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Class 9 | Physic

01 Motion

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Atoms, molecules, planets, stars and galaxies are all in motion. We often perceive an object to be in motion when its position changes with time.
An object may appear to be moving for one person and stationary for some other. For the passengers in a moving bus, the roadside trees appear to be moving backwards. A person standing on the road–side perceives the bus along with the passengers as moving. However, a passenger inside the bus sees his fellow passengers to be at rest.

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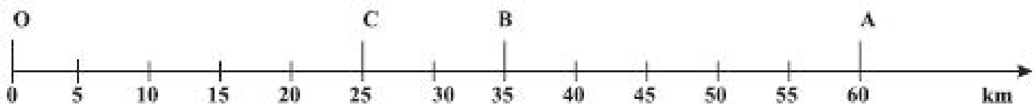
02. MOTION ALONG A STRAIGHT LINE

Assume the motion of an object moving along a straight path. The object starts its journey from O which is treated as its reference point (Fig.). Let A, B and C represent the position of the object at different instants. At first, the object moves through C and B and reaches A. Then it moves back along the same path and reaches C through B.



Positions of an object on a straight line path

The total path length covered by the object is OA + AC, that is 60 km + 35 km = 95 km. This is the distance covered by the object.
The shortest distance measured from the initial to the final position of an object is known as the displacement.

03. UNIFORM AND NON- UNIFORM MOTION

Assume an object moving along a straight line. Let it travel 9 m in the first second, 9 m more in the next second, 9 m in the third second and 9 m in the fourth second. In this case, the object covers 9 m in each second. As the object covers equal distances in equal intervals of time, it is said to be in uniform motion.

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Example 1 An object travels 60 m in 4 s and then another 60 m in 2 s. What is the average speed of the object?

Solution Total distance travelled by the object =
60 m + 60 m = 120 m
Total time taken = 4 s + 2 s = 6 s

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

$$= \frac{120\text{ m}}{6\text{ s}}$$

Therefore, the average speed of the object is 20 m s^{-1}.

SPEED WITH DIRECTION

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

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

$$\text{Average velocity} = \frac{\in ial\ velocity + final\ velocity}{2}$$

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

where vav is the average velocity, u is the initial velocity and v is the final velocity of the object.

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

04. Rate of Change of Velocity

During uniform motion of an object along a straight line, the velocity remains constant with time. In this case, the change in velocity of the object for any time interval is zero.

However, in non-uniform motion, velocity varies with time. It has different values at different instants and at different points of the path. Thus, the change in velocity of the object during any time interval is not zero.

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

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

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05. DISTANCE–TIME GRAPHS

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

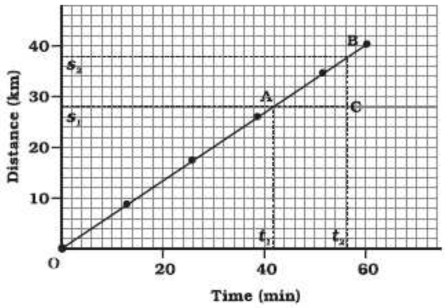

Fig. Distance-time graph of an object moving with uniform speed

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

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

$$v = \frac{s_2 - s_1}{t_2 - t_1} \qquad ...(i)$$

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

Equations of Uniformly Accelerated Motion

There are three equations for the motion of those bodies which travel with a uniform acceleration.

(i) **First Equation of Motion :**

The first equation of motion is : $v = u + at$. It gives the velocity acquired by a body in time t.

The equation $v = u + at$ is known as the first equation of motion and it is used to find out the velocity $'v'$ acquired by a body in time $'t'$, the body having an initial velocity $'u'$ and a uniform acceleration $'a'$.

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(ii) **Second Equation of Motion :**

The second equation of motion is : $s = ut + \frac{1}{2}at^2$. It gives the distance travelled by a body in time t.

(iii) Third Equation of Motion

The third equation of motion is : $v^2 = u^2 + 2as$. It gives the velocity acquired by abody in travelling a distance s.

To solve the problems on motion we should remember that :

(a) if a body starts from rest, its initial velocity, $u = 0$

(b) if a body comes to rest (it stops), its final velocity, $v = 0$

(c) if a body moves with uniform velocity, its acceleration, $a = 0$

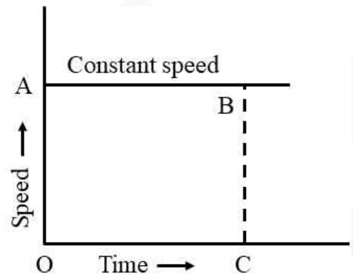
06. Speed-Time Graphs (Or Velocity-Time Graphs)

We can have three types of speed-time graphs for a moving body. These three cases are :

(i) When the speed of the body remains constant (and there is no acceleration)

(ii) When the speed of the body changes at a uniform rate (there is uniform acceleration)

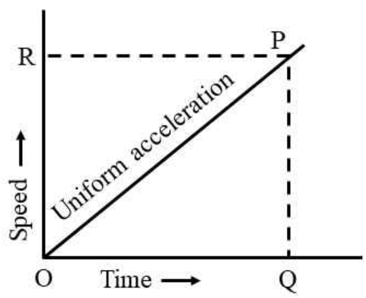
(iii) When the speed of the body changes in a non-uniform way (there is non-uniform acceleration)



If the speed-time graph of a body is a straight line parallel to the time axis, then the speed of the body is constant (or uniform).

07. Speed-Time Graphs when Speed Changes at a Uniform Rate (Uniform Acceleration)

The speed-time graph for a uniformly changing speed (or uniform acceleration) will be a straight line.



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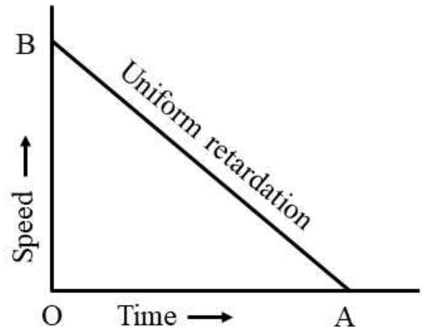
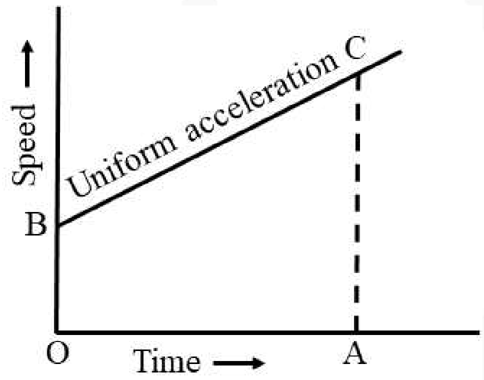
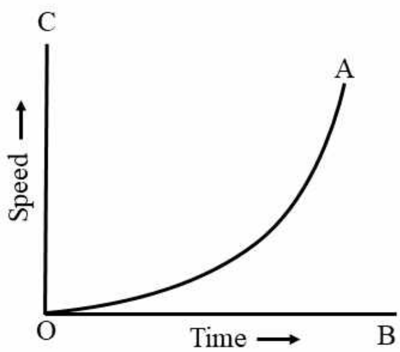
We can find out the value of acceleration from the speed-time graph of a moving body. The slope of a speed-time graph of a moving body gives its acceleration.
The distance travelled by a moving body in a given time can also be calculated from its speed-time graph.
In a speed-time graph of a body, a straight line sloping upwards shows uniform acceleration, in a speed-time graph of a body, a straight line sloping downwards indicates uniform retardation. We will now discuss the speed-time graph of a body whose initial speed is not zero.



Speed-Time Graph when the Initial Speed of the Body is Not Zero



08. Speed-Time Graph when Speed Changes at a Non-Uniform Rate (Non-Uniform Acceleration)



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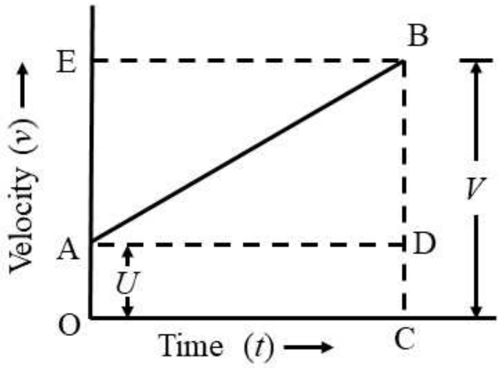
09. Derive The Equations of Motion by Graphical Method

The three equations of motion : $v = u + at$; $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$ can be derived with the help of graphs as described below.

(i) **To Derive $v = u + at$ by Graphical Method**



Now, Initial velocity of the body, $u = OA$
And, Final velocity of the body, $v = BC$
But from the graph $BC = BD + DC$
Therefore, $v = BD + DC$
Again $DC = OA$
So, $v = BD + OA$
Now, From equation (i), $OA = u$
So, $v = BD + u$

We should find out the value of BD now. We known that the slope of a velocity-time graph is equal to acceleration, a.

Acceleration, a = slope of line AB

or $a = \frac{BD}{AD}$

$a = \frac{BD}{t}$

$BD = at$

$v = at + u$

$v = u + at$

(ii) **To Derive $s = ut + \frac{1}{2}at^2$ by Graphical Method**

Distance travelled = Area of figure $OABC$
= Area of rectangle $OADC$ + Area of triangle ABD

We will now find out the area of the rectangle $OADC$ and the area of the triangle ABD.

(a) Area of rectangle $OADC = OA \times OC$
$= u \times t$
$= ut$

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(b) rea of triangle $ABD = \frac{1}{2} \times$ Area of rectangle $AEBD$

$$= \frac{1}{2} \times AD \times BD$$

$$= \frac{1}{2} \times t \times at \qquad \text{(because } AD = t \text{ and } BD = at\text{)}$$

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

So, Distance travelled, s = Area of rectangle $OADC$ + Area of triangle ABD

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

This is the second equation of motion. It has been derived here by the graphical method.

(iii) **To Derive $v^2 = u^2 + 2as$ by Graphical Method**

Distance travelled, $$s = \frac{(Sum\ of\ parallel\ sides) \times Height}{2}$$

or $$s = \frac{(OA + CB) \times OC}{2}$$

Now, $OA + CB = u + v$ and $OC = t$. Putting these values in the above relation, we get :

$$s = \frac{(u + v) \times t}{2}$$

Thus, $$v = u + at \qquad \text{(First equation of motion)}$$

And, $$at = v - u$$

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

Now, putting this value of t equation above, we get :

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

or $$2as = v^2 - u^2 \qquad [\text{because } (v + u) \times (v - u) = v^2 - u^2]$$

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

09. Uniform Circular Motion

When a body (or an object) moves in a circle, it is called circular motion.
When a body (or object) moves along a circular path, then its direction of motion (or direction of speed) keeps changing continuously. Since the velocity changes (due to continuous change in direction), therefore, the motion along a circular path is said to be accelerated.
When a body moves in a circular path with uniform speed (constant speed), its motion is called uniform circular motion.

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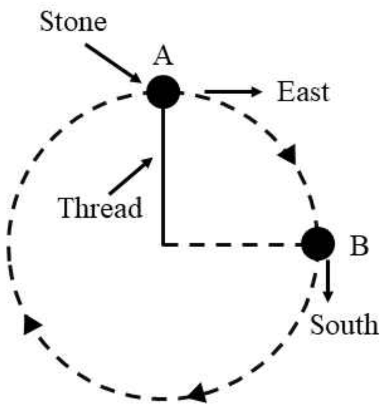

A stone tied to a thread moving with uniform circular motion.

Circular motion is acceleration even though the speed of the body remains constant. Thus, the motion in a circle with constant speed is an example of accelerated motion. A force is needed to produce circular motion. The force which is needed to make an object travel in a circular path is called centripetal force.

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CBSE Pattern
Exercise (1)

(Q 1 to 2) Very Short Type

1. Change the speed of 6 m/s into km/h?

2. What is the other name of negative acceleration?

(Q 3 to 5) Short Answer Type

3. What type of motion, uniform or non-uniform, is exhibited by a freely falling body?

4. A tortoise moves a distance of 100 metress in 15 minutes. What is the average speed of tortoise in km/h?

5. If a bus travelling at 20 m/s is subjected to a steady deceleration of 5 m/s^2, how long will it take to come to rest?

(Q 6 to 8) Multiple Choice

6. A particle is moving in a circular path of radius r. The displacement after half a circle would be :
   (a) 0
   (b) πr
   (c) $2r$
   (d) $2\pi r$

7. The speed of a moving object is determined to be 0.06 m/s. This speed is equal to :
   (a) 2.16 km/h
   (b) 1.08 km/h
   (c) 0.216 km/h
   (d) 0.0216 km/h

8. A bus moving along a straight line at 20 m/s undergoes an acceleration of 4 m/s^2. After 2 seconds, its speed will be :
   (a) 8 m/s
   (b) 12 m/s
   (c) 16 m/s
   (d) 28 m/s

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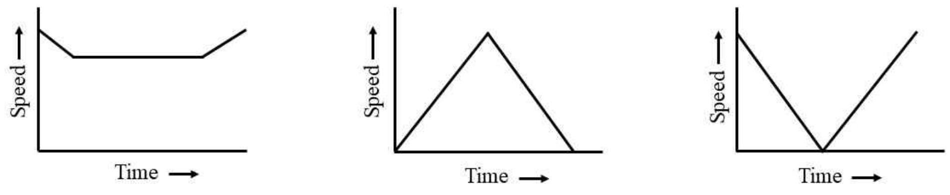
(Q 9 to 10) High Order Thinking Skills

9. Three speed-time graphs are given below :



(a) (b) (c)

Which graph represents the case of :

(a) a cricket ball thrown vertically upwards and returning to the hands of the thrower?

