the iron pipe much before you hear it coming through air. This shows that sound travels faster in iron than in air.

The distance covered by a point on the wave (for example the point of highest density or lowest density) in unit time is the velocity of the sound wave.

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$

Any point on the sound wave covers a distance equal to λ (wavelength) in time T (time period). Thus the velocity of sound is given by

$$v = \upsilon \lambda \text{ because } \frac{1}{T} = \upsilon$$

$$\text{Velocity} = \frac{\text{Wavelength}}{\text{Time period}} \qquad v = \frac{\lambda}{T}$$

Thus, the velocity of sound = wavelength x frequency.

In any medium at fixed physical conditions the velocity of sound of different frequencies is very nearly the same. The velocity is highest in solids and least in gases. It increases with an increase in the temperature of the medium.

The Italian physicists Borelli and Viviani, in the 1660s, first calculated the speed of sound. They measured the time between seeing the flash of a gun and hearing its sound from a long distance. Their value of 350 m/s is very close to the value of 346 m/s which is accepted today.

Velocity of sound in various mediums at 25^0C

State	Substance	Speed (m/s)
Solid	Aluminum	5420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass	3980
Liquid	Sea water	1531
	Pure water	1498
	Ethanol	1207
	Methanol	1103
Gas	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

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Velocity of sound in a gaseous medium: The velocity of sound in a gaseous medium depends on the physical conditions i.e. the temperature, density of the gas and its molecular weight.

Temperature (T): The velocity of sound is directly proportional to the square root of the temperature of the medium. This means that increasing the temperature four times doubles the velocity.

$$v \propto \sqrt{T}$$

Density (ρ): The velocity of sound is inversely proportional to the square root of density. Thus, increasing the density four times, reduces the velocity to half its value.

$$v \propto \frac{1}{\sqrt{\rho}}$$

Molecular weight (M): The velocity sound is inversely proportional to the square root of molecular weight of the gas. Thus, increasing the molecular weight four times, reduces the velocity to half its value. $v \propto \frac{1}{\sqrt{M}}$

Think

The molecular weight of oxygen gas (O_2) is 32 while that of hydrogen gas (H_2) is 2. Prove that under the same physical conditions, the velocity of sound in hydrogen is four times that in oxygen.

For a fixed temperature, the velocity of sound does not depend on the pressure of the gas.

Audible, infra- and ultra-sound

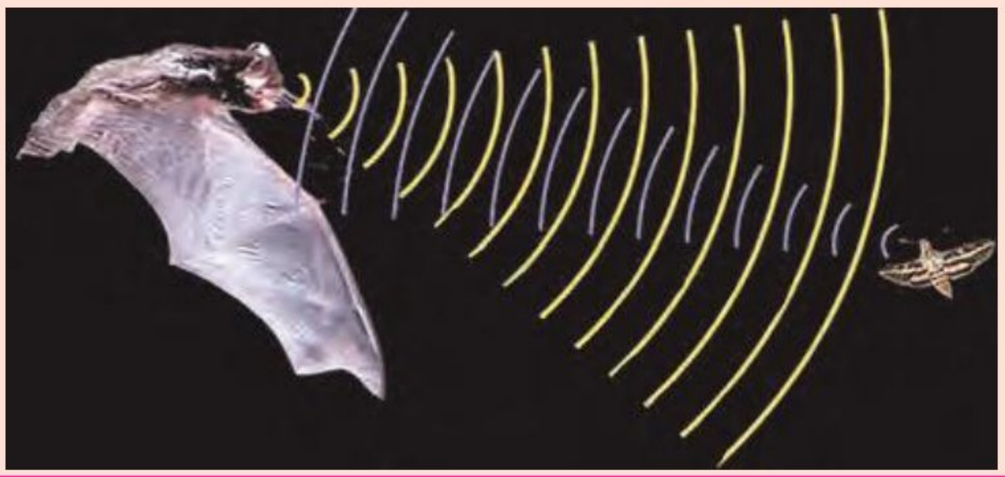
The limits of hearing of the human ear are 20 Hz to 20,000 Hz. That is, the human ear can hear sounds of frequencies in this range. These sounds are called audible sounds. Our ears cannot hear sounds of frequencies lower than 20 Hz and higher than 20,000 Hz (20 kHz). Sound with frequency smaller than 20 Hz is called infra sound. The sound produced by a pendulum and the sound generated by the vibrations of the earth's crust just before an earthquake are examples of such sounds. Sound waves with frequency greater than 20 kHz are called ultrasound.

The dog, mouse, bat, dolphin etc have a special ability to hear ultrasonic sounds. Thus, they can sense some noise which are inaudible to us. Children under 5 years of age and some creatures and insects can hear waves with frequency up to 25 kHz. Bats, mice, dolphins, etc, can also produce ultrasound.

A peep into the past

The Italian scientist Spallanzani was the first to discover a special mechanism present in bats. He covered various organs of bats like the eyes, ears, nose, etc. one by one and allowed them to fly in the dark thereby discovering how they can fly easily in the dark. He found that the bats with their ears covered began to collide with whatever came in their path. Even though their eyes were open. They were of no use to the bats. He thus discovered that their ability to fly in the dark depends on their ears and not eyes.

The ultrasonic sound produced by bats, gets reflected on hitting an obstacle. This reflected sound is received by their ears and they can locate the obstacle and estimate its distance even in the dark.



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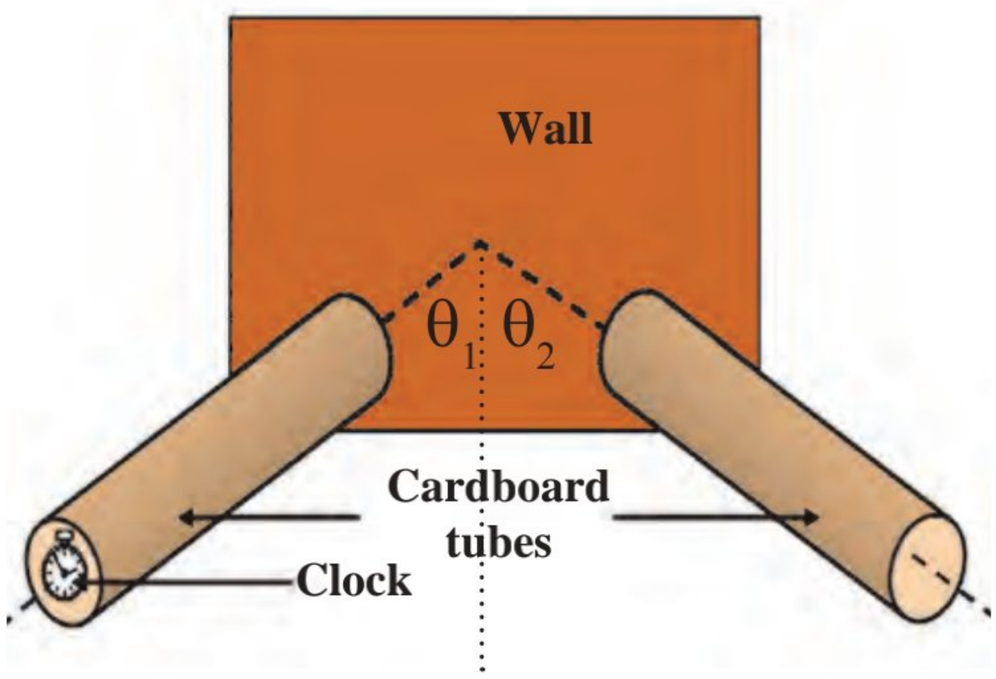
Uses of ultrasonic sound

1. For communication between ships at sea.
2. To join plastic surfaces together.
3. To sterilize liquids like milk by killing the bacteria in it so that the milk keeps for a longer duration.
4. Echocardiaography which studies heartbeats, is based on ultrasonic waves (Sonography technology).
5. To obtain images of internal organs in a human body.
6. In industry, to clean intricate parts of machines where hands cannot reach.
7. To locate the cracks and faults in metals blocks.

Reflection of sound

Try this

1. Make two sufficiently long, identical tubes out of a cardboard.
2. Arrange them on a table, in front of a wall as shown in figure 12.2.
3. Place a clock near the end of one of the tubes and try to hear the ticking of the clock at the end of the other tube by placing your ear there.
4. Adjust the angles of the two tubes till you can hear the sound very clearly.
5. Measure the angle of incidence θ_1 and the angle of reflection θ_2. Try to see if they are related in any way.



12.2 Reflection of sound

Like light waves, sound waves, too, get reflected from a solid or a liquid surface. These waves also follow the laws of reflection. A smooth or a rough surface is needed for the reflection of sound. The direction of the incident sound wave and reflected sound wave make equal angles with the perpendicular to the surface and all these three lie in the same plane.

Good and bad reflectors of sound

How much of the incident sound gets reflected decides whether a reflector is a good or a bad reflector. A hard and flat surface is a good reflector while clothes, paper, curtains, carpet, furniture, etc. absorb sound instead of reflecting it and, therefore are called bad reflectors.

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Use your brain power !

In the above activity, what will happen if you lift one of the tubes to some height?

Echo

You must have visited an echo point at a hill station. If you shout loudly at such a point, you hear the same sound just after a little while. This sound is called an echo.

An echo is the repetition of the original sound because of reflection by some surface.

In order to be able to hear the original sound and its reflection distinctly, at 22 ^{0}C, what must the minimum distance be between the source and the reflecting surface? At 22 ^{0}C, the velocity of sound in air is 344 m/s. Our brain retains a sound for 0.1 s. Thus, for us to be able to hear a distinct echo, the sound should take more than 0.1 s after starting from the source to get reflected and come back to us. Thus we can determine the minimum distance between the source and the reflecting surface as follows:

Distance = speed × time

= 344 m/s × 0.1 s

= 34.4 m

Thus, to be able to hear a distinct echo, the reflecting surface should be at a minimum distance of half of the above i.e. 17.2 m. As the velocity of sound depends on the temperature of air, this distance depends on the temperature.

Use your brain power !

1. To hear the echo distinctly, will the distance from the source of sound to the reflecting surface be same at all temperatures? Explain your answer.
2. When is the reflection of sound harmful?

Science in the surroundings.....

Echo can be heard multiple times due to continuous or multiple reflections. The golghumat at Vijapur in Karnataka is an excellent example of this.

Reverberation

Compare the two cases:

1. Go to an empty, closed house with your friends.
2. Once inside, chat with your friends.
3. Note what you sense.

1. Close the doors and windows of your house and switch on the music system.
2. Increase the loudness of the system as much as possible.
3. Note what you sense.

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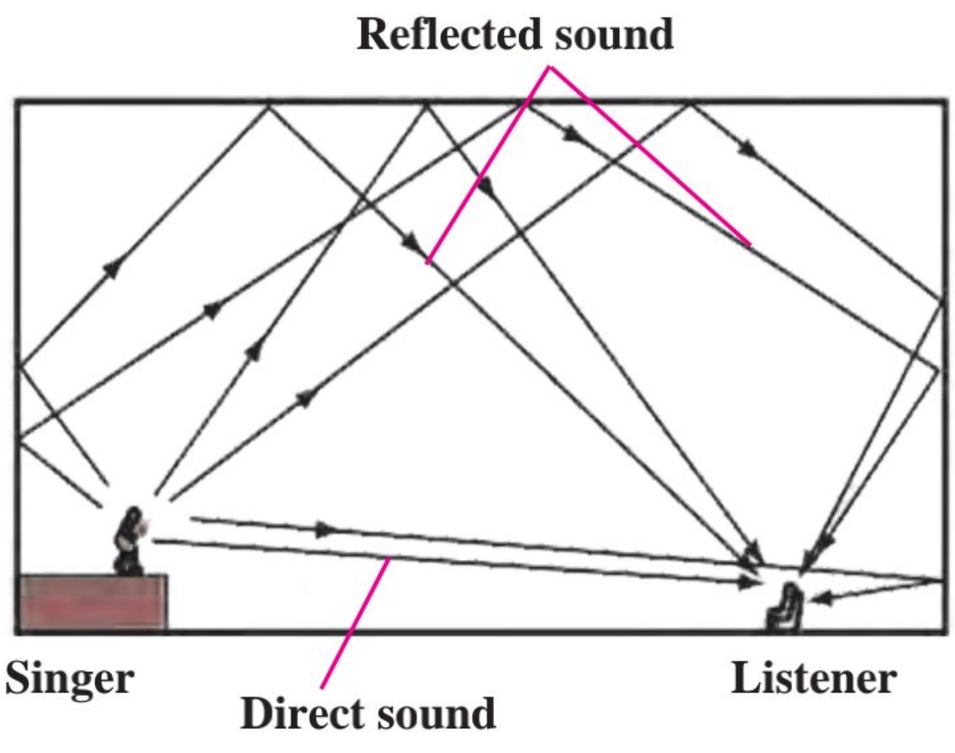
Sound waves get reflected from the walls and roof of a room multiple times. This causes a single sound to be heard not once but continously. This is called reverberation. The time between successive reflections of a particular soundwave reaching us becomes smaller and the reflected sounds get mixed up and produce a continuous sound of increased loudness which cannot be deciphered clearly. This is the reason why some auditoriums or some particular seats in an auditorium have inferior sound reception. This is shown in figure 12.3.



12.3 Reverberation

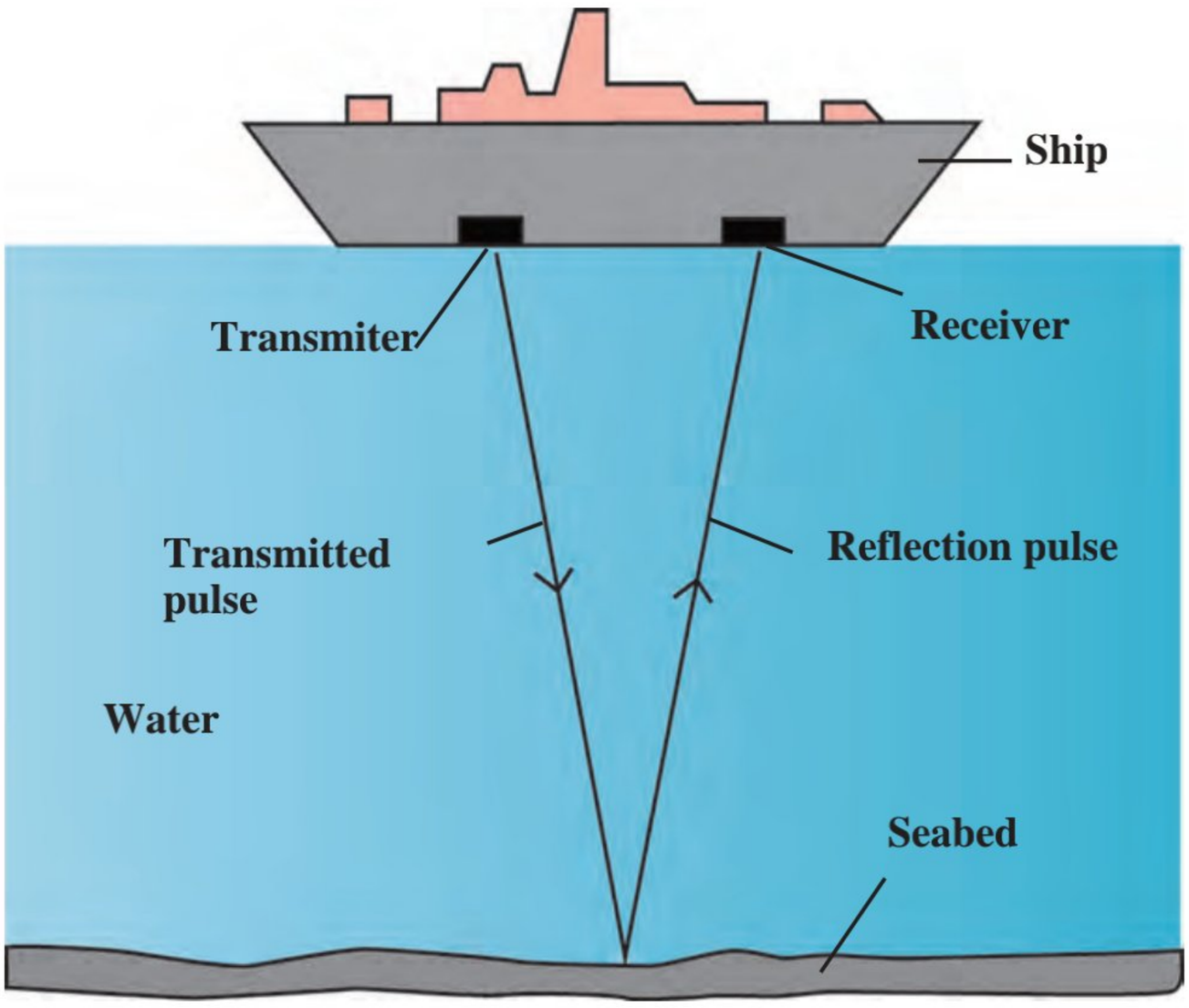
Use your brain power !

