Physics Point

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Chapter

1

FORCE AND PRESSURE

INTRODUCTION

Physics Point

Forces can be defined and studied only through their effects. It is present in all parts of the universe. It was Aristotle who first studied the motion of an object. He believed that a force is required to keep an object moving. But Galileo proved that if an object once comes in motion, it continues its motion forever if there is no friction between the surfaces. This tendency of an object by which a moving object keeps on moving was named as "inertia" by him. Galileo's work set the stage for Isaac Newton, when he developed the three laws of motion. He put these three laws in his famous book, namely Philosophiae Naturalis Principia Mathematica (The Latin title means "Mathematical principles of natural philosophy"), often simply known as the principia.The first law is a restatement of Galileo's concept of inertia, the second law relates acceleration to its cause-force, and the third is the law of action and reaction.

The force acting normally per unit area is called pressure, Liquids and gases both flow when a force acts on them. Fluids-which include both liquids and gases play an important role in our day to day life. Life is not possible without them . We breathe them, drink them and cook our foods with their help. The force exerted by the atmosphere i.e., envelop of air surrounding the earth, per unit area on the surface of the earth is called atmospheric pressure.

FORCE

Force is an external agent which changes or tries to change the state of an object. It is a vector quantity and its S.I. **unit** is newton (N). Its **C.G.S unit** is dyne (1dyne = 10^{-5} newton).

Note that when we say "force", we imply the total force, or net force, acting on an object. Generally, more than one forces act on an object. For example, when a ball is sailing through the air, the force of gravity and air resistance both act on it. The net force on the ball is the combination of force.

It is the net force that changes an object's state. If the net force on a body is zero, it will remain in its original state. The foregoing figure will help in understanding what net force is .

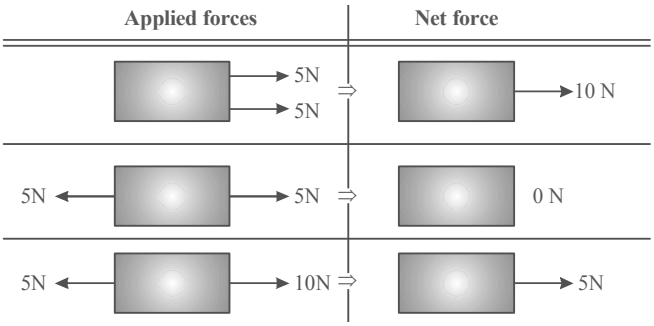
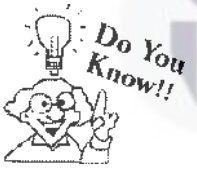


Fig. 1.1 : *Net force*

When the net of all the forces acting on a body is zero forces are called **balanced forces** and if net force is non-zero, forces acting on a body are called **unbalanced forces**.



A force produces or tries to produce motion in a body at rest, stops or tries to stop a moving body, changes or tries to change the direction of motion of a body and produces a change in the shape of a body.

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Think it Over

Let the net force acting on an object be zero. Does it always mean that the body remain at rest ? If yes, why? If not, give one example.

THE RULE OF EQUILIBRIUM

When the net force acting on a system is zero, it is said to be in mechanical equilibrium. You will read in higher classes that is said to be in rotational equilibrium if net torque acting on it is zero.

Let us consider a mass M hanging from a support with a massless string. Its weight (=Mg) acts vertically downward and the tension (T) in the string acts vertically upwards as shown in the figure. Both forces are equal in magnitude but opposite in direction. Hence, the net force is zero. Therefore, the mass is in mechanical equilibrium.

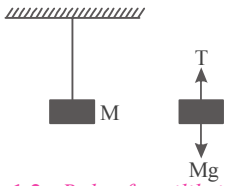
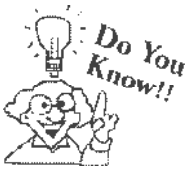


Fig. 1.2 : *Rule of equilibrium*



A number of forces acting at the same point are called concurrent forces. A number of concurrent forces are said to be in equilibrium if their resultant or net force is zero.

CHECK Point

1. **Consider a gymnast hanging from the rings. If the girl shown in figure 1.3 hangs with her weight evenly divided between the two rings, how would scale readings in both supporting ropes compare with her weight?**
2. **Suppose the girl hangs with slightly more of her weight supported by the left ring. How would a scale on the right read?**

Fig. 1.3

SOLUTION

1. The reading on each scale will be **half her weight**. the sum of the reading on both scales then equals her weight.
2. When more of her weight is supported by the left ring, the reading on the right is **less than half her weight**. No matter how she hangs, the sum of the scale readings equals her weight
   For example, if one scale reads two-thirds her weight, the other scale will read one-third her weight.

FORCES ARE DUE TO AN INTERACTION

Consider a book lying at rest on a table. It is in equilibrium. What forces act on the book? One is the force due to gravity – the weight of the book. Since the book is in equilibrium, there must be another force acting on it to produce a net force of zero an upward force opposite to the force of gravity. The table exerts this upward force, called the support force. This upward support force, often called the normal force, must be equal to the weight of the book.

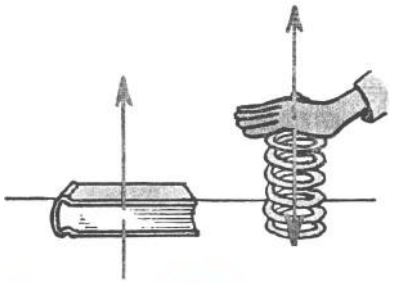
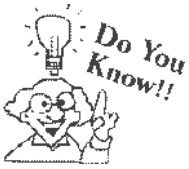


Fig. 1.4 : *The table pushes up on the book with as much force as the downward force of gravity on the book. The spring pushes up on your hand with as much force as you exert to push down on the spring.*

To better understand that the table pushes upon the book, compare the case of compressing a spring (figure) If you push the spring down, you can feel the spring pushing upon your hand. similarly, the book lying on the table compresses atoms in the table which behave like microscopic springs. The weight of the book squeezes downward on the atoms, and the squeeze upward on the book. In this way, the compressed atoms produce the support force.



The normal force is always acts in a direction perpendicular to the surface of contact. The number of normal forces acting on a body depends on the number of points or surfaces of contact.

Think it Over

A person of weight 50N is standing on the surface of the earth. What force does the person exert on the earth? What force does the earth exert on the person?

CONTACT AND NON-CONTACT FORCE

Frictional force, muscular force etc. are **contact force**. It is being applied by actually touching the body.

Non-contact force is the force being applied without touching the body e.g., gravitational force, electrostatic force, magnetic force etc.

FRICTON

When one object rubs against something else (which may be in any state such as solid, liquid or gas), a force acts on the surfaces in contact which opposes the relative motion between them. This force is called the force of friction. It always acts in a direction opposite to the direction of motion. If we pull a block of wood on a surface to the right, the force of friction on the block will be to the left.

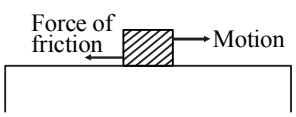


Fig. 1.5 : *Force of friction opposite to the applied force*

Similarly, a boat propelled to the east by its motor experiences water friction to the west. An object falling downward through the air, experiences air friction, called air resistance, in upward direction. The amount of friction between two surfaces depends on the kinds of material and how much they are pressed together. The force of friction between two rough surfaces is more than that between two smooth surfaces.

Friction is due to roughness of surfaces. All surfaces, on microscopic view, have tiny bumps as shown in the figure.

Due to these irregularities in the surfaces, friction appears in solid surfaces.

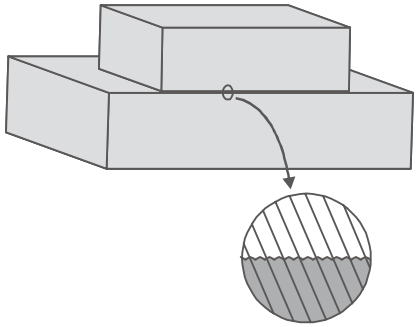


Fig. 1.6 : *Friction results from the mutual contact of irregularities in the surfaces of sliding objects. Even surfaces that appear to be smooth have irregular surfaces when viewed at the microscopic level.*

- *Frictional force does not oppose the motion in all cases, infact in some cases the body moves due to it.*

  In the fig. 1.7, book B moves to the right due to friction between A & B. If book A is totally smooth (i.e., frictionless) the book B does not move to the right. This is because of no force applied on the book B in the right direction.

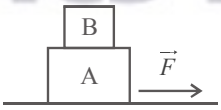


Fig. 1.7

- *The force of friction is independent of area of surfaces in contact & relative velocity between them (if it is not too high), but it depends on the nature of material of surfaces in contact (i.e., force of adhesion).*

Think it Over

A body on a rough surface is pushed by a force. But the body is still at rest. When the magnitude of force is increased slowly, the body comes in a state of "about to move". The frictional force acting at this state is called the force of limiting friction. Whether the force of limiting friction is less or more than the force of static friction?

CHECK Point

An aeroplane flies through the air at a constant velocity. In other words, it is in equilibrium. Two horizontal forces act on the plane. One is the thrust of the propeller that pushes it forward and the other is the force of air resistance that acts in the opposite direction. Which force is greater?

Fig. 1.8

SOLUTION

Both forces have the same magnitude. If you call the forward force exerted by the propeller positive, then the air resistance is negative. Since the plane is in equilibrium. the two forces combine to equal to zero.

NEWTON'S FIRST LAW OF MOTION

The first law of motion is generally called the **Law of inertia**. It is a restatement of Galileo's idea. It is stated as : *Every object continues in a state of rest or in a state of uniform motion in a straight line, unless it is compelled to change that state by external unbalanced forces exerted upon it.*

The key word "continues" in this law means an object continues to do whatever it happens to be doing unless a force is exerted upon it. This property of objects to resist changes in motion is called "inertia". If the object is at rest, it continues in a state of rest. This tendency of an object is called "the inertia of rest". This is nicely demonstrated when a bus starts moving, leaving the passengers leaning backward. Other examples are involved in the answers of the following illustrations.

(a) Why will the coin drop into the glass when a force accelerates the card?

(b) Why does the downward motion and sudden stop of the hammer tighten the hammer head?

Fig. 1.9 : *Examples of inertia*

On the other hand, if an object is moving, it continues to move without changing its speed or direction. This tendency of the object is called "the inertia of motion". This is demonstrated when a moving bus comes to rest accidently, leaving the passengers leaning forward.

Newton's first law gives the qualitative definition of force according to which 'force is that external cause which tends to change or actually changes the state of rest or of uniform motion of a body. Newton's first law of motion is the same as ***law of inertia*** *given by Galileo.*

CHECK Point

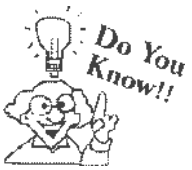
When a space shuttle travels in a nearly circular orbit around the earth, is a force required to maintain its high speed? If suddenly the force of gravity were cut off, what type of path would the shuttle follow?

SOLUTION

No force in the direction of the shuttle's motion exists. The shuttle coasts at a constant speed by its own inertia. The only force acting on it is the force of gravity, which acts at right angles to its motion (towards the earth's centre). We'll see later that this right-angled force holds the shuttle in a circular path. If it were cut off, the shuttle would move in a straight line at a constant speed (constant velocity).

Mass and Inertia

Inertia is directly related to the mass of an object. A heavier body has higher inertia than that of a lighter body. Mass in this context is called "inertial mass".



Inertia of direction is the property due to which a resistancy, change in its motion due to a change in direction.

NEWTON'S SECOND LAW OF MOTION

Newton formulated his second law, one of the most central rules of nature, which relates force to mass in producing acceleration, in the following way.

The acceleration produced by a net force on an object is directly proportional to it and is in the same direction as the net force but is inversely proportional to the mass of the object.

In shorter notation,

$$\text{Acceleration} = \frac{\text{net force}}{\text{mass}}$$

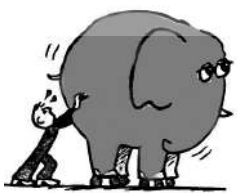


Fig. 1.10 : *Acceleration depends both on the amount of push and on the mass being pushed*

If we use consistent units such as newtons (N) for force, kilograms (kg) for mass and meter per second square (m/s^2) for acceleration, then mathematically,

$$a = \frac{F}{m}$$

where a = acceleration
F = net force
m = mass

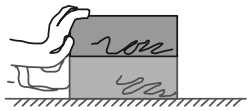


Fig. 1.11 : *Acceleration is directly proportional to force*

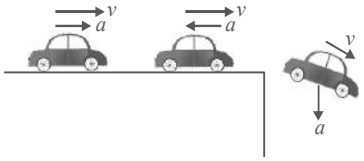


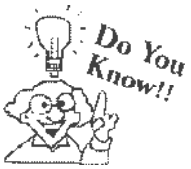
Fig. 1.12 : *When you accelerate in the direction of your velocity, you speed up; against your velocity, you slow down; at an angle to your velocity, your direction changes.*

Illustration : 1

Two blocks made of different metals identical in shape and size are acted upon by equal forces, which cause them to slide on a horizontal surface. The acceleration of the second block is found to be 5 times that of the first, what is the ratio of the mass of the second to first?

SOLUTION :

Let F be resultant force on each block.
For 1st block, $F_1 = m_1 a_1$
For 2nd block, $F_2 = m_2 a_2$
or, $m_1 a_1 / m_2 a_2 = 1$, i.e., $m_2 / m_1 = a_1 / a_2$ ....(i)
Here, $a_2 = 5a_1$ ....(ii)
From (i) and (ii), $m_2 / m_1 = 1 : 5$



Newton's first law of motion follows from Newton's second law of motion. By second law $F = ma$
If $F = 0$, then $a = 0$, which means the body is either at rest or moves with a constant velocity.

Think it Over

Can Newton's laws of motion be applied for an object moving in an accelerated lift?