(b) a trolley decelerating to a constant speed and then accelerating uniformly?

10. A car is travelling along the road at 8 m s^{-1}. It accelerates at 1 m s^{-2} for a distance of 18 m. How fast is it then travelling?

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Answer & Solution

Q1
21.6 km/h

Q2
Retardation (or Deceleration)

Q3
Uniformely accelerated motion with increasing velocity if no friction of air. Because ‘g’ is constant.

Q4
0.4 km/h

Q5
4 s

Q6
(c)

Q7
(c)

Q8
(d)

Q9
(i) c

Q10
10 m s^{-1}

CLASS 9

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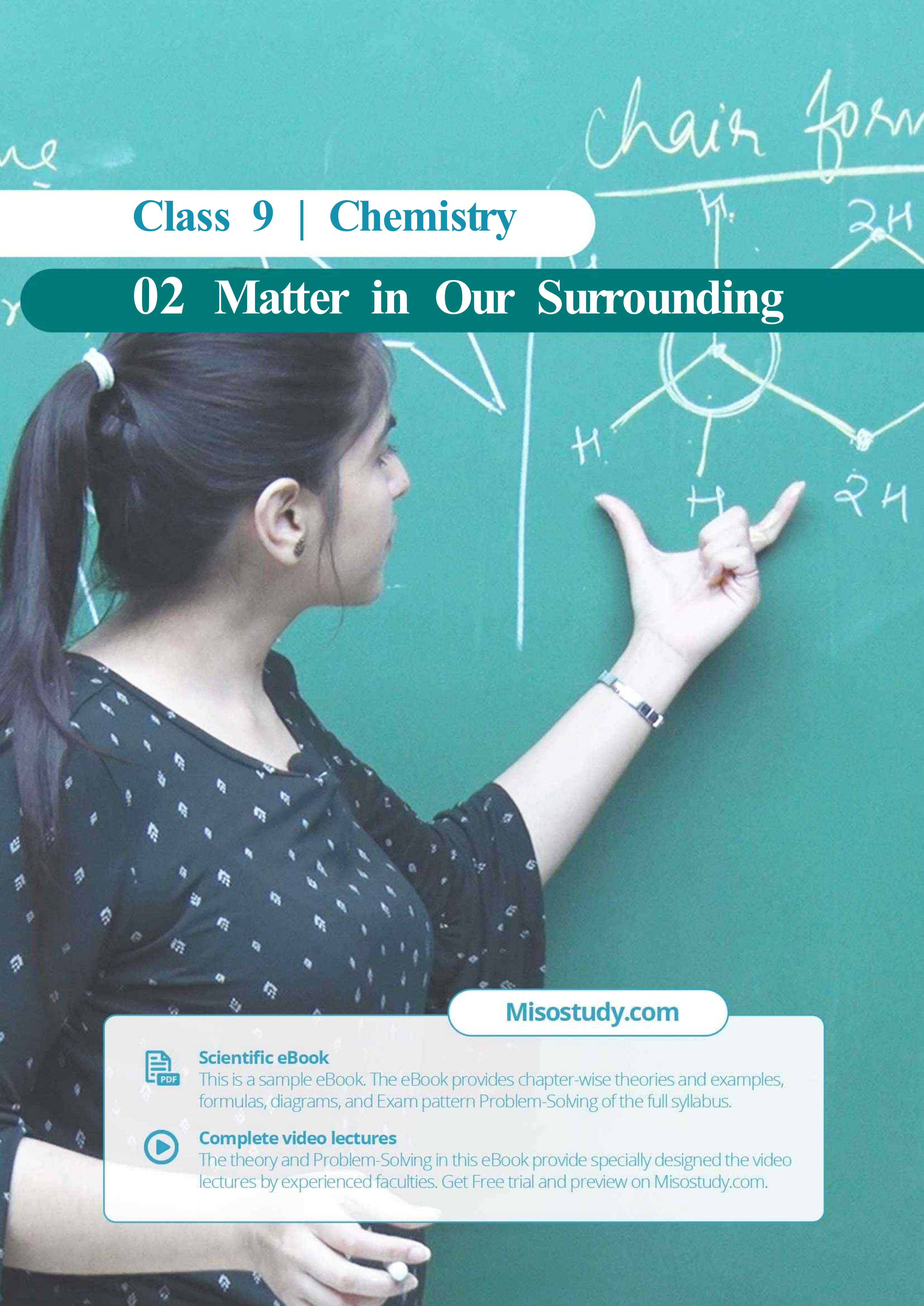

Class 9 | Chemistry

02 Matter in Our Surrounding

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Anything which occupies space and has mass is called matter. Modern day scientists classify matter in two ways : on the basis of its physical properties and on the basis of its chemical properties. On the basis of physical properties matter is classified as solids, liquids and gases. And on the basis of chemical properties, matter is classified as elements, compounds and mixtures.

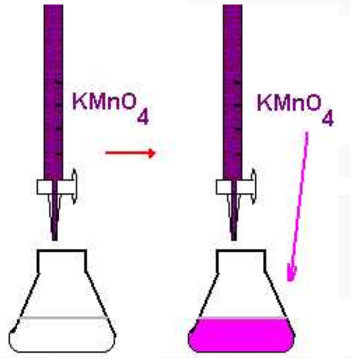
01. Matter is made of particles

Everything around us is made of tiny pieces or particles.

Evidence for Particles in Matter

(i) **Dissolving a Solid in Liquid**

we will first study the dissolving of potassium permanganate in water.



Actually, on dissolving, the particles of potassium permanganate into the spaces between the particles of the water. Since the particles of potassium permanganate and particles of water spread into each other and mix up on their own, it is concluded that ′they are moving˙ or ′they are in motion If the particles were not moving the colours could not spread throughout the beaker on its own. This movement of different particles among each other (on their own), so that they become mixed uniformly, is called diffusion.
We will now discuss the case of sugar dissolving in water. when sugar is added to water and stirred, it dissolves quickly. The sugar seems to disappear. These sugar particles go into the spaces between the particles of water, and mix with them.

(ii) **Mixing of Two Gases**

The process of diffusion give us two conclusions about the nature of matter :
(a) that matter is made up of tiny particles, and
(b) that the particles of matter are constantly moving.

(iii) **Movement of pollen Grains in Water**

The best evidence for the existence and movement of particles in liquids was given by Robert Brown in 1827. Robert Brown suspended extremely small pollen grains in water. On looking through the microscope. it was found that the pollen grains were moving rapidly throughout water in a very irregular way (or zig-zag way) It was also observed that warmer the water, faster the pollen grains move on the surface of water. The pollen grains move on the surface of water because they are constantly being hit by the fast

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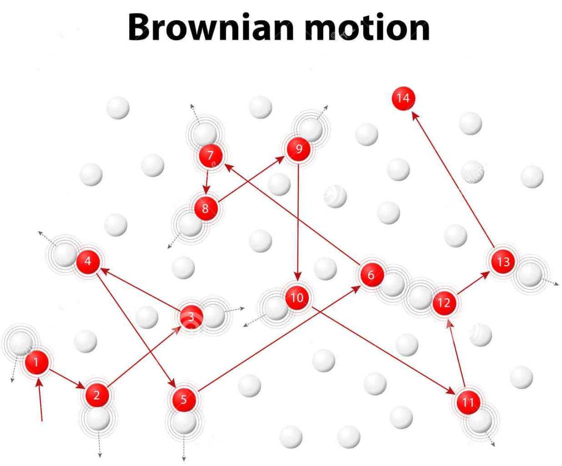
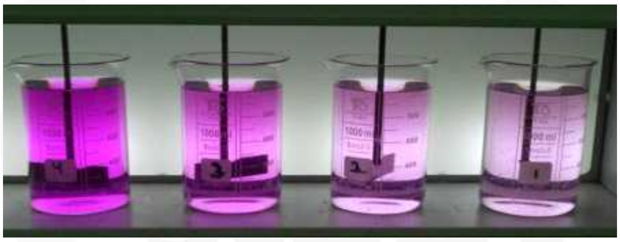
(iv) moving particles of water. The random motion of visible particles (pollen grains) caused by the much smaller invisible particles of water is an example of Brownian motion (after the name if the scientist Robert Brown who first observed this phenomenon. The zig-zag movement of the small particles suspended in a liquid (or gas) is called Brownian motion.)



Characteristics of Particles of Matter

The important characteristics of particles of matter (like atoms or molecules are the following:

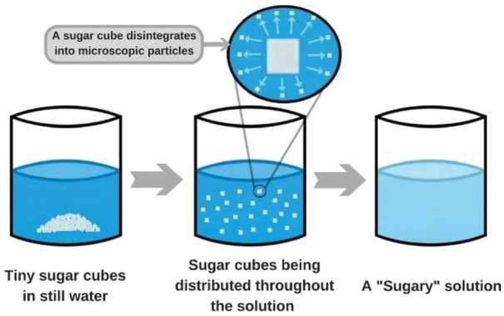
(i) **The particles of matter are very, very small**



From this observation we conclude that each potassium permanganate crystal itself must be made up of millions of small particles which keep on spreading and imparting colours to more and more of water (on dilution.)

(ii) **The particles of matter have spaces between them**

The fact that there is no change in volume on dissolving sugar in water tells us that there are spaces between the particles of water. And these spaces accommodate the sugar particles. This also gives us another conclusion that the particles (or molecules) in water are not tightly packed, they are somewhat loose, having spaces between them.



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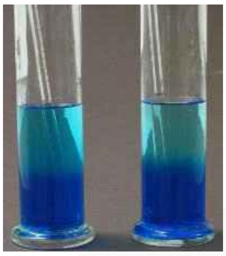
(iii) **The particles of matter are constantly moving**

The best evidence that particles of matter constantly moving comes from the studies of diffusion and brownian motion

(a) When we light (or burn) an incense stick (*agarbatti*) in one corner of room, its fragrance (pleasant smell) spreads in the whole corner of a room, quickly. When a few crystals of copper sulphate are placed at the bottom of a beaker (or a gas jar) containing water then water in the whole beaker turns blue slowly, thus, the spreading of blue colours of copper sulphate crystals in water is due to the movement of both, copper sulphate particles as well as water particles.



(iv) **The particles of matter attract each other**

There are some forces of attraction between the particles of matter which bind them together.

02. Classification of matter as solids, liquids and gases

On the basis of physical states all the matter can be classified into three groups: solids, and liquids Gases. for example :

(a) Sugar, sand, sand, iron, wood, rocks, minerals and ice are solids,
(b) Water, milk, oil, kerosene, petrol, and alcohol, are liquids, and
(c) Air, oxygen, dioxide and steam are gases.

Properties of solids

- Solids have a fixed shape and a fixed volume.
- Solids cannot be compressed much.
- solids have high densities. They are heavy.
- Solids do not fill their container completely
- Solids do not flow

Properties of Liquids

- Liquids have a fixed volume but they have no fixed shape Liquids take the shape of the common gases. the vessel in which they are placed
- Like solids, liquids cannot be compress
- Liquids have moderate to high densities. They are usually less dense than solid.
- Liquid do not fill their container completely.
- Liquid generally flow easily.

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Properties of Gases

- Gases have neither a fixed shape nor a fixed volume Gases acquire the shape and volume of the vessel in which they are kept.
- Gases can be compressed easily (into a small volume).
- Gases have very low densities. They are very, very light. A gas is much lighter then the same volume of a solid or a liquid
- Gases fill their container completely.
- Gases flow easily.

03. Diffusion

The spreading out and mixing of a substance with another substance due to the motion of its particles is called diffusion.

Diffusion in Gases

- The smell of food being cooked in the kitchen in the reaches us even from a considerable distance
- The fragrance of burning incense stick (or agarbatti) spreads all around due to the diffusion of its smoke into the air.
- The smell of perfume due to diffusion of perfume vapours into air.

Diffusion in Liquids

- The spreading of purple colour of potassium permanganate into water, on its own, is due to the diffusion of potassium permanganate particles into water
- The spreading of blue colour of copper sulphate into water, on its own is due to the diffusion of copper sulphate particles into water.
- The spreading of ink water, on its own, is due to the diffusion of ink particles into water.
- The carbon dioxide gas and oxygen gas present in air (or atmosphere) diffuse into water (of pond, lakes, rivers and sea) and dissolve in it.

Diffusion in Solids

Diffusion in solids is a very, very slow process.

- If two metal block are bound together tightly and kept undisturbed for a few year then the particles of one metal are found to have diffused into the other metal.