How will you reduce reverberation in public halls or buildings?

SONAR

SONAR is the short form for Sound Navigation and Ranging. It is used to determine the direction, distance and speed of an underwater object with the help of ultrasonic sound waves. SONAR has a transmitter and a receiver, which are fitted on ships or boats.

The transmitter produces and transmits ultrasonic sound waves. These waves travel through water, strike underwater objects and get reflected by them. The reflected waves are received by the receiver on the ship.



12.4 The SONAR technique

The receiver converts the ultrasonic sound into electrical signals and these signals are properly interpreted. The time difference between transmission and reception is noted. This time and the velocity of sound in water give the distance from the ship, of the object which reflects the waves.

SONAR is used to determine the depth of the sea. SONAR is also used to search underwater hills, valleys, submarines, icebergs, sunken ships etc.

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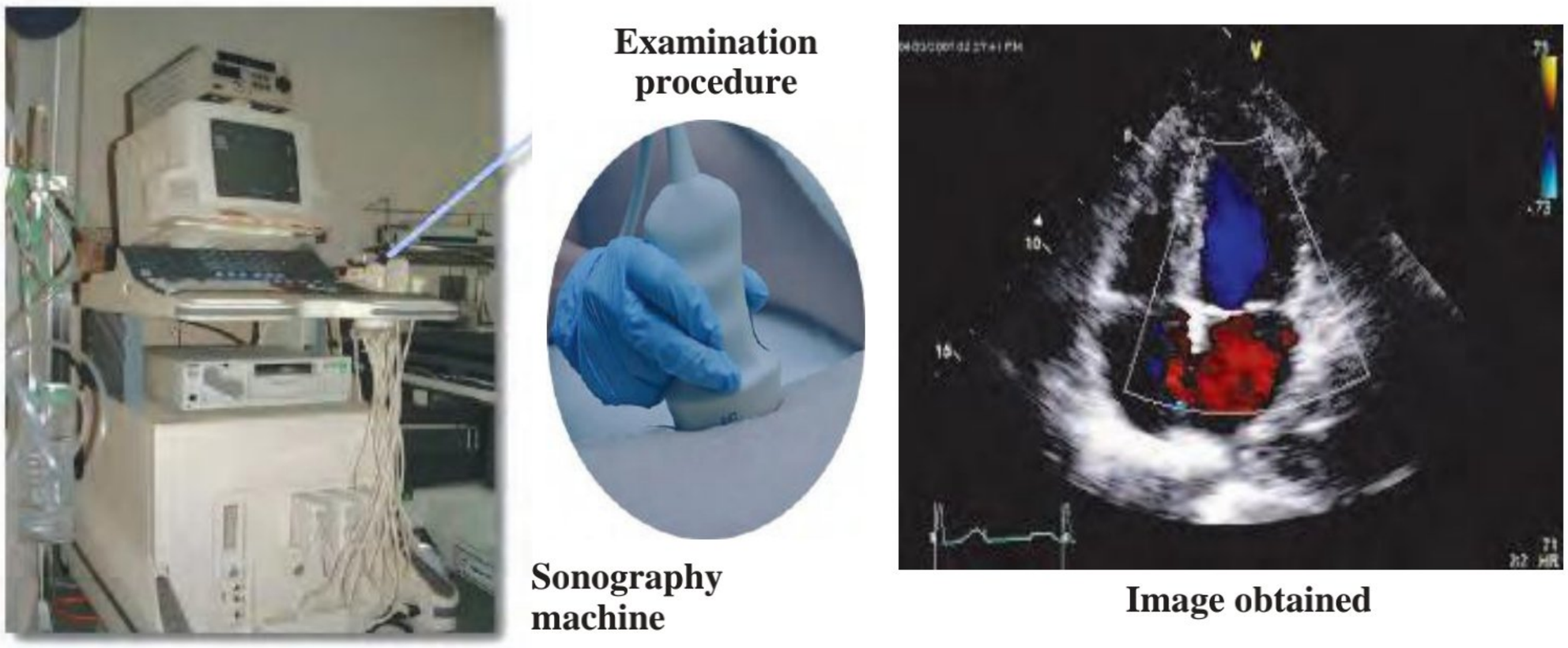
Sonography

Sonography technology uses ultrasonic sound waves to generate images of internal organs of the human body. This is useful in finding out the cause of swelling, infection, pain, etc. The condition of the heart, the state of the heart after a heart attack as well as the growth of foetus inside the womb of a pregnant woman are studied using this technique.



12.5 Sonography machine and images obtained

This technique makes use of a probe and a gel. The gel is used to make proper contact between the skin and the probe so that the full capacity of the ultrasound can be utilized.

The gel is applied to the skin outside the internal organ to be studied. High frequency ultrasound is transmitted inside the body with the help of the probe. The sound reflected from the internal organ is again collected by the probe and fed to a computer which generates the images of the internal organ. As this method is painless, it is increasingly used in medical practice for correct diagnosis.

Find out

How is ultrasound used in medical science?

Always remember

Developments in science have led to advances in technology which have helped us make much progress. However, every coin has two sides and the misuse of science has had serious consequences for human life. The sonography technique can help to follow the growth and well being of an unborn baby. But the increasing incidence of female foeticide as a result of the discrimination between the girl and the boy child is an example of the grave misuse of this technique. Female foeticide is now a cognizable offence under the PNDT Act.

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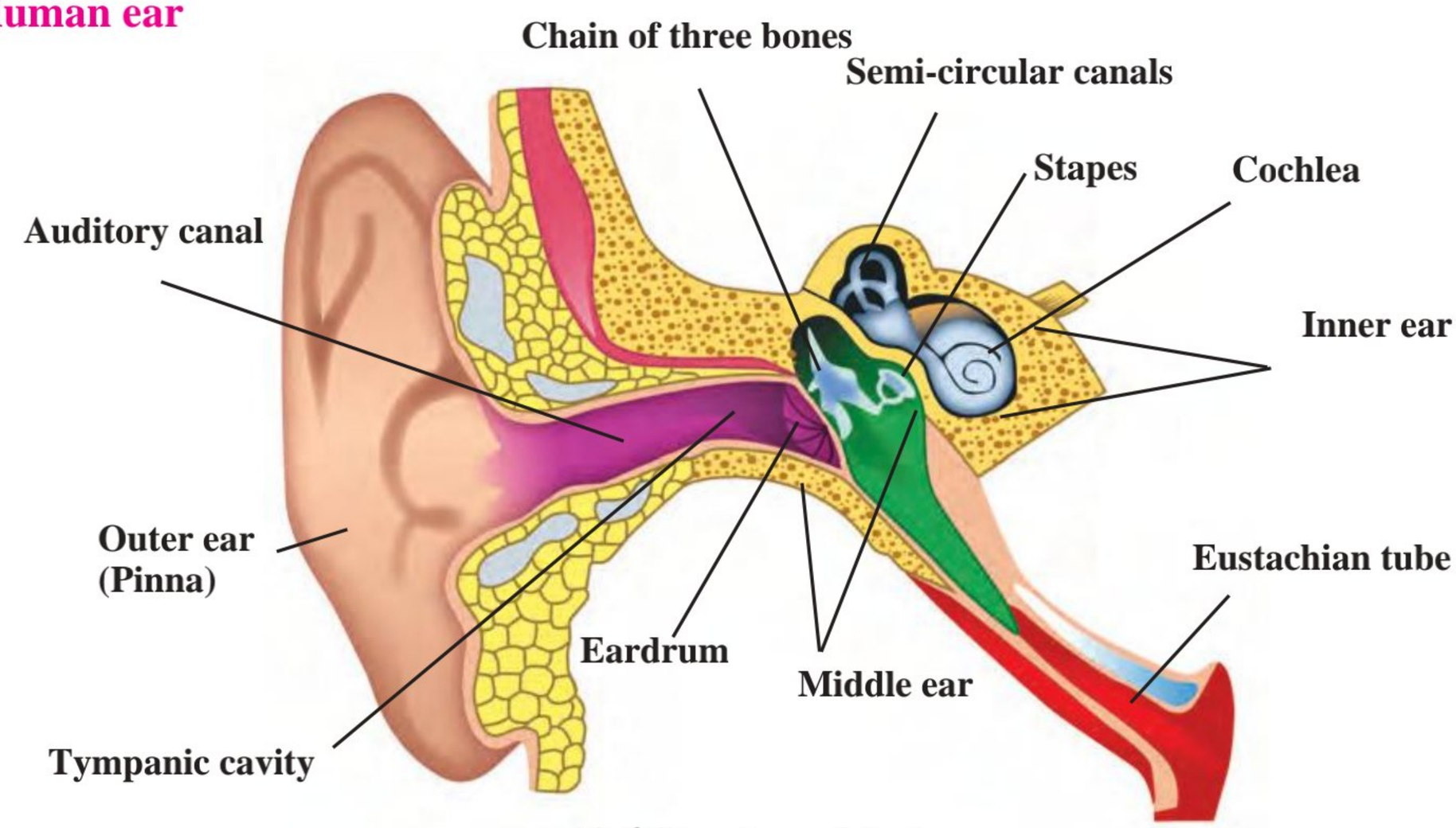
Human ear



12.6 Structure of the human ear

The ear is an important organ of the human body. We hear sounds because of our ear. When sound waves fall on the eardrum, it vibrates. These vibrations are converted into electrical signals which travel to the brain through nerves. The ear can be divided into three parts: 1. Outer ear 2. Middle ear 3. Inner ear.

Outer ear or Pinna

The outer ear collects the sound waves and passes them through a tube to a cavity in the middle ear. Its peculiar funnel like shape helps to collect and pass sounds into the middle ear.

Middle ear

There is a thin membrane in the cavity of the middle ear called the eardrum. When a compression in a sound wave reaches the eardrum, the pressure outside it increases and it gets pushed inwards. The opposite happens when a rarefaction reaches there. The pressure outside decreases and the membrane gets pulled outwards. Thus, sound waves cause vibrations of the membrane.

Inner ear

The auditory nerve connects the inner ear to the brain. The inner ear has a structure resembling the shell of a snail. It is called the cochlea. The cochlea receives the vibrations coming from the membrane and converts them into electrical signals which are sent to the brain through the nerve. The brain analyses these signals.

Always remember

The ear is an important sensory organ. Sticks or other pointed objects should never be inserted into the ear for cleaning it. Also, one should not hear very loud music using earphones. It may cause grave injury to the eardrum.

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Solved examples

Example 1 : How long will it take for a sound wave of 25 cm wavelength and 1.5 kHz frequency of, to travel a distance of 1.5 km?

Given : Frequency (υ) = 1 5 kHz

$= 1\ 5 \times 10^3$ Hz

Wavelength (λ) = 25 cm = 0 25 m

distance (s) = 1 5 km = $1\ 5 \times 10^3$ m

time (t) = ?

Velocity of sound = Frequency × Wavelength

$v = \upsilon\ \lambda$

$v = 1\ 5 \times 10^3 \times 0\ 25$

$v = 0\ 375 \times 10^3$

$v = 375$ m/s

$$\text{Time} = \frac{\text{Distance}}{\text{Velocity}}$$

$$t = \frac{s}{v} = \frac{1.5 \times 10^3}{375} = \frac{1500}{375} = 4 \text{ s}$$

The sound wave takes 4 s to travel the distance of 1.5 km.

Example 2 : Ultrasonic waves are transmitted downwards into the sea with the help of a SONAR. The reflected sound is received after 4 s. What is the depth of the sea at that place?

(Velocity of sound in seawater = 1550 m/s)

Given :

Velocity of sound in seawater = 1550 m/s

Time for echo to be heard = 4s

Time taken by sound waves to reach the bottom of the sea $= \frac{4}{2} = 2$ s

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$

Distance = Velocity × Time

$= 1550 \times 2 = 3100$ m

Depth of the sea at that place = 3100 m

Example 3 : Sound waves of wavelength 1 cm have a velocity of 340 m/s in air. What is their frequency? Can this sound be heard by the human ear?

Given : Wavelength = λ =1cm=1×10^{-2}m, Velocity of sound = v = 340 m/s

$$v = \upsilon\ \lambda$$

$$\therefore \upsilon = \frac{v}{\lambda} = \frac{340}{1 \times 10^{-2}} = 340 \times 10^2$$

$\therefore \upsilon = 34000$ Hz

This frequency is higher than 20000 Hz and, therefore, this sound cannot be heard by the human ear.

The SONAR technology was first developed during World War I to detect enemy submarines. This technology can be used in air also. In fact, bats use this technique to detect obstacles in their path so that they can avoid them and fly freely even in the dark.

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Exercises

1. Fill in the blanks and explain.

a. Sound does not travel through ……

b The velocity of sound in steel is ……. than the velocity of sand in water.

c. The incidence of …… in daily life shows that the velocity of sound is less than the velocity of light.

d. To discover a sunken ship or objects deep inside the sea, ... technology is used.

2. Explain giving scientific reasons.

a. The roof of a movie theatre and a conference hall is curved.

b. The intensity of reverberation is higher in a closed and empty house.

c. We cannot hear the echo produced in a classroom.

3. Answer the following questions in your own words.

a. What is an echo? What factors are important to get a distinct echo?

b. Study the construction of the Golghumat at Vijapur and discuss the reasons for the multiple echoes produced there.

c. What should be the dimensions and the shape of classrooms so that no echo can be produced there?

4. Where and why are sound absorbing materials used?

5. Solve the following examples.

a. The speed of sound in air at 0 ^{0}C is 332 m/s. If it increases at the rate of 0.6 m/s per degree, what will be the temperature when the velocity has increased to 344 m/s?

(Ans: 200 ^{0}C)

b. Nita heard the sound of lightning after 4 seconds of seeing it. What was the distance of the lightning from her?
(The velocity of sound in air is 340 m/s?)

(Ans: 1360 m)

c. Sunil is standing between two walls. The wall closest to him is at a distance of 360 m. If he shouts, he hears the first echo after 4 s and another after another 2 seconds.

1. What is the velocity of sound in air?
2. What is the distance between the two walls?

(Ans: 330 m/s; 1650 m)

d. Hydrogen gas is filled in two identical bottles, A and B, at the same temperature. The mass of hydrogen in the two bottles is 12 gm and 48 gm respectively. In which bottle will sound travel faster? How may times as fast as the other?

(Ans: In A; Twice)

e. Helium gas is filled in two identical bottles A and B. The mass of the gas in the two bottles is 10 gm and 40 gm respectively. If the speed of sound is the same in both bottles, what conclusions will you draw?

(Ans: Temperature of B is 4 times the temperature of A.)

Project :

Collect information about the musical instrument called *Jaltarang* and find out how the different notes are produced in it.

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13. Carbon : An Important Element

- **Carbon – occurrence, properties, allotropes**
- **Hydrocarbons**
- **Carbon dioxide and methane – occurrence, properties, uses**

Can you recall?

1. What is an element? What are the different types of elements?
2. What remains behind on complete combustion of any organic compound?
3. What type of element is carbon? Give some information about it.

You have learnt that carbon is a non-metallic element. You have also learnt about its occurrence in nature in the form of some compounds.

Try this

1 Take some milk in an evaporating dish. Heat the evaporating dish on a Bunsen burner. What remains behind at the bottom of an evaporating dish on complete evaporation of the milk?

2. Take small samples of sugar, wool, dry leaves, hair, seeds, split pulses and plastic in separate test tubes. Heat each test tube and observe the changes taking place in the substances.

What does the black substance remaining in each test tube indicate?

Carbon

The element carbon is available abundantly in the nature and occurs in free as well as in the combined state. In this chapter, let us study the properties of the non-metallic element carbon.

Make a list of all substances/objects that you use in daily life from morning till night and divide those substances into the columns in the following table.

1. Symbol of carbon – C
2. Atomic number – 6
3. Atomic mass – 12
4. Electron configuration – 2,4
5. Valency – 4
6. Non-metallic element

Metallic objects	Earthen/glass objects	Other objects/substances

Now look at the list of objects in the last column. It contains foodstuffs, clothes, medicines, fuels, wooden objects, etc. Carbon is the common and important constituent of all these substances.

Can you tell? What is a compound ? How are compounds formed ?