CHECK Point

1. **The net external force acting on an object is zero. Is it possible for the object to be travelling with a velocity that is not zero? If your answer is yes, state whether any conditions must be placed on the magnitude and direction of the velocity. If your answer is no, provide a reason for your answer.**
2. **Is it possible for an object to be at rest (have a velocity of zero) yet the net external force acting on the object is non-zero? Explain.**
3. **Newton's second law indicates that when a net force acts on an object, it must accelerate. Does this mean that when two or more forces are applied to an object simultaneously, it must accelerate? Explain.**

SOLUTION

1. If the net external force acting on an object is zero, it is possible for the object to be travelling with a non-zero velocity. According to Newton's second law, $F = ma$, if the net external force F is zero, the acceleration a is also zero. If the acceleration is zero, the velocity must be constant, both in magnitude and in direction. Thus, an object can move with a constant nonzero velocity when the net external force is zero.
2. An object at rest has a constant velocity (of zero), which means that it has an acceleration of zero (it is at rest!). Newton's first law indicates that the object will stay at rest only if the net force acting on the object is zero.
3. An object will not necessarily accelerate when two or more forces are applied to the object simultaneously. The applied forces may cancel so the net force is zero; in such a case, the object will not accelerate. The resultant of all the forces that act on the object must be nonzero in order for the object to accelerate.

Physics Point

CONNECTING TOPIC

FREE FALL

We know that a falling object accelerates towards the earth because of the gravitational force of attraction between the object and the earth. When the force of gravity is the only force – that is, when air resistance is negligible – we say that the object is in a state of **free fall**. An object in **free fall** accelerates towards the earth at 10 m/s^2 (or, more precisely, at 9.8 m/s^2).

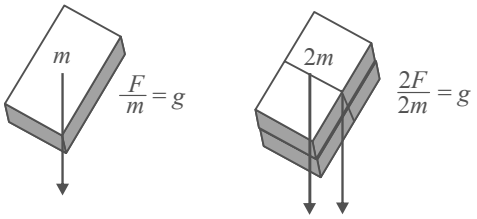
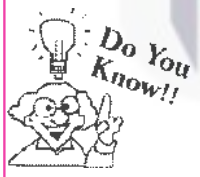


Fig. 1.13 : *The ratio of weight (F) to mass (m) is the same for all objects in the same locality; hence, their accelerations are the same in the absence of air resistance.*

The greater the mass of an object, the stronger is the gravitational pull between it and the earth. The double book in Fig. 1.13 (b) above, for example, has twice the gravitational attraction to earth as the single book. Why, then, doesn't the double book fall twice as fast (as Aristotle supposed it would)? The answer is evident in Newton's second law : the acceleration of an object depends not only on the force (weight, in this case), but on the object's resistance to motion – its inertia. Whereas a force produces an acceleration, inertia is a *resistance* to acceleration. So twice the force exerted on twice the inertia produces the same acceleration as half the force exerted on half the inertia. Both accelerate equally. The acceleration due to gravity is symbolised by *g*. We use the symbol *g*, rather than *a*, to denote acceleration due to gravity.



When an object is in a state of free fall, it experiences no weight. That is, it is in a state of "weightlessnes".

Physics Point

Think it Over

In a vacuum, a coin and a feather fall at an equal rate, side by side. Would it be correct to say that equal forces of gravity act on both the coin and the feather when in a vacuum?

NON-FREE FALL

In practice, air resistance is not negligible for falling objects. Then the acceleration of the object's fall is less. Air resistance depends on two things : speed and surface area. When a skydiver steps from a high-flying plane, the air resistance on the skydiver's body builds up as the falling speed increases. The result is reduced acceleration. The acceleration can be reduced further by increasing the surface area. A skydiver does this by orienting the body so that more air is encountered – by spreading out like a flying squirrel. So, air resistance depends both on speed and on the surface area encountered by the air.

For free fall, the downward net force is weight – only weight. But when air is present, the downward net force = weight – air resistance. Can you see that the presence of air resistance reduces net force? And that less net force means less acceleration? So, as a skydiver falls faster and faster, the acceleration of fall decreases. What happens to the net force if air resistance builds up to equal weight? The answer is, net force becomes zero. Then acceleration becomes zero. Does this mean the diver comes to a stop? No! What it means is that the diver no longer gains speed. Acceleration terminates – it no longer occurs. We say the diver has reached **terminal speed**. If we are concerned with direction – down, for falling objects, we say that the diver has reached **terminal velocity.**

In mathematical notation,

$$a = \frac{F_{net}}{m} = \frac{mg - R}{m}$$

where *mg* is the weight and *R* is the air resistance. Note that, when $R = mg$, $a = 0$; then, with no acceleration, the object falls at a constant velocity. With elementary algebra, we can proceed another step and get

$$a = \frac{F_{net}}{m} = \frac{mg - R}{m} = g - \frac{R}{m}$$

We see that the acceleration *a* will always be less than *g* if air resistance *R* impedes falling. Only when $R = 0$ does $a = g$.

Any object falling through a resistive medium attains a constant velocity after some time which called the terminal velocity. This velocity depends on the nature and density of the medium and also on the shape of the object.

Think it Over

A skydiver jumps from a high-flying helicopter. As she falls faster and faster through the air, does her acceleration increase, decrease, or remain the same?

Fig. 1.14

CHECK Point

Consider two parachutists, a heavy person and a light person, who jump from the same altitude with parachutes of the same size.

1. **Which person reaches the terminal speed first?**
2. **Which person has the higher terminal speed?**
3. **Which person reaches the ground first?**
4. **If there were no air resistance, like on the moon, how would your answers to these questions differ?**

Physics Point

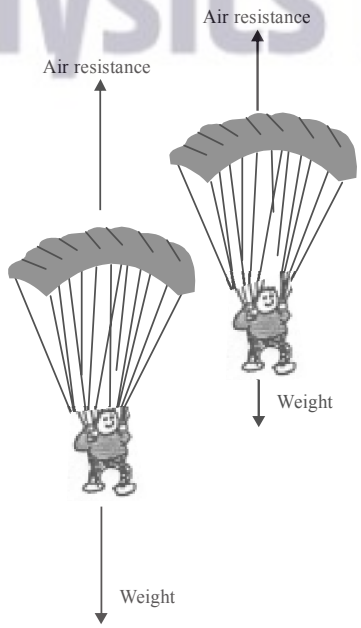


Fig. 1.15 : *The heavier parachutist must fall faster than the lighter parachutist for air resistance to cancel her greater weight.*

SOLUTION

To answer these questions correctly, think of a coin and a feather falling in air.

1. Just as a feather reaches terminal speed very quickly, the lighter person reaches terminal speed first.
2. Just as a coin falls faster than a feather through air, the heavy person falls faster and reaches a higher terminal speed.
3. Just as in the race between a falling coin and a falling feather, the heavier person falls faster and will reach the ground first.
4. If there were no air resistance, there would be no terminal speed at all. Both would be in free fall, and both would hit the ground at the same time.

Linear Momentum and The Newton's Second Law of Motion

Linear momentum of an object is the effect produced in it due to its mass and velocity. Quantitatively, it is product of the mass and the velocity of an object.

Mathematically, *Momentum = mass × velocity*

It is a vector having direction in the direction of velocity. Its S.I. unit is kilogram meter per second (kg m/s).

Symbolically, $p = mv$

where, p = momentum; m = mass and v = velocity

Newton's second law is related to linear momentum. It is stated as "*The force acting on an object is directly proportional to the rate of change of momentum with time*".

i.e., $\text{Force} = \dfrac{\text{change in momentum}}{\text{time}}$

If an object of mass m moving with velocity v_1 changes its velocity to v_2 in time t then force acting on it

$$F = \frac{mv_2 - mv_1}{t} = \frac{m(v_2 - v_1)}{t}$$

Also, we know

$$\frac{v_2 - v_1}{t} = (a) \text{ acceleration}$$

$\therefore \quad F = ma$ or $a = \dfrac{F}{m}$, which is the second law.

The change in the linear momenta is called 'impulse'. Therefore, impulse = force × time
A cricketer pulls his hands backward while catching a ball. He does so to maximise the time and hence to minimise the force on his hands due to the ball.

Illustration : 2

Two billiard ball, each of mass 0.05 kg, moving in opposite directions with speed of 6 ms^{-1}, collide and rebound with the same period. What is the impulse imparted to each ball due to the other?

SOLUTION :

Before collision, mass of each ball = 0.05 kg, speed of ball = 6 ms^{-1},
$\therefore$ momentum, $p = mv = 0.05 \times 6 = 0.3$ kg ms^{-1}.
After collision, mass of each ball = 0.05 kg, speed of ball = – 6 ms^{-1},
$\therefore$ momentum = $0.05 \times (-6) = -0.3$ kg ms^{-1}.
(Change in momentum after collision = $p_2 - p_1$)
$\therefore$ change of momentum = impulse = $-0.3 - 0.3 = -0.6$ kg ms^{-1}

Hence an impulse of 0.6 kg ms^{-1} will be imported to each ball in opposite directions.

CONNECTING TOPIC

THE LAW OF CONSERVATION OF LINEAR MOMENTUM

It states that in absence of external force, the total linear momentum of a system remains conserved. During collision of two particles, for example, the total linear momenta before collision is equal to the total linear momenta after collision. Mathematically, if two objects of masses m_1 and m_2 moving with velocities u_1 and u_2 collide and moves with velocities v_1 and v_2 after collision, then

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

The principle of conservation of momentum is nicely involved in the process of firing a bullet by a gun. Let a bullet of mass m is fired with a velocity v from a gun of mass M. As gun exerts a forward force on bullet, by third law of motion (see next topic), the bullet also exerts an equal force in backward direction. Due to this force, gun recoil in backward direction with a velocity, say, v_{rec} known as recoil velocity.

Fig. 1.16

By conservation of momentum,
Total momenta before firing bullet = total momenta after firing bullet

$$\Rightarrow (M \times 0) + (m \times 0) = -M v_{rec} + mv$$

Negative sign in first term of R.H.S. is due to the fact that the gun recoils in opposite direction.

$$\therefore \quad Mv_{rec} = mv \Rightarrow v_{rec} = \frac{mv}{M}$$

Think it Over

The propulsion of rocket is an example of momentum conservation. In a rocket gases at high temperature and pressure are produced by the combustion of fuel. In a rocket fuel is consumed at the rate of 100 kgs^{-1}. The exhaust gases are ejected at speed of 4.5 × 10^4 ms^{-1}. What is the thrust experience by the rocket?

Illustration : 3

A gun weighing 4 kg fires a bullet with a velocity 50ms^{-1}. If the weight of the bullet is 15g, find the velocity of recoil of the gun.

SOLUTION :

Here, $M = 4$ kg; $m = 15$ g $= 0.015$ kg; $v = 50$ ms^{-1}

$$v_{rec} = \frac{mv}{M} = \frac{0.015 \times 50}{4} = 0.17 \text{ ms}^{-1}$$

NEWTON'S THIRD LAW OF MOTION

According to this law, whenever an object exerts a force on another object, the latter object exerts an equal and opposite force on the first. We can call one force the action force, and the other the reaction force. In action-reaction form, the third law is stated as

To every action there is always an equal and opposite reaction.

Although action and reaction are equal and opposite but they never add to zero resultant force because both acts on two different objects which can't be added.

It doesn't matter which force we call the *action* and which we call the *reaction*. The important thing is that they are coequal parts of a single interaction and that neither force exists without the other. Action and reaction forces are equal in strength and opposite in direction. They occur in pairs and make up a single interaction between two things.

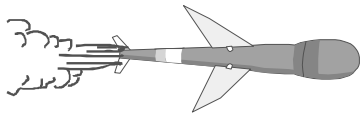
Simple Rule to Identify Action and Reaction

There is a simple rule for identifying action and reaction forces. First, identify the interaction – one thing (object A) interacts with another (object B). Then, action and reaction forces can be stated in the following form :

Action : *Object A exerts a force on object B.*

Reaction : *Object B exerts a force on object A.*

Action : Tyre pushes on road **Reaction :** Road pushes on tyre



Action : Rocket pushes on gas **Reaction :** Gas pushes on rocket

Action : Man pulls on spring  **Reaction :** Spring pulls on man

Fig. 1.17

CHECK Point

1. **A car accelerates along a road. Identify the force that moves the car.**
2. **Identify the action and reaction forces for the case of an object in free fall (no air resistance).**

SOLUTION

1. It is the road that pushes the car along. Except for air resistance, only the road provides a horizontal force on the car. How does it do this? The rotating tyres of the car push back on the road (action). The road simultaneously pushes forward on the tyres (reaction).
2. To identify a pair of action-reaction forces in any situation, first identify the pair of interacting objects. In this case, the earth interacts with the falling object via the force of gravity. So the earth pulls the falling object downward (call it action). Then reaction is the falling object pulling the earth upward. It is only because of the earth's enormous mass that you don't notice its upward acceleration.

CONNECTING TOPIC

FREE BODY DIAGRAM (FBD)

To apply Newton's laws of motion, first of all we choose our system and then indicate all the forces acting on it which we call the **free body diagram (FBD).**

Motion of a Mass on a Surface

Case (I) If friction is absent between the surfaces, the free body diagram is as shown in **Fig. 1.18**. The forces acting on mass are
(i) mg, the weight, vertically downward
(ii) N, the normal reaction, vertically upward
(iii) F, in right direction, due to external agent.

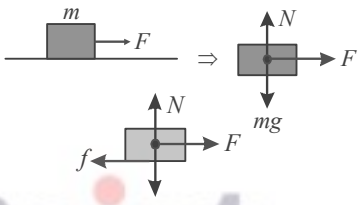


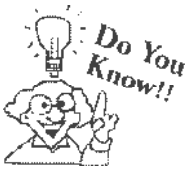
Fig. 1.18

Clearly, mg and N cancel each other, so, there is no motion in vertical direction. In horizontal direction, there is only force F, in right direction, hence the mass moves in this direction. If a be the acceleration of the mass, then

$$F = ma \Rightarrow a = \frac{F}{m}$$

Case (II) If friction is present between the surfaces, the acceleration of the mass will be

$$a = \frac{F - f}{m} \text{ where } f = \text{force of friction}$$

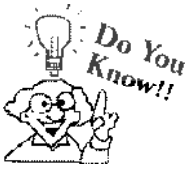


Two masses hanging on a massless pulley with massless, and inextensible string, move with same acceleration.