04. The common unit of temperature and si unit of temperature

$$0^{\circ}C = 273K$$

The relation between kelvin scale and Celsius scale of temperature can be written as :

$$\text{Temp. on Kelvin scale} = \text{Temp. on Celsius} + 273$$

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05. Change of state of matter

We can change the physical state of matter in two ways:
(a) By changing the temperature, and
(b) By changing the pressure.

06. Effect of change of temperature

(i) **Solid to Liquid Change : Melting** The process in which a solid substance changes into a liquid on heating, is called melting (or fusion). The temperature at which a solid substance melts and changes into a liquid at atmospheric pressure, is called melting point of the substance. Different solids have different melting point for example, the melting point of ice is $0^{\circ}C$; the melting point of wax is $63^{\circ}C$; whereas the melting point of iron is $1535^{\circ}C$. the melting point of a solid is a measure of the force of attraction between its particles (atoms or molecules).

(ii) **Liquid to Gas Change : Boiling (or Vaporisation)**The process in which a liquid substance changes into a gas rapidly on heating, is called boiling. the temperature at which a liquid boils and changes rapidly into a gas at atmospheric pressure is called boiling point of the liquid. Different liquid have different boiling point. For example the boiling point af alcohol is $78^{\circ}C$, the boiling point of water $100^{\circ}C$,
whereas the boiling point of mercury is $357^{\circ}C$ the boiling point of a liquid is a measure of the force of attraction between its particles.

(iii) **Gas to Liquid Change : Condensation** The process of changing a gas (or vapour) to a liquid by cooling is called condensation.

(iv) **Liquid to Solid Change : Freezing** The process of changing a liquid into a solid by cooling is called freezing For example, when water is cooled it gets converted into a solid called ice this is called freezing. of water freezing means solidification. Please note that freezing is the reverse of melting.

$$\boxed{\text{Solid State}} \underset{\text{Cool (Freezing)}}{\overset{\text{Heat (Melting)}}{\rightleftharpoons}} \boxed{\text{Liquid State}} \underset{\text{Cool (Condensation)}}{\overset{\text{Heat (Boiling)}}{\rightleftharpoons}} \boxed{\text{Gaseous State}}$$

07. Latent heat

The heat energy which has to be supplied to change the state of a substance is called its latent heat. Latent heat does not raise (or increase) the temperature. The latent heat which we supply is used up in overcoming the forces of attraction between the particles of a substance during the change of state.
Latent heat is of two type:
(a) Latent heat of fusion and
(b) Latent heat of vaporisation.

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08. Sublimation

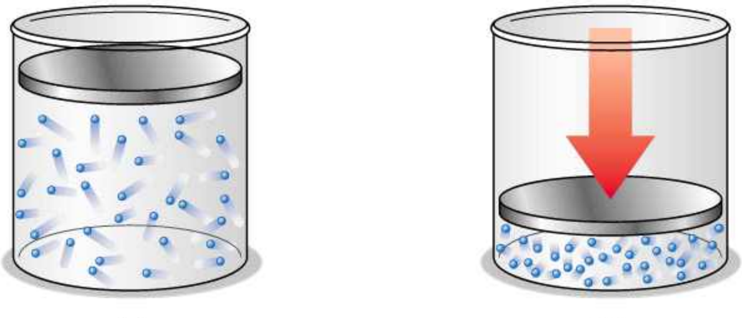
The changing of a solid directly into vapours on heating, and of vapours into solid on cooling, is known as sublimation.

$$\text{Solid} \underset{\text{Cooling}}{\overset{\text{Heating}}{\rightleftharpoons}} \text{Vapour (or Gas)}$$

Please note that :
(a) the changing of a solid directly into vapour (or gas) is called sublimation and
(b) the changing of vapour (or gas) directly into solid is also called sublimation
The common substances which undergo sublimation are : Ammonium chloride, Iodine, Camphor, Naphthalene and anthracene. Solid carbon dioxide (or dry ice) sublimes to form carbon dioxide gas.

09. Effect of change of pressure

The physical state of matter can also be changed by changing the pressure.
Gases can be Liquefied by Applying Pressure And Lowering Temperature



(a) (b)

10. Evaporation

The process of a liquid changing into vapour (or gas) even below its boiling point is called evaporation.

Factors Affecting Evaporation
The evaporation of a liquid depends mainly on the following factors:
- **Temperature :** The rate of evaporation increasing the temperature of the liquid
- **Surface Area of the Liquid :** The rate of evaporation increases on increasing the surface area of the liquid
- **Humidity of Air :** When the humidity of air is low, then the rate of evaporation is high and water evaporates more readily. when the humidity of air of is high then rate of evaporation is low, and water evaporates very slowly.
- **Wind Speed :** The rate of evaporation of a liquid increases with increasing wind speed.

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Cooling Caused by Evaporation : The cooling caused by evaporation is based on the fact that when a liquid evaporates, it draws (or takes) the latent heat of vaporisation from anything which it touches. losing heat, this anything gets cooled,

- If we put a little of spirit (ether or petrol) at the back of our hand wave it around the spirit evaporates rapidly and our hand feels very cold.
- During hot summer days, water is usually kept in an earthen pot (called pitcher or matka) to keep it cool.
- Perspiration (or sweating) is our body s method of maintaining a constant temperature.
- We should wear cotton clothes in hot summer days to keep cool and comfortable.

Two More States of Matter : Plasma and Bose-Einstein Condensate

Scientist now say that there are actually five states of matter : Solid Liquid, Gas, Plasma and bose-Einstein Condensate.

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CBSE Pattern
Exercise (1)

(Q 1 to 2) One Mark

1. What is the chemical name of dry ice?

2. If the fish is being fried in a neighbouring home, we can smell it sitting in our own home. Name the process which brings this smell to us.

(Q 3 to 5) Two Marks

3. What do you understand by the term 'latent heat'? What are the two types of latent heat?

4. Which contain more heat, 1 kg of water at 100°C or 1 kg of steam at 100°C? Give reason for your answer.

5. Why does our palm feel cold when we put some acetone (or perfume) on it?

(Q 6 to 7) Three Marks

6.
   (a) What are the two ways in which the physical states of matter can be changed?
   (b) Draw the 'states of matter triangle' to show the interconversion of states of matter.
   (c) How can the evaporation of a liquid be made faster?

7.
   (a) What is meant by 'diffusion'? Give one example of diffusion in gases.
   (b) Why do gases diffuse very fast?
   (c) Name two gases of air which dissolve in water by diffusion. What is the importance of this process in nature?

8. When extremely small particles X derived from the anther of a flower were suspended in a liquid Y and observed through a microscope, it was found that the particles X were moving throughout the liquid in a very zig-zag way. It was also observed that warmer the liquid Y, faster the particles X moved on its surface.
   (a) What could particles X be?
   (b) What do you think liquid Y is?
   (c) What is the zig-zag movement of X known as?
   (d) What is causing the zig-zag movement of particles X?
   (e) Name the scientist who discovered this phenomenon.
   (f) What does this experiment tell us about the nature of liquid Y?

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(Q 9 to 10) Five Marks

9. There are four substances W, X, Y, Z. The substances W is dark violet solid having diatomic molecules. A solution of W in alcohol is used as a common antiseptic C. The substance X is a white solid which is recovered from sea water on large scale. The substance Y is a white solid which is insoluble in water and used in the form of small balls for safe storage of woollen clothes. The substances Z is a yet another white solid used in dry cells.
   (a) Name (i) W (ii) X (iii) Y (iv) X
   (b) Out of W, X, Y, and Z, which substance/substances can undergo sublimation?
   (c) Which substance is organic in nature?
   (d) What is the name of substance C?
   (e) Which substance belongs to halogen family?

10. When water is cooled to a temperature x, it gets converted into ice at temperature x by a process called P. And when ice at temperature x is warmed, it gets re-converted into water at the same temperature x in a process called Q.
   (a) What is the value of temperature x in kelvin?
   (b) What is the process P known as?
   (c) What is the name of energy released during the process P?
   (d) What is the process Q known as?
   (e) What is the name of the energy absorbed during the process Q?

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Answer & Solution

1. Carbon dioxide, CO_2

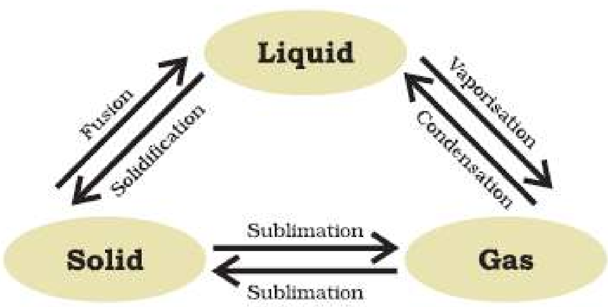
2. Diffusion

3. The heat required to convert a solid into a liquid or vapour, or a liquid into a vapour, without change of temperature. The two types of latent heats are:
    - Latent heat of fusion
    - Latent heat of vaporisation

4. 1 Kg of heat at 100 degree celsius contains more heat because of the following relationship: Water at 100°C + Heat $\rightleftarrows$ Steam at 100°C

5. The acetone has low boiling point and thus it gets evaporated immediately by absorbing heat from the palm making us feel cold.

6.
    (a) Temperature, Pressure

    (b) 

    (c) Evaporation can be made faster by following ways:
    - Increasing temperature
    - Increasing surface area

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- Decreasing humidity in the surrounding area
- Increasing the speed of wind

7.

(a) The spreading out and mixing of a substance with another, due to the motion of the particles is known as diffusion. Example: The smell of the perfume spreads due to the diffusion of perfume vapours in the air.
(b) Particles move very quickly in all the directions.
(c) O_2 and CO_2, both are dissolved in water which is required by marine animals and plants, respectively, for their survival.

8.

(a) Pollen Grains
(b) Water
(c) Brownian Motion
(d) The fast moving water particles are constantly hitting particles X, causing them to move in a zig-zag manner.
(e) Robert brown
(f) The liquid Y is made up of very small particles which are constantly moving.

9.

(a) (i) Iodine, (ii) Sodium Chloride, (iii) Naphthalene, (iv) Ammonium Chloride
(b) W, Y, Z
(c) Y
(d) Tincture of Iodine
(e) W

10.

(a) 273K
(b) Freezing
(c) Latent Heat of Freezing
(d) Melting Latent Heat of Fusion

CLASS 9

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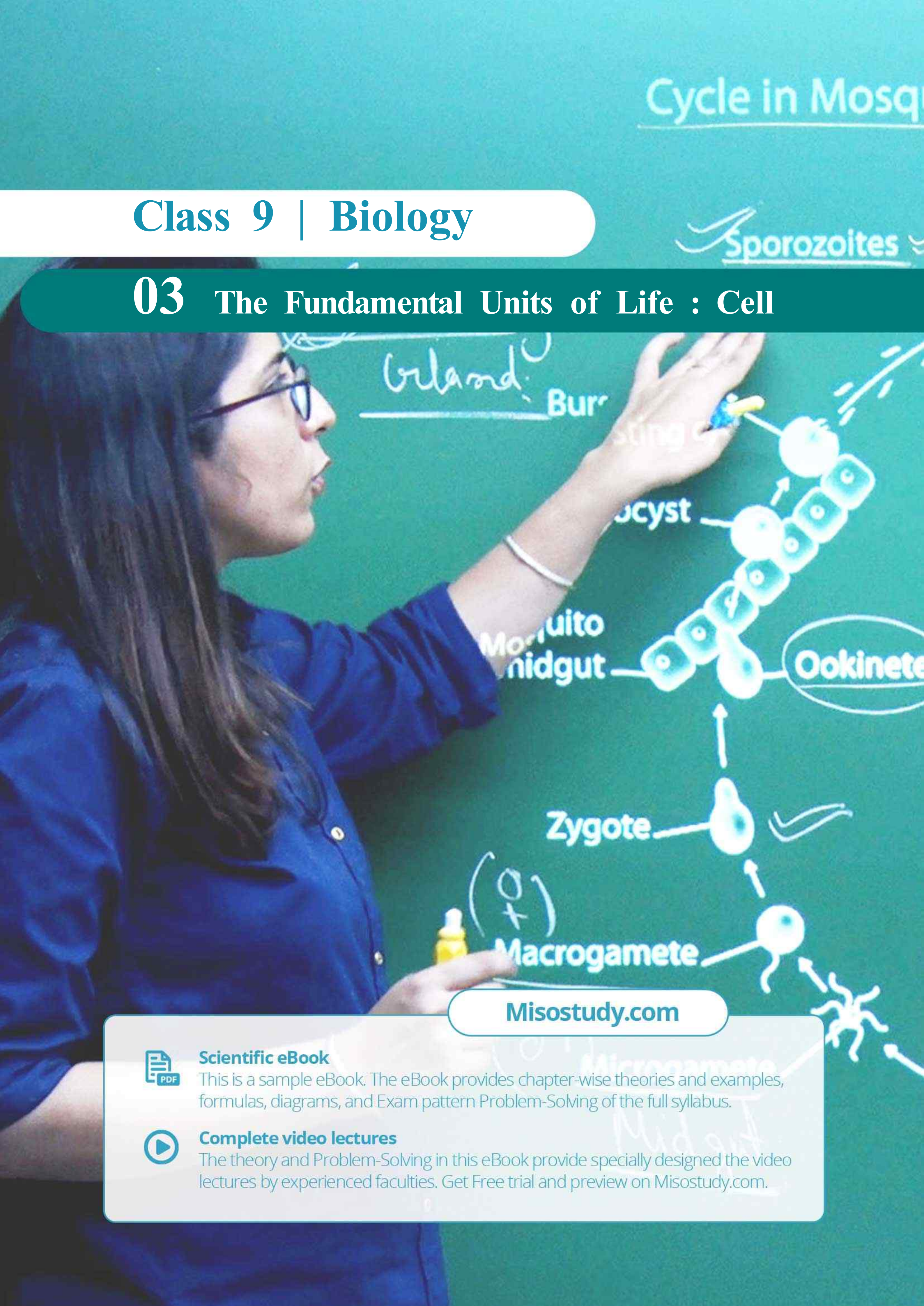
Class 9 | Biology

03 The Fundamental Units of Life : Cell



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01. What is The Living Being Made Up of ?