Compounds obtained directly or indirectly from plants and animals are called organic compounds and compounds obtained from minerals are called inorganic compounds. All the organic compounds contain carbon. Carbon is the main element even in cellular DNA and RNA that transfer hereditary characteristics from one generation to the next.

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An introduction to scientists

The German chemist Wohler synthesized an organic compound urea from an inorganic compound ammonium cyanate. Ever since then, many organic compounds have been made from inorganic compounds. Carbon was found to be the main element in all these compounds. Hence, organic chemistry is also referred to as chemistry of carbon compounds.

$$NH_4^+CNO^- \xrightarrow{\text{Heat}} NH_2CONH_2$$

Occurrence of carbon

The name 'carbon' is derived from the Latin word 'carbo' meaning coal. Carbon is found in nature in free as well as compound state. Carbon in the free state is found as diamond and graphite, and in the combined state in the following compounds.

1. As carbon dioxide and in the form of carbonates such as calcium carbonate, marble, calamine ($ZnCO_3$)
2. Fossil fuel – coal, petroleum, natural gas
3. Carbonaceous nutrients – carbohydrates, proteins, fats
4. Natural fibres – cotton, wool, silk

Science capsule

In the earth's crust, carbon is present to the extent of approximately 0 27% in the form of carbonate, coal, petroleum. In atmosphere, the proportion of carbon in the form of carbon dioxide is approximately 0 03 %

Some types of plants which grow on the ocean floor convert carbon in marine water into calcium carbonate.

Properties of carbon

Allotropic nature of Carbon

Allotropy – Some elements occur in nature in more than one form. The chemical properties of these different forms are the same but their physical properties are different. This property of elements is called allotropy. Like carbon, sulphur and phosphorus also exhibit allotropy.

Allotropes of carbon

A. Crystalline forms

1. A crystalline form has a regular and definite arrangement of atoms.
2. They have high melting points and boiling points.
3. A crystalline form has a definite geometrical shape, sharp edges and plane surfaces.

Carbon has three crystalline allotropes.

1. Diamond

Diamonds are found in India mainly in Govalkonda (Karnatak) and Panna (Madhya Pradesh). Diamonds are also found in South Africa, Brazil, Belgium, Russia and America.

13.1 Diamond

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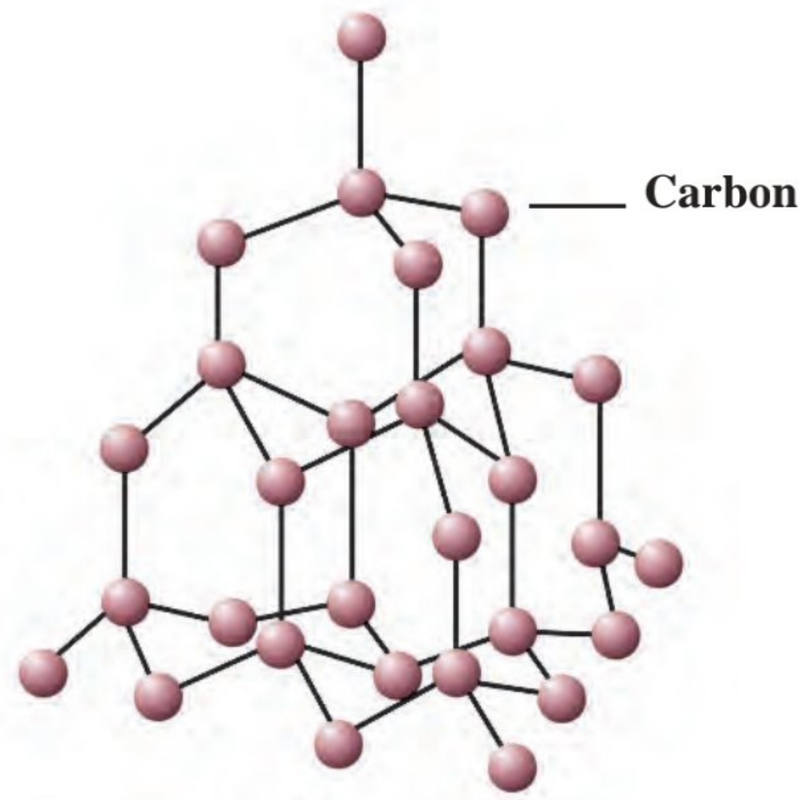
Structure : In diamond, every carbon atom is bonded to four neighbouring atoms by covalent bonds. Therefore, diamond has a tetragonal three dimensional structure which makes it very hard.

Properties

1. Brilliant and pure diamond is the hardest natural substance.
2. The density of diamond is 3.5 g/cm^3.
3. The melting point of diamond is 3500 ^{0}C
4. When diamond is heated at 800 ^{0}C in the presence of oxygen CO_2 is given away. In this process no other product besides CO_2 is formed.
5. Diamond does not dissolve in any solvent.
6. Acids/bases have no effect on diamond.
7. Diamond is a bad conductor of electricity as it does not have free electrons.



13.2 Structure of carbon atoms in diamond

A peep into the past

Once upon a time, India was famous for the 'Kohinoor' diamond. This diamond was found in the 13th century in the mine at Guntur (Andhra Pradesh). Its weight was 186 carats.

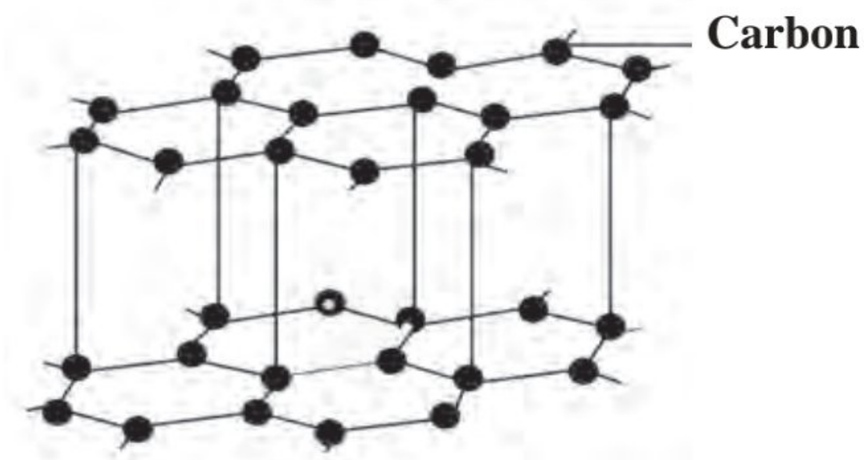
Uses

1. Diamonds are used in glass cutting and rock drilling machines.
2. Diamonds are used in ornaments.
3. Diamond knives are used in the eye surgery.
4. Diamond dust is used for polishing other diamonds.
5. Diamond is used to make windows giving protection from radiation in space and in artificial satellites.

2. Graphite

Graphite is found in the natural state in Russia, New Zealand, America and India. The lead used in pencil is made by mixing graphite with clay. This process was discovered by Nicholas Jacques Conte in 1795.

Structure : Every carbon atom in graphite is bonded to three other carbon atoms in such a way that a hexagonal layered structure is formed. A graphite crystal is made of many sheets or layers of carbon atoms. These layers slip over each other on applying pressure. One layer of graphite is called graphene.



13.3 Graphite and structure of carbon atoms in graphite

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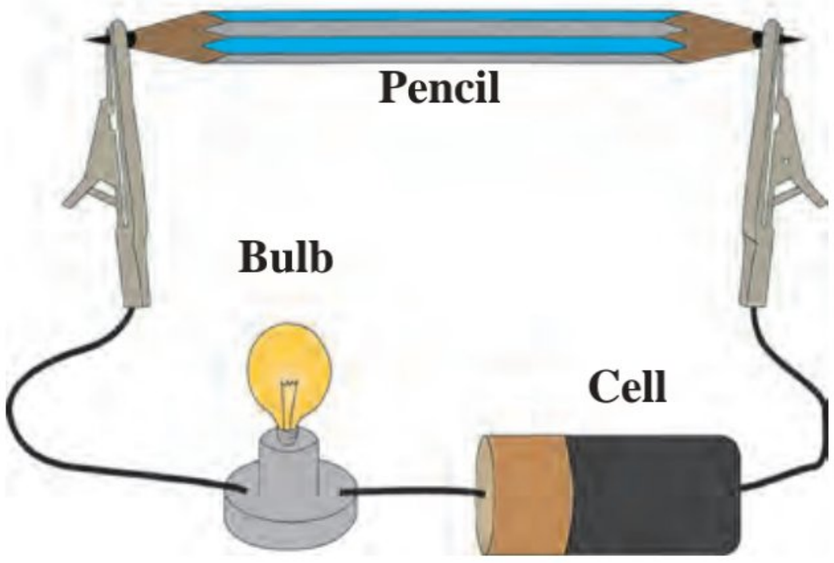
Try this

Apparatus : Pencil, electrical wires, battery/cell, small bulb, water, kerosene, test tubes, lead pencil, etc.



13.4 Flow of electric current through graphite

Procedure :

1. Remove the lead from a pencil, and feel it with your fingers. What colour is it? Try to break the lead with your hand.
2. Assemble the apparatus as shown in the diagram. Start the electric current in the circuit. Observe. What did you find?
3. Take some water in a test tube. Take some kerosene in another test tube. Put lead dust in both the test tubes. What did you find?

Properties of graphite

1. Graphite found in nature is black, soft, brittle and slippery.
2. Inside each layer of graphite, free electrons move continuously within the entire layer. That is why graphite is a good conductor of electricity.
3. Due to the layered structure graphite can be used for writing on paper.
4. The density of graphite is 1.9 to 2.3 g/cm^3.
5. Graphite does not dissolve in most solvents.

Uses of graphite

1. Graphite is used for making lubricants.
2. Graphite is used for making carbon electrodes.
3. Graphite is used in pencils for writing.
4. Graphite is used in paints and polish.
5. Graphite is used in arc lamps which give a very bright light.

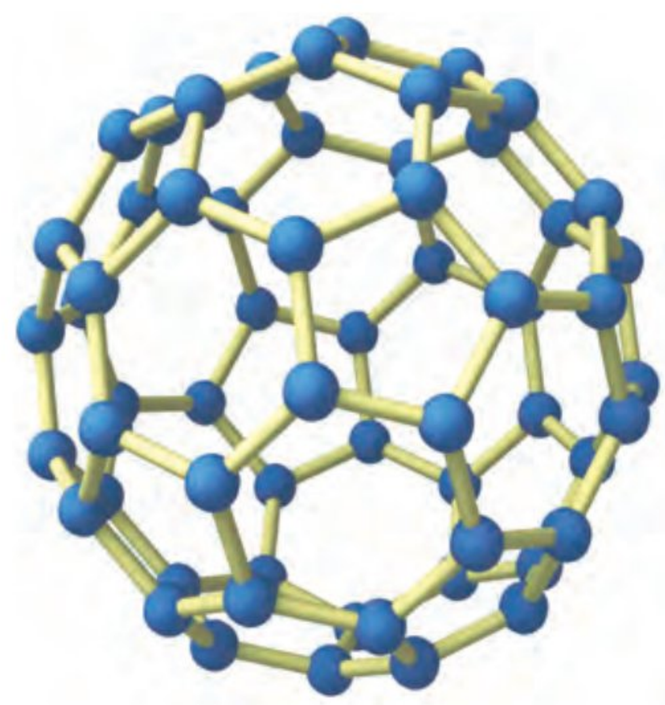
Buckytubes (Carbon nano-tube)

3. Fullerene

Fullerene, an allotrope of carbon, is rarely found in nature. It is found in soot and in interstellar space. The first example of fullerene is Buckminsterfullerene (C_{60}). This allotrope of carbon is named fullerene after the architect Richard Buckminster Fuller because the structure of C_{60} resembles the structure of the geodesic dome he designed.

Harold Kroto, Robert Curl and Richard Smalley were given the Nobel prize in chemistry 1996, for the discovery of this carbon allotrope, fullerene C_{60}.

C_{60}, C_{70}, C_{76}, C_{82} and C_{86} are other examples of fullerene. Their molecules occur in small numbers in soot.



Buckyball (C_{60})

13.5 Structure of fullerene

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Properties

1. Molecules of fullerenes are found in the form of buckyballs and buckytubes.
2. There are 30 to 900 carbon atoms in one molecule of a fullerene.
3. Fullerenes are soluble in organic solvents such as carbon disulphide, chlorobenzene.

Uses

1. Fullerenes are used as insulators.
2. Fullerenes are used as a catalyst in water purification.
3. At a certain temperature fullerene exhibits superconductivity.

B. Non-crystalline / Amorphous forms

The arrangement of carbon atoms in this form is not regular. Coal, charcoal, coke are the non-crystalline forms of carbon.

1. Coal : Coal is a fossil fuel. It contains carbon, hydrogen and oxygen. It also contains nitrogen, phosphorus and sulphur. It occurs in the solid state. It is of four types.

a. Peat : Formation of peat is the first step in the formation of coal. It contains a high proportion of water and less than 60% of carbon. Therefore, not much heat can be obtained from peat.

b. Lignite : Peat was transformed into Lignite due to increased pressure and temperature inside the earth. It contains 60 to 70% of carbon. Lignite is the second step of the formation of coal.

c. Bituminous coal : Bituminous coal was formed as the third step of formation of coal. It contains 70 to 90% of carbon.

d. Anthracite : Anthracite is known as the pure form of coal. This coal is hard and contains about 95% of carbon.

2. Charcoal : The charcoal that is made from animals is made from their bones, horns, etc. On the other hand, the charcoal made from plants is formed by combustion of wood in an insufficient supply of air.

Uses of coal :

1. Coal is used as fuel in factories and homes.
2. Coal is used to obtain coke, coal gas and coal tar.
3. Coal is used in thermal power plants for generation of electricity.

3. Coke : The pure coal that remains when coal gas has been taken away from coal, is called coke.

Uses of coke :

1. Used as domestic fuel.
2. Coke is used as a reducing agent.
3. Coke is used in production of water gas ($CO + H_2$) and producer gas ($CO + H_2 + CO_2 + N_2$)

Peat

Lignite

Bituminous coal

Anthracite

Coke

13.6 Non-crystalline forms of carbon

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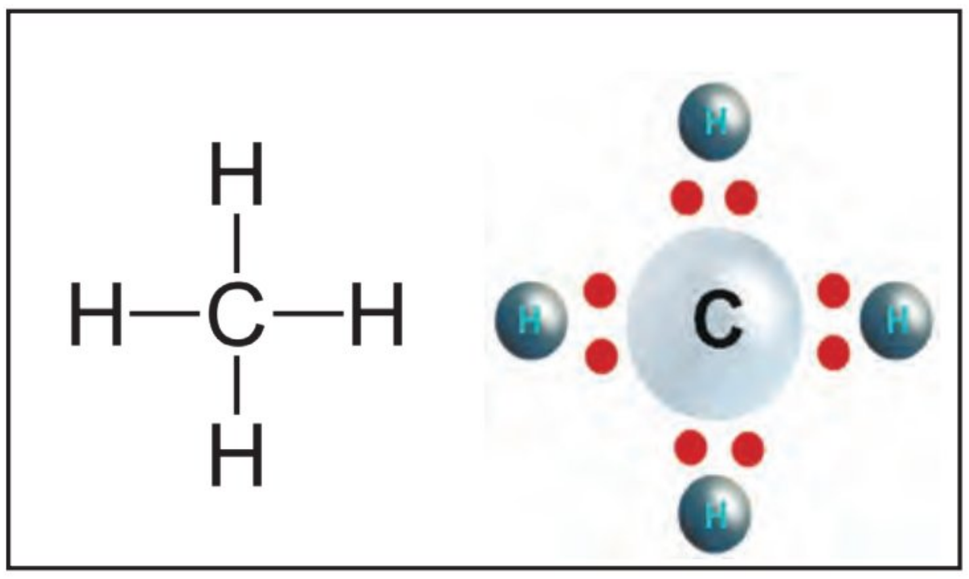
Hydrocarbons : basic organic compounds

Along with carbon, the element hydrogen is also included in most organic compounds. The compounds formed from only carbon and hydrogen are called basic organic compounds. These are also called hydrocarbons.

The electronic configuration of carbon is 2, 4. If four electrons are added to the second orbit of carbon, its octet becomes complete and its electronic configuration becomes stable like that of the nearest inert gas neon (2, 8). Therefore, the valency of carbon is 4. However, this occurs by sharing of electron rather than a give and take of electrons. In other words a carbon atom can form four covalent bonds with other carbon atoms or atoms of different elements.

When a carbon atom shares one electron each with four hydrogen atoms and forms four C-H bonds, a methane CH_4 molecule is formed.