PRESSURE

Pressure is defined as the force or thrust exerted over a unit area.

$$\text{Pressure} = \frac{\text{force / thrust}}{\text{area}}$$



Pressure plays the same role in fluids as force plays in case of solids.
Force is a vector quantity but pressure is a scalar.

Think it Over

We see in our day-to-day life that paper pins and nails are made to have pointed ends. Think proper reasons behind it.

Physics Point

Thrust

The net force acting normal to a surface is called thrust. Thus, a body kept in any orientation exert equal thrust on the surface. It is the net force, so, its S.I. unit is newton (N). It is also expressed in kilogramme weight (kg wt)

1 kg wt = 9.8 N

The *pressure* of the book depends on the area over which the force is distributed.

Pressure may be measured in any unit of force divided by any unit of area. The standard international **(SI) unit** of pressure is newton per square metre called the *pascal* (Pa).

Huge pressure is measured in kilopascal (1 kPa = 1000 Pa).

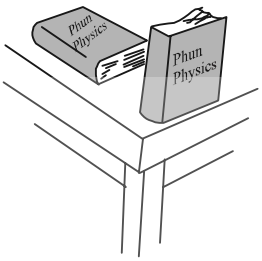


Fig. 1.19 : *Although the weight of both books is the same, the upright book exerts greater pressure against the table.*

Atmospheric Pressure

We live at the bottom of an ocean of air. The atmosphere, much like the water in a lake, exerts a pressure.

Just as water pressure is caused by the weight of water, **atmospheric pressure** is caused by the weight of air. We have adapted so completely to the invisible air that we sometimes forget it has weight. Perhaps a fish "forgets" about the weight of water in the same way. The reason we don't feel this weight crushing against our bodies is that the pressure (*blood pressure*) inside our bodies equals that of the surrounding air. There is no net force for us to sense.

The pressure of the atmosphere is not uniform. Atmospheric pressure is measured by **barometer**. Measurement of changing air pressure is important to meteorologists in predicting weather.

Atmospheric pressure is maximum at the surface of the earth and decreases as we move upwards. The value of the atmospheric pressure at sea level is 1.013 × 10^5 Nm^{-2} (or Pa) or 76 cm of Hg.

PRESSURE IN A LIQUID

When we swim in a river, we feel the water pressure acting against our eardrums. The deeper we swim, the greater the pressure. The cause of this pressure is the weight of the fluid, water plus air directly above us. As we swim deeper, there is more water above us. Therefore, there is more pressure. If we swim twice as deep, there is twice the weight of water above us, so the water's contribution to the pressure felt by us is doubled. The pressure due to a liquid also depends upon its density.

Mathematical expression for fluid pressure

Let us consider a liquid of density ρ in a beaker of base area 'A'. If 'h' be the height of the liquid column then

Volume of liquid in beaker, $V = A \times h$

Force (or thrust) acting at the bottom of the beaker is given by

F = Weight of liquid = mg

$= V\rho g$ ($\because$ $m = V\rho$ and $V = A \times h$)

$= (A \times h)\,\rho g = \rho g h A$

$\therefore$ Pressure at the bottom of the beaker $P = \frac{F}{A} = \frac{\rho ghA}{A} = \rho gh$,

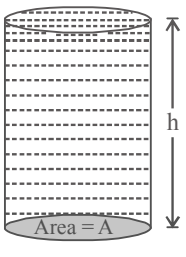


Fig. 1.20

Thus, we observe that pressure at a depth 'h' due to a liquid column is directly proportional to

(i) the density 'ρ' of the liquid.

(ii) the height 'h' of the liquid column and

(iii) the accelaration due to gravity 'g'

Total Pressure at a Point in a Liquid

Let us consider a point B at a depth 'x' from the surface of a liquid of density 'ρ'.
Total pressure at the point B is the sum of the pressure due to atmosphere and the pressure due to the liquid column.
That is, total pressure at B
= atmospheric pressure (P_{atm}) + pressure due to liquid column $= P_{atm} + \rho g x$

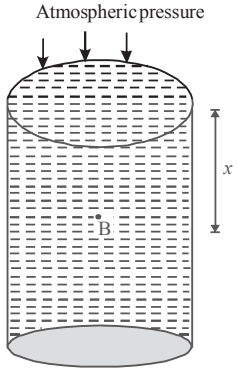
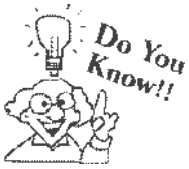


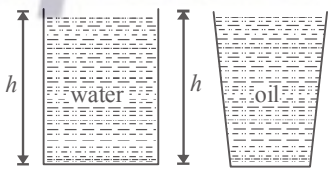
Fig. 1.21



A vessel filled with water exerts a pressure P on its bottom. Now the whole set-up is carried on the moon. What would be the pressure exerted by the water column on the bottom of the vessel now?
Water pressure acts perpendicular to the sides of its container, and it increases with increasing depth.
The relation P = rgh holds strictly only in case of an incompressible liquid.

Think it Over

The two vessels have water and oil inside there. Whether the pressure exerted by them on the bottoms of the vessels will be same, or different. Why?



(a) (b)

Fig. 1.22

Illustration : 4

Find the pressure at a point 5 cm inside the liquid column as shows in fig. 1.23. The atmospheric pressure is given to be 1.013×10^5 Nm^{-2}.
(The density of liquid = 1000 kg/m^3)

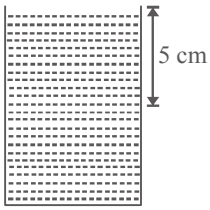


Fig. 1.23

SOLUTION :

Total pressure at given point
= Atmospheric pressure + Pressure due to liquid column
$= (1.013 \times 10^5) + h\rho g$
$= (1.013 \times 10^5) + (5 \times 10^{-2} \times 1000 \times 10)$
$= 1.018 \times 10^5$ Pa

CONNECTING TOPIC

PASCAL'S LAW

Blaise Pascal formulated a law regarding the flow of liquid pressure. This law is stated as "*the pressure exerted by a liquid at rest is transmitted unchanged and equally in all directions, and acts at right angles to the surface of the container*".

The liquid has the property due to which its molecules exert great repulsive forces when they are pushed closer to each other than their normal distance. Due to this property it is difficult to compress a liquid by application of thrust on the surface. Thus any force applied on a liquid surface is immediately transmitted to every part of the liquid and the applied pressure at the surface is felt equally at every part of the liquid.

This may be demonstrated by filling a long necked bulb, having a number of holes, with water. When pressure is applied on the water by pushing the piston fitted in the neck of the bulb, water rushed out with equal pressure from all the holes.

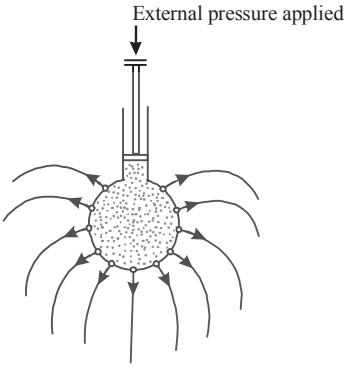


Fig. 1.24 : *Liquid exerts equal pressure*

Applications of Pascal's Law

Hydraulic Lever or Press : A hydraulic lever is used to magnify a force.

Let us consider two cylinders A_1 and A_2. Let the area of cross– section of A_1 be 'x' square units and that of A_2 be 'y' square units such that 'y' is n times 'x'.

The two cylinders are connected at the bottom by a horizontal connecting tube (T). The apparatus is filled with a liquid. The cylinders A_1 and A_2 are fitted with air tight pistons P_1 and P_2. Let us apply an external force F_i (or input) on the piston P_1.

The pressure exerted on P_1 is F_i/x.

According to Pascal's law the pressure exerted on P_1 is transmitted unchanged equally by the liquid to piston P_2.

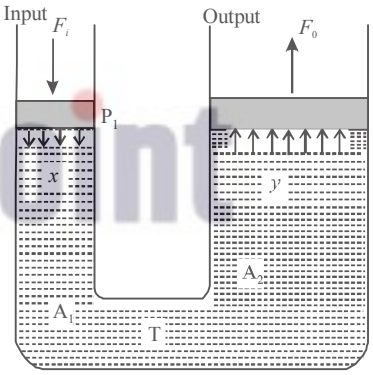


Fig. 1.25

The downward pressure exerted on $P_1 = \frac{F_i}{x}$

The upward force exerted on P_2

= pressure on P_2 × area of cross-section of A_2

For the piston P_2 to be in equilibrium, there must be a downward force of magnitude F_0 on the output piston from an external load (not shown).

Then, $F_0 =$ (Pressure on P_2) y.

But according to Pascal's law, pressure on P_2 = pressure on $P_1 = \frac{F_i}{x}$ $\quad \therefore \quad F_0 = \left(\frac{F_i}{x}\right) y$, but $y = nx \Rightarrow F_0 = \frac{F_i}{x} \times nx = F_i n$

This shows $F_0 > F_i$. Therefore, a small force applied at a point can be used to exert a much larger force at another point.

A hydraulic press is also used

(i) to press the bales of cotton,

(ii) to extract oil from oil seeds, and

(iii) in hydraulic brakes that are used in brake systems of vehicles.

Think it Over

Air bubbles are dangerous to hydraulic brake. Why?

In the fig.1.26, if thrust F is applied on the piston of the side tube A, how much pressure will transmit through each of the tubes A, B and C ?

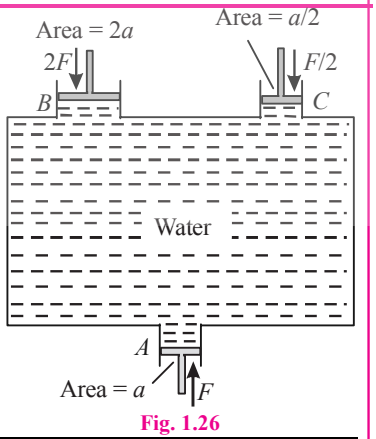


Fig. 1.26

BUOYANCY

When we lift a submerged object out of the water, the weight of the object felt by us is less than its actual weight. This loss in the weight of the object is due to a force called 'buoyant' force and the property of the liquid is called **buoyancy**. Buoyant force due to a fluid is the force acting upward on a submerged object exactly opposite in direction to gravity. This force arises due to the pressure difference at different depths.

Figure shows why the buoyant force acts upward. Pressure is exerted everywhere against the object in a direction perpendicular to its surface. The arrows represent the magnitude and the direction perpendicular to its surface. The arrows represent the magnitude and the direction of the forces at different locations. Forces that produce pressures against the sides due to equal depths cancel one another. Pressure is greatest against the bottom of the boulder because the bottom of the boulder is at a greater depth. Since the upward forces against the bottom are greater than the downward forces against the bottom are greater than the downward forces against the top, the forces do not cancel, and there is a net force upward. This net force is the byoyant force.

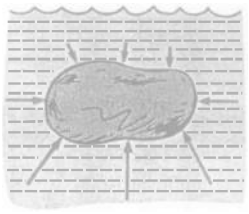


Fig. 1.27 : *The greater pressure against the bottom of a submerged object produces an upward buoyant force.*

If the weight of the submerged object is greater than the buoyant force, the object will sink. If the weight is equal to the buoyant force acting up on the submerged object, it will remain at any level, like a fish. If the buoyant force is greater than the weight of the completely submerged object, it will rise to the surface and float.

To understand buoyancy, the meaning of the term "volume of liquid displaced" should be clearly understood. If a stone is placed in a container that is full of water, some water will overflow as shown in fig. The volume of water overflown is alone equal to the volume of the stone. That is, *a completely submerged object always displaces a volume of liquid equal to its own volume.*

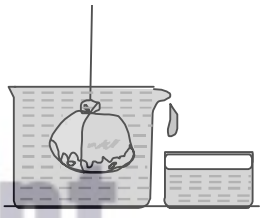


Fig. 1.28

Buoyant force is also called *upthrust.*

Upthrust or buoyant force = $h\rho gA = V\rho g$ ($\because hA = V$, volume of the solid)

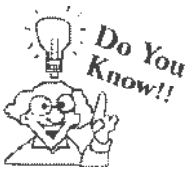
where, V = volume of the third displaced

ρ = density of fluid

$\therefore$ Upthrust = weight of the liquid displaced.

Thus, the upthrust or buoyant force is directly proportional to

1. the volume (V) of the fluid displaced by a solid.
2. the density (ρ) of the liquid in which the solid is immersed.



Upthrust depends on the density of the liquid, not on the density of the object.

Think it Over

It is easier to swim in a sea than that in a river. Why ?

CHECK Point

1. **Drop a stone in a tall water filled container. As it descends beneath the surface, pressure on it increases. Does this imply that buoyant force likewise increases?**
2. **Because buoyant force is the upward force that a fluid exerts on a body, and as we learned forces produce accelerations, why doesn't a submerged body accelerate?**

SOLUTION

1. No! Once the stone is beneath the water's surface, it has displaced all the water it can. This is evidenced by the initial rise of the water level in the container, which corresponds to the volume of the stone (and, hence, to the volume of water displaced by the stone). The level remains the same as the stone descends further, showing that the water displacement, and therefore the buoyant force on the stone, remains the same– even though water pressure on the stone increases with depth. Buoyancy and pressure are different concepts.
2. It does accelerate if the buoyant force is not balanced by other forces that act on it-the force of gravity and fluid resistance. The net force on a submerged body, is the result of the force the fluid exerts (buoyant force), the weight of the body and, if the body is moving, the force of fluid friction. When the net force is zero, the body is in equilibrium.