(a) **Cell is termed as the structural unit of life as it** provides structure to our body.
(b) **Cell is considered as the functional** unit of life as all the functions of the body take place at cell level.

Discovery of Cell :

(a) Discovered by Robert Hooke in 1665 in cork resembling the structure of honeycomb consisting of many little compartments in self designed microscope. Cork is a substance which is obtained from the bark of a tree.
(b) Robert Brown in 1831 discovered the nucleus in the cell.

02. Discovery of Cell

(i) Discovered by Robert Hooke in 1665 in cork resembling the structure of honeycomb onsisting of many little compartments in self designed microscope. Cork is a substance which is obtained from the bark of a tree.
(ii) Robert Brown in 1831 discovered the nucleus in the cell.

Cell Theory : Given by **Jacob Matthias Schleiden** (18-04-1881), a German botanist, first proposed the idea that all plants consist of cells. A year later, in 1839, **Theodor Schwann** (18-10-1882), a German zoologist, independently asserted that all animals and plants are made up of cell. Cell theory states that:

All living organisms are composed of cells.

- Cell is the fundamental unit of life.
- All new cells come from pre-existing cells.

Types of Organisms on the Basis of Number of Cells

There are two kinds of organisms on the basis of cells:

Different between unicellular and multicellular organisms.

Unicellular Organisms	Multicellular Organisms
• An unicellular organisms is represented by a single cell.	• A multicellular organisms consists of large number of cells.
• All activities of the organisms are performed by a single cell.	• A single cell performs one or few activities of the organisms.
• There is no division of labour as the single cell perform all life activities.	• Cells are specialised to perform different functions of the body so that there is a division of labour within cells.
• Reproduction consumes a single cell.	• Only some cells of the body called germ cells take part in reproduction. Other cells (somatic cells) remain intact.
• The life span of an individual is short.	• The life span of an individual is long.

Shape and Size of Cells

(a) Cells vary in shape and size. They may be oval, spherical, rectangular, spindle shaped, or totally irregular like the nerve cell.
(b) The size of cell also varies in different organisms. Most of the cells are microscopic in size like red blood cells (RBC) while some cells are fairly large like nerve cells

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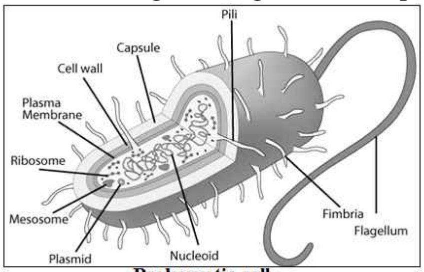
03. Types of Cells

The cells can be categorized in two types:

(i) **Prokaryotic cell :**

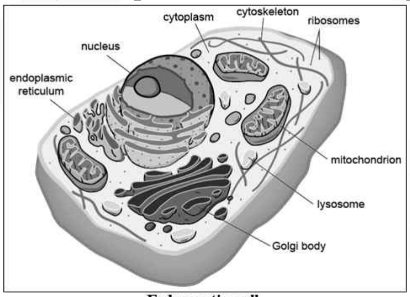
Prokaryotic cells are cells in which true nucleus is absent. They are primitive and incomplete cells. Prokaryotes are always unicellular organisms. For example, archaebacteria, bacteria, blue green algae are all prokaryotes.



Prokaryotic cell

(ii) **Eukaryotic Cell**

Eukaryotic cells are the cells in which true nucleus is present. They are advanced and complete cells. Eukaryotes include all living organisms (both unicellular and multicellular organisms) except bacteria and blue green algae.



Eukaryotic cell

Prokaryotic cell	Eukaryotic cell
• Size of a cell generally small (1-10mm).	• Size of a cell is generally large (5-100mm.)
• Nucleus is absent (Nuclear region or nucleoid is not surrounded by a nuclear membrane).	• Nucleus is present (Nuclear material is surrounded by a nuclear membrane).
• It contains single chromosome.	• It contains more than one chromosome.
• Nucleolus is absent.	• Nucleolus is present.
• Membrane bound cell organelles are absent.	• Membrane bound cell organelles such as mitochondria, plastids, endoplasmic reticulum, Golgi apparatus, lysosmes, peroxisomes, etc., are present.
• Cell division takes place by fission or budding (no mitosis).	• Cell division occurs by mitotic or meiotic cell division.

04. Cell Shape

The basic shape of eukaryotic cell is spherical, but the shape of cell is ultimately determined by the specific function of the cell. Thus, the shape of the cell may be **variable** (*i.e.*, frequently changing its shape) or **fixed.** Variable or irregular shape occurs in *Amoeba* and

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white blood cells or leucocytes. Fixed shape of cell occurs in most plants and animals (including *Euglena* and *Paramecium.*) In unicellular organisms, the cell shape is maintained by tough plasma membrane (e.g. *Paramecium*) and exoskeleton (e.g., *Elphidium* or *Polystomella*). In multicellular organisms, the shape of a cell depends mainly on its functional adaptation and partly on the surface tension, viscosity of the protoplasm, the mechanical action exerted by adioning cell and rigidity of the cell membrane (*e.g.,* presence of rigid cell wall in plant cells). Thus, cell may have diverse shapes such as **polyhedral** (with 8,12 or 14 sides), **spherical** (e.g., eggs of many animals),spindle-shaped (e.g., smooth muscle fibre), elongated (e.g., nerve cell), **branched** (e.g., chromatophores or pigment cells of skin), discoidal (e.g., erythrocytes or red blood cells) and so on

05. Cell Size

The size of cells varies from the very small cells of bacteria (0.2 to 5.0 μm) to the very large eggs of the ostrich (18 cm).

06. Structure of Cell

Cell is generally composed of three basic components:

(i) **Cell membrane or Plasma Membrane:**

Plasma membrane is the covering of the cell that separates the contents of the cell from its external environment. It is a living part of the cell and is present in cells of plants, animals and microorganisms.

It is very thin, delicate, elastic and selectively permeable membrane.

It is composed of lipid and protein.

Function :

As it is selectively permeable membrane, it allows the flow of limited substances in and out of the cell.

Diffusion

(a) The spontaneous movement of a substance from region of high concentration to the region of low concentration is called diffusion

(b) Some substances like carbon dioxide or oxygen can move across the cell membrane by a process called diffusion. Cell also obtains nutrition from the environment.

Osmosis

(a) The movements of water molecules through selectively permeable membrane along the concentration gradient is called osmosis.

(b) Plant cell tend to obtain water through osmosis.

Hypotonic or Hypertonic or Isotonic Solution

What happened to cell in sugar or salt solution?

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Name of the Solution	Condition	Result
Hypotonic solution	Medium surrounding cell has higher water concentration that cell.	Cell will gain water by osmosis and likey to swell up.
Isotonic solution	Medium has exactly same water concentration as the cell.	Water crosses the cell membrane in both directions. Cell will stay the same size.
Hypertonic solution	Medium has lower concentration of water than the cell.	Water crosses the cell in both directions, but more water leaves the cell than enters it.

Mediated Transport

Plasma membrane acts as an effective barrier to the free diffusion of most molecules of biological significance. Yet , it is essential that some materials enter and leave the cell. Nutrients such as sugars and materials of growth such as amino acids must enter the cell, and the wastes of metabolism must be thrown out. Such molecules are moved across the membrane by special proteins called transport **proteins** or **permeases.**

Endocytosis

Endocytosis is the ingestion of material by the cell through the plasma membrane. It is a collective term that describes three similar processes: **phagocytosis** (’’cell eating), **potocytosis** (cell drinking) and **receptor – mediated endocytosis** These processes are pathways to specifically internalize solid particles, small molecules and ion, and macromolecules, respectively. All of them require energy, so they may be regarded as different form of active transport.

Exocytosis

Just as materials can be brought into a cell by invagination and formation of a vesicle, the membrane of a vesicle can fuse with the plasma membrane and extrude its contents to the surrounding medium. This process is called cell **vomiting** or **exocytosis.** Exocytosis occurs in various cells to 1. remove undigested residues of substance completely across a cellular barrier. For example, a substance (*e.g.*, IgA or immunoglobulin/ antibody) may be picked up on one side of the wall of blood vessel by phagocytosis, moved across the cell, and released by exocytosis.

Cell Wall :

Cell wall is non-living, thick and freely permeable covering made up of cellulose.
It is present in eukaryotic plant cells and in prokaryotic cells.

Functions :

(a) It determines the shape and rigidity to the plant cell.
(b) It protects the plasma membrane.
(c) It prevents desiccation or dryness in cell.
(d) It helps in the transport of various substances in and out of the cell.

Plasmolysis

When a living plant cell loses water through osmosis, there is a shrinkage or contraction of the protoplasm away from the cell wall This phenomenon is called **plasmolysis**

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(ii) **Nucleus :**

Nucleus is dense and spherical organelle. Nucleus is bounded by two membranes, both forming nuclear envelope. Nuclear envelope contains many pores known as nuclear pores. The fluid which present inside the nucleus is called nucleoplasm.

Nucleus contains chromosomes and chromosomes contain genes which are the centres of genetic information.

Difference Between Nucleus and Nucleoid.

Nucleus	Nucleoid
• It has larger in size.	• It is comparatively smaller in size.
• It has a covering of double membrane envelope.	• A covering membrane is absent. It lies free in the cytoplasm.
• Nucleolus is present in it.	• Nucleolus is absent in it.
• Its DNA is associated with histone proteins to form chromatin.	• In it histones are absent. DNA of a nucleoid is often naked.

Functions :

(a) Nucleus controls all the metabolic activities of the cell.

(b) It regulates the cell cycle.

(c) Nucleus is the storehouse of genes. It is concerned with the transmission of hereditary traits from the parent to offspring.

(iii) **Ncytoplasm :**

It is a jelly-like, viscous, colourless semi-fluid substance that occurs between the plasma membrane and the nuclear membrane.

Functions :

(a) Protoplasm acts as a store of vital chemicals like amino acids, proteins, sugars, vitamins, etc.

(b) It is the site of certain metabolic reactions, like glycolysis, synthesis of fatty acids, nucleotides, etc.

Difference Between Organs and Organelles.

Organs	Organelles
• They are found in multicellular organisms.	• They are found in all eukaryotic cells.
• They are large sized or macroscopic.	• They are very small sized, either microscopic or submicroscopic.
• They may be external or internal to the body of an organisms.	• They are mostly internal (*i.e.*, intracellular).
• The organs are formed of tissues, tissues comprise of cells and cells are formed of organelles.	• An organelle is made up of micromolecules and macromolecules.
• Organs coordinate to form organ system, while organ systems form the body of an organisms.	• Organelles coordinate to produce the cell.

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07. Cell Organelles

Inside the cell there are different parts performing different activities to keep the cell alive an functionable. These part are called Cell organelles. They are explained below:

(i) **Golgi Apparatus :** Golgi apparatus consists of a set of membrane bound, fluid filled vesicles, vacuoles and flattened cisternae (closed sacks). Cisternae are usually arranged parallel to each other.

Functions :

(a) Its main function is to store, modify, package and dispatch the substances.

(b) It is also involved in the synthesis of cell wall, plasma membrane and lysosomes.

(ii) **Endoplasmic Reticulum :** It is a membranous network of tube like structures extending from nuclear membrane to plasma membrane. It is absent in prokaryotic cells and matured RBCs of mammals. There are two types of endoplasmic reticulum:

- Rough Endoplasmic Reticulum (RER): Here ribosomes are present on the surface for the synthesis of proteins.
- Smooth Endoplasmic Reticulum (SER): Here ribosomes are absent and is meant for secreting lipids.

Functions :

(a) It gives internal support to cell.

(b) It helps in transport of various substances from nuclear membrane to plasma membrane or vice versa.

(c) RER helps in synthesis and transportation of proteins.

(d) SER helps in synthesis and transportation of lipids.

(iii) **Ribosomes :** These are extremely small, dense and spherical bodies which occur freely in the matrix (cytosol) or remain attached to the endoplasmic reticulum.

These are made up of ribonucleic acid (RNA) and proteins.

Functions :

They play a major role in the synthesis of proteins.