13.7 Structural formula and electron dot model of methane

Properties of covalent compounds

1. Covalent compounds have low melting points and boiling points.
2. Generally they are insoluble in water and soluble in organic solvents.
3. They are poor conductors of heat and electricity.

Saturated and unsaturated hydrocarbons

A carbon atom exhibits a characteristic property. It can form a chain of carbon atoms by forming covalent bonds with other carbon atoms. The hydrocarbons having only single bonds between carbon atoms are called saturated hydrocarbons. For example ethane (C_2H_6) which is (CH_3—CH_3), propane (CH_3—CH_2—CH_3).

Some hydrocarbons have a multiple bond between two carbon atoms. A multiple bond can be a double bond or a triple bond. Hydrocarbons having at least one multiple bond are called unsaturated hydrocarbons. For example, ethene ($H_2C{=}CH_2$), ethyne ($HC{\equiv}CH$), propene (CH_3-$CH{=}CH_2$), propyne (CH_3-$C{\equiv}CH$).

Use your brain power !

Does an electric charge form on atoms when a covalent bond is formed between them? Why is a single bond between two carbon atoms strong and stable?

Solubility of carbon

Try this

Apparatus : 3 conical flasks, stirrer.

Chemicals : Water, kerosene, cooking oil, coal powder, etc.

Procedure : Take 3 conical flasks and take cooking oil, water and kerosene respectively in each. Add half a spoonful of coal powder in each of the conical flasks and stir with the help of stirrer. Observe the mixtures in the three conical flasks.

13.8 Solubility of coal in water

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Use your brain power!

1. In which of the solvents- water, kerosene and cooking oil does the coal powder dissolve?
2. What inference will you draw about the solubility of carbon?

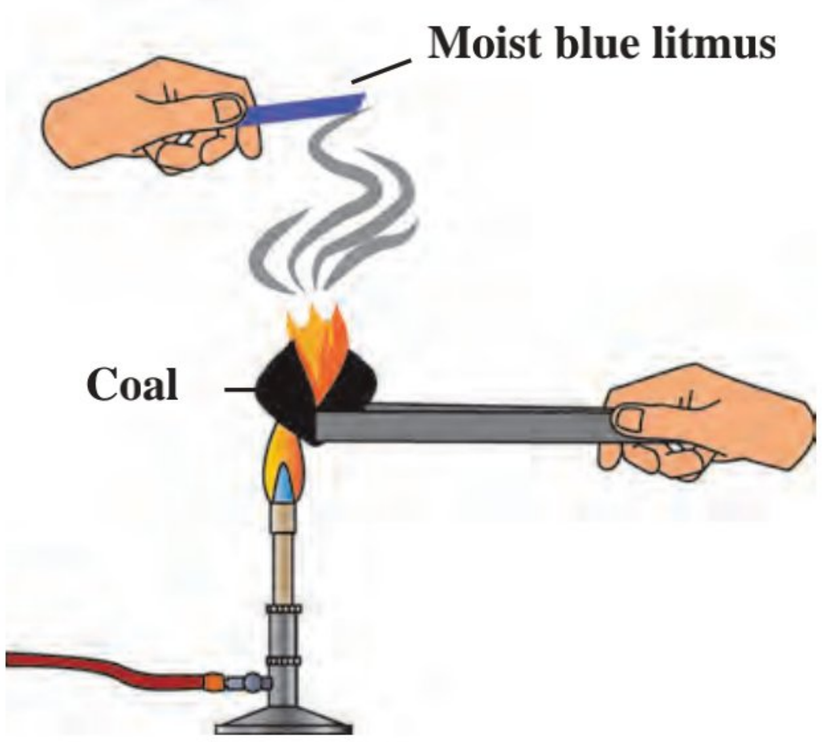
Reaction of carbon with oxygen

Try this

Apparatus : Coal, match box, moist litmus paper, etc.

Procedure : Ignite the coal. Hold the moist blue litmus paper over the gas released on igniting the coal. Note the observation.

1. With which gas in the air does the coal react on igniting?
2. What is the substance formed?
3. What change takes place in the litmus paper?
4. Write down the chemical reaction taking place in the above procedure.

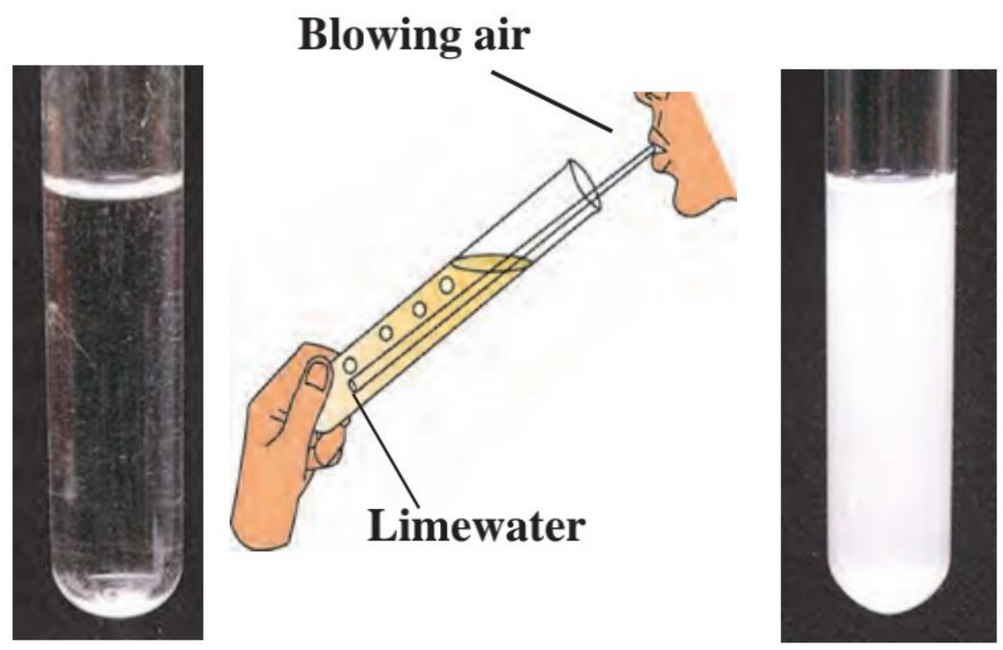


13.9 Reaction of carbon with oxygen

Apparatus : Test tube, straw, limewater, etc.

Procedure : Take freshly prepared limewater in a test tube. Blow for sometime into the limewater through the straw and observe the limewater. What did you see?

What might be the reason behind the change?



13.10 Reaction of limewater with CO_2

Carbon dioxide

Molecular formula: CO_2, molecular mass : 44, melting point : - 56.6 ^{0}C

Occurrence : Carbon dioxide occurs in the air in the free state to the extent of about 0.03%. Exhaled air contains about 4% of CO_2. CO_2 is present as a salt in chalk and Shahabad tiles/ marble/ limestone. CO_2 is given out in the combustion of wood and the fossil fuel coal.

Try this

Apparatus : Retord stand, round bottom flask, thistle funnel, gas delivery tube, gas jars.

Chemicals : Calcium carbonate (Pieces of Shahabad tiles / marble pieces / limestone), dilute hydrochloric acid.

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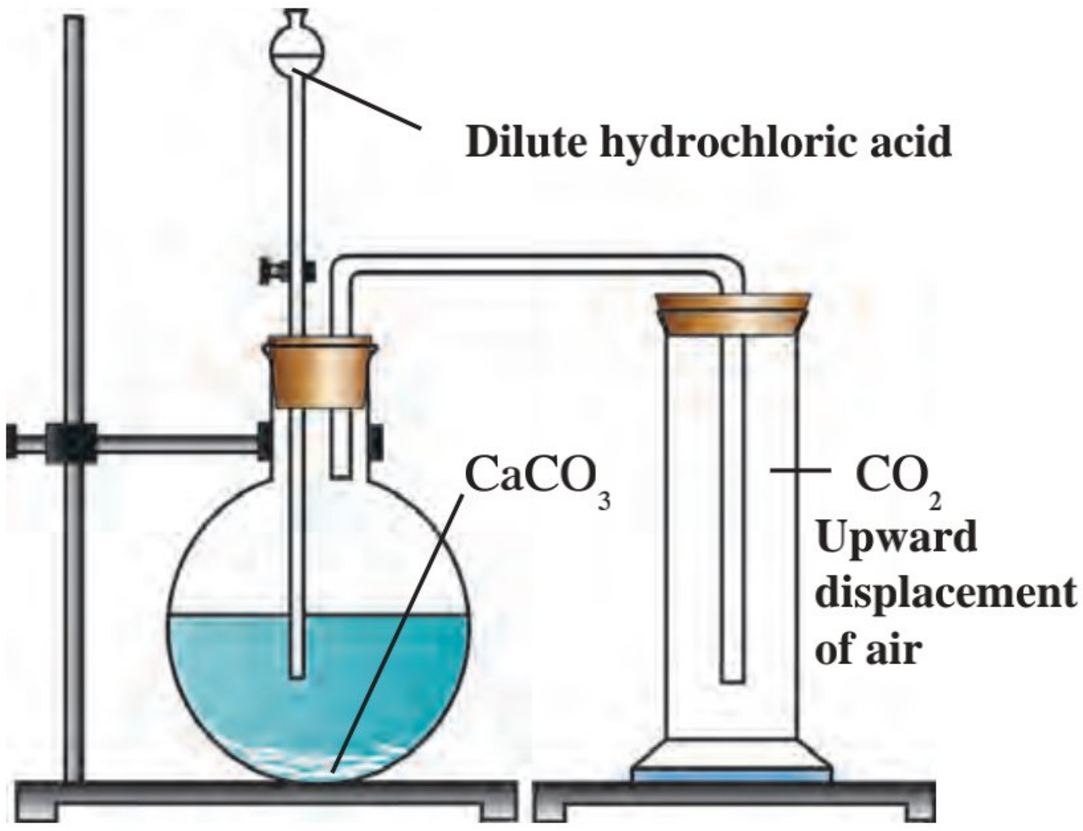
Procedure :

1. Assemble the apparatus as shown in the figure. While assembling place $CaCO_3$ in the round bottom flask.
2. Add dilute HCl in the flask through thistle funnel. See to it that the end of the funnel dips in the acid.
3. CO_2 is formed as a result of the reaction between $CaCO_3$ and HCl. Collect this gas in four to five gas jars. The chemical equation of the above reaction is as follows.



13.11 Preparation of carbon dioxide

$$CaCO_3 + 2\,HCl \rightarrow CaCl_2 + H_2O + CO_2 \uparrow$$

Physical and chemical properties of carbon dioxide

1. Observe the colour of the gas formed in the above experiment.
2. Smell the gas in the gas jar.

   Use separate gas jars for the activities 3 to 7 below:
3. Remove the lid of a gas jar and put some limewater in it.
4. Place a burning candle in a gas jar.
5. Drop a small amount of a solution of some universal indicator in one gas jar filled with CO_2 and shake it.
6. Pour some water in a gas jar and shake it.
7. Moisten a blue and a red litmus paper and drop them in a gas jar of CO_2.

   Enter your observations in all the above activities in the following table.

Physical properties of CO_2

Test	Observations
Odour	
Colour	

Chemical properties of CO_2

Test	Observations
Burning candle	
Universal indicator	
Limewater	
Water	
Litmus paper	

Use your brain power! Is the density of CO_2 more or less than that of air?

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Some more chemical properties of carbon dioxide

1. Sodium carbonate is formed when carbon dioxide is passed through an aqueous solution of sodium hydroxide (Sodium carbonate = washing soda)

   Chemical equation of the reaction $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

2. Sodium bicarbonate is formed on passing CO_2 through an aqueous solution of sodium carbonate. (sodium bicarbonate = baking soda)

   Chemical equation of the reaction $Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$

a. Write down the equation of the chemical reaction taking place between water and carbon dioxide in the above experiment.

b. Write down the equation of the chemical reaction taking place on putting limewater in the gas jar of CO_2.

Uses of carbon dioxide

1. CO_2 is used to make aerated drinks
2. Solid carbon dioxide is used in cold storage and also to keep milk and milk products and frozen substances cool during transport. It is also used for getting special effects of a mist in dramas and movies.
3. CO_2 obtained by chemical reaction or kept under pressure is used in fire extinguishers.
4. Liquified CO_2 is used to remove caffeine from coffee.
5. Liquid CO_2 is used as solvent in modern eco-friendly dry cleaning.
6. Plants use CO_2 in air for photosynthesis.

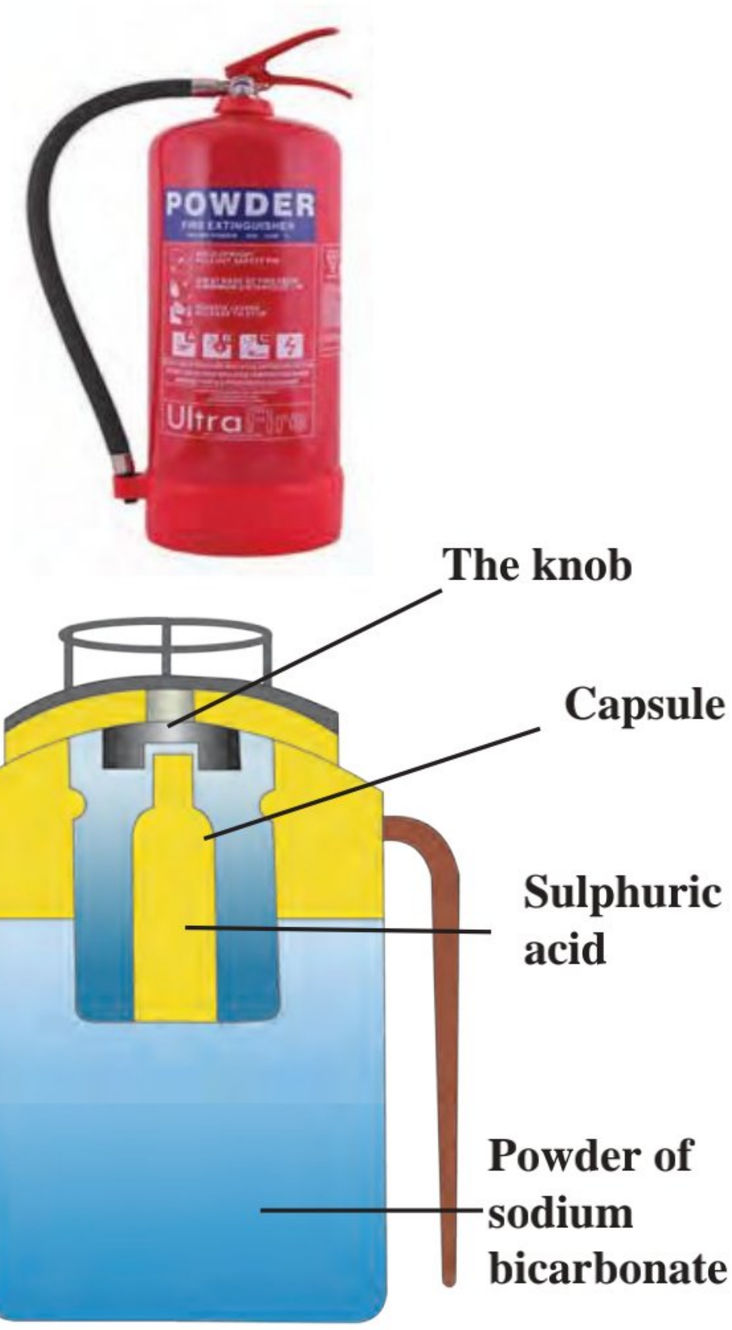
Regular fire extinguisher

A fire extinguisher contains sodium bicarbonate powder. There is also dilute sulphuric acid placed in a glass capsule. The capsule breaks on pressing the knob, the sulphuric acid comes in contact with the sodium bicarbonate and the two react chemically to release CO_2 which comes out.

CO_2 based fire extinguishers do not cause corrosion and are non conductors of electricity. Therefore these are used when electrical and electronic equipment catches fire.

CO_2 based fire extinguishers are used to extinguish small scale fire. It is beyond their capacity to extinguish a big fire.

In modern fire extinguishers liquid and solid CO_2 is filled under pressure. On reducing the pressure it becomes gaseous and comes out forcefully through the horn-like hose pipe.



13.12 Internal structure of fire extinguisher

Chemical reaction $2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2\,H_2O + 2\,CO_2 \uparrow$

Nowadays, many types of fire extinguishers are used. Collect more information about the way CO_2 is used in them to extinguish a fire.