Illustration : 5

A piece of cork is embedded inside a block of ice which floats on water. What will happen to the level of water when all the ice melts?

SOLUTION :

Let, M = mass of the block of ice, m = mass of piece of cork and V = volume of water displaced.

Now $(M+m) = V \times 1 = V$ ...(1)

When the ice melts, let it be converted into V' c.c. of water.

Also $M = V' \times 1 = V'$

The piece of cork floats on the surface of water when all ice melts. Let the cork displaces a volume V'' c.c. of water.

Then $m = V'' \times 1 = V''$

If V_1 be the volume of water displaced by melted ice and cork, then

$(M+m) = V' + V'' = V_1$ ...(2)

From eqs. (1) and (2), $V = V_1$ (no change in the level)

Illustration : 6

A boat having a length of 3 metres and breadth 2 metres is floating on a lake. The boat sinks by one cm when a man gets on it. What is the mass of the man?

SOLUTION :

Weight of a man = Wt. of water displaced

$$= \text{volume} \times \text{density} = 3 \times 2 \times \frac{1}{100} \times 10^3 = 60 \text{ kg}$$

ARCHIMEDES' PRINCIPLE

The Greek scientist Archimedes' established a relationship between buoyancy and displaced liquid in the third century BC. It is stated as follows: *when an object is partially or wholly immersed in a fluid, it loses some of its weight which is equal to the weight of the displaced fluid.*

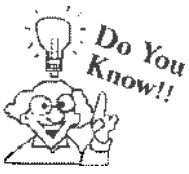
It applies to both liquids and gases. If an immersed object displaces 1 kg of fluid, the buoyant force acting on it is equal to the weight of 1 kg of the fluid.

Notice that unless the container is compressed, the buoyant force is equal to the weight of the displaced liquid at any depth, as long as it is completely submerged. This is because, at any depth, it can displace no greater volume of the liquid than its own volume.

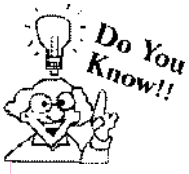
Archimedes' (287 – 212 BC) and the Gold Crown

According to popular legend, Archimedes' had been given the task of determining whether a crown made for King Hiero II of Syracuse was of pure gold or whether it contained some less expensive metals, such as silver. Archimedes' problem was to find the density of the crown without destroying it. He could weigh the gold, but determining its volume was a problem. The story has it that Archimedes' came to the solution when he noted the rise in water level while immersing his body in the public baths of Syracuse. Legend reports that he excitedly rushed naked through the streets shouting " Eureka! Eureka!" ("I have found it! I have found it!").

What Archimedes' had discovered was a simple and accurate method of finding the volume of an irregular object – the displacement method of determining volumes. Once he knew both the weight and volume, he could calculate the density. Then the density of the crown could be compared to the density of gold. Archimedes' insight preceded Newton's laws of motion, from which Archimedes' principle can be derived, by almost 2000 years.



If the weight of a body submerged in a liquid is more than the weight of the liquid displaced, the body will sink in it.
If the weight of a body submerged in a liquid is equal or less than the weight of the liquid displaced, the body will float.



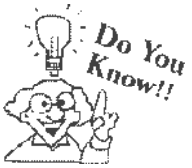
Only in the special case of floating does the buoyant force acting on an object equal the object's weight.
For a floating body, the weight of the body is balanced by the upthrust.

RELATIVE DENSITY

Relative density of a substance is defined as the ratio of its density to the density of water at 4°C. It is also called *specific gravity*. Mathematically,

$$\text{Relative density R.D.} = \frac{\text{density of substance}}{\text{density of water at 4°C}}$$

Since relative density is a ratio of same quantities, it has no unit.



If W_1 & W_2 represent the weight of a solid in air and water respectively, then the relative density of the solid R.D. $= \frac{W_1}{W_1 - W_2}$

Think it Over

People who can't float are, nine times out of ten, males. Most males are more muscular and slightly denser than most females. Also, cans of diet soda float whereas cans of regular soda sink in water. What does this tell you about their relative densities?

CHECK Point

1. **Does Archimedes' principle tell us that, if an immersed block displaces 10 N of fluid, the buoyant force on the block is 10 N?**
2. **A 1 litre container completely filled with lead has a mass of 11.3 kg and is submerged in water. What is the buoyant force acting on it?**
3. **A boulder is thrown into a deep lake. As it sinks deeper and deeper into the water, does the buoyant force on it increase? decrease?**

SOLUTION

1. Yes. If you look at this question with Newton's third law in mind, you can see that, when the immersed block pushes 10 N of fluid aside, the fluid reacts by pushing back on the block with a force of 10 N.
2. The buoyant force is equal to the weight of 1 kg (9.8 N) because the volume of water displaced is 1 L, which has a mass of 1 kg and a weight of 9.8 N. The 11.3 kg mass of the lead is irrelevent; 1 L of anything submerged in water will displace 1 L and be buoyed upward with a force of 9.8 N, the weight of 1 kg. (Get this straight before going further!)
3. Buoyant force does not change as the boulder sinks because the boulder displaces the same volume of water at any depth. Because water is practically incompressible, its density is very nearly the same at all depths; hence, the weight of water displaced, or the buoyant force, is practically the same at all depths.

FLOATATION

Iron is much denser than water and therefore iron needle sinks, but an iron ship floats. Why is this so? Consider a solid 1- ton block of iron. Iron is nearly eight times as dense as water. When it is submerged, it will displace only 1/8 ton of water, which is certainly not enough to prevent it from sinking. Suppose that we reshape the same iron block into a bowl, as shown in Figure. Although its surface area is increased, it still weighs 1 ton. When settling in water, it displaces a greater volume of water than before. The deeper it is immersed, the more water it displaces and the greater the buoyant force acting upon it. When the buoyant force equals 1 ton, it will sink no further.

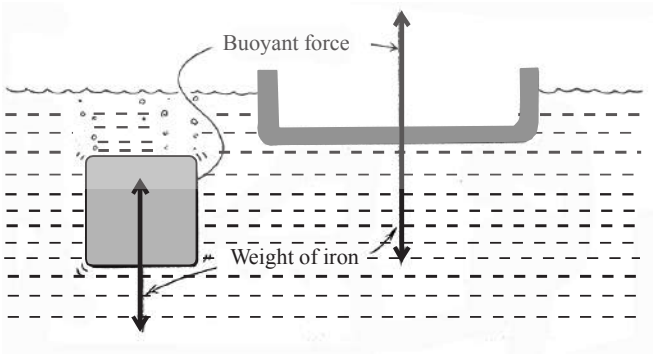


Fig. 1.29

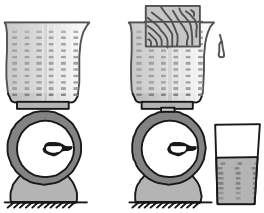


Fig. 1.30

A floating object displaces a weight of fluid equal to its own weight.

When the iron boat displaces a weight of water equal to its own weight, it floats. This is called the principle of flotation.

Every ship, submarine, and dirigible must be designed to displace a weight of fluid equal to its own weight. Thus, a 10,000 ton ship must be built wide enough to displace 10,000 tons of water before it sinks too deep in the water. The same applies to vessels in the air. A dirigible or a huge balloon that weighs 100 tons displaces at least 100 tons of air. If it displaces more, it rises; if it displaces less, it descends. If it displaces exactly its weight, it hovers at a constant altitude.

Since the buoyant force upon a body equals the weight of the fluid it displaces, denser fluids will exert a greater buoyant force upon a body than less dense fluids of the same volume. A ship, therefore, floats higher in salt water than in fresh water because salt water is slightly denser than fresh water. In the same way, a solid chunk of iron will float in mercury even though it sinks in water.

Think it Over

All bodies are buoyed up by a force equal to the weight of air they displace.

Why, then, don't all objects float like this balloon?

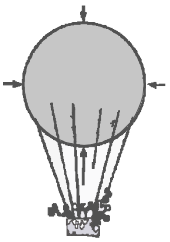


Fig. 1.31

CHECK Point

Figure shows four solid objects floating in corn syrup. Rank the objects according to their density, greatest first.

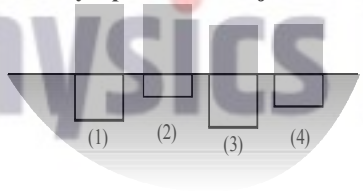


Fig.1.32

SOLUTION

The increasing portions of the objects submerged in the syrup are as below
3 > 1 > 4 > 2. Hence, the objects can be ranked as below
Rank 1 – object 3
Rank 2 – object 1
Rank 3 – object 4
Rank 4 – object 2

PRESSURE IN A GAS

The molecules in a gas are relatively farther placed with respect to a liquid. Therefore, their motions are less restricted. A gas expands, fills all space available to it, and exerts a pressure against its container.

Boyle's Law

Robert Boyle related the gas pressure with its volume in a container. It states that *if temperature of a gas remains constant then for a given mass of the gas, pressure is inversely proportional to its volume*.

Mathematically, $P \propto \frac{1}{V}$ (T = constant) or, PV = constant

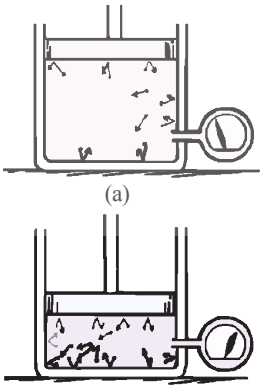
where, P = Pressure of gas

V = Volume of gas

Therefore, if (P_1, V_1) and (P_2 , V_2) be the pressure and volume in two states then

$P_1 V_1 = P_2 V_2$

When the volume of gas is decreased, the density, and therefore pressure, are increased.



(a) (b)

Fig. 1.33

Buoyancy in a Gas

Buoyancy in gas acts in the same way as that in a liquid. Objects in a liquid are buoyed upward because the pressure acting up against the bottom of the object exceeds the pressure acting down against the top. Likewise air pressure acting up against an object immersed in air is greater than the pressure above pushing down. The buoyancy in both cases is numerically equal to the weight of fluid displaced. Archimedes' principle applies to air just as it does for liquid: *When an object is wholly or partially immersed in a gas, it loses some of its weight which is equal to the weight of the displaced gas.*

CHECK Point

1. **Is there a buoyant force acting on you? If there is, why are you not buoyed up by this force?**
2. **How does buoyancy change as a helium filled balloon ascends?**

SOLUTION

1. There is a buoyant force acting on you, and you are buoyed upward by it. You aren't aware of it only because your weight is so much greater.
2. If the balloon is free to expand as it rises, the increase in volume is counteracted by a decrease in the density of higher– altitude air. So, interestingly, the greater volume of displaced air doesn't weigh more, and buoyancy stays the same. If a balloon is not free to expand, buoyancy will decrease as the balloon rises because of the lesser density of the displaced air. Usually, balloons initially expand when they rise, and, if they don't eventually rupture, fabric stretching reaches a maximum and the balloons settle where buoyancy matches their weight.

CONNECTING TOPIC

MOTION OF FLUIDS

The motion of fluids are of following four types :

(i) Streamline motion : *In a fluid in motion, if fluid particles preceeding or succeeding a fluid particle follow the same path, then the path is called streamline; and then the motion of the fluid is called streamline motion*. This type of motion takes place in non-viscous fluids having very small speed.

Principle of continuity : When incompressible, non-viscous liquid flows in non-uniform tube then in streamline flow product of area and velocity at any section remains same. The mass of liquid flowing in equals the mass flowing out.

i.e., $m_1 = m_2$

or, $v_1 A_1 \rho_1 \Delta t = v_2 A_2 \rho_2 \Delta t$ ..... (1)

As we have considered the fluid incompressible thus,

$v_1 A_1 = v_2 A_2$ or $Av = constant$ ....(2)

Since $\rho_1 = \rho_2$

Equations (1) and (2) are said to be as **equation of continuity**.

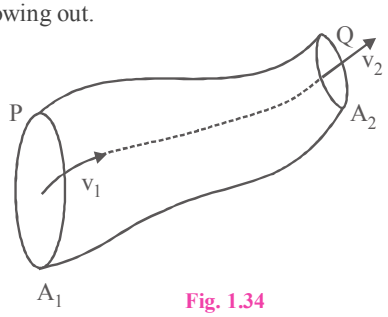


Fig. 1.34

(ii) Steady state motion : *In a liquid in motion, when liquid particles, crossing a point, cross it with same velocity, then the motion of the liquid is called steady state motion*. This type of motion takes place in non-viscous liquids having very small speed.

(iii) Laminar motion : *Viscous liquids flow in bounded region or in a pipe, in layers and when viscous liquid is in motion, different layers have different velocities. The layers in contact with the fixed surface has least velocity and the velocity of other parallel layers increases uniformly and continuously with the distance from the fixed surface to the free surface of the liquid. This is called laminar motion of the liquid.*

(iv) Turbulent motion : *When the velocity of a liquid is irregular, haphazard and large, i.e. Beyond a limiting value called critical velocity the flow of liquid loses steadiness then the motion of the liquid is called turbulent motion.*

$$\text{Critical velocity } V_c = \frac{K\eta}{\rho r}$$

Here η is called coefficient of viscosity.

BERNOULLI'S PRINCIPLE

When incompressible, non-viscous, irrotational liquid i.e., ideal liquid flow from one position to other in streamline path then in its path at every point, the sum of pressure energy, kinetic energy and potential energy per unit volume remains constant.

i.e., $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$ ..... (1)

$\therefore \quad P + \rho g h + \frac{\rho v^2}{2} = constant$

where P = pressure energy per unit volume

ρgh = potential energy per unit volume and

$\frac{1}{2}\rho v^2$ = kinetic energy per unit volume.

The equation (1) is known as **Bernoulli's equation**.