(iv) **Mitochondria :** They are small rod-shaped organelles. It is a double membrane structure with outer membrane being smooth and porous whereas inner membrane being thrown into a number of folds called cristae. They contain their own DNA and ribosomes. They are absent in bacteria and red blood cells of mammals.

Functions:

- They are the sites of cellular respiration, hence provide energy for the vital activities of living cells.
- They store energy releases during reactions, in the form of ATP (Energy currency of the cell). Therefore, they are also called 'power house' of the cell.

(v) **Centrosome and Centrioles :** Centrosome is found only in eukaryotic animal cells. It is not bounded by any membrane but consists of centrioles. Centroles are hollow cylindrical structures arranged at right angle to each other and made up of microtubules.

Functions:

Centrioles help in cell division and also help in the formation of cilia and flagella.

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(vi) **Plastids:** Plastids are present in most of the plant cells and absent in animal cells. They are usually spherical or discoidal in shaped and double membrane bound organelles. They also have their own DNA and ribosomes. Plastids are of three types:

(a) **Chloroplasts :** These are the green coloured plastids containing chlorophyll. Chloroplasts aid in the manufacture food by the process of photosynthesis.

(b) **Chromoplasts :** These are the colourful plastids (except green colour).

(c) **Leucoplasts :** These are the colourless plastids.

Difference Between Leucoplasts and Chromoplasts (Nongreen Plastids)

Mitochondria	Chloroplasts
• They are colourless.	• They range from brownish to reddish n colour.
• They are cylindrical or ounded in shape.	• They are irregular in shape.
• They are found in unexposed cells.	• They are found in both exposed and unexposed cells.
• They can change to other type of plastids.	• They do not change into other types of plastids.
• They take part in storage of zood, e.g., amyloplasts (carbohydrates), elaioplasts (lipids), aleuroplasts (proteins).	• They provide colour to organs to attract pollination and disseminators.

Difference Between Chloroplasts and Chromoplasts.

Chloroplasts	Chromoplasts
• They are green plastids.	• They are non-green coloured plastids.
• They ontain chlorophylls and carotenoids	• Chlorophylls are absent. Only carotenids are present.
• Lamellae are present.	• Lamellae are absent.
• Chloroplasts are sites of photosynthesis.	• They add colour to the organs (*e.g.,* flowers, fruits) for attracting animals to perform pollination and fruit dispersal.

Functions :

- Chloroplasts trap solar energy and utilise it to manufacture food for the plant.
- Chromoplasts impart various colours to flowers to attract insects for pollination.
- Lecuoplasts help in the storage of food in the form of starch, proteins and fats.

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Mitochondria	Chloroplasts
• They occur in the cells of the aerobic organisms (plants and animals) with the exception of mammalin RBcs.	• They occur in the cells of green photosynthetic parts (*e.g.,* leaves) of plants
• They are colourless.	• They are green in colour.
• The shape is rod-like or sausage-shaped.	• They are generally dis-like in outline.
• Inner membrane of each mitochondria is thrown into folds called cristae.	• Their inner membrane forms flattened sacs called thylakoids or lamellae.
• They liberate energy	• They trap solar energy and convert it into chemical energy.
• They perform oxidation of food.	• They synthesize food by photosynthesis.
• They perform oxidation of food.	• They synthesize food by hotosynthesis.
• They consume O_2 and liberate CO_2.	• They consume CO_2 and liberate O_2.

(i) **Lysosomes :**

Lysosomes are small, spherical, sac like structures which contain several digestive enzymes enclosed in a membrane.

They are found in eukaryotic cells mostly in animals. 0

Functions :

- Lysosomes help in digestion of foreign substances and worn-out cell organelles.
- They provide protection against bacteria and virus.
- They help to keep the cell clean.
- During the disturbance in cellular metabolism, for example when the cell gets damaged, Lysosomes may burst and the enzymes digest their own cell. Therefore, lysosomes are also known as **suicide bags** of a cell
- They provide turgidity and rigidity to the plant cell.

(ii) **Vacuoles :**

Vacuoles are liquid/solid filled and membrane bound organelles.

In plant cells, vacuoles are large and permanent. In animal cells, vacuoles are small In size and temporary.

In mature plant cell, It occupies 90% space of cell volume.

Due to its size, other organelles, including nucleus shift towards plasma membrane.

Function :

- They help to maintain the osmotic pressure in a cell.
- They provide turgidity and rigidity to the plant cell.

(iii) **Plastids :**

Nature and occurrence. Plastids occur in most plant cells and are absent in animals cells. Like the mitochondria, the plastids also have their own genome (i.e., DNA) ribosome. They are self-replicating organelles like the mitochondria, i.e., they have the power to divide. Plastids are of following three types :

(a) Chromoplasts. Coloured plastids (except green colour).

(b) Chloroplasts. Green-coloured plastids.

(c) Leucoplasts. The colourless plastids.

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Function :

- Chloroplasts trap solar energy and utilise it to manufacture food for the plant.
- Chromoplasts impart various colours to flowers to attract insects for pollination.
- Lecuoplasts help in the storage of food in the form of starch, proteins and fats.

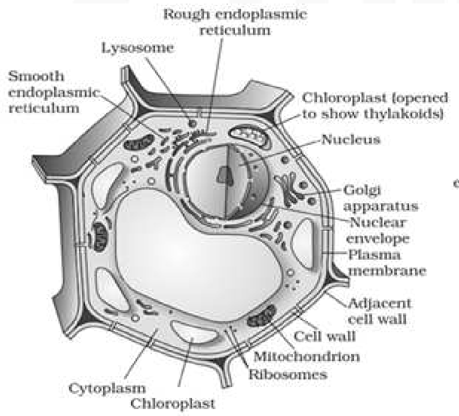
Peroxiomes : They are small and spherical organelles containing powerful oxidative enzymes. They are bounded by a single membrane. They are found in kidney and liver cells.

Function : They are specialized to carry out some oxidative reactions, such as detoxification or removal of toxic substances form cell.

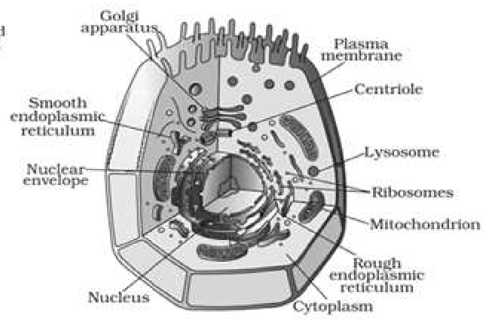
Difference Between Animal Cell and Plant Cell:

S.No.	Animal cell	Plant cell
•	Animal cells are generally small in size.	Plant cells are larger than animal cells.
•	Cell wall is absent.	Plasma membrane of plant cell is surrounded by a rigid cell wall of cellulose.
•	Plastids are absent except in case of protozoan Euglena.	Plastids are present.
•	Here vacuoles are many, small and temporary.	They have a permanent and large central sap vacuole.
•	They have centrosome and centrioles.	They lack centrosome and centrioles.

Structure of Plant Cell and Animal Cell :



Plant cell



Animal cell

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CBSE Pattern
Exercise (1)

(Q 1 to 3) One Mark

1. State two important functions of nucleus.

2. Which organelles is called factory of ribosomes

3. What is plasmolysis

(Q 4 to 6) Two Marks

4. What are lysosomes termed as suicide bags of cell

5. Name any cell organelles which is non membranous

6. Why do plant cell posses large sized vacuole

(Q 7 to 8) Three Marks

7. How is prokaryotic cell differ from eukaryotic cell

8. Differentiat between unicellular and multicellular organism

(Q 9 to 10) Five Marks

9. Draw a well labeled diagram of plant cell

10.
   (a) What are genes. what is difference between genes and chromosome.
   (b) Why is the inner membrane of mitochondria folded.

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Answer & Solution

Q1.
(i) The nucleus controls all metabolic activities of the cell. If the nucleus is removed from a cell, the protoplasm ultimately dries up and dies.
(ii) It regulates the cell cycle.

Q2. Nucleolus is called factory of ribosomes

Q3. When a living plants cell loses water through osmosis. there is a shrinkage or contraction of the protoplasm away from the cell wall This phenomenon is called **plasmolysis.**

Q4. During breakdown of cell structure, when the cell gets damaged, lysosomes may burst and the enzymes eat up their own cells. Therefore, lysosomes are also known as **suicide bags** of a cell

Q5. Nonmembranous organelles do not contain a definite boundary for organelles. On that account, these organelles do not possess fluid-filled cavities. All organelles in prokaryotes are nonmembranous. Ribosomes, nucleoid, centrioles, cilia, flagella, and components of the cytoplasm like microtubules, microfilaments, and intermediate filaments are nonmembranous organelles

Q6. Plant cells have large sized vacuoles because these ghelp the cell in maintaining stiffness while it withstands all the environmental conditions. They store food materials, water required by the plant. Over a period of time the excretory products accumulated will break down in the vacuole. Vacuoles maintain the shape of the cell constantly without getting disturbed by the availability of the water to the plant. Hence, plants have larger vacuoles.
Animals can move f10rom place to place in search of food, water and others while plants cannot.

Q7. **Differences between prokaryotic cells and eukaryotic cells.**

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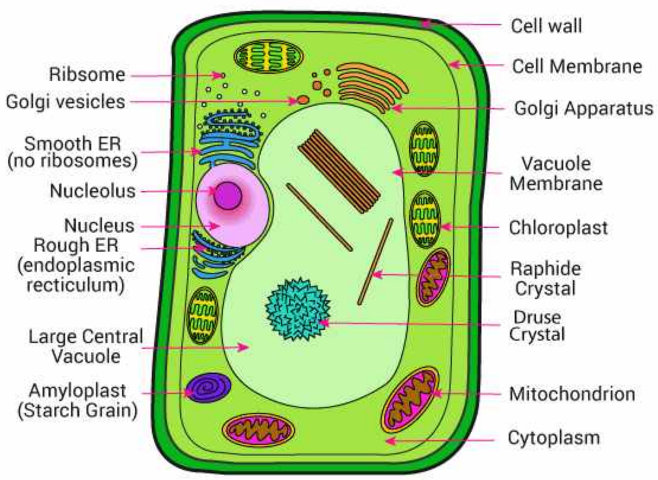
Prokaryotic cell	*Eukaryotic cell*
(i) Size of a cell is generally small (1—10 mm).	(i) Size of a cell is generally large (5—100 mm.)
(ii) Nucleus is absent (Nuclear region or nucleoid is not surrounded by a nuclear membrane.)	(ii) Nucleas is present (Nuclear material is surrounded by a nuclear membrane.)
(iii) It contains single chromosome.	(iii) It contains more than one chromosome.
(iv) Nucleolus is absent.	(iv) Nucleolus is present
(v) Membrane bond cell organelles are absent.	(v) Membrane. bond cell organelles such as mitochondria, plastids, endoplasmic reticulum, Golgi apparatus. lysosomes, peroxisomes, etc., are present
(vi) Cell division takes place by fission or budding (no mitosis)	(vi) Cell division, occurs by mitotic or meiotic cell division.

Q8. **Differences between unicellular and multicellular organisms.**

Unicellular organisms	*Multicellular organisms*
(i) An unicellular organisms is represented by a single cell.	(i) A multicellular organism consists of large number of cells.
(ii) All activities of the organisms are performed by a single cell.	(ii) A single cell performs one or few activities of the organisms.
(iii) There is no division of labour as the single cell perform all life activities.	(iii) Cells are specialized to perform different functions of the body so that there is a division of labour within cells.
(iv) Reproduction consumes a single cell.	(iv) Only some cells of the body called germs cells take part in reproduction. Other cells (somatic cells) remain intact.
(v) The life span of an individual is short.	(v) The life span of an individual is long.

Q9.



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Q10.(a)

A gene is a section of DNA which is involved in carrying information for a particular trait. They are functional units of heredity and are made of DNA. Genes are responsible for the hereditary and this is the reason why we all have similar characteristics of both the parents like the pigmentation of the eye, hair color, etc. There are about 29 to 30 thousands of genes in every cell of the human body. The term gene was first coined in the year 1909 by a Danish botanist Wilhelm Johannsen.

Chromosomes

Chromosomes are thread-like structures merged together and are made of proteins and a single molecule of deoxyribonucleic acid – DNA. They are mainly found inside the nucleus of both animal and plant cells. They are passed to offspring from their parents, over generations. The term chromosome is derived from the Ancient Greek word meaning coloured body. Every human cell contains 46 or 23 pairs of chromosomes These chromosomes play an important role in cell division process and ensure that DNA molecules are copied and distributed evenly.

Gene	Chromosome
(i) Gene is located on the chromosome	(i) Chromosomes are the packed structure of a DNA with proteins
(ii) Genes are not visible under the microscope.	(ii) Chromosomes are visible under the microscope
(iii) A single gene is a locus on a chromosome.	(iii) A single chromosome comprises of many genes.
(iv) Genes are composed of either DNA or RNA	(iv) Chromosomes are composed of DNA, histones, and RNA.
(v) Gene mutations are small.	(v) Chromosomal mutations are relatively large.
(vi) Gene mutations lead to point mutations and frameshift mutations: insertions and deletions	(vi) Chromosomal mutations lead to chromosomal abnormalities such as deletion, duplication, rearrangement and inversion of genes.