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Methane – molecular formula CH_4, molecular mass – 16

Occurrence

1. Methane occurs in natural gas to the extent of 87%.
2. Decomposition of organic matter in the absence of air (anaerobic) produces methane.
3. Methane is present in biogas.
4. Methane is found in coal mines.
5. Methane is found at the surface of marshy places which is why it is also called marsh gas.
6. On heating a mixture of hydrogen and carbon monoxide gases at 300 ^{0}C in the presence of nickel (catalyst) methane gas is formed.
7. Fractional distillation of natural gas gives methane in pure form.

Physical properties of methane

1. Melting point of methane is (-182.5 ^{0}C).
2. Boling point of methane is (-161.5 ^{0}C).
3. It is a colourless gas.
4. The density of liquid methane is less than that of water.
5. Methane is sparingly soluble in water. It is highly soluble in organic solvents like gasoline, ether and alcohol.
6. Methane is in gaseous state at room temperature.

Chemical properties of methane

1. Methane is highly inflammable. It burns by reacting with oxygen to give a bluish flame. In this reaction, 213 kcal/mol of heat is given out. Methane burns completely.

   Chemical reaction $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat

2. **Chlorination**

   Methane and chlorine gases react with each other at the temperature of 250 ^{0}C to 400 ^{0}C in presence of ultraviolet light and form mainly methyl chloride (chloromethane) and hydrogen chloride. This reaction is called chlorination of methane.

Chemical reaction $CH_4 + Cl_2 \xrightarrow{\text{Light}} CH_3Cl + HCl$

Uses of methane

1. Methane in the form of natural gas is used in industries such as fabric mills, paper mills, food processing industry, petrol purification.
2. Being the smallest hydrocarbon, the proportion of CO_2 released in the combustion of methane is small and, therefore, it is used as a domestic fuel.
3. Methane is used for production of organic compounds such as ethanol, methyl chloride, methylene chloride and acetylene.

Methane gas was discovered by the Italian scientist Alessandro Volta between 1776 and 1778 while he was studying the gases found in marshy land.

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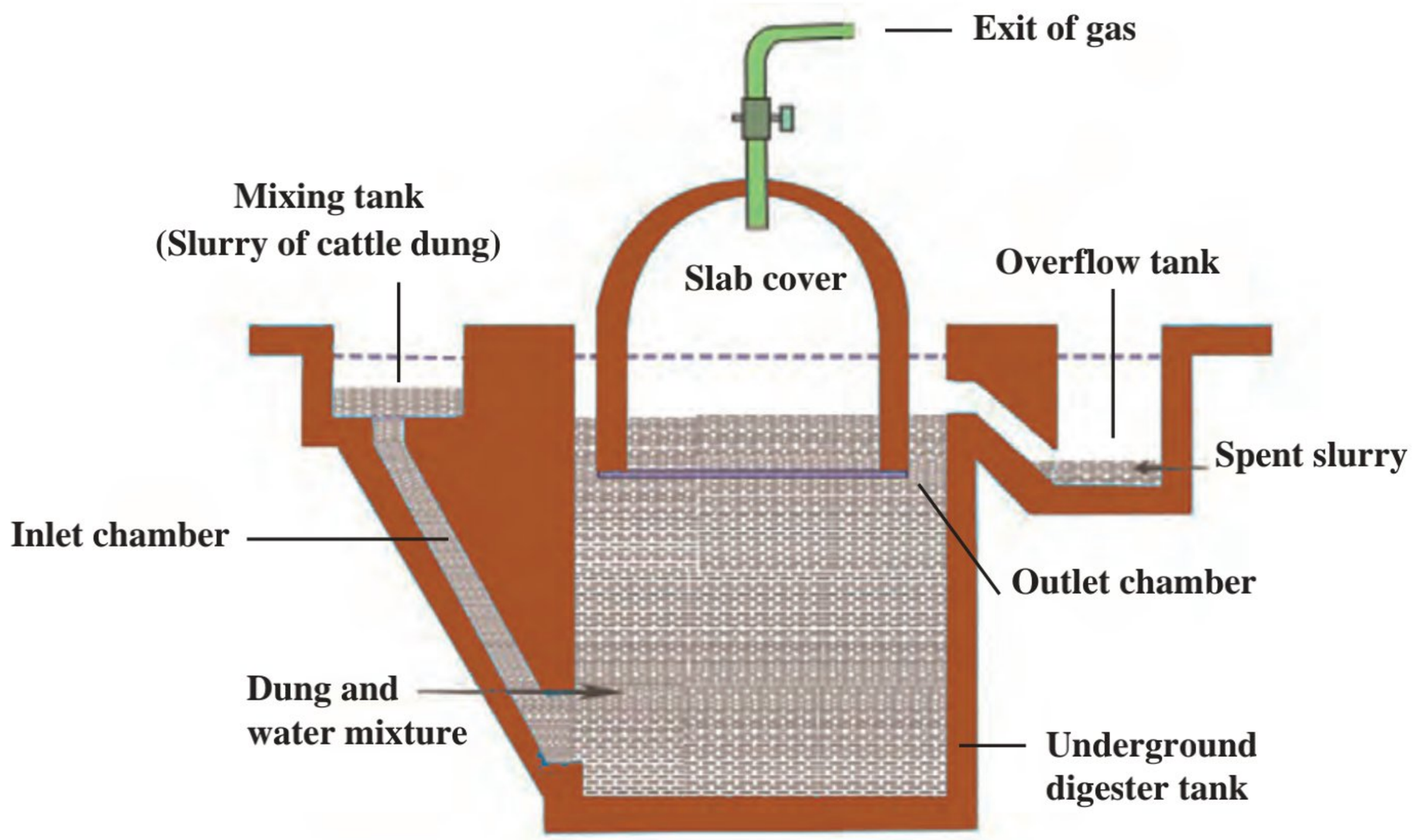
Biogas plant : Animal dung, dry leaves, wet garbage get decomposed by anaerobic microbes in a biogas plant. This produces methane gas also called biogas. Biogas is a very cheap fuel option which meets the demand for cooking gas. It is also used for production of an electricity. Biogas contains about 55% to 60% methane and the rest is carbon dioxide. Biogas is a fuel which is convenient to use and, in addition to this, a very good manure is also produced as a side product of the process.



13.13 Biogas plant

Biogas production process

Production of biogas is an anaerobic process. It takes place in two stages.

1. Production of acids

The microbes act on the biodegradable complex organic compound and produce organic acids.

2. Methane gas production

The methanogenic bacteria act on the organic acids to produce methane gas

$$CH_3COOH \rightarrow CH_4 + CO_2\uparrow$$

Find out

Visit a biogas plant and get to know the actual functioning of the plant. Find out which electrical instruments are run on that plant.

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Exercises

1. Select the proper option and complete the statements

(single, all, double, ionic, carbon, give and take, hydrogen, multiple, share, most, covalent)

a. A carbon atom forms a …… bond with other atoms. In this bond the two atoms ….electrons.

b. All the carbon bonds in a saturated hydrocarbon ..... electrons.

c. At least one carbon bond in an unsaturated hydrocarbon is ….

d. ….. is the essential element in all the organic compounds.

e. The element hydrogen is present in ….. organic compound.

2. Answer the following questions

a. Why are carbon and its compounds used as fuels?

b. In which compound forms does carbon occur?

c. Write the uses of diamond.

3. Explain the difference:

a. Diamond and graphite.

b. Crystalline and non-crystalline forms of carbon.

4. Write scientific reasons

a. Graphite is a conductor of electricity.

b. Graphite is not used in ornaments.

c. Limewater turns milky when CO_2 is passed through it.

d. Biogas is an eco-friendly fuel.

5. Explain the following.

a. Diamond, graphite and fullerenes are crystalline forms of carbon.

b. Methane is called marsh gas.

c. Petrol, diesel, coal are fossil fuels.

d. Uses of various allotropes of carbon.

e. Use of CO_2 in fire extinguisher.

f. Practical uses of CO_2.

6. Write two physical properties each.

a. Diamond

b. Charcoal

c. Fullerene

7. Complete the following Chemical reactions.

1. ……..+…….→ $CO_2 + 2H_2O$ + Heat

2 ……..+……→ $CH_3Cl + HCl$

3 $2\,NaOH + CO_2$ →……..+……..

8. Write answers to the following in detail.

a. What are the different types of coal? What are their uses?

b. How will you prove experimentally that graphite is good conductor of electricity?

c. Explain the properties of carbon.

d. Classify carbon.

9. How will you verify the properties of carbon dioxide?

Project

Make a model of a biogas plant and make a presentation in the class about the process of gas production.

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14. Substances in Common Use

- **Important salts in day to day life -NaCl, $NaHCO_3$, Na_2CO_3**
- **Radioactive substances**
- **Some chemical substances in day to day life**

Can you recall?

1. What are the important substances that we use in day to day life? For what purposes do we use them?
2. How are the various substances in day to day use classified from the scientific point of view?

We use various substances in day to day life. We have previously learnt in some detail about a few of them, their uses and constituents and the method of their preparation.

Classify

The names of some substances in everyday use are given below. Classify them into groups like acids, bases, metals, non--metals and salts.

Substances : Table salt, soap, toothpaste, baking soda, water, curds, milk, alum, iron, sulphur, washing powder.

Important salts in daily life

Can you tell? What are salts?

The ionic compounds which do not contain H^+ and OH^- ions and contain only one kind of cation and anion are called simple salts. For example, Na_2SO_4, K_3PO_4, $CaCl_2$.

Inorganic substances occur naturally in the form of salts rather than acids or bases. About 80 million tons of salts are added every year to seawater. Therefore, the sea is said to be a rich source of salts. In fact, the sea is a rich source of several salts of various elements such as chlorine, sodium, magnesium, potassium, calcium, bromine., However, we also use other salts apart from these in day to day life. Let us learn more about them.

Do you know?

The important salts found in sea water

1. Sodium chloride
2. Magnesium chloride
3. Magnesium sulphate
4. Potassium chloride
5. Calcium carbonate
6. Magnesium bromide

Try this

Prepare saturated solutions of some salts and put 2-3 drops of the universal indicator in them and note your observations in the table alongside.

Salt	Original color (of the solution)	Color on addition of universal indicator	pH value	Nature
Table salt	Colorless	Green	7	Neutral
Soap				
Washing soda				
Baking soda				
Baking powder				
POP				

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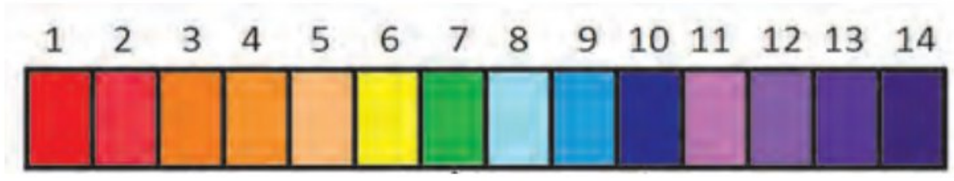
Can you tell?

1. What is the strip shown below? What is it used for?
2. How is it determined whether a substance is acidic, basic or neutral?
3. Make a list of substances in day to day use in accordance with their pH value (1 to 14).



We have seen in the previous lesson that a salt is neutral when its pH value is 7. Such a salt is made from a strong acid and a strong base. The pH value of a salt made from a strong acid and a weak base is less than 7 and it is acidic. On the other hand, the pH value of a salt made from a weak acid and strong base is more than 7 and it is basic. Let us now learn about some salts of everyday use.

Sodium chloride (Table salt- NaCl)

Table salt, or common salt, which gives a salty taste to food, is the most used of all salts. Its chemical name is sodium chloride. Sodium chloride is formed by a neutralization reaction between sodium hydroxide and hydrochloric acid.

We have already seen that this is a neutral salt and that the pH value of its aqueous solution is 7.

Properties and uses

1. Common salt is a colourless and crystalline ionic compound. There is no water of crystallization in its crystalline structure.
2. It is a neutral salt, salty in taste.
3. This compound is used for the production of salts like Na_2CO_3, $NaHCO_3$.
4. When an electric current is passed through a saturated solution of sodium chloride (brine) it is electrolysed and hydrogen gas is released at the cathode while chlorine gas is released at the anode. This method is used for production of chlorine gas. In this method an important basic compound NaOH is formed in the cell.

$$2NaCl + 2H_2O \rightarrow 2NaOH + Cl_2\uparrow + H_2\uparrow$$

5. When salt is heated to a high temperature (about 800 ^{0}C), it melts. This is called the fused state of the salt.
6. When fused salt is electrolysed, chlorine gas is released at the anode and liquid sodium metal, at the cathode.

Do you know?

Salt is also obtained from a certain type of rock. This salt is called rock salt. The mineral halite and Himalayan rock salt are some examples of rock salt. This salt is used to treat many diseases.

The 25% aqueous solution of salt is called saturated brine. When $\frac{1}{5}$ of this solution is evaporated the dissolved salt gets crystallized and salt gets separated from the solution.

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Sodium bicarbonate (Baking soda – $NaHCO_3$)

Your mother brings cake on your birthday or makes it at home. She also makes crisp *bhaji*. Have you ever asked your mother what makes the cake porous or the *bhaji* crisp?

Mother adds baking soda in the batter. Baking soda is a white non-crystalline powder. Its chemical name is sodium hydrogen carbonate or sodium bicarbonate and its molecular formula is $NaHCO_3$.

Properties and uses

1. $NaHCO_3$ reacts with moist litmus paper and red litmus turns blue which means that it is basic in nature.
2. It is used to make bread, cake, *dhokla*.
3. Being basic in nature it is used to reduce acidity in the stomach.
4. $NaHCO_3$ is used to make the active substance CO_2 in the fire extinguisher.
5. Baking soda is used to clean an oven.

Research

What are the constituents of baking powder? Where is the baking powder used?

Bleaching powder (Calcium oxychloride $CaOCl_2$)

Try this

Take a piece of coloured cloth. Put some saturated solution of bleaching powder on a small part and observe.

What change takes place in the colour of the cloth?

Tap water has a typical strong odour in the rainy season. Have you experienced it? Water in a swimming pool also has the same odour. It is the odour of the chlorine gas used to destroy the microbes in the water. Chlorine gas is a strong oxidizing agent and therefore, it has a strong disinfecting as well as bleaching action.

Chlorine is inconvenient to handle because of its gaseous state. Instead, the solid bleaching powder which has the same effect is more convenient to use. Bleaching powder undergoes slow decomposition due to the carbon dioxide in air and chlorine gas is released. Bleaching powder gets its property because of this release of chlorine gas.

$$CaOCl_2 + CO_2 \rightarrow CaCO_3 + Cl_2 \uparrow$$

Bleaching powder is obtained by the reaction of chlorine gas with slaked lime.

$$Ca(OH)_2 + Cl_2 \rightarrow CaOCl_2 + H_2O$$

Find out

1. About various types of bleaching powder available in the market.
2. What distinguishes these different types?

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Properties and uses

1. Bleaching powder is a yellowish white coloured solid substance.
2. Its chemical name is calcium oxychloride.
3. It has a strong odour of chlorine gas.
4. It is used for disinfection of drinking water at the water works and the water in the swimming pool.
5. It is used for bleaching of cloth.
6. It is used for disinfection by the road side and garbage sites.
7. Dilute sulphuric acid and dilute hydrochloric acid react rapidly with bleaching powder to release chlorine gas completely.
   $CaOCl_2 + H_2SO_4 \longrightarrow CaSO_4 + Cl_2 \uparrow + H_2O$
8. Calcium oxychloride reacts slowly with carbon dioxide to form calcium carbonate and chlorine.

Washing soda $Na_2CO_3.H_2O$

Try this

Procedure : Take a sample of water from a well or a bore-well, in a beaker, add some soap to it and stir. Then take another sample, add one spoonful of washing soda and stir; then add some soap and stir again. Observe the changes that take place. Which changes did occur? Why do they occur?

The hard water from a well or a bore-well becomes soft on adding washing soda and we come to know this from the lather formed on it. The hardness of water is due to the presence of chlorides and sulphates of calcium and magnesium in it. Na_2CO_3 is added to it to soften such water and make it suitable for use. The reaction with Na_2CO_3 causes the formation of insoluble carbonate salts of magnesium and calcium.

$$MgCl_2\,(aq) + Na_2CO_3\,(s) \rightarrow MgCO_3(s) + 2\,NaCl\,(s)$$

Sodium carbonate is a water soluble salt of sodium. Crystalline sodium carbonate,on keeping, loses its water of crystallization readily and a white powder is obtained. This powder is called washing soda.

$$Na_2CO_3.10\,H_2O \xrightarrow{-\,H_2O} Na_2CO_3.H_2O$$

white powder (washing soda)

Properties and uses

1. Washing soda is a whitish and odourless powder at room temperature.
2. Litmus has a blue color in its aqueous solution.
3. It is hygroscopic, that is, it absorbs moisture if left exposed to air.
4. It is used mainly for washing clothes.
5. Sodium carbonate is used in the glass and paper industry and also in refining of petrol.