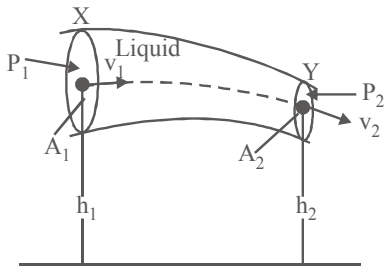


Fig. 1.35

- *A flowing fluid possesses three kinds of energies*
  (i) potential energy
  (ii) kinetic energy and
  (iii) pressure energy
- *Wings of an aeroplane are shaped such that air travel faster over their top surfaces*
- *The curved shape of an umbrella can be disadvantageous on a windy day.*

Fig. 1.36

Applications of Bernoulli's Principle

Venturi-meter : It is a device used for the measurement of rate of flow of incompressible fluid through a tube. The working of venturi-meter is based on Bernoulli's principle.

The rate of flow of fluid

$$V = A_1 A_2 \sqrt{\frac{2gh}{A_1^2 - A_2^2}}$$

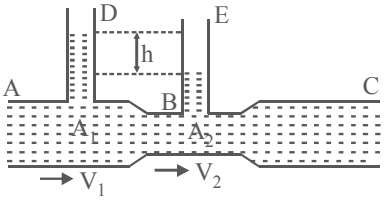


Fig. 1.37

Torricelli's law (speed of efflux) : The speed with which the liquid flows out of an orifice is equal to the speed of a freely falling body, would acquire in falling through a vertical distances equal to the depth of orifice below the free surface of liquid.

i.e., velocity of efflux, $v = \sqrt{2gh}$

Horizontal range, $R = 2\sqrt{hh'}$

The time after which liquid strikes the horizontal surface at the base level of the liquid,

$$t = \sqrt{\frac{2h'}{g}}$$

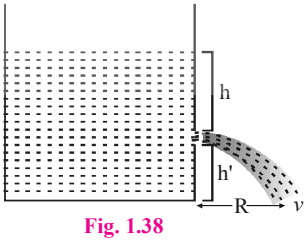
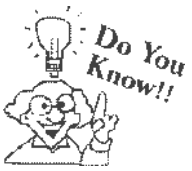


Fig. 1.38

VISCOSITY

If water in a tube is whirled and then left to itself, the motion of the water stops after some time. This is very common observation. What stops the motion? There is no external force to stop it. A natural conclusion is, therefore, that whenever there is relative motion between parts of a fluid, internal forces are set up in the fluid, which oppose the relative motion between the parts in the same way as forces of friction operate when a block of wood is dragged along the ground. To maintain relative motion between layers of a fluid an external force is needed.

"The property of a fluid by virtue of which it opposes the relative motion between its different layers is known as viscosity and the force that is into play is called the viscous force".



Viscous force plays the same role in fluids as the frictional force plays in case of solids. The viscosity of a liquid decreases with increase in temperature but the viscosity of a gas increases with increase in temperature.

SURFACE TENSION

If we place an iron needle slowly on the surface of water it floats on it. Rain drops are spherical in shape, soap water cleans clothes, these phenomena are due to the property of the liquid which is called surface tension. It is the property of a liquid at rest, due to which the top of a liquid contained in a vessel behaves like a stretched membrane occupying minimum surface area.

Examples of surface tension:

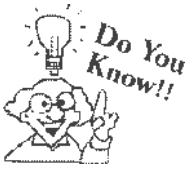
(i) After putting a glass rod in a burner flame its end becomes spherical.

(ii) Rain drops are spherical in shape.

(iii) Soap water cleans clothes well in comparison to impure water.

(iv) Filling the ink in the nib of a pen.

(v) The dancing of camphor on the water surface.



Liquids behave as if there is a skin on their surfaces.

Think it Over

Hair of a brush, when dipped in water spread out; but as soon as it is taken out, its hair cling together. Think of the physics behind it.

Physics Point

SUMMARY

- **Force :** It is an external agent (a push or a pull) which changes or tries to change the state of an object.
  It is a vector quantity and its S.I. unit is newton(N). Its C.G.S. unit is dyne (1 dyne = 10^{-5} newton).
- **The rule of equilibrium :** When the net force acting on a system is zero, it said to be in mechanical equilibrium.
- **Normal force :** The force exerted by the surface on the body placed on it which always acts in a direction perpendicular to the surface is called normal force.
- **Force of friction :** The force acting on two bodies in contact which always opposes their relative motion is called force of friction.
- **First law of motion :** Every object continues in a state of rest or in a state of uniform motion in a straight line, unless it is compelled to change that state by external forces exerted upon it.
- **Inertia :** The property of an object due to which it resist any change in its state of motion is called inertia. It is of three kinds (i) inertia of rest, (ii) inertia of motion and (iii) inertia of direction.
- **Second law of motion :** The acceleration produced by a net force on an object is directly proportional to it and is in the same direction as the net force but is inversely proportional to the mass of the object.
- **Linear momentum :** The product of mass and velocity of a body is called its momentum.
- **Conservation of linear momentum :** It states that in absence of external force, the total linear momentum of a system remains conserved.
- **Third law of motion :** This law states that to every action there is always an equal and opposite reaction.
- **Free fall :** A body falling under the action of gravity only is said to be in free fall.
- **Pressure :** The net force acting over a unit area is called pressure. Pressure $= \frac{\text{force or thrust}}{\text{area}}$.
- **Thrust :** The net force acting normal to a surface is called thrust.
- **Atmospheric pressure :** The pressure caused by the weight of air is called atmospheric pressure. It is generally measured in mm of Hg or cm of Hg by a barometer.
- **Liquid pressure :** The pressure exerted by a liquid column of height h is given by $P = h\rho g$ where, ρ = density of the liquid
- **Total pressure at a point in a liquid :** Total pressure at a point at a depth 'x' from the surface of a liquid is given by
  $P = P_{atm} + \rho g x$ where, P_{atm} = atmospheric pressure
- **Pascal's law:** "The pressure exerted by a liquid at rest is transmitted unchanged and equally in all directions, and acts at right angles to the surface of the container".
- **Buoyancy in a liquid:** When we lift a submerged object out of the water, the weight of the object felt by us is less than its actual weight. This loss in the weight of the object is due to a force called 'buoyant' force and the property of the liquid is called **buoyancy**.
- **Mathematical expression for upthrust :** Upthrust = Volume of object × density of liquid × acceleration due to gravity = $V\rho g$
- **Archimedes' principle:** When an object is partially or wholly immersed in a fluid, it loses some of its weight which is equal to the weight of the displaced fluid.
- **Relative density:** Relative density of a substance is defined as the ratio of its density to the density of water at 4°C.
- **Bernoulli's principle:** If an ideal i.e., non-viscous, incompressible liquid is flowing in a streamlined flow then total energy i.e., sum of pressure energy, kinetic energy and potential energy per unit volume of the liquid remain constant
- **Viscosity :** The property of a fluid by virtue of which it opposes the relative motion between its different layers.
- **Surface tension:** It is the property of a liquid at rest, due to which the top of a liquid contained in a vessel behaves like a stretched membrane occupying minimum surface area.

Physics Point

1 EXERCISE

Fill in the Blanks :

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. A change in the state of rest or of uniform motion is produced by .....
2. 1 newton = ... dyne
3. Frictional force is a ..... force.
4. The change in momentum of a body has the same ..... as that of force applied on it.
5. A car at rest can be moved or a moving car can be stopped by applying.....
6. A body is acted upon by a constant force then it will have a uniform .....
7. When we jump out a boat standing in water it moves .....
8. When a body is travelling at constant velocity, the force on it is .....
9. At constant temperature, the pressure of a gas is inversely proportional to its.....
10. The length of water column that can exert 1 atm pressure is .....
11. The property of a fluid to exert buoyant force on an object immersed in it is known as .....
12. The pressure exerted by mixture of atmospheric gases on its surroundings and on the surface of the earth is known as .....
13. As height of the liquid column increases, the pressure exerted by a liquid at a point .....

True/False :

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Gravitational force and electrostatic force are non-contact forces.
2. If net force acting on a body is zero, it is said to be in equilibrium.
3. If a body is moving with a constant speed along a straight line then in order to change its direction of motion, an external force has to be applied in direction normal to the direction of motion.
4. The area under a force-time graph gives acceleration.
5. It is not advisable to tie any luggage kept on the roof of a bus with rope.
6. As the vertical height from mean sea level increases, the atmospheric pressure decreases.
7. Atmospheric pressure is 1.013×10^5 N/m^2.
8. Liquids exert pressure in all directions.
9. Archimedes' principle is a consequence of the conservation of energy.

Match the Following :

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D)in Column I have to be matched with statements (p, q, r, s) in Column II.*

1.

Column-I	Column-II
(A) Contact force	(p) Electrostatic
(B) Non-contact force	(q) Gravity
(C) Weight	(r) Max. at sea level
(D) Atmospheric pressure	(s) Friction

2.

Column I	Column II
(A) dyne/cm^2	(p) 760 mm of Hg
(B) 76 cm of Hg	(q) Nm^{-2}
(C) 1 Pa	(r) 1.013×10^{-5} Nm^{-2}
(D) 1 atm	(s) 10^{-1} Nm^{-2}

Very Short Answer Questions :

DIRECTIONS : *Give answer in one word or one sentence.*

1. Define force.
2. Is acceleration directly proportional to force, or is it inversely proportional to force?
3. Does a heavy object accelerate more than a light object when both are freely falling?
4. What is the net force that acts on a 10-N falling object with it encounters 4N of air resistance?
5. If body A and body B are both within a system, can forces between them affect the acceleration of the system?
6. Define atmospheric pressure.
7. Which instrument is used to measure atmospheric pressure?
8. Give two examples each of contact and non-contact force.
9. Give the expression for the pressure at a point inside a liquid.

Short Answer Questions :

DIRECTIONS : *Give answer in two to three sentences.*

1. State three effects that a force can produce.
2. When two horizontal forces are exerted on a cart, 600 N forward and 400N backward, the cart undergoes acceleration. What additional force is needed to produce non-accelerated motions?
3. If mass of 1 kg is accelerated 1 m/s^2 by a force of 1 N, what would be the acceleration of 2 kg acted on by a force of 2 N?
4. A boxer punches a sheet of paper in midair, and thereby brings it from rest upto a speed of 25 m/s in 0.5 second. If the mass of the paper is 0.003 kg, what force does the boxer exert on it?

Physics Point

5. Suppose that you are standing on a skateboard near a wall and that you push on the wall with a force of 30 N. How hard does the wall with a force of push you?
6. Forces of 3 N and 4 N act at right angles on a block of mass 5 kg. How much acceleration occurs?
7. Define force. Write its S.I. and C.G. S. unit.
8. Define pressure. Write its S.I. unit.
9. A nail has 2 cm^2 at one end and $\frac{1}{100}$ cm^2 at the other end. A force of 1000 gwt is applied on the first end. Calculate the pressure acting on the wall?
10. A liquid of mass 200 g exerts a pressure of 0.1 Pa at a bottom of container. What pressure would it exert if the area of cross section of container is doubled?

Long Answer Questions :

DIRECTIONS : *Give answer in four to five sentences.*

1. State Newton's second law of motion. How does it help to measure force. Also state the units of force.
2. State Newton's third law of motion. Discuss its consequences.
3. A sphere of relative density σ and diameter d has concentric cavity of diameter D. What is the ratio of d/D if it just floats on water in a tank?
4. A truck of mass M is moved under a force F. If the truck is then loaded with an object equal to the mass of the truck and the driving force is halved, then how does the acceleration change?
5. Why gas filled balloons rise up, only to a certain height?

2 EXERCISE

Text-Book Exercise :

1. Give two examples each of situations in which you push or pull to change the state of motion of objects.
2. Give two examples of situations in which applied force causes a change in the shape of an object.
3. Fill in the blanks in the following statements:
   (a) To draw water from a well we have to _____ at the rope.
   (b) A charged body _____ an uncharged body towards it.
   (c) To move a loaded trolley we have to _____ it.
   (d) The north pole of a magnet _____ the north pole of another magnet.
4. An archer stretches her bow while taking aim at the target, She then releases the arrow, which begins to move towards the target. Based on this information fill up the gaps in the following statements using the following terms:

   Muscular, contact, non-contact, gravity, friction, shape, attraction

   (a) To stretch the bow, the archer applies a force that causes a change in its _____.
   (b) The force applied by the archer to stretch the bow is an example of ____ force.
   (c) The type of force responsible for a change in the state of motion of the arrow is an example of a _____ force.
   (d) While the arrow moves towards its target, the forces acting on it are due to _____ and that due to _____ of air.
5. In the following situations, identify the agent exerting the force and the object on which it acts. State the effect of the force in each case.
   (a) Squeezing a piece of lemon between the fingers to extract its juice.
   (b) Taking out paste from a toothpaste tube.
   (c) A load suspended from a spring while its other end is on a hook fixed to a wall.
   (d) An athlete making a high jump to clear the bar at a certain height.
6. A blacksmith hammers a hot piece of iron while making a tool. How does the force due to hammering affect the piece of iron?
7. An inflated balloon was pressed against a wall after it has been rubbed with a piece of synthetic cloth. It was found that the balloon sticks to the wall. What force might be responsible for the attraction between the balloon and the wall?
8. Name the forces acting on a plastic bucket containing water held above ground level in your hand. Discuss why the forces acting on the bucket do not bring a change in its state of motion.
9. A rocket has been fired upwards to launch a satellite in its orbit. Name the two forces acting on the rocket immediately after leaving the launching pad.
10. When we press the bulb of a dropper with its nozzle kept in water, air in the dropper is seen to escape in the form of bubbles. Once we release the pressure on the bulb, water gets filled in the dropper. The rise of water in the dropper is due to
    (a) pressure of water (b) gravity of the earth
    (c) shape of rubber bulb (d) atmospheric pressure

Exemplar Questions :

1. Two persons are applying forces on two opposite sides of a moving cart. The cart still moves with the same speed in the same direction. What do you infer about the magnitudes and direction of the forces applied.

2. 