(b) The folding of the inner membrane increases the surface area inside the organelle. Since many of the chemical reactions happen on the inner membrane, reactions to occur

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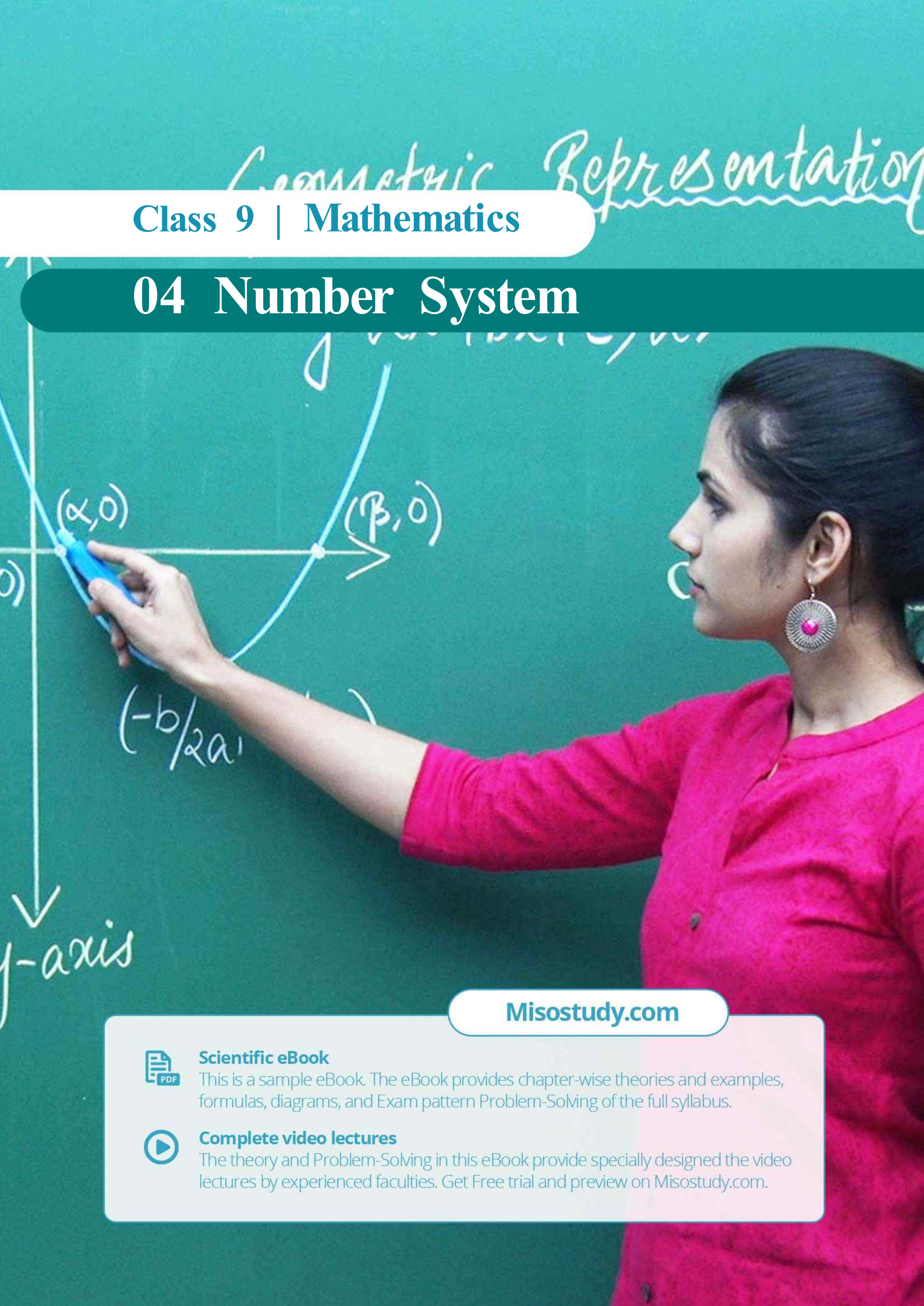

Class 9 | Mathematics

04 Number System

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01. Decimal Representation of Rational Numbers

A rational number is a number which can be expressed in the form $\frac{m}{n}$, where m and n are both integers and $n \neq 0$. A rational number $\frac{m}{n}$ is said to be in its lowest terms, if $n \in N$ and m and n have no common factor other than 1. For example, $\frac{2}{3}, \frac{7}{4}, \frac{12}{5}$ etc are rational numbers in their lowest terms, whereas $\frac{22}{32}$ is not in its lowest terms.

A rational number $\frac{m}{n}$ is positive rational number if m and n are of the same sign. If m and n are such that one of them is positive and another one is negative, then the rational number $\frac{m}{n}$ is negative.

Note Every integer m is also a rational number, as it can be written as $\frac{m}{1}$.

Example Find the decimal expansions of $\frac{10}{3}, \frac{7}{8}$ and $\frac{1}{7}$.

Solution

3.333…	0.875	0.142857…
3) 10	8) 7.0	7) 1.0
9	64	7
10	60	30
9	56	28
10	40	20
9	40	14
10	0	60
9		56
1		40
		35
		50
		49
		1
Remainders : 1, 1, 1, 1, 1… Divisor : 3	Remainders : 6, 4, 0 Divisor : 8	Remainders : 3, 2, 6, 4, 5, 1, 3, 2, 6, 4, 5, 1,... Divisor : 7

Here,

(i) The remainders either become 0 after a certain stage, or start repeating themselves.

(ii) The number of entries in the repeating string of remainders is less than the divisor (in $\frac{10}{3}$ one number repeats itself and the divisor is 3, in $\frac{1}{7}$ there are six entries 326451 in the repeating string of remainders and 7 is the divisor.)

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(iii) If the remainders repeats, then we get a repeating block of digits in the quotient (for $\frac{10}{3}$, 3 repeats in the quotient and for $\frac{1}{7}$, we get the repeating block 142857 in the quotient).
Although we have noticed this pattern using only the examples above, its is true for all rationals of the form $\frac{p}{q}(q \neq 0)$. On division of p by q, two main things happen – either the remainder becomes zero or never becomes zero and we get a repeating string of remainders.

Case (i) The remainder becomes zero

In the example of $\frac{7}{8}$, we found that the remainder becomes zero after some steps and the decimal expansion of $\frac{7}{8} = 0.875$. Other examples are $\frac{1}{2} = 0.5$, $\frac{639}{250} = 2.556$. In all these cases, the decimal expansion terminates or ends after a finite number of steps. We call the decimal expansion of such numbers *terminating*.

Case (ii) The remainder never becomes zero

In the examples of $\frac{10}{3}$ and $\frac{1}{7}$, we notice that the remainders repeat after a certain stage forcing the decimal expansion to go on for ever. In other words, we have a repeating block of digits in the quotient. We say that this expansion is non-terminating recurring. For example,
$\frac{10}{3} = 3.3333...$ and $\frac{1}{7} = 0.142857142857142857...$

Remark The usual way of showing that 3 repeats in the quotient of $\frac{10}{3}$ is to write it as $3.\overline{3}$. Similarly, since the block of digits 142857 repeats in the quotient of $\frac{1}{7}$, we write $\frac{1}{7}$ as $0.\overline{142857}$, where the bar above the digits indicates the block of digits that repeats. Also $3.57272...$ can be written as $3.5\overline{72}$. So, all these examples give us *non-terminating recurring* (*repeating*) decimal expansions.
Thus, we see that the decimal expansion of rational numbers have only two choices: either they are terminating or non-terminating recurring.

02. Conversion of Decimal Numbers into Rational Numbers of the Form $\frac{m}{n}$

We shall learn how to convert a given decimal number into an equivalent rational number in the form $\frac{p}{q}$.

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We shall divide it into-two parts.

(i) When the decimal number is of terminating nature.

(ii) When the decimal representation is of non-terminating nature.

Conversion of a Terminating Decimal Number to the From $\frac{p}{q}$

In order to convert a rational number having finite number of digits after the decimal point, we follow the following steps :

Step I *Obtain the rational number.*

Step II *Determine the number of digits in its decimal part.*

Step III *Remove decimal point from the numerator. Write 1 in the denominator and put as many zeros on the right side of 1 as the number of digits in the decimal part of the given rational number.*

Step IV *Find a common divisor of the numerator and denominator and express the rational number to lowest terms by dividing its numerator and denominator by the common divisor.*

Example Express each of the following decimal numbers in the form $\frac{p}{q}$:

(i) 15.75 (ii) 8.0025 (iii) –25.6875

Solution

(i) We have,

$$15.75 = \frac{1575}{100} = \frac{1575 \div 25}{100 \div 25} = \frac{63}{4}$$

(ii) We have,

$$8.0025 = \frac{80025}{10000} = \frac{80025 \div 25}{10000 \div 25} = \frac{3201}{400}$$

(iii) We have,

$$-25.6875 = \frac{-256875}{10000} = \frac{-256875 \div 625}{1000 \div 625} = \frac{-411}{16}$$

Conversion of a Pure Recurring Decimal to the Form $\frac{p}{q}$

In a non-terminating repeating decimal, there are two types of decimal representations.

(i) A decimal in which all the digits after the decimal point are repeated. These types of decimal are known as pure recurring decimals.

For Example : $0.\overline{6}, 0.\overline{16}, 0.\overline{123}$ are pure recurring decimals.

(ii) A decimal in which at least one of the digits after the decimal point is not repeated and then some digit or digits are repeated. This type of decimals are known as *mixed recurring decimals*.

For Example : $2.1\overline{6}, 0.3\overline{5}, 0.7\overline{85}$ are mixed recurring decimals.

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In order to convert a pure recurring decimal to the form $\frac{p}{q}$, we follow the following steps :

Step I *Obtain the repeating decimal and put it equal to x (say).*

Step II *Write the number in decimal form by removing bar from the top of repeating digits and listing repeating digits at least twice.*

For Example, write $x = 0.\overline{8}$ as $x = 0.888...$ and $x = 0.1\overline{4}$ *as* $x = 0.141414...$

Step III *Determine the number of digits having bar on their heads.*

Step IV *If the repeating decimal has 1 place repetition, multiply by 10; a two place repetition, multiply by 100; a three place repetition, multiply by 1000 and so on.*

Step V *Subtract the number in step II from the number obtained in step IV.*

Step VI *Divide both sides of the equation by the coefficient of x.*

Step VII *Write the rational number in its simplest form.*

Example Express the following decimal in the form $\frac{p}{q}$:

$0.\overline{35}$

Solution Let $x = 0.\overline{35}$

$\Rightarrow \quad x = 0.353535 \ ... \qquad ...(i)$

Here, we have two repeating digits after the decimal point. So, we multiply sides of (i) by $10^2 = 100$ to get

$10x = 35.3535 \ ... \qquad ...(ii)$

Subtracting (i) from (ii), we get

$100x - x = (35.3535 \ ...) - (0.3535 \ ...)$

$\Rightarrow \quad 99x = 35$

$\Rightarrow \quad x = \frac{35}{99}$

Hence, $\quad 0.\overline{35} = \frac{35}{99}$

Conversion of a Mixed Recurring Decimal to the Form $\frac{p}{q}$

While converting a recurring decimal that has one or more digits before the repeating digits,, it is necessary to isolate the repeating digits.

In order to convert a mixed recurring decimal to the form $\frac{p}{q}$, we follow the following steps:

Step I *Obtain the mixed recurring decimal and write it equal to x (say).*

Step II *Determine the number of digits after the decimal point which do not have bar on them. Let there be n digits without bar just after the decimal point.*

Step III *Multiply both sides of x by 10^n so that only the repeating decimal is on the right side of the decimal point.*

Step IV *Use the method of converting pure recurring decimal to the form $\frac{p}{q}$ and obtain the value of x.*

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Example Express the following decimals in the form $\frac{p}{q}$.

$0.003\overline{52}$

Solution Let $x = 0.003\overline{52}$

Clearly, there are three digits on the right side of the decimal point which are without bar. so, we multiply both sides of x by $10^3 = 1000$ so that only the repeating decimal is left on the right side of the decimal point.

$\therefore \quad 1000x = 3.\overline{52}$

$\Rightarrow \quad 1000x = 3 + 0.52$

$\Rightarrow \quad 1000x = 3 + \frac{52}{99}$

$\Rightarrow \quad 1000x = \frac{3 \times 99 + 52}{99}$

$\Rightarrow \quad 1000x = \frac{297 + 52}{99} \Rightarrow 1000x = \frac{349}{99} \Rightarrow x = \frac{349}{99000}$

03. Irrational Numbers

Irrational Numbers

A number is an irrational number, if it has a non-terminating and non-repeating decimal representation.

We have seen that a number in terminating decimal form or in a non-terminating but repeating decimal form can always be written in the form $\frac{p}{q}$, where p, q are integers such that $q \neq 0$. It follows from this that an irrational number cannot be written in the form $\frac{p}{q}$, where p and q are both integers and $q \neq 0$.