Write down the reaction of Na_2CO_3 with H_2SO_4

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Some crystalline salts

You have learnt about water of crystallization in the previous chapter. We use various salts which contain water of crystallization.

Some substances in our daily use which contain water of crystallization

1. Alum (Potash alum – $K_2SO_4.Al_2(SO_4)_3.24H_2O$)
2. Borax ($Na_2B_4O_7.10H_2O$)
3. Epsom salt (Magnesium sulphate $MgSO_4.7H_2O$)
4. Barium chloride ($BaCl_2.2H_2O$)
5. Sodium sulphate (Glauber's salt $Na_2SO_4.10\ H_2O$)

Collect more information on the properties and uses of the substances listed above.

You have learnt that alum is used in the process of water purification. Because of property of coagulation, the solid impurities in water come together, become heavy and settle to the bottom. As a result, the water above becomes clear.

Blue vitriol is used in the blood test for diagnosing anaemia. In the Bordeaux mixture which is used as a fungicide on fruits like grapes, musk melon, slaked lime it is used with blue vitriol.

Soap

Can you recall?

1. What are detergents?
2. Which chemicals and apparatus will you use in the laboratory for making soap?

When oil or animal fat is boiled with an aqueous solution of sodium or potassium hydroxide, sodium or potassium salts of carboxylic acids (fatty acids) are formed. These salts are called soap. When soap is mixed with hard water calcium and magnesium salts of fatty acids are formed. These being water insoluble they form a precipitate and that is why lather is not formed.

Complete the table by writing the differences between bathing soap and washing soap

Bathing soap	Washing soap
1. High grade fats and oils are used as the raw material	1. Low grade fats and oils are used
2	2

Radioactive substances

Elements with a high atomic number such as uranium, thorium, radium have a property of spontaneously emitting invisible, highly penetrating and high energy radiation. This property is called radioactivity. A substance having this property is called a radioactive substance. The nucleus of radioactive elements is unstable. Radiation occurs from an unstable nucleus. Radioactive substances are relevant to our day to day life. However, before going further, let us learn something more about these substances.

Three types of radiation are given out by radioactive substances. These are alpha, beta and gamma rays.

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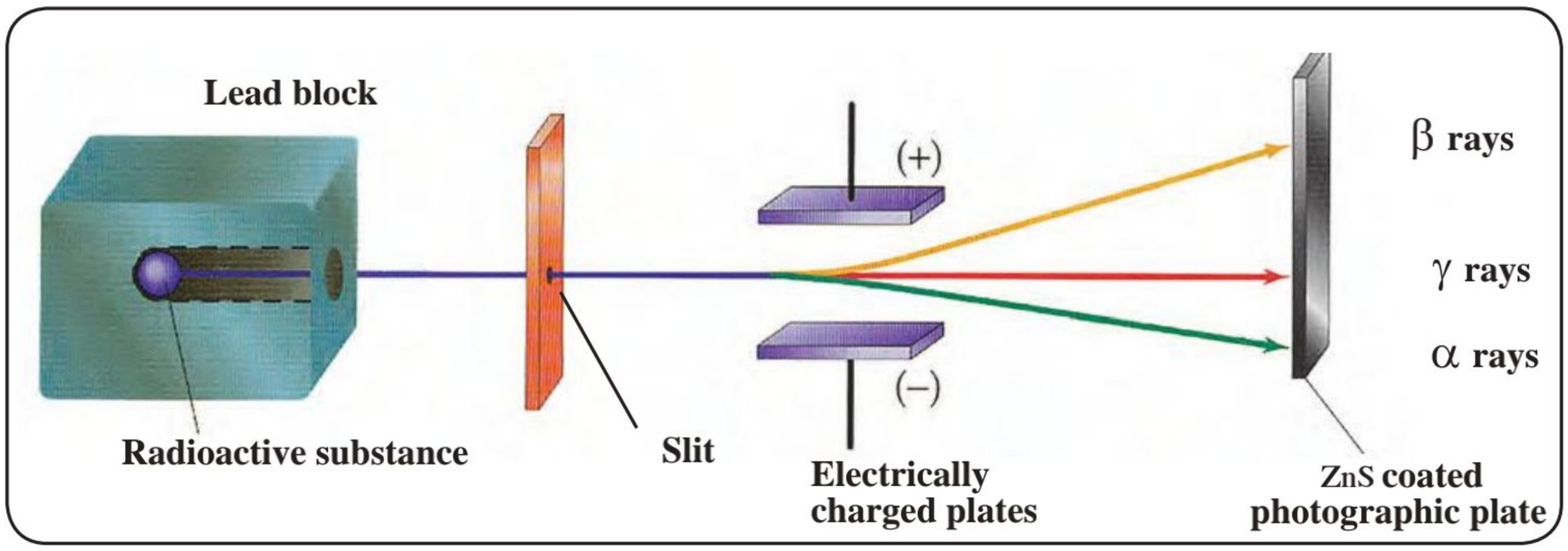
An introduction to scientists

The French scientist Henry Becquerel was studying pitch-blende, a compound of uranium. He had kept some unused photographic plates in a cardboard box in a drawer. A key was lying on the box. He happened to leave the uranium compounds on it. After a few days, he washed the plates only to find that the plates were cloudy and showed the shape of the key. As this incidence occurred in the dark, Becquerel inferred that the uranium compounds might be emitting from their interiors, rays like x-rays which penetrate substances. These rays were called Becquerel rays. After a few days, Madame Curie discovered similar properties in compounds of thorium.

Nature of radioactive radiation

In 1889 Rutherford discovered that the radiations emitted by radium were of two types. They are called alpha and beta radiation. Willard discovered the third type namely gamma radiation.

When these rays are allowed to pass through two oppositely charged plates they get separated. This method was introduced by Rutherford in 1902. Rutherford and Willard studied the radiation emitted by radioactive substances. For this purpose, the rays were allowed to pass through an electrical field and a photographic plate was held in their path. It was found that the radiation was divided into three types. One type of radiation deviated slightly towards the negatively charged plate, while the second type of radiation deviated substantially towards the positively charged plate. However, the third type of radiation did not deviate at all in the electrical field. The rays which deviated slightly toward negatively charged plate are called alpha rays, those which deviate substantially towards the positively charged plate are called beta rays and those which do not deviate at all are called gamma rays.



14.1 Alpha, beta and gamma rays

An introduction to scientists : Ernest Rutherford (1871-1937), a scientist from New Zealand did research on radioactivity under the guidance of J.J. Thomson at the Cavendish Laboratory at Cambridge and McGill University, Canada. He showed that the nitrogen atom could be split by bombarding it with alpha particles. This experiment ushered in a new era in the field of Physics.

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Characteristics of alpha, beta and gamma rays

Sr. No.	Property	Alpha rays (α)	Beta rays (β)	Gamma rays (γ)
1	Nature	Current of alpha (He^{++}) particles	Current of beta (e^-) particles	Electromagnetic radiation
2	Mass	4 0028 u	0 000548 u	No mass
3	Charge	+2	−1	Electrically neutral
4	Velocity	1/5 to 1/20 times the velocity of light	1/5 to 9/10 times the velocity of light	Same as the velocity of light
5	Deviation in the electric field	Attracted toward negatively charged plate	Attracted toward positively charged plate	Not deviated
6	Penetrating power	Can penetrate an aluminum sheet of thickness < 0.02 mm	Can penetrate an aluminium sheet of thickness 2mm, which is 100 times the penetration of alpha particles.	Can penetrate 15 cm thick lead screen which is 10,000 times the penetration of alpha particles
7	Ionization power	Very high	Low	Very low
8.	Power to produce fluorescence	Very high	Very low	Low

Uses of radioactive isotopes : It is a misconception that radioactive elements are used only for making an atom bomb. Radioactive isotopes are used in various fields such as scientific research, agriculture, industry, medicine, etc. Radioactive substances are used in two ways.

a. By using the radiation alone.

b. By using the radioactive element itself.

Natural radioactivity : Generally, the elements with atomic numbers from 82 to 92 are found to radiate spontaneously in nature. These are called natural radioactive elements.

Artificial radioactive elements – The couple Fredric Joliot Curie and Irene Joliot Curie first invented induced radioactivity. The radioactive elements produced in the nuclear fission processes brought about in the laboratory by bombardment of particles are called artificial radioactive elements. They were awarded the Nobel prize in 1935 for this invention.

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Radioactive isotopes are used in various fields as follows

1. Industrial field

Radiography – Internal cracks and voids in cast iron articles and iron solder can be detected with the help of gramma rays. For this purpose, isotopes like cobalt-60, iridium-192 are used in the radiography camera. This technique is used for detecting flaws in metal work.

Measurement of thickness, density and level- It is necessary to maintain the required thickness in the manufacture of aluminium, plastic, iron sheets of differing thickness. In the manufacturing process, a radioactive substance is placed on one side and an instrument to measure radiation on the other. The radiation read by the measuring instrument varies with the thickness of the sheet. Material inside a packing can also be examined by the same technique.

Luminescent paint and radioluminescence – The radioactive substances radium, promethium, tritium with some phosphor are used to make certain objects visible in the dark, for example, the hands of a clock, and certain other objects. Krypton-85 is used in HID (High Intensity Discharge) lamps while promethium-147 is used in portable X-ray units as the source of beta rays.

Use in Ceramic articles – Luminous colours are used to decorate ceramic tiles, utensils, plates, etc. Earlier uranium oxide was used in these paints.

2. Field of agriculture

1. The genes and chromosomes that give seeds properties like fast growth, higher productivity, etc. can be modified by means of radiation.
2. The radioactive isotope cobalt-60 is used for food preservation.
3. Onions, potatoes are irradiated with gamma rays from cobalt-60 to prevent their sprouting.
4. Strontium-90 is used as a tracer in the research on various crops.

Medical science

1. **Polycythemia :** The red blood cell count increases in the disease polycythemia. Phosphorus-32 is used in its treatment.
2. **Bone cancer :** Strontium-89, strontium-90, samarium-153 and radium-223 are used in the treatment of bone cancer.
3. **Hyperthyroidism :** Enlargement of thyroid gland, weight loss in spite of appetite, insomnia are the symptoms of hyperthyroidism. It occurs due to overproduction of hormones by the thyroid gland. Iodine-123 is used in the treatment of hyperthyroidism .
4. **Tumour detection :** Boron-10, iodine-131, cobalt-60 are used in treatment of brain tumour, while arsenic-74 is used in detection of small tumours in the body.

Hazards of radioactive substances and radiation

1. The central nervous system is affected by radioactive radiations.
2. Hereditary defects are generated by bombardment of radiation on D.N.A in the body.
3. Radioactive radiation can penetrate the skin, and causes diseases like skin cancer, leukemia.
4. The radiative pollutants created due to explosions enter the body through air and it is difficult to control them.
5. The radioactive pollutants released in the sea enter the bodies of fishes and through them enter the human body.
6. The radioactive paint on the watch can cause cancer.
7. The radioactive isotopes strontium-90 can enter the body through plants, fruits, flowers, cereals, milk, etc. and cause diseases like bone cancer, leukemia.

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A peep into the past

Chernobyl disaster : On 26th April 1986 the graphite reactor in the Chernobyl atomic power plant exploded, and suddenly the radioactive isotopes and radiation came out. Due to this episode radioactive isotopes entered the human body through water and land and caused genetic disorders. These got carried further into the next generation. Thyroid disorders increased in children as well as adults. As a result, the incidence of throat diseases is greater there than in other places.

Some chemical substances in day to day life.

The food that we eat, objects like clothes, utensils, watches, medicines and other objects are made from various kinds of matter. These affect our health directly or indirectly. Let us learn about some such substances.

Can you tell?

1. A sweets shop looks attractive because of the colorful sweets displayed there. Which colours are used in these substances?
2. A doctor gives you medicines when you fall ill. What are the medicines made from?

Food colours and essences

Food colours are mixed in most soft drinks and foodstuffs available in the market. These food colours are in the form of powders, gels and pastes. Food colours are used in domestic as well as commercial products. Certain colours and essences are added to ice cream, ice candies, sauce, fruit juices, cold drinks, pickles, jams and jelly. Food colors are often found to be added to packaged meat (chicken, mutton), chilli powder, turmeric, sweets and other similar substances so as to give them a good colour.

14.2 Colourful eatables

Harmful effects of artificial food colours

1. Food colours added to pickles, jam and sauce contain small quantities of lead and mercury. These can be harmful for those who consume these products on a regular basis.
2. Diseases like ADHD (Attention Deficit Hyperactivity Disorder) can affect children due to excessive consumption of foods with added food colours.

Always remember

Food colours are natural as well as artificial. The food colours prepared from seeds, beetroot, flowers and fruit concentrate are natural. Tetrazene, sunset yellow are artificial food colours used extensively. However, over-consumption of artificial food colours can be detrimental to health. Therefore, usage of natural food colours is always good.

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Dye

The coloured substance which on applying to an article, imparts that colour to the article, is called a dye. Generally, a dye is soluble in water and insoluble in oil. Often a mordant has to be used to fix the colour after dying a cloth.

Plants are the main source of colour for preparing a natural dye. Roots, leaves, flowers, bark, fruits, seeds, fungus and pistil are used for making dyes. In Kashmir a very good dye is made from saffron, which is used to dye fibres from which saris, shawls and dresses are made. These are very costly. Many people are engaged in this occupation as their means of earning a livelihood.The use of henna leaves to colour hair is safe for health.

William Henry Perkin invented an artificial dye in 1856. Artificial dyes are classified into many types on the basis of chemical properties and solubility. Petroleum products and minerals are used in these dyes.

Uses

1. They are used for colouring cloth and hair.
2. Fluorescent colours are used to make street boards that are visible at night.
3. Dyes are used to polish leather shoes, purses and chappals.

Adverse effects

1. Dyeing hair can have adverse effects like hair fall, damage to hair texture, burning of skin, adverse effect on eyes, etc.
2. Lipstick contains a dye named carmine. It does not affect lips but causes stomach disorders.
3. Excessive use of plants for making natural dyes results in deterioration of the environment.

Artificial colours

Can you tell?

1. What problems do you get after playing colours on Rang Panchami? Why?
2. Which colors will you use to prevent the occurence of these problems?
3. What problem do you have on painting the house and furniture?

We regularly use artificial colours on Rang Panchami, decorating the housd by painting. The red color use on Rang Panchami is very dangerous. It contains a high proportion of mercury in it. This poses risks like blindness, skin cancer, asthma, itching of the skin, permanent blocking of sweat pores etc. Therefore, it is necessary that artificial colours are used cautiously.

14.3 Harmful effects of artificial colours

Find out

Find out the hazardous chemicals present in the artificial colours and their harmful effects.

Try this

Prepare colours for Rang Panchami from natural resources such as beet root, flowers of flame of forest, spinach, flame tree (gulmohar) and protect your health by using these.

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Deodorant

Body odour is caused by the bacterial decomposition of the sweat. A deodorant is used to prevent this odour. Everybody likes a fragrant deodorant to remain fresh the whole day. School children use deo on a large scale. This large scale use of deo in adolescent is a result of the advertisements shown on television. Deodorants contain parabens (methyl, ethyl, propyl, benzyl and butyl) and also alcohol in large proportions. Aluminium compounds and silica are also used.

1. Ordinary deo – It contains a smaller proportion of aluminium. It decreases the odour of the sweat.

2. Antiperspirant deo – This decreases the extent of sweating. It contains about 15% of aluminium chlorohydrate. It clogs the sweat pores on the skin.

3. Clinical deo – Some people sweat heavily and it has harmful effects on the skin. Clinical deo is meant for such people. It contain 20 to 25% aluminium. It is used during the night.

Harmful effects

1. Aluminium – Zirconium compounds are the most harmful chemicals in the deodorant. Disorders like headache, asthma, respiratory disorders, heart disease are likely to occur without our knowledge.
2. There is a possibility of various skin disorders and also skin cancer due to the aluminium chlorohydrates.

Teflon

Teflon is used for coating cooking utensils and industrial equipment to avoid sticking. It is the polymer of tetrafluoroethylene. Roy J. Plunkett discovered it in 1938. Its chemical name is polytetrafluoroethene $(C_2F_4)_n$.

14.4 Teflon coating

Can you tell? What is the property of Teflon because of which it is used in nonstick ware ?