Fig. shows a man with a parachute. Name the force which is responsible for his downward motion. Will he come down with the same speed without the parachute?

3. Fruits detached from a tree fall down due to force of gravity. We know that a force arises due to interaction between two objects. Name the objects interacting in this case.

4. An archer shoots an arrow in the air horizontally. However, after moving some distance, the arrow falls to the ground. Name the initial force that sets the arrow in motion. Explain why the arrow ultimately falls down.

5. Two women are of the same weight. One wears sandals with pointed heels while the other wears sandals with flat soles. Which one would feel more comfortable while walking on a sandy beach? Give reasons for your answer.

Hots Questions :

1. An athelete runs same distance before taking a jump. Explain why?

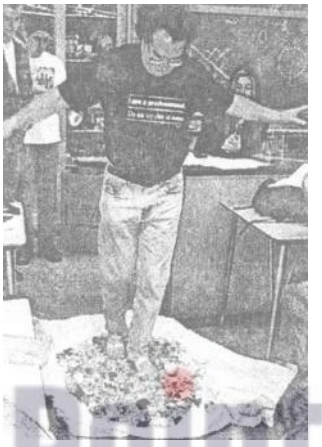
2. What is the angle between frictional force and instantaneous velocity of the body moving over a rough surface?

3. (a) According to Newton's third law of motion, every force is accompanied by an equal (in magnitude) and opposite (in direction) force called reaction, then how can a movement takes place?

   (b) You can move a brick easily by pushing it with your foot on a smooth floor, but, if you kick it, then your foot is hurt. Why?

4. Why is it easier to maintain the motion than to start it?

5. The photo shows the Physics teacher Mr. Chaurasiya walking barefoot on broken glass bottles in his class. What concept is he demonstrating, and why is he carefull that broken pieces are small and numerous?

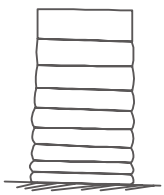


6. When a vessel containing a liquid is falling freely, does Archimedes's principle hold good in it?

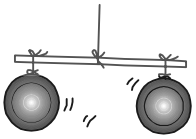
7. A block of wood floats in a bucket of water in a lift. Will there be any change in the equilibrium of wood if the lift starts accelerating upwards?

8. Why is the water reservoir of a dam thicker at the bottom?

9. We can understand how pressure in water depends on depth by considering a stack of bricks. The pressure below the bottom brick is determined by the weight of the entire stack. Halfway up the stack, the pressure is half because the weight of the bricks above is half. To explain atmospheric pressure, we should consider compressible bricks like foam rubber. Why is this so?



10. Two identical balloons of the same volumes are pumped up air to more than atmospheric pressure and suspended on the ends of a stick that is horizontally balanced. One of the balloons is then punctured. Is there a change in stick's balance? If so, which way does it trip?



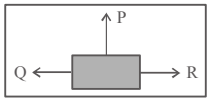
Physics Point

3 EXERCISE

Single Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

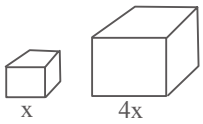
1. Three persons P, Q and R pull block with equal forces as shown in figure. Identify the direction of motion of the block?



(a) In horizontal direction towards left.
(b) In horizontal direction towards right.
(c) In vertically upward direction.
(d) The block remains stationary.

2. Which of the following is an example of a non-contact force?
(a) Muscular force (b) Frictional force
(c) Magnetic force (d) None of these

3. A cube of side 'x' rests on the floor as shown in the figure. Given that the pressure exerted by this cube on the floor is P, what is the pressure exerted by another cube of the same material of side 4x? (Take $g = 10\ N kg^{-1}$)



(a) P (b) 2P
(c) 4P (d) 16P

4. When a body is stationary, then
(a) there is no force acting on it
(b) the body is in vacuum
(c) the force acting on it is not in contact with it
(d) the net forces acting on it balances each other

5. An object will continue moving uniformly when
(a) the resultant force on it is increasing continuously
(b) the resultant force is at right angles to its rotation
(c) the resultant force on it is zero
(d) the resultant force on it begins to decrease

6. The force exerted by the floor of an elevator on the foot of a person standing there, is more than his weight, if the elevator is
(a) going down and slowing down
(b) going up and speeding up
(c) going up and slowing down
(d) either (a) and (b)

7. Pressure at a point inside a liquid does not depend on
(a) the depth of the point below the surface of the liquid
(b) the nature of the liquid
(c) the acceleration due to gravity at that point
(d) the shape of the containing vessel

8. Pressure varies with force (F) as (provided area is same)
(a) F (b) $\frac{1}{F}$ (c) F^2 (d) $\frac{1}{F^2}$

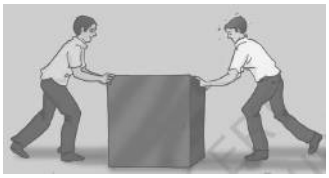
9. The pressure exerted by a women wearing shoes with pointed heels is ..... than what an elephant with one foot can exert on ground
(a) much lesser (b) much greater
(c) both equal (d) none of these

10. Liquid pressure at a point in a liquid does not depend on the
(a) density of liquid
(b) shape of the vessel in which the liquid is kept
(c) depth of the point from the surface
(d) acceleration due to gravity

11. Pressure at a certain depth in river water is P_1 and at the same depth in sea water is P_2. Then (density of sea water is greater than that of river water)
(a) $P_1 = P_2$ (b) $P_1 > P_2$
(c) $P_1 < P_2$ (d) $P_1 - P_2$ = atmospheric pressure

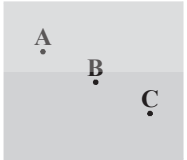
12. If the force on the surface is doubled and area is reduced to half, pressure will
(a) become 2 times (b) become 3 times
(c) become 4 times (d) remain unchanged

13. In Fig. two boys A and B are shown applying force on a block. If the block moves towards the right, which one of the following statements is correct?



(a) Magnitude of force applied by A is greater than that of B.
(b) Magnitude of force applied by A is smaller than that of B.
(c) Net force on the block is towards A.
(d) Magnitude of force applied by A is equal to that of B.

14. Fig. shows a container filled with water. Which of the following statements is correct about pressure of water?



(a) Pressure at A> Pressure at B> Pressure at C
(b) Pressure at A=Pressure at B=Pressure at C
(c) Pressure at A< Pressure at B>Pressure at C
(d) Pressure at A< Pressure at B<Pressure at C

Physics Point

15. A force of 100 N acts on a body of mass 2 kg for 10 s. The change in momentum of the body is
(a) 100 N –s (b) 250 N–s
(c) 500 N–s (d) 1000 N–s

16. A man is at rest in the middle of a pond of perfectly smooth ice. He can get himself to the shore by making use of Newton's
(a) First law (b) Second law
(c) Third law (d) All the laws

17. A cannon after firing recoils due to
(a) Conservation of energy
(b) Backward thrust of gases produced
(c) Newton's third law of motion
(d) Newton's first law of motion

18. A body of mass 4 kg moving on a horizontal surface with an initial velocity of 6 ms^{-1} comes to rest after 3 seconds. If one wants to keep the body moving on the same surface with the velocity of 6 ms^{-1}, the force required is
(a) Zero (b) 4 N
(c) 8 N (d) 16 N

19. A force of 10 N acts on a body of mass 20 kg for 10 seconds. Change in its momentum is
(a) 5 kg m/s (b) 100 kg m/s
(c) 200 kg m/s (d) 1000 kg m/s

20. When an object is made to float in two different liquids of density d_1 and d_2, the lenght of the object seen above the liquid surface are l_1 and l_2 respectevely. Which of the following is the correct alternative?
(a) $d_1 > d_2$ if $l_1 > l_2$ (b) $d_1 > d_2$ if $l_2 > l_1$
(c) $d_1 < d_2$ if $l_1 > l_2$ (d) $d_1 < d_2$ if $l_2 > l_1$

21. When an object of weight W is immersed in a liquid, its weight in the liquid is found to be W_1. When it is immersed in water, the weight of the water displaced is found to be W_2. The relative density of the liquid is
(a) $\frac{W_2}{W_1}$ (b) $\frac{W - W_1}{W_2}$
(c) $\frac{W_2}{W - W_1}$ (d) $\frac{W - W_2}{W_1}$

22. A solid cylinder of density 800 kg m^{-3} floats in water. The percentage volume of solid cylinder outside the water is
(a) 10 (b) 80
(c) 50 (d) 20

23. When a body of density ρ and volume V is floating in a liquid of density
(a) its true weight is $V\sigma g$
(b) loss in its weight is $V\sigma g$
(c) its apparent weight is zero
(d) its density ρ is greater than that of liquid σ

24. Two pieces of metal when immersed in a liquid have equal upthrust on them; then
(a) both pieces must have equal weights
(b) both pieces must have equal densities
(c) both pieces must have equal volumes
(d) both are floating to the same depth

25. The apparent weight of wood floating on water if it weighs 100 g in air is
(a) 400 g (b) 300 g
(c) 100 g (d) zero

26. An egg when placed in ordinary water sinks but floats when placed in brine. This is because
(a) density of brine is less than that of ordinary water
(b) density of brine is equal to that of ordinary water
(c) density of brine is greater than that of ordinary water
(d) None of these

27. Two pieces of metals are suspended from the arms of a balance and are found to be in equilibrium when kept immersed in water. The mass of one piece is 32 g and its density 8 g cm^{-3}. The density of the other is 5 g per cm^3. Then the mass of the other is
(a) 28 g (b) 35 g
(c) 21 g (d) 33.6 g

28. A man is sitting in a boat which is floating in pond. If the man drinks some water from the pond, the level of water in the pond will
(a) rise a little (b) fall a little
(c) remain stationary (d) none of these

29. A man is walking from east to west on a level rough surface. The frictional force on the man is directed
(a) from the west to east (b) from the east to west
(c) along the north (d) along the west

30. A spring balance is graduated on sea level. If a body is weighted at consecutively increased height from earth's surface, the weight indicated by the balance
(a) will go on increasing continuously
(b) will go on decreasing continuously
(c) will remain same
(d) will first increase and then decrease

31. A sample of metal weighs 210 g in air, 140 g in water and 120 g in an unknown liquid. Then
(a) the density of the metal is 3 g/cm^3
(b) the density of the metal is 7 g/cm^3
(c) density of the metal is 4 times the density of unknown liquid
(d) the metal still float in water

Physics Point

More than One Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Two similar buses are moving with same velocity on a straight road. One of them is empty and the other is loaded with passengers
- (a) Both buses are stopped by the application of same force
- (b) Loaded bus will be stopped by applying large force
- (c) Loaded bus will be stopped by applying less force
- (d) Empty buses will be stopped by applying less force and loaded bus will be stopped by appplying large force.

2. Which of the following action cannot be describes as pushing by a body ?
- (a) kicking (b) lifting
- (c) picking (d) opening

3. Choose the correct options
- (a) A force is applied to an object in the direction of its motion. The speed of object will increase
- (b) If no force acts on a body it will either remain in rest or move in a straight line
- (c) Friction force can change speed of an object
- (d) None of these

4. Choose the correct options ?
- (a) A body floats in water because the net force acting on this body is zero
- (b) A mountain climber experiences a nose bleed due to increase in atmospheric pressure
- (c) A body floats in water because the net force acting on this body is non-zero
- (d) A mountain climber experiences a nose bleed due to decrease in atmospheric pressure

5. Pressure at a point in a fluid is directly proportional to
- (a) depth of the point from the surface
- (b) density of the fluid
- (c) acceleration due to gravity
- (d) the area of cross section

6. Which of the following factors affect pressure?
- (a) Area (b) Acceleration
- (c) Force (d) Current

7. Which of the following statements are true?
- (a) When the mass of a body is doubled then the momentum of a body is also doubled, provided the body maintains the same velocity
- (b) We feel pain in the hand on hitting the wall, this is a consequence of Newton's third law of motion.
- (c) A table cloth can be pulled from the table without dislodging the dishes. This is due to inertia of rest.
- (d) Momentum is a vector quantity.

8. A large truck and a car, both moving with a velocity of same magnitude have a head-on-collision. Car suffers more damage than the truck. This is because
- (a) the material used in car is inferior than the material used in truck.
- (b) car experience the greater force of impact than the truck.
- (c) momentum transferred to the truck is greater than the momentum transferred to the car
- (d) momentum transferred to the car is greater than the momentum transferred to the truck.

9. Choose the correct options
- (a) An object of mass 10g acquires a speed of 100m/s after 1 second. If the force acting on the object is constant, its magnitude will be 1N.
- (b) If a force of 2.5N acts on a body of mass 0.5 kg, then the acceleration produced in the body would be 5 m/s^2.
- (c) An object of mass 10g acquires a speed of 100m/s after 1 second. If the force acting on the object is constant, its magnitude will be 2N.
- (d) If a force of 2.5N acts on a body of mass 0.5 kg, then the acceleration produced in the body would be 2.5 m/s^2.

Multiple Matching Questions :

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r , s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

	Column-I	Column-II
A.	Force	(p) non-contact force
B.	Change in object	(q) contact force
C.	Magnet pulling iron pins	(r) air pressure
D.	Pulling the window pane	(s) effect
E.	Bloating of tube of cycle tyre	(t) cause

2.

	Column-I	Column-II
A.	Going up an inclined plane is more tiring than walking on a horizontal plane	(p) Magnetic force
B.	It is difficult to inflate balloon beyond a certain point	(q) Pressure
C.	Waling on a sanday beach is more tiring than waling on a road	(r) Gravitational Force
D.	A compass needle always point in the north-south direction	(s) Friction

Physics Point

3.

Column A	Column B
A. Thrust	(p) F/A
B. Pressure	(q) Force
C. Atmospheric pressure	(r) Pascal
D. Fluid pressure acts	(s) Decrease with altitude
	(t) In downward direction

Passage Based Questions :

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Liquid pressure in a container doesn't depend on the shape of the container but it only depends on the height of the liquid column.