Example *Prove that $\sqrt{3}$ is an irrational number.*

Solution We find the square root of $\sqrt{3}$ by long division method.

	1.732050807
1	3.00 00 00 00 00 00 00 00 1
27	200 189
343	1100 1029
3462	7100 6924
346405	1760000 1732025
34641008	279750000 277128064
3464101607	26219360000 24248711249
	1970648751

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$\therefore \quad \sqrt{3} = 1.732050807 \ldots$

We observe that the decimal representation of $\sqrt{3}$ is neither terminating nor repeating. Hence, $\sqrt{3}$ is an irrational number.

Remark $\sqrt{n}$ *is not a rational number, if n is not a perfect square.*

Example *Find three different irrational numbers between the rational numbers* $\frac{5}{7}$ *and* $\frac{9}{11}$.

Solution We have,

$$a = \frac{5}{7} = 0.\overline{714285} \text{ and } b = \frac{9}{11} = 0.\overline{81}$$

We observe that in the first decimal place a has digit 7 and b has digit 8, therefore $a < b$. In the second decimal place a has digit 1. So, if we consider irrational numbers

$x = 0.72072007200072000072...$
$y = 0.73073007300073000073...$
$z = 0.74074007400074000074...$

We find that

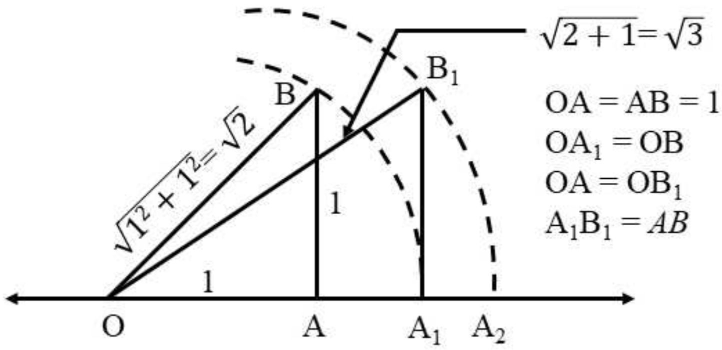
$$a < x < y < z < b$$

Hence, x, y and z are required irrational numbers.

04. Representing Irrational Numbers on the Number Line

Draw a number line and mark a point O, representing zero, on it. suppose point A represents 1 as shown in Fig. Then, $OA = 1$. Now, draw a right triangle OAB such that $AB = OA = 1$. By pythagoras theorem, we have

$OB^2 = OA^2 + AB^2$
$\Rightarrow \quad OB^2 = 1^2 + 1^2$
$\Rightarrow \quad OB^2 = 1 + 1 = 2$
$\Rightarrow \quad OB = \sqrt{2}$



Now, draw a circle with centre O and radius OB, We find that the circle cuts the number line at A_1.

Clearly, $\quad OA_1 = OB = \text{radius of the circle} = \sqrt{2}$

Thus, $\quad A_1$ represents $\sqrt{2}$ on the number line.

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But, we have seen that $\sqrt{2}$ is not a rational number. Thus, we find that there is a point on the number which is not a rational number.
Now, draw a right triangle OA_1B_1 such that $A_1B_1 = AB = 1$.
Again, by Pythagoras theorem, we have

$$OB_1^2 = OA_1^2 + A_1B_1^2$$

$$\Rightarrow \quad OB_1^2 = (\sqrt{2})^2 + 1^2$$

$$\Rightarrow \quad OB_1^2 = 3$$

$$\Rightarrow \quad OB_1 = \sqrt{3}$$

Now, draw a circle with centre O and radius $OB_1 = \sqrt{3}$. This circle cuts the number line at A_2 as shown in Fig.
Clearly, $\quad OA_2 = OB_1 = \sqrt{3}$
Thus, $\quad A_2$ represents $\sqrt{3}$ on the number line.
Also, A_2 is a point on the number line not representing a rational number.
Continuing in this manner, we can show that there are many other points on the number line representing $\sqrt{5}, \sqrt{6}, \sqrt{7}, \sqrt{8}$, etc. which are not rational numbers. In fact, such numbers are irrational numbers.

05. Real Numbers and Real Number Line

Existence of Square Root of a Positive Real Number

For any positive real number x, we have

$$\sqrt{\left(\frac{x+1}{2}\right)^2 - \left(\frac{x-1}{2}\right)^2} = \sqrt{\frac{x^2+2x+1}{4} - \frac{x^2-2x+1}{4}} = \sqrt{\frac{4x}{4}} = \sqrt{x}$$

Therefore, to find the positive square root of a positive real number, we may follow the following algorithm.

Algorithm

Step I *Obtain the positive real number x (say).*
Step II *Draw a line and mark a point A on it.*
Step III *Mark a point B on the line such that $AB = x$ units.*
Step IV *From point B mark a distance of 1 unit and mark the new point as C.*
Step V *Find the mid-point of AC and mark the point as O.*
Step VI *Draw a circle with centre O and radius OC.*
Step VII *Draw a line perpendicular to AC passing through B and intersecting the semi-circle at D. Length BD is equal to $\sqrt{x}$.*

Justification : We have,
$AB = x$ units and $BC = 1$ unit.

$$\therefore \quad AC = (x + 1) \text{ units}$$

$$\Rightarrow \quad OA = OC = \frac{x+1}{2} \text{units}$$

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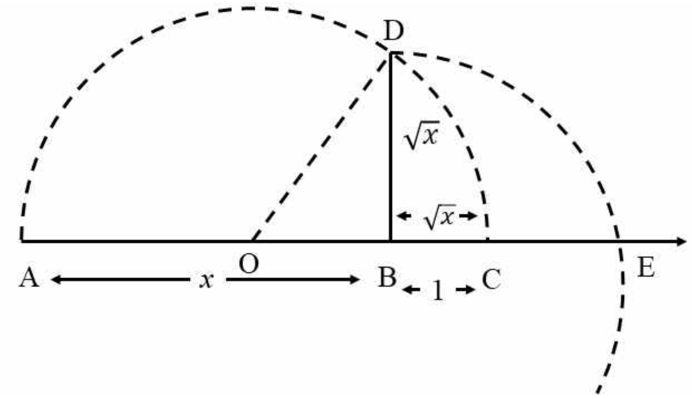


$\Rightarrow$ $OD = \dfrac{x+1}{2}$ units [$\because$ $OA = OC = OD$]

Now, $OB = AB - OA = x - \dfrac{x+1}{2} = \dfrac{x-1}{2}$

Using Pythagoras Theorem in ΔOBD, we obtain

$$OD^2 = OB^2 + BD^2$$

$$\Rightarrow \quad BD^2 = OD^2 - OB^2$$

$$\Rightarrow \quad BD^2 = \left(\frac{x+1}{2}\right)^2 - \left(\frac{x-1}{2}\right)^2$$

$$\Rightarrow \quad BD = \sqrt{\frac{(x^2+2x+1)-(x^2-2x+1)}{4}} = \sqrt{\frac{4x}{4}} = \sqrt{x}$$

This shows that $\sqrt{x}$ exists for all real numbers $x > 0$.

Algorithm

In order to find the position of $\sqrt{x}$ on the number line, we consider BC as the number line, with B as the origin to represent zero. Since $BC = 1$ so, C represents 1. Now, mark points C_1, C_2, C_3,... such that $CC_1 = BC = 1$, $C_1C_2 = BC = 1$; $C_2C_3 = BC = 1$ and so on. Clearly, C_1, C_2, C_3,... represent 2,3,4,... respectively.

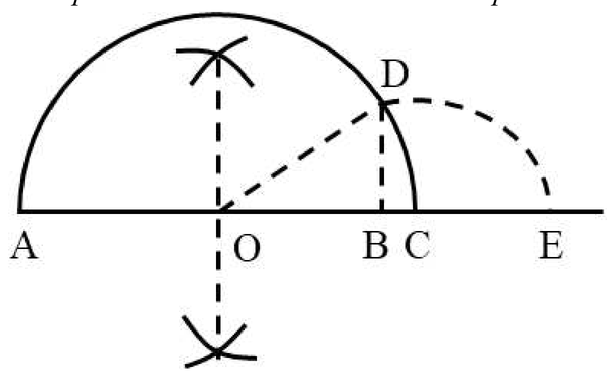
Now, draw an arc with centre at B and radius equal to BD. Suppose this arc cuts the number line BC with B as the origin at E. Then, $BE = \sqrt{x}$. Consequently, E will represent $\sqrt{x}$.

Example *Represent* $\sqrt{9.3}$ *on the number line.*

Solution In order to represent $\sqrt{9.3}$ on number line, we follow the following steps :

Step I *Draw a line and mark a point A on it.*

Step II *Mark a point B on the line drawn in step I such that AB = 9.3 cm.*



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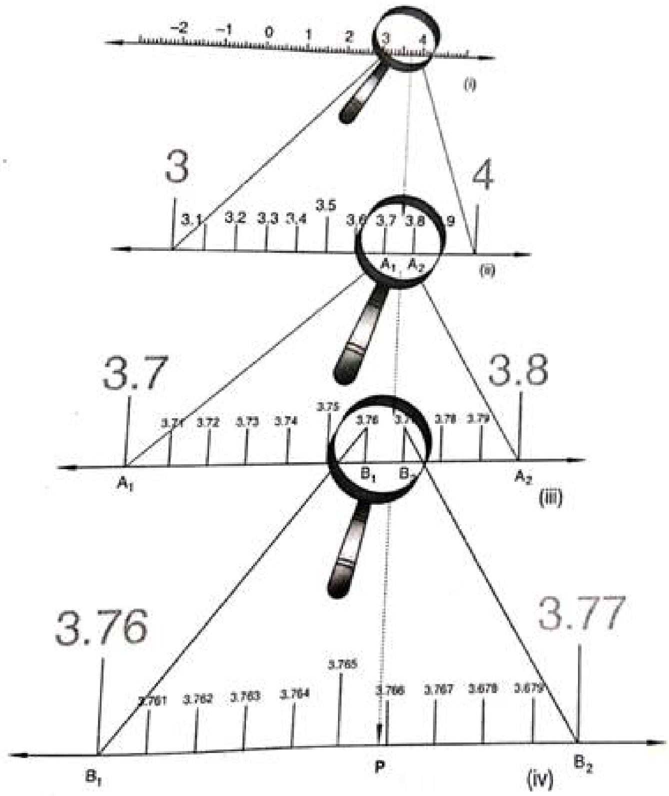
Step III *Mark a point C on AB produced such that BC = 1 unit.*

Step IV *Find mid-point of AC. Let the mid-point be O.*

Step V *Taking O as the centre and OC = OA as radius draw a semi-circle. Also, draw a line passing through B perpendicular to OB. Suppose it cuts the semi-circle at D.*

Step VI *Taking B as the centre and BD as radius draw an arc cutting OC produced at E. Point E so obtained represent* $\sqrt{9.3}$.

Suppose we want to visualise the representation of 3.765 on the number line. We observe that 3.765 lies between 3 and 4. So, let us look closely at the portion of the number line between 3 and 4. We divide this portion into 10 equal parts and mark each point of division as shown in Fig.



The first mark to the right of 3 will represent 3.1, the second 3.2 and so on. to see this clearly, we magnify this portion by taking a magnifying glass and look at the portion between 3 and 4. Though magnifying glass this portion between 3 and 4 will look like what we see in Fig. As 3.765 lies between 3.7 and 3.8. So, let us mark 3.7 as A_1 and 3.8 as A_2 and focus on the portion A_1 A_2 of the number line. Now, we imagine that the portion A_1 A_2 of the number line has been divided into ten equal parts. The first mark on the right of A_1 (representing 3.7) will represent 3.71, the next 3.72, and so on. As we may find some difficulty in observing these points of division between 3.7 and 3.8. Therefore, to have a clear view of the same, we magnify this portion as shown in Fig. As 3.765 lies between 3.76 and 3.77. So, we identify points representing 3.76 and 3.74 and mark them as B_1 and B_2 respectively as shown in Fig.

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Since 3.765 lies between 3.76 and 3.77. So, let us now focus on the portion B_1 B_2 of the number line (Fig.) and imagine that it has been divided into ten equal parts. Let us magnify this portion to have clear view of this portion. The first mark on the right of 3.76 will represent 3.761, the next one represent 3.762, and so on. Clearly, 3.765 is the fifth mark in these subdivisions as shown in Fig. and is represented by point P on the number line.
This process of visualisation of numbers on the number line, through a magnifying glass, is known as the process of successive magnification. Thus it is possible to visualise the position (or representation) of a real number with a terminating decimal expansion on the number line by successive magnification. Let us now try to visualise the position (or representation) of a real number with a non-terminating recurring decimal expansion on the number line.