Properties

1. The atmosphere and chemical substances have no effect on Teflon.
2. Neither water nor oil will stick to Teflon coated articles.
3. High temperatures do not affect Teflon as its melting point is 327 ^{0}C.
4. Teflon coated articles are easy to clean.

Uses

1. Teflon is a poor conductor of electricity. Therefore, Teflon cladded wires and parts are used in high technology electronics instruments.
2. It is used for making non-stick kitchenware.
3. The colored metal sheets of two-wheelers and four-wheelers are given a Teflon coating to protect them from damage due to high temperature and rain.

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Powder coating : Powder coating is a method of applying a layer harder than paint on the surface of an iron object to prevent rusting. In this method, a polymer resin, a pigment and some other ingredients are melt mixed, cooled and ground into a uniform powder. This powder is sprayed on the polished metal surface by electrostatic spray deposition (ESD). In this method, the particles of the powder are given an electrostatic charge due to which a uniform layer of the powder sticks to the metal surface. Then the object is heated in the over along with the coating. A chemical reaction occurs in the layer, resulting in the formation of long cross-linked polymeric chains. This powder coating is highly durable, hard and attractive. Powder coating can be done on plastic and medium density fibre (MDF) board in day to day use as well.

Anodizing : A protective layer is formed naturally on the surface of aluminium metal by reaction with oxygen in air. In the anodizing process, this layer can be made of the desired thickness. Anodizing is done by electrolysis. Dilute acid is taken in the electrolytic cell and the aluminium article is dipped in it as the anode. When an electric current is passed hydrogen gas is released at the cathode and oxygen gas at the anode. A reaction with oxygen occurs and a layer of hydrated aluminium oxide is formed on the anode, i.e. the iron article..This layer can be made attractive by adding colour in the cell during electrolysis. We use anodized cooking utensils like griddles and cookers. Why?

Ceramic : Ceramic is a heat resistant substance formed by kneading an inorganic substance in water and then shaping it and hardening it by heating. Pots made by a potter, Mangalore roofing tiles , construction bricks, pottery, terracotta articles are some examples of common ceramic articles that we see around.

This is how a ceramic article is made

When clay is kneaded in water, shaped and then fired in a kiln at a temperature of 1000 to 1150^{0}C , a porous ceramic is formed. To overcome the porosity the fired object is covered with finely ground glass powder suspended in water (glaze) and is then fired again. As a result, the surface of the ceramic becomes shiny and its porosity disappears

14.5 Ceramics

Porcelain : This is a hard, translucent and white coloured ceramic. It is made by using the white clay called kaolin, found in China. Glass, granite and the mineral feldspar is mixed with kaolin and kneaded with water. The resulting mixture is shaped and fired in a kiln at a temperature of 1200 to 1450 ^{0}C. On firing again after glazing, beautiful articles of porcelain are obtained. Which porcelain vessels are used in the laboratory?

Bone china – Bone china is made by adding some ash of animal bones in the mixture of china clay, feldspar and fine silica while making porcelain. This ceramic is harder than porcelain.

Advanced ceramics : Oxides like Alumina (Al_2O_3), Zirconia (ZrO_2) Silica (SiO_2) and some other compounds like silicon carbide (SiC), boron carbide (B_4C) are used instead of clay for making advanced ceramic. This ceramic requires a temperature of 1600 to 1800 ^{0}C and an oxygen free atmosphere for firing. This process is called sintering.

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Ceramics can withstand high temperatures without decomposing. Ceramic is brittle, water resistant and an electrical insulator. Therefore, it is used in electrical instruments, for coating the interior of a kiln, the outer surfaces of ships and blades of jet engines. A certain type of ceramic tiles are fixed on the outer layer of a space shuttle. Some types of ceramics are used as superconductors.

Exercises

1. Fill in the blanks.

a. The number of molecules of water of crystallization in washing soda is .....

b. The chemical name of baking soda is ....

c. ..... is used in treatment of hyperthyroidism.

d. The chemical name of Teflon is ....

2. Match the pairs

Group A	Group B
1. Saturated brine	a. sodium metal freed
2. Fused salt	b. basic salt
3. $CaOCl_2$	c. crystallization of salt
4. $NaHCO_3$	d. oxidation of colour

3. Write answers to the following

a. What is meant by radioactivity?

b. When is said to be the nucleus unstable?

c. Which diseases are caused by artificial food colours ?

d. Where in the industrial field is radioactivity used?

e. Write down properties of teflon.

f. What type of colours will you use to celebrate ecofriendly Rang Panchami? Why?

g. Why has the use of methods like Teflon coating become more common?

4. Give scientific explanation

a. Bleaching powder has the odour of chlorine.

b. The hard water of a well becomes soft on adding washing soda to it.

c. Soap forms a precipitate in hard water.

d. The particles of powder are given an electric charge while spraying them to form the powder coating.

e. The aluminium article is used as an anode in the anodising process.

f. When the radiation coming out from certain radioactive substance is passed through an electric field, marks are found at three places on the photographic plate placed in its path.

g A certain type of ceramic tiles are fixed on the outer layer of a space shuttle.

5. Write answers to the following

a. Write about artificial food colours, the substances used in them and their harmful effects.

b. What is meant by water of crystallization? Give examples of salts with water of crystallization, and their uses.

c. Write briefly about the three methods of electrolysis of sodium chloride.

6. Write the uses.

a. Anodizing b. Powder coating

c. Radioactive substances d. Ceramic

7. Write the harmful effects

a. Artificial dye b. Artificial food colour

c. Radioactive substances d. Deodorant

8. Write the chemical formula

Bleaching powder, common salt, baking soda, washing soda

9. Explain what you see in the following picture

Project : Visit the places where powder coating, Teflon coating is done. Get information about the process and present it in the class.

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18. Observing Space : Telescopes

- Forms of light
- Telescopes and types of telescopes
- Telescopes in space
- Indian Space Research Orgnaisation (ISRO)

Can you recall?

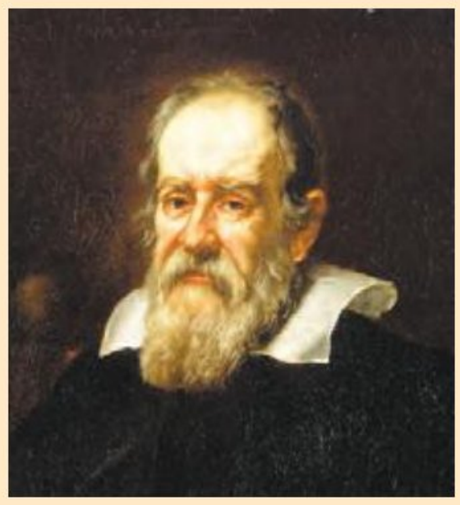
1. What is the difference between the sky and space?
2. What is meant by space observation? Why is it important?

From early days, man has been curious about the sun as well as the moon and stars seen in the night sky. Using his boundless imagination, he tried to understand the sky as observed by the naked eyes. He noticed that the position of the stars changed with time and had something to do with the occurrence of seasons. As the knowledge of the cycle of seasons was necessary for agriculture, sky watching began to prove useful to him. The position of the constellations was also useful to sea goers for navigation. Man began to make determined efforts to find answers to questions which arose out of his sky watching. But he did not have any equipment to get a closer view of the stars and planets in the sky.

Today, 400 years after Galileo's use of the telescope, tremendous progress has been made in telescope technology and in space science and technology on the whole. This great leap in technology has helped to construct for us an astounding picture of our universe. Space science and technology are not only important for research purposes, but also to help provide us with many of the comforts and facilities we enjoy in our everday life. A telescope is used to observe space, but will one telescope be sufficient for us to observe space completely? Why do we need different telescopes for the purpose? Are telescopes installed even in space? In this chapter, we are going to study the science behind many such questions.

An introduction to scientists

In 1608, spectacle maker and researcher, Hans Lippershey discovered that seeing through two lenses kept one behind the other, seems to brings objects closer to us. He thus made the first telescope. Galileo made a telescope in 1609 and used it for space observations. He realized that there are many more stars than what could be seen with naked eyes. Using his telescope, he also discovered the moons of Jupiter, the black spots on the sun, etc.



Galileo Galilei

Different forms of light

Light is an electromagnetic wave. Every wave has a characteristic wavelength. Our eyes can see only that light which has wavelengths between 400 nm to 800 nm. Such light is called visible radiation. However, there are electromagnetic waves of wavelengths other than the visible ones most of which we cannot 'see' as our eyes are not sensitive to them.

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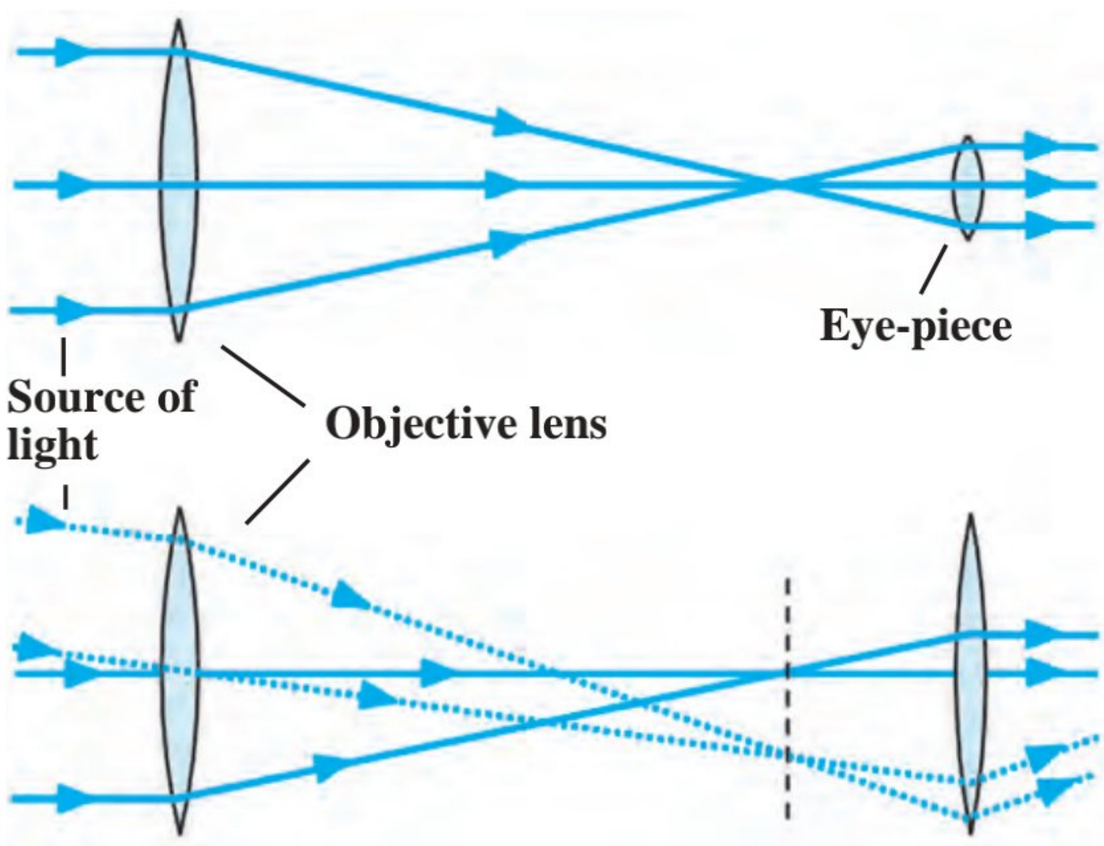
Study the following table.
1 nm (nanometer) = 10^{-9} m and 1 pm (picometer) = 10^{-12} m

Type of radiation	Wavelength
Radio waves	Longer than about 20 cm
Micro waves	0.3 mm – 20 cm
Infrared waves	800 nm – 0.3 mm
Visible light rays	400 nm – 800 nm
Ultraviolet rays	300 pm – 400 nm
X-rays	3 pm – 300 pm
Gamma rays	Shorter than 3pm

Of all the above types, our eyes are only capable of seeing the visible radiation. Thus, we use the visible radiation telescopes i.e. optical telescopes, made from regular lenses or mirrors to see the visible radiation coming from the space. However many heavenly bodies emit radiations other than the visible light. Thus we need different types of telescopes like the X-ray, gamma-ray and radio telescopes to receive such radiation and to study their sources.

Telescopes



18.1 **A refracting telescope**

Optical telescopes

Most optical telescopes are made with two or more lenses as shown in figure 18.1. To collect the maximum amount of light coming from a heavenly object, the objective lens should be made as large as possible. Using the light collected by the objective a smaller lens, called the eyepiece, produces a large image of the source. Light rays change their direction as they enter a lens from the atmosphere and again when they enter the atmosphere after passing through the lens. This is called refraction. Hence such telescopes are called **refracting telescopes**. We shall study image formation by lenses in the next standard.

Even though such a telescope is useful for space observations, it presents certain difficulties.

1. As we saw above, if we wish to obtain a bright image of a source by collecting the maximum possible light from it, the objective lens must be made as large as possible. However, it is very difficult to make very large lenses. Also, large lenses are very heavy and tend to get distorted.
2. As the objective and eyepiece are placed at the opposite ends of the telescope, the length of the telescope also increases with increase in the size of the lenses and the telescope becomes difficult to manage.
3. The images formed by lenses have erorrs of colours. This is called chromatic aberration.

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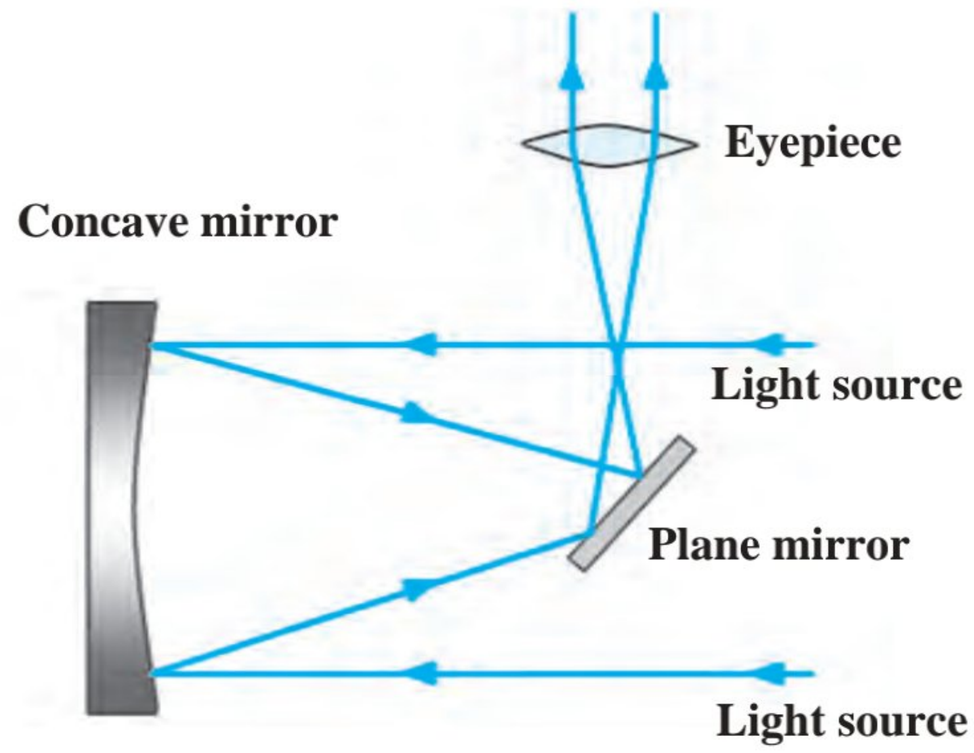
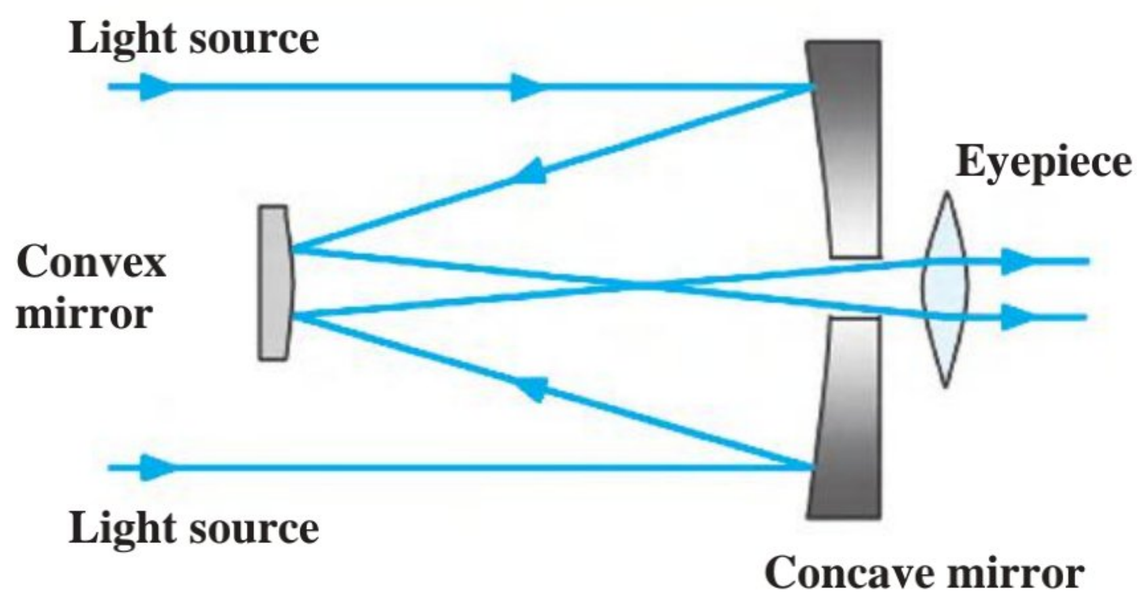
To overcome these difficulties, telescopes are made using concave mirrors. As light rays get reflected by mirrors in these telescopes, they are called **reflecting telescopes**. In order to get a bright image of a source, large mirrors are necessary (so that they can collect a large amount of light from the source), but it is easier to make large mirrors as compared to making large lenses. Also, big mirrors can be made by combining several smaller pieces. The weight of a large mirror too is less than that of a lense of the same size. The images formed by mirrors do not have errors of colour. Only by using these large telescopes, can we see far away stars and galaxies, which we could never have seen using our naked eyes.