1. A cylinderical container is full of water. The pressure will be maximum at

(a) top surface (b) mid of container

(c) bottom (d) None of these

2. If half of the water is taken out, what is the pressure at the bottom? (P = pressure when container full of liquid)

(a) P (b) $\frac{1}{2}P$

(c) $\frac{3}{2}P$ (d) $2P$

Assertion & Reason :

DIRECTIONS : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.

(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.

(c) If **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** The acceleration produced by a force in the motion of a body depends only upon its mass.

Reason : Larger is the mass of the body, lesser will be the acceleration produced.

2. **Assertion :** If the net external force on the body is zero, then its acceleration is zero.

Reason : Acceleration does not depend on force.

3. **Assertion :** An object can move with constant velocity if no net force acts on it.

Reason : No net force is needed to move an object with constant velocity.

4. **Assertion :** The pressure at a point is the ratio of force to the area on which force is acting.

Reason : Pressure is the thrust acting per unit area.

Integer/Numeric type Questions :

DIRECTIONS : *Following are integer based/Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

1. A force produces an acceleration of 16 m/s^2 in a body of mass 0.5 kg, and an acceleration of 4 m/s^2 in another body. If both the bodies are fastened together, the acceleration produced by that force is (1.6)x m/s^2. Find the value of x.

2. A 20 gm bullet moving at 300 m/s stops after penetrating 3 cm of bone. The average force exerted by the bullet is $-x \times 10^4$ N. Find the value of x.

3. A rocket of initial mass 6000 kg ejects mass at a constant rate of 16 kg/s with constant relative speed of 11 km/s. What is the acceleration of the rocket one minute after blast?

4. If the water pressure gauge shows the pressure at ground floor to be 270 k Pa, 3x metre high would water rise in the pipes of a building. Find the value of x.

5. A water tank is 20 m deep. What is the pressure at the bottom of the tank in atmosphere?

Physics Point

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

DIRECTIONS (Qs. 1–24) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. China wares are wraped in straw of paper before packing. This is the application of concept of
(a) impulse (b) momentum
(c) acceleration (d) force

2. The impulse of a body is equal to
(a) rate of change of its momentum
(b) change in its momentum
(c) the product of force applied on it and the time of application of the force.
(d) both (b) and (c)

3. A bullet of mass 20 g is fired from a rifle of 8 kg with a velocity of 100 m s^{-1}. The velocity of recoil of the rifle is
(a) 0.25 m s^{-1} (b) 25 m s^{-1}
(c) 2.5 m s^{-1} (d) 250 m s^{-1}

4. Conservation of linear momentum is equivalent to
(a) Newton's first law of motion
(b) Newton's second law of motion
(c) Newton's third law of motion
(d) None of these

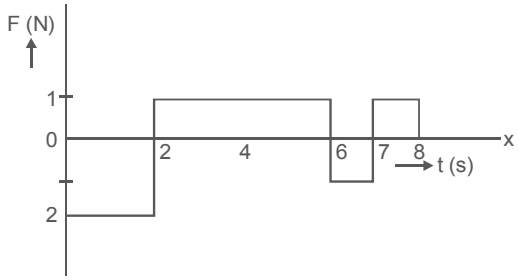
5. If two balls each of mass 0.06 kg moving in opposite direction with speed of 4 m s^{-1} collide and rebound with same speed, then the impulse imparted to each ball due to other is
(a) 0.48 kg m s^{-1} (b) 0.53 kg m s^{-1}
(c) 0.81 kg m s^{-1} (d) 0.92 kg m s^{-1}

6. When an elevator cabin falls down, the cabin and all the bodies fixed in the cabin are accelerated with respect to
(a) ceiling of elevator
(b) floor of elevator
(c) man standing on earth
(d) man standing in the cabin

7. The tension in the cable of 1000 kg elevator is 1000 kg wt, the elevator
(a) is ascending upwards
(b) is descending downwards
(c) may be at rest or accelerating
(d) may be at rest or in uniform motion

8. Consider an elevator moving downwards with an acceleration a, the force exerted by a passenger of mass m on the floor of the elevator is
(a) ma (b) $ma - mg$
(c) $mg - ma$ (d) $mg + ma$

9. A force time graph for the motion of a body is shown in Fig.. Change in linear momentum between 0 and 8s is



(a) zero (b) 4 N-s
(c) 8 Ns (d) None of these

10. Kerosene oil rises up in a wick of a lantern because of
(a) Diffusion of the oil through the wick
(b) Surface tension
(c) Buoyant force of air
(d) the gravitational pull of the wick

11. In a stream line (laminar flow) the velocity of flow at any point in the liquid
(a) does not vary with time
(b) may vary in direction but not in magnitude
(c) may vary in magnitude but not in direction
(d) may vary both in magnitude and direction

12. Water is flowing through a horizontal pipe in streamline flow. At the narrowest part of the pipe
(a) Velocity is maximum and pressure is minimum
(b) Pressure is maximum and velocity is minimum
(c) Both the pressure and velocity are maximum
(d) Both the velocity and pressure are minimum

13. The constant velocity attained by a body while falling through a viscous medium is termed as :
(a) critical velocity (b) terminal velocity
(c) threshold velocity (d) none of these

14. The difference between viscosity and solid friction is
(a) viscosity depends on area while solid friction does not.
(b) viscosity depends on nature of material but solid friction does not.
(c) both (a) and (b)
(d) neither (a) nor (b)

Physics Point

15. If r is the radius of influence of molecules of a certain liquid, then thickness of its surface film is

(a) r (b) $\frac{r}{2}$

(c) $2r$ (d) none of these

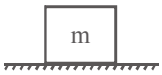
16. Bernoulli's theorems explains the phenomenon of

(a) blowing of roob's due to wind
(b) spinning of ball
(c) dynamic lift of aeroplane
(d) all of these

17. Toricelli's theorem is used to find :

(a) the velocity of efflux through an orifice.
(b) the velocity of flow of liquid through a pipe.
(c) terminal velocity
(d) critical velocity.

18. A block of mass m is placed on a smooth horizontal surface as shown. The weight (mg) of the block and normal reaction (N) exerted by the surface on the block



(a) form action-reaction pair
(b) balance each other
(c) act in same direction
(d) both (a) and (b)

19. A pin of density greater than that of water can float on the surface of water. It is due to :

(a) viscosity (b) buoyancy
(c) surface tension (d) none of these

20. With increase in temperature, the viscosity of gases :

(a) increases
(b) decrease
(c) remains same
(d) depends on the nature of the gas.

21. Paint-gun is based on :

(a) Bernoullis theorem
(b) Archimede's principle
(c) Boyle's law
(d) Pascal's law

22. Water is flowing through a horizontal pipe having a restriction, then

(a) Pressure will be greater at the restriction.
(b) Pressure will be greater in the wider portion.
(c) Pressure will be same through out the length of the pipe
(d) none of the above

23. The direction of impulse is

(a) same as that of the net force
(b) opposite to that of the net force
(c) same as that of the final velocity
(d) same as that of the initial velocity

24. A monkey is climbing up a rope, then the tension inthe rope.

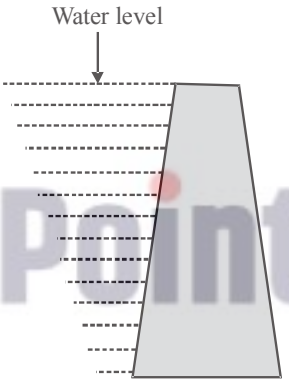
(a) must be equal to the force applied by the monkey on the rope.
(b) must be less than the force applied by the monkey on the rope.
(c) must be greater than the force applied by the monkey on the rope.
(d) may be equal to, less than or greater the force applied by the monkey on the rope.

DIRECTIONS (Qs. 25–27): *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which one or more may be correct.*

25. Which of the following statements are correct regarding linear momentum of a body?

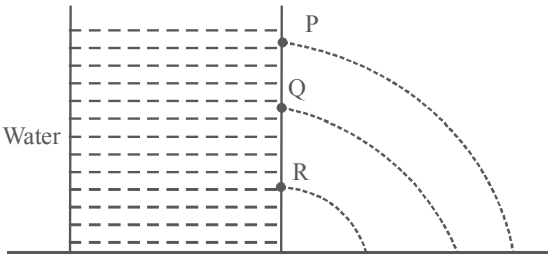
(a) It is measure of quantity of motion contained by the body
(b) Change in momentum is the measurement of impulse
(c) Impulse and acceleration act in same direction to the change in momentum
(d) In case of uniform circular motion, the linear momentum is conserved

26. The given figure shows the cross section of a dam and its reservoir. Choose the correct options



(a) The widening of the wall, towards the bottom is because of increase in pressure with depth of water.
(b) The widening of the wall, towards the bottom is because of decrease in pressure with depth of water.
(c) Torque about the base tries to turn the dam.
(d) None of these

27. Choose the correct statements from the figure ?



(a) water flowing through hole P will move a smaller distance as compared to Q and R
(b) water flowing through hole Q will be maximum
(c) water flowing through R will be more than Q but less than p
(d) water flowing through all holes will travel same distance as pressure exerted by a liquid is equal in all direction

Physics Point

DIRECTIONS (Qs. 28-29) : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r , s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

28.

Column I	Column II
(A) Action and reaction	(p) Rate in change of momentum
(B) Impulse	(q) Vector
(C) Force	(r) On two different bodies
(D) Momentum	(s) In opposite direction
	(t) Force for a very short time

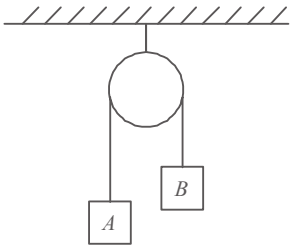
29.

Column A	Column B
(A) 1 atm	(p) newton
(B) Buoyant force	(q) 10^5 Pa
(C) Thrust	(r) bar
(D) Hydrometer	(s) upthrust
	(t) fluid pressure

DIRECTIONS (Qs. 30–32) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Two blocks A and B of mass 2 kg and 3 kg respectively are connected with the help of a massless, inextensible string passing over a smooth pulley as shown, The system is released from rest at $t = 0$, then: (take $g = 10\ ms^{-2}$)



30. Acceleration of blocks is
(a) $5\ ms^{-2}$ (b) $2\ ms^{-2}$
(c) $20/3\ ms^{-2}$ (d) $6\ ms^{-2}$

31. If at t = 1s, block B is stopped momentarily and released, after how much time will the string become taut again?
(a) 0.2s (b) 0.4s
(c) 0.5s (d) 1s

32. What will be the velocity of the blocks, just after the string becomes taut?
(a) $0.2\ ms^{-1}$ (b) $0.4\ ms^{-1}$
(c) $1\ ms^{-1}$ (d) $2\ ms^{-1}$

DIRECTIONS (Qs. 33–37) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements..*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

33. **Assertion :** A rocket works on the principle of conservation of linear momentum.
Reason : Whenever there is change in momentum of one body, the same change occurs in the momentum of the second body of the same system but in the opposite direction.

34. **Assertion :** Inertia of an object of mass 10 kg is greater than the inertia of an object of mass 5 kg.
Reason : Inertia is inversely proportional to the mass of an object.

35. **Assertion :** Smaller the droplets of water, spherical they are.
Reason : Force of surface tension is equal, and opposite to force of gravity.

36. **Assertion :** The velocity of flow of a liquid is smaller when pressure is larger and vice-versa.
Reason : According to Bernoulli's theorem, for the stream line flow of an ideal liquid, the total energy per unit mass remains constant.

37. **Assertion :** Falling raindrops acquire a terminal velocity.
Reason : A constant force in the direction of motion and a velocity dependent force opposite to the direction of motion, always result in the acquisition of terminal velocity.

DIRECTIONS (Qs. 38 - 41) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

38. A body of mass 1 kg moving with a uniform velocity of $1\ ms^{-1}$. If the value of g is $5\ ms^{-2}$, then find the force acting on the frictionless horizontal surface on which the body is moving.

39. Two blocks of masses 2 kg and 1 kg are placed on a smooth horizontal table in contact with each other. A horizontal force of 3 newton is applied on the first so that the block moves with a constant acceleration. Find the force between the blocks would be

40. A cubical block is floating in a liquid with $\frac{3}{4}$ of its volume immersed in the liquid. When the whole system accelerates downwards with a net acceleration of g/4, the fraction of volume immersed in the liquid $\frac{3}{x}$. Find the value of x.

41. A cylindrical body of area of cross-section 100 cm^2 and length 4 cm is immersed in a liquid whose density is 1.5 $g\,cm^{-3}$. If the density of the solid is 2 $g\,cm^{-3}$, calculate the upthrust acting on the body.

SOLUTIONS

Brief Explanations of Selected Questions

1 EXERCISE

FILL IN THE BLANKS :

1. net external force
2. 10^5
3. contact
4. direction
5. external unbalanced force
6. acceleration
7. backwards
8. zero
9. volume
10. 10.336 m
11. buoyancy
12. atmospheric pressure
13. increases

TRUE/FALSE :

1. True
2. True
3. True
4. False
5. False
6. True
7. True
8. True
9. False

MATCH THE COLUMNS :

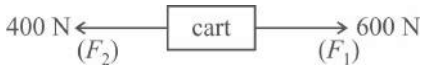
1. A → (s), B → (p), C → (q), D → (r)
2. A → (s), B → (p), C → (q), D → (r)

VERY SHORT ANSWER QUESTIONS :

1. Force is an external agent which changes or tries to change the state of an object
2. The acceleration is directly proportional to force and not inversely related.
3. No, both will accelerate with same acceleration, $g = 9.8\ m/s^2$
4. The net force will be $F_1 - F_2 = 10\ N - 4\ N = 6\ N$
5. No, if two bodies A and B are within a system, then their mutual forces are equal and opposite and cancel each other so that they do not affect the acceleration of the system.
6. The pressure exerted by air.
7. Barometer
8. **Contact force :** Frictional force and muscular force.
   Non-contact force : Gravitational force and electrostatic force.
9. $P = \rho gh$

SHORT ANSWER QUESTIONS :

1. Effects produced by a force. :
   (i) Force can change speed of an object.
   (ii) Force can change the direction of motion of an object.
   (iii) Force can change the shape of an object.
2. Two horizontal forces are acting on a cart in opposite directions as shown below



Thus the net force is, $F_1 - F_2 = 600 - 400$

$= 200\ N$

This net force is in the forward direction. This force produces acceleration in the forward direction. Hence to produce non-accelerated motion, an equal and opposite force must be applied to make the net force on the cart zero. Thus, required force = 200 N in the backward direction.