Suppose we wish to visualise the representation (or position) of $4.\overline{26}$ (upto 4 decimal places, i.e. upto 4.2626) on the number line. We observe that 4.2626 is located somewhere between 4 and 5 on the number line. So, let us look at the portion of the number line between 4 and 5. We divide this portion into 10 equal parts and mark each point of division as shown in Fig. The first mark to the right of 4 will represent 4.1, the next 4.2 and so on. To see this clearly, we magnify this portion of the number line by taking a magnifying glass and look at the portion between 4 and 5. through magnifying glass this portion will look like what we see in Fig. We observe that 4.2626 lies between 4.2 and 4.3. So, we mark these points as A_1 and A_2 respectively as shown in Fig. As 4.26 lies between 4.2 and 4.3. So, let us focus on the portion A_1 A_2 of the number line. We imagine that the portion A_1 A_2 has been divided into ten equal parts. The first mark on the fight side of A_1 will represent 4.21, the number 4.22, and so on.
To see this clearly, we magnify this portion. Through magnifying glass this portion will look like what we see in Fig. Now, 4.262 lies between 4.26 and 4.27.
So, let us mark 4.26 as B_1 and 4.27 as B_2 and focus on the portion B_1 B_2 of the number line. Let us imagine that the portion B_1 B_2 has been divided into ten equal parts. The first mark on the right side of B_1 (representing 4.26) will represent 4.261, then next 4.262, and so on.
To have clear view of these points of division, we magnify this portion as shown in Fig. As 4.2626 lies between 4.262 and 4.263. So, we mark the points representing 4.262 and 4.263 as C_1 and C_2 respectively.
We imagine that the portion C_1 C_2 of the number line has been divided into ten equal parts. The first mark on the right side of C_1 (representing 4.262) will represent 4.2621, then next 4.2622, and so on. clearly, sixth point will represent 4.2626 as shown in Fig. and marked as point P.

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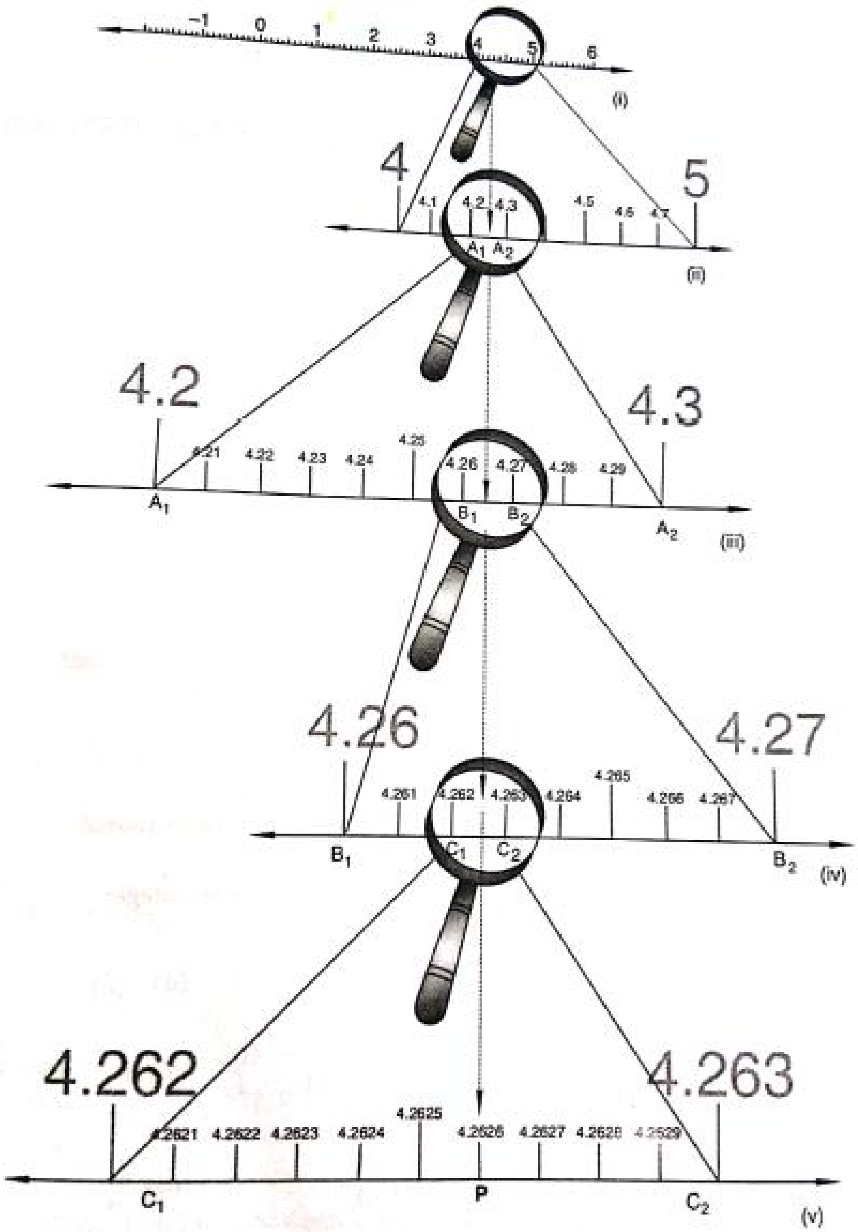

It is evident from the above discussion on visulalisation of real numbers on number line that every real number is represented by a unique point on the number line and every point on the number line represents a unique real number. That is why number line is also known as real number line or simply real line.

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CBSE Pattern
Exercise (1)

(Q 1 to 3) One Mark

1. State whether the following statements are true or false. Justify your answers.
   (i) Every irrational number is a real number.
   (ii) Every point on the number line is of the form $\sqrt{m}$, where m is a natural number
   (iii) Every real number is an irrational number

2. State whether the following statements are true or false. Give reasons for your answers.
   (i) Every natural number is a whole number.
   (ii) Every integer is a whole number.
   (iii) Every rational number is a whole number.

3. Show that 3.142678 is a rational number. In other words, express 3.142678 in the form $\frac{p}{q}$, where p and q are integers and $q \neq 0$.

(Q 4 to 7) Two Marks

4. Find five rational numbers between $\frac{3}{5}$ and $\frac{4}{5}$.

5. Show that 1.272727... $= 1.\overline{27}$ can be expressed in the form $\frac{p}{q}$, where p and q are integers and $q \neq 0$.

6. Rationalise the denominator of $\frac{1}{2+\sqrt{3}}$.

7. Visualise $4.\overline{26}$ on the number line, up to 4 decimal places.

(Q 8 to 10) Four Marks

8. Look at several examples of rational numbers in the form $\frac{p}{q}$ $(q \neq 0)$, where p and q are integers with no common factors other than 1 and having terminating decimal representations (expansions). Can you guess what property q must satisfy?

9. Represent $\sqrt{9.3}$ on the number line.

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10. Find :

(i) $9^{\frac{3}{2}}$

(ii) $32^{\frac{2}{5}}$

(iii) $16^{\frac{3}{4}}$

(iv) $125^{\frac{-1}{3}}$

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Answer & Solution

Q1

(i) True

Because all rational numbers and all irrational numbers form the group (collection) of real numbers.

(ii) False

Because negative numbers cannot be the square root of any natural number.

(iii) False

Because rational numbers are also a part of real numbers.

Q2

(i) True

$\because$ The collection of all natural numbers and 0 is called whole numbers.

(ii) False

$\because$ Negative integers are not whole numbers.

(iii) False

$\because$ Rational numbers are of the form p/q $\neq$ 0 and q does not divide p completely that are not whole numbers.

Q3

We have $3.142678 = \frac{3142678}{1000000}$, and hence is a rational number.

Now, let us consider the case when the decimal expansion is non-terminating recurring.

Q4

Since, we need to find five rational numbers, therefore, multiply numerator and denominator by 6.

$$\therefore \frac{3}{5} = \frac{3\times 6}{5\times 6} = \frac{18}{30} \text{ and } \frac{4}{5} = \frac{4\times 6}{5\times 6} = \frac{24}{30}$$

$\therefore$ Five rational numbers between $\frac{3}{5}$ and $\frac{4}{5}$

are $\frac{19}{30}, \frac{20}{30}, \frac{21}{30}, \frac{22}{30}, \frac{23}{30}$.

Q5

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Let $x = 1.272727...$ Since two digits are repeating, we multiply x by 100 to get

$$100x = 127.2727...$$

So, $100x = 126 + 1.272727... = 126 + x$

Therefore, $100x - x = 126$, i.e., $99x = 126$

i.e. $x = \frac{126}{99} = \frac{14}{11}$

You can check the reverse that $\frac{14}{11} = 1.\overline{27}$.

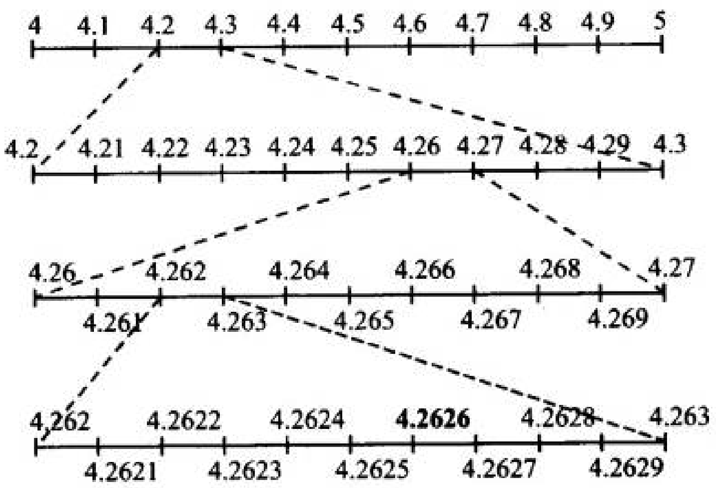
Q6

We use the identity $(a+\sqrt{b})(a-\sqrt{b}) = a^2 - b$. Multiply and divide $\frac{1}{2+\sqrt{3}}$ by $2-\sqrt{3}$ to get

$$\frac{1}{2+\sqrt{3}} \times \frac{2-\sqrt{3}}{2-\sqrt{3}} = \frac{2-\sqrt{3}}{4-3} = 2-\sqrt{3}.$$

Q7

$4.\overline{26}$ or 4.2626 lies between 4 and 5.



(i) 4.2 lies between 4 and 5

(ii) 4.26 lies between 4.2 and 4.3

(iii) 4.262 lies between 4.26 and 4.27

(iv) 4.2626 lies between 4.262 and 4.263

Q8

Let us look decimal expansion of the following terminating rational numbers :

$\frac{3}{2} = \frac{3\times5}{2\times5} = 1.5$ [Denominator = 2 = 2^1]

$\frac{1}{5} = \frac{1\times2}{5\times2} = \frac{2}{10} = 0.2$ [Denominator = 5 = 5^1]

$\frac{7}{8} = \frac{7\times125}{8\times125} = \frac{875}{1000} = 0.875$ [Denominator = 8 = 2^3]

$\frac{8}{125} = \frac{8\times8}{125\times8} = \frac{64}{1000} = 0.064$ [Denominator = 125 = 5^3]

$\frac{13}{20} = \frac{13\times5}{20\times5} = \frac{65}{100} = 0.65$ [Denominator = 20 = $2^2 \times 5^1$]

$\frac{17}{16} = \frac{17\times625}{16\times625} = \frac{10625}{10000} = 1.0625$ [Denominator = 16 = 2^4]

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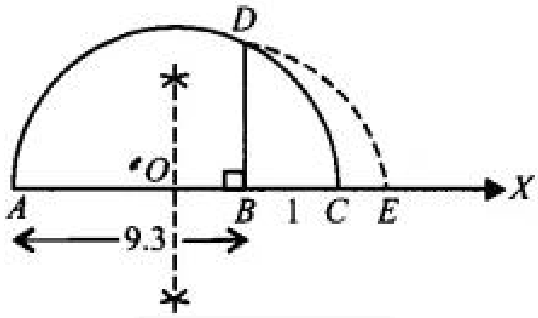
We observe that the prime factorisation of q (i.e. denominator) has only powers of 2 or powers of 5 or powers of both.

Q9
Draw a line segment $AB = 9.3$ units and extend it to C such that $BC = 1$ unit.
Find mid point of AC and mark it as O.
Draw a semicircle taking O as centre and AO as radius. Draw $BD \perp AC$.



Draw an arc taking B as centre and BD as radius meeting AC produced at E such that $BE = BD = \sqrt{9.3}$ units.

Q10
(i) $9 = 3 \times 3 = 3^2$
$\therefore (9)^{3/2} = (3^2)^{3/2} = 3^{2\times 3/2} = 3^3 = 27$
$[(a^m)^n = a^{mn}]$
(ii) $32 = 2 \times 2 \times 2 \times 2 \times 2 = 2^5$
$\therefore (32)^{2/5} = (2^5)^{2/5} = 2^{5\times 2/5} = 2^2 = 4$
$[(a^m)^n = a^{mn}]$
(iii) $16 = 2 \times 2 \times 2 \times 2 = 2^4$
$\therefore (16)^{3/4} = (2^4)^{3/4} = 2^{4\times 3/4} = 2^3 = 8$
$[(a^m)^n = a^{mn}]$
(iv) $125 = 5 \times 5 \times 5 = 5^3$
$\therefore (125)^{-1/3} = (5^3)^{-1/3} = 5^{3\times(-1/3)} = 5^{-1}$
$= \frac{1}{5} [a^{-n} \ \frac{1}{a^n}]$