The reflecting telescopes are mainly of two types: Newtonian and Cassegrain. As shown in figure 18.2 light rays coming from space are reflected by the concave mirror. Before these reflected rays converge at the focus, they are deflected again by a small plane mirror. As a result, they get focused at a point lying on the perpendicular to the axis of the telescope's cylinder. They pass through the eyepiece and we get a magnified image of the source.



18.2 The Newtonian telescope

The construction of a Cassegrain type of telescope is shown in figure 18.3. The Cassegrain telescope also uses a concave mirror. However, here light rays, after reflection from the concave mirror, are reflected back towards it by a small convex mirror. They pass through a hole at the centre of the concave mirror and then through the eyepiece situated at the back of the mirror. The eyepiece gives us a magnified image of the source.



18.3 The Cassegrain telescope

In India, we have several telescopes with concave mirrors of 2 m diameter that have been in use for many years. The biggest optical telescope in India, having a mirror of 3.6 m diameter is situated in the Aryabhatt Research Institute of Experimental Sciences, Nainital. This is the largest optical telescope in Asia.

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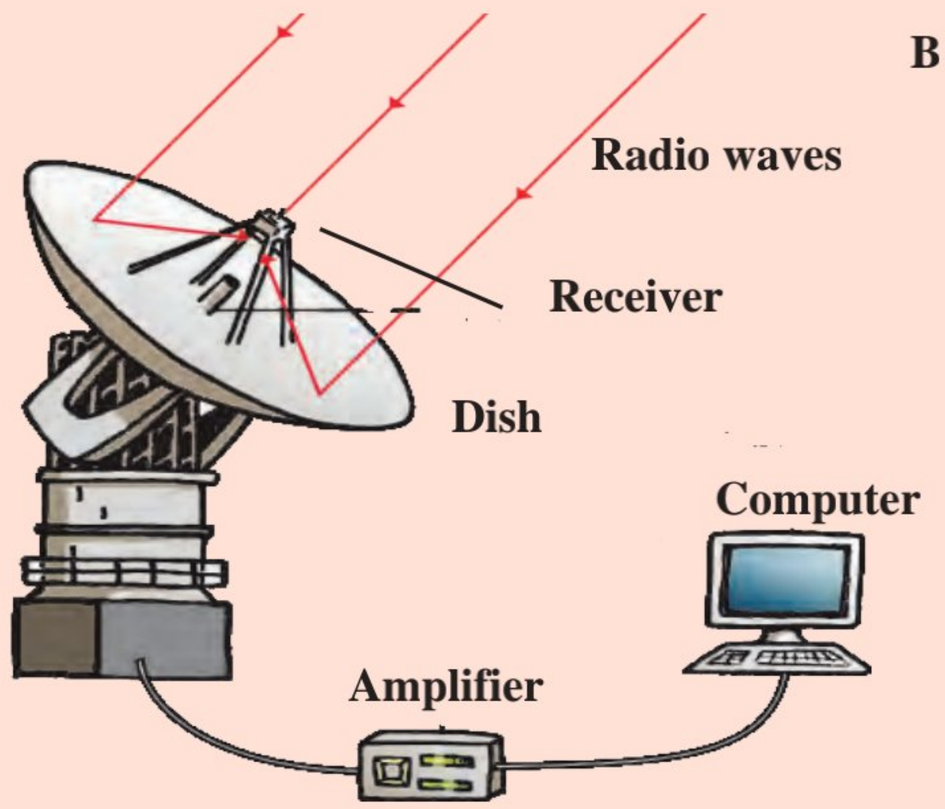
Radio telescope

Many heavenly objects emit radio waves in addition to visible radiation. We cannot see this radiation with our eyes. Hence, a special type of telescope is used to receive these rays. It is called a radio telescope. It is made from one or more dishes of a particular parabolic shape. As in optical telescope the incident radio waves are reflected by these dishes and converge at the focus. A radio receiver is placed at the focal point. The information gathered by this receiver is passed on to a computer which analyses it and constructs an image of the source.

A large radio telescope called the Giant Meterwave Radio Telescope (GMRT) has been erected at Narayangaon near Pune. It uses radio waves having wavelengths of about a metre, coming from heavenly bodies to study those bodies. This telescope is actually a collection of 30 dishes, each having a diameter of 45 m. It is called a giant telescope as the arrangement of the 30 dishes over an area which measures up to 25 km across, is made in such a way that it works as a single dish having a diameter of 25 km. This means that the GMRT gives the same data that we would have got from a telescope having a single dish of 25 km diameter! GMRT has been made by Indian scientists and engineers at minimum cost. It is a world standard research facility. Scientists study the solar system, solar winds, pulsars, supernova, interstellar hydrogen clouds, etc. with the help of the GMRT. Scientists from all over the world come to India to make use of this facility.

A



18.4 A. Radio telescope (photograph) B. The structure of a radio telescope

Telescopes in space

Visible light and the radio waves emitted by heavenly bodies in space can pass through the earth's atmosphere and reach the earth's surface. So, optical and radio telescopes can be erected on the surface of the earth. However, these earth-based telescopes present some problems in making good quality observations.

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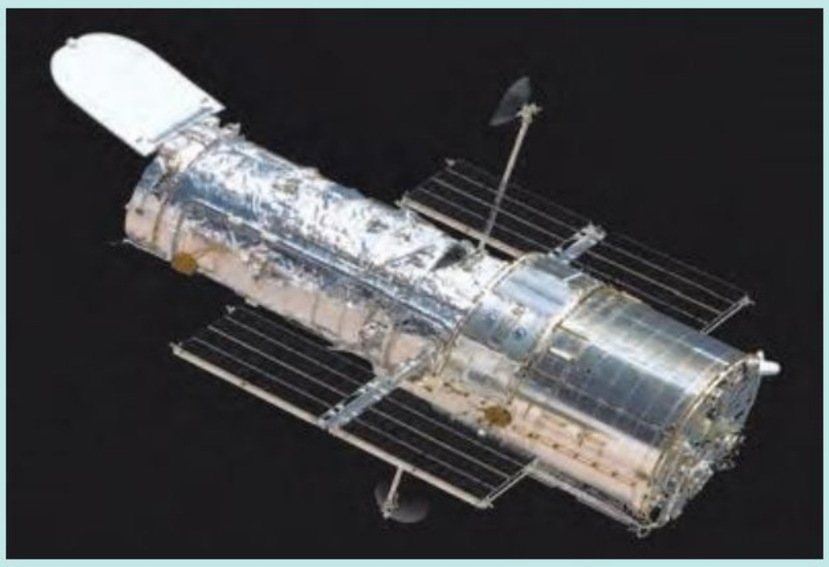
The visible light coming from a heavenly body has to pass through the earth's atmosphere to reach the earth's surface. During this journey, some of the light is absorbed by the atmosphere and the intensity of the light reaching the earth's surface decreases. A second problem is caused by the changes in atmospheric pressure and temperature. These changes cause turbulence in the atmosphere which in turn cause of the light rays to change their path slightly and thereby shake the position of the image. Also, because of Sunlight, we cannot use optical telescopes during the day. During the night too city lights and cloudy weather can cause difficulties in observing the heavenly bodies. To reduce these problems, optical telescopes are situated on top of mountains, at in uninhabitated places. However, if we want to get rid of all the above problems completely, we should place the telescope above the earth's atmosphere, in space itself. These problems do not exist in the space and thus the image obtained by space telescopes would be bright and very clear and will ramain at one place. Scientists have turned this idea into reality.

In 1990, the National Aeronautics and Space Administration launched into space an optical telescope called the **Hubble telescope**. It has a mirror of diameter 94 inches and is orbiting the earth at a height of 589 km from it. This telescope is still working and has helped to make important discoveries.



In 1999, the National Aeronautics and Space Administration launched an X-ray telescope named **Chandra**, in space, to study X-rays coming from heavenly objects. Special mirrors which can reflect X-rays were used in this telescope. Chandra has given us very useful information about stars and galaxies. The telescope is named after the famous Indian scientist Subramanian Chandrashekhar.

Indian Space Research Organization (ISRO) Bengaluru

This institute was established in 1969 with the aim of developing technology for making and launching of artificial satellites. Till date, ISRO has successfully launched a large number of satellites. ISRO's programme is foremost among the successful programs undertaken by independent India. India's progress in space science has played a big role in national and social development.

The INSAT and GSAT series of satellites support our telecommunication network, television broadcasting and meteorological services. It is because of them that telephone, television and internet services are available everywhere in the country. The EDUSAT satellite in this series is used exclusively for education. The IRS satellite series is used for the monitoring and management of natural resources as well as disaster management.

Website : www.isro.gov.in

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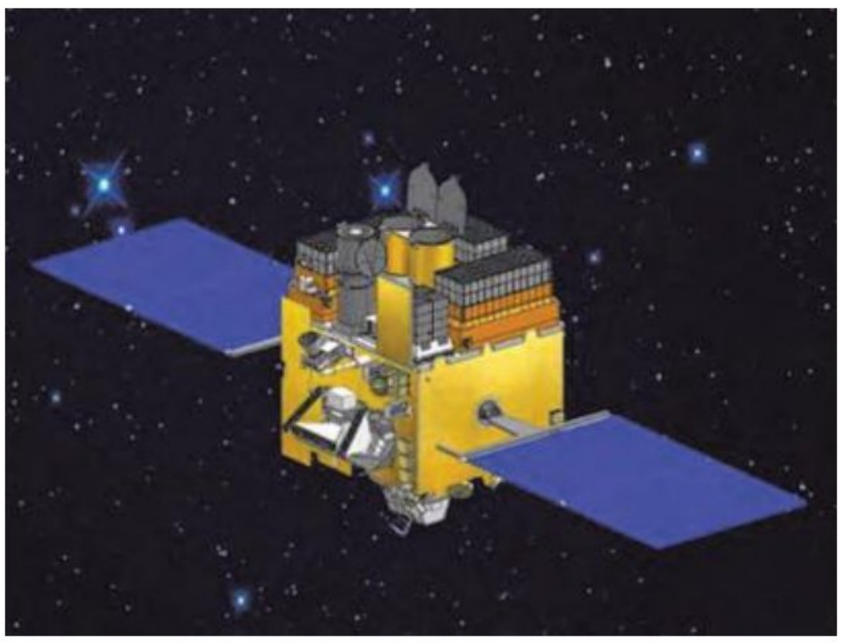
Astrosat

In 2015, Indian Space Research Organization (ISRO) launched an artificial satellite called Astrosat, in space. This satellite has ultraviolet and X-ray telescopes and detectors. Most of the parts used in this satelite are made in India. It is a unique system having different kinds of telescopes on a single satellite. Indian scientists are studying various aspects of the Universe using the data obtained with these telescopes.



Find out Collect more information about telescopes that work in space apart from the Hubble and Chandra telescopes.

Exercises

1. Fill in the blanks with the proper words.

a. The wavelength of visible light is between …….. and ……
b. GMRT is used for ……. waves.
c. A certain X-ray telescope is named after scientist ……..
d. The first scientist to use a telescope for space observationwas ..... .
e. The biggest optical telescope in India is situated at …….

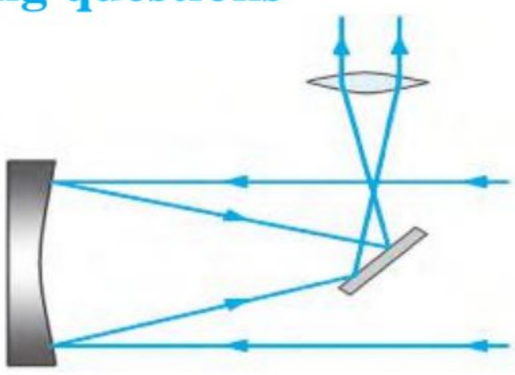
2. Form pairs

'A' Groups	'B' Groups
(i) X-rays	(a) GMRT
(ii) Optical Telescope	(b) ISRO
(iii) Indian radio telescope	(c) Hubble
(iv) Launching artificial satellites	(d) Chandra

3. What are the difficulties in using ground based optical telescopes? How are they overcome?

4. Which type of telescopes can be made using a concave mirror, convex mirror, plane mirror and a lens? Draw diagrams of these telescopes.

5. Study the figure and answer the following questions



a. What type of telescope is shown in the figure?
b. Label the main parts of the telescope.
c. Which type of mirror does the telescope use?
d. What other type of telescope uses a curved mirror?
e. Explain the working of the above telescope.

6. Answer the following questions.

a. Explain the construction of Galileo's telescope.
b. Explain the construction of a radio telescope.
c. Why are optical telescopes located in uninhabited places on mountains?
d. Why can an X-ray telescope not be based on the earth?

Project : Collect information about various observatories in India and present it in the class.

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Science and Technology - Educational Planning

There are altogether eighteen chapters in which the subject of Science and Technology has been covered. Of these, the first ten chapters deal with the topics included in the portion of Paper I and Paper II to be studied the first term. There are two separate papers for the two subjects namely Science and Technology in each term. The sequence of the chapters in the textbook has been planned accordingly. Paper I includes physics and chemistry while Paper II deals with Biology and the rapidly developing and indispensable topics related to Environment, Space, Weather and climate, Disaster management and Information communication technology all of which have a great impact on all our lives.

Even though, in both terms, the subject has been separated into Paper I (physics and chemistry) and Paper II (biology and other Science-related subjects such as environment, space, weather and climate, disaster management and information communication technology), teachers must adopt an integrated approach and consistently teach with that attitude. Some important points which teachers may keep in mind for the purpose of making annual plans are given below.

Term-wise plan of chapters

First Term

	Part I		Part II
Chapter No.	Name of chapter	Chapter No.	Name of chapter
1	Laws of Motion	6	Classification of plants.
2	Work and Energy	7	Energy Flow in an Ecosystem
3	Current Electricity	8	Useful and Harmful Micro-organisms
4	Measurement of matter	9	Environmental Management
5	Acids Bases and Salts	10	Information Communication Technology (ICT) : The new direction of progress

Second Term

	Part I		Part II
Chapter No.	Name of chapter	Chapter No.	Name of chapter
11	Reflection of Light	15	Life Processes in Living Organisms
12	Study of Sound	16	Heredity and Variation
13	Carbon : An important element	17	Introduction to Biotechnology
14	Substances in Common Use	18	Observing Space.....Telescopes

1. Practical work, written exams and all information about it will be given separately.
2. While doing practical work, along with the given experiments, the various activities given in the textbook must also be done.
3. A record of practical work done should be organized under the heads Title, Apparatus/Materials/ Chemicals, Diagram, Procedure, Observations, Inference/Conclusion.
4. As the questions given at the end of each lesson are based on the content of the lesson as well as the various activities and projects, a deliberate effort will have to be made to guide the students to the expected answers.
5. Several of the given activities are newly included in our textbooks and each of them should be completed separately. The report of the activity should be written in the following order : Preface, Need/ Necessity, Methodology, Observations, Inferences and Conclusion.

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