3. As we know,

$$\text{acceleration} = \frac{\text{force}}{\text{mass}}$$

A mass of 1 kg experiences an acceleration of 1 m/s^2 under a force of 1 N using above formula.

For a mass of 2 kg, under a force of 2 N, acceleration will be given by

$$\text{acceleration} = \frac{\text{force}}{\text{mass}} = \frac{2\ N}{2\ kg} = 1\ m/s^2$$

Thus the mass of 2 kg accelerates by 1 m/s^2 under a force of 2 N.

4. $a = \frac{25}{0.5}\ m/s^2 = 50\ m/s^2$ use formula $F = ma = 0.15\ N$

5. We are standing on a skateboard and pushing the wall. The wall in turn pushes us back. These two forces form an action-reaction pair. By Newton's third law these two forces are equal and opposite of each other. This means that the wall pushes us with an equal amount of force = 30*N* in a direction away from the wall.

6. Let us assume that there is a mass '*m*' = 5 *kg* which is acted upon by two forces at right angles to each other as shown in figure.

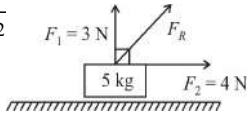
The first force is $F_1 = 3N$ acting in vertical direction.

The second force is $F_2 = 4N$ acting in horizontal direction.

These two force form two adjacent sides of a rectangle and their resultant force 'F_R' can be calculated using parallelogram law of vectors as

$$F_R = \sqrt{F_1^2 + F_2^2} = \sqrt{3^2 + 4^2}$$

$$\Rightarrow F_R = \sqrt{9 + 16} = 5\ N$$



A net force of 5 N acts on the mass at an angle inclined to it.
Now by Newton's second law

$$\text{acceleration of the mass} = \frac{\text{force on the mass}}{\text{mass of the body}}$$

$$= \frac{5\text{ N}}{5\text{ kg}} = 1\text{ m/s}^2$$

$\Rightarrow$ The mass will accelerate at a rate of 1 m/s^2.

10. $\text{Pressure} = \frac{\text{force}}{\text{area}}$

LONG ANSWER QUESTIONS :

1. Newton's second law of motion states that the rate of change of momentum of a rigid body is directly proportional to the applied force on it.
The law implies that when a bigger force is applied on a body of given mass, its linear momentum changes faster and vice-versa. The momentum will change in the direction of the applied force.
Let, m = mass of a body,
$\vec{v}$ = velocity of the body
$\therefore$ The linear momentum of the body

$$\vec{p} = m\vec{v} \qquad \text{...(i)}$$

Now, suppose $\vec{F}$ = external force applied on the body in the direction of motion of the body.
$\Delta\vec{p}$ = a small change in linear momentum of the body in a small time Δt.
Rate of change of linear momentum of the body

$$= \frac{\Delta\vec{p}}{\Delta t}$$

According to Newton's second law,

$$\frac{\Delta\vec{p}}{\Delta t} \alpha \vec{F} \text{ or } \vec{F} \alpha \frac{\Delta\vec{p}}{\Delta t}$$

$$\text{or } \vec{F} = k\frac{\Delta\vec{p}}{\Delta t} \qquad \text{...(ii)}$$

where k is a constant of proportionality.
Taking the limit $\Delta T \to 0$, the term $\frac{\Delta\vec{p}}{\Delta t}$ becomes the derivative or differential coefficient of $\vec{p}$ w.r.t. time t. It is denoted by $\frac{d\vec{p}}{dt}$.

$$\therefore \vec{F} = k\frac{d\vec{p}}{dt}$$

Using eqn (i) $\vec{F} = k\frac{d}{dt}(m\vec{v}) = km\frac{d\vec{v}}{dt}$

$$\vec{F} = km\vec{a} \qquad \text{...(iii)}$$

where $\vec{a} = \frac{d\vec{v}}{dt}$ represents acceleration of the body.
The value of constant of proportionality k depends on the units adopted for measuring the force.
Now, putting $k = 1$

$\vec{F} = m\vec{a}$, This gives mean of measuring force.

Units of Force : Force in SI units is measured in 'Newton' or N. From the relation $\vec{F} = m\vec{a}$, we can see that a newton force is that force which produces 1 ms^{-2} acceleration in a body of mass 1 kg.
1 newton = 1 kilogram × 1 metre/second^2
$\Rightarrow$ 1 N = 1kg × 1 ms^{-2} = 1 kg ms^{-2}
In CGS system, force is measured in 'dyne'.
1 dyne = 1 gram × 1 cm s^{-2} = 1g cm s^{-2}
Since 1 N = 1kg ms^{-2} = 1000 g × 100 cm s^{-2}
= 10^5 g cm s^{-2} = 10^5 dyne.
$\Rightarrow$ 1 N = 10^5 dyne.
or 1 dyne = 10^{-5} N.

2. Newton's third law of motion states that for any action, there is equal and opposite reaction.
So, if a body applies a force F_{12} on body 2 (action), then body 2 also applies a force F_{21} on body 1 but in opposite direction, then

$$F_{21} = -F_{12}$$

In terms of magnitude

$$|F_{21}| = |F_{12}|$$

It is very important to note that F_{12} and F_{21} though are equal in magnitude and opposite in direction yet act on different point or else no motion will be possible.
For example, hands pull up a chest expander (spring) and spring in turn exerts force on the arms. A football pressed reacts on the foot with the same force and so on.
The most important consequence of the third law of motion is the law of conservation of linear momentum and its application in collision problems.

Since $F_{12} = -F_{21}$ and $F = m\frac{\Delta v}{\Delta t}$

$$\therefore m_1\frac{\Delta v_1}{\Delta t} = -m_2\frac{\Delta v_2}{\Delta t}$$

Here Δt is the time for which the bodies come in contact during impact. This is same for the two bodies of masses m_1 and m_2 and having velocity Δv_1 and Δv_2 respectively.
Therefore,
$m_1\Delta v_1 = m_2\Delta v_2$
or $m_1\Delta v_1 + m_2\Delta v_2 = 0$
Let u_1, u_2 and v_1, v_2 be the initial and final velocities of the two masses before and after collision, then,
$m_1(v_1 - u_1) = -m_2(v_2 - u_2)$
or $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Physics Point

Momentum before impact = Momentum after impact.
(This is known as the law of conservation of momentum).

3. Let $\rho \rightarrow$ density of the sphere, $\rho' \rightarrow$ density of water.
The sphere will float if weight of the sphere = weight of the displaced water

$$\Rightarrow \frac{4}{3}\pi\left[\left(\frac{d}{2}\right)^3 - \left(\frac{D}{2}\right)^3\right]\rho g = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \rho' g$$

$$\Rightarrow (d^3 - D^3)\frac{\rho}{\rho^1} = d^3$$

$$\Rightarrow (d^3 - D^3)\,\sigma = d^3$$

$$\Rightarrow d^3(\sigma - 1) = \sigma D^3$$

$$\Rightarrow \frac{d}{D} = \left(\frac{\sigma}{\sigma - 1}\right)^{1/3}$$

2 EXERCISE

TEXT-BOOK EXERCISE :

1. (i) Applying the breaks to stop the vehicle
(ii) Opening or shutting the door.

2. (i) Applying the force to give shape to clay and make pots.
(ii) Bursting of a inflated balloon by pressing between the palms.

3. (a) apply the force of pull
(b) pulls or attracts
(c) either pull or push
(d) repels

4. (a) shape (b) muscular
(c) contact (d) gravity; friction

5. (a) Agent : Fingers Object : Lemon outer surface
Effect : shape of piece of lemon gets changed by squeezing and juice gets extracted.
(b) Agent : Fingers Object : Wall of tube and paste
Effect : Shape of the tube gets changed and paste is squeezed out.
(c) Agent : Weight of load Object : Spring
Effect : Spring will expand downward.
(d) Agent : Athlete Object : Athlete's body
Effect : The athlete will jump on the other side of the bar at a certain height.

6. When a blacksmith hammers a hot piece of iron, he uses his muscular force. This muscular force changes the shape of iron so that it can be given a desired shape.

7. When an inflated balloon is rubbed with a piece of synthetic cloth, it becomes charged. A charged body attracts an uncharged body so, when this charged balloon is pressed against a wall, it sticks to the wall.
Electrostatic force is responsible for the attraction between the balloon and the wall.

8. The forces acting on the plastic bucket containing water held above the ground level are:
(a) Gravitational force (b) Muscular force
These forces donot change in the state of motion of bucket because they are balancing each other and as a result the net force becomes zero.

9. The forces acting on the rocket immediately after leaving the launching pad are:
(a) Force of gravitation in downward direction
(b) Friction force due to air

10. The rise of water in the dropper is due to atmospheric pressure. When all the air escapes from the nozzle, the atmospheric pressure, which is acting on the water, forces the water to fill the nozzle of the dropper.

EXEMPLAR QUESTIONS :

1. Both the forces are of equal magnitudes and applied in the opposite directions.

2. Force of gravity. No, without the parachute his speed will be higher.

3. Earth and fruits.

4. The archer stretches the string of the bow by applying muscular force. In the process the shape of the bow changes. When the string is released, it regains its original position that provides the initial force to set the arrow in motion. The force of gravity that acts on the arrow in the downward direction brings it to the ground.

5. The woman wearing sandals with flat soles will feel more comfortable while walking on the sandy beach. The flat soles have larger area compared to the sandals with pointed heels. Since the two women are of the same weight, they will apply same force on the ground. Therefore, the pressure exerted by the pointed heels will be more compared to that with sandals having flat soles. As a result the pointed heel sandals will sink more in the sand than the flat sole sandals. Hence, walking with flat sole sandals will be more comfortable.

HOTS QUESTIONS:

1. Running provides greater momentum which helps in jumping through a longer distance.

2. The angle is 180°, because force of friction always opposes the relative motion.

3. (a) As the action and reaction never act on the same body, so the motion is possible.
(b) As Ft remains constant, so if t is reduced, then F will be increased and hence hurt our foot.

4. As the dynamic friction is less than the force of limiting friction.

5. The teacher is demonstrating the concept of pressure.
The broken pieces of glass are having small cross-sectional area, so, the pressure on his feet increases and the glass pieces pierce through his skin. The relation between pressure and area is given by the formula,

Physics Point

Pressure $= \frac{\text{Force}}{\text{Area}}$

So, for a constant force (body weight of the person) if the area decreases, pressure increases. The teacher is careful that the broken pieces are small and numerous because if the number of broken pieces is large, the combined surface area will be more, which results in a lesser pressure, and the glass pieces do not pierce through his skin.

6. No - because in free fall Buoyant force doesn't exist.

7. No - because equilibrium of floating bodies remain unaffected by variation of acceleration due to gravity.

8. Because the pressure of water increases with increase in depth.

9. Atmospheric pressure can be explained by using compressible bricks made up of foam rubber because larger the pressure, larger will be the compression on the surface of the bricks.

10. There will be a change in balance of the stick. It will tip on the side of the punched balloon. As the balloon is punched, air comes out through the hole, so the volume of the balloon decreases, so the buoyant force decreases. So due to its own weight the stick bends down on the side of the picked balloon.

3 EXERCISE

SINGLE OPTION CORRECT :

1. (c) It will move in vertically upward direction.

2. (c) Magnetic force is a non-contact force.

3. (c) The pressure exerted by another cube of the same material of side 4X is 4P.(P=F/A)

4. (d) **5.** (c) **6.** (b) **7.** (d)

8. (a) Pressure $= \frac{\text{Force}}{\text{area}}$ **9.** (b)

10. (b) Pressure , $P = \rho gh$ **11.** (b) **12.** (c)

13. (a) **14.** (d) **15.** (d) **16.** (c) **17.** (c)

18. (c)

19. (b) Change in momentum $= F \times t$
$= 10 \times 10 = 100$ Ns or 100 kg. m/s

20. (c) **21.** (b) **22.** (d) **23.** (c) **24.** (c)

25. (d)

26. (c) Brine due to its high density exerts an upthrust which can balance the weight of the egg.

27. (b) Volume of first piece of metal $= \frac{32}{8} = 4\,cm^3$

Upthrust = 4 gf

Effective weight = (32 – 4) gf = 28 gf

If m be the mass of second body, volume of second body is $\frac{m}{5}$

Now, $28 = m - \frac{m}{5} \Rightarrow m = 35$ g .

28. (c) **29.** (b) **30.** (b)

31. (a) $\frac{W_{air}}{W_{liq} - W_{water}} = \frac{210}{70} = 3\,g/cm^3$

MORE THAN ONE OPTION CORRECT :

1. (b, d) Inertia is $\propto$ mass

2. (b,c,d)
Kicking is a pushing action while all others are pulling action.

3. (a,b,c)
(a) Since the force is in the direction of motion, the speed of object will increase.
(b) Force is required for a, b & d. In absence of a force an object will either remain at rest (static object) or move in a straight line (moving object).
(c) Friction force between two surfaces tends to decrease the speed of a moving object.

4. (a,d) The weight of the body is balanced by the upthrust of water. Hence net force acting on the body is zero.
The atmospheric pressure decreases with height due to thinning of atmosphere. Thus the internal body pressure becomes higher than atmospheric pressure causing a nose bleed.

5. (a, c) **6.** (a, c) **7.** (a, b, c, d) **8.** (b, d)

9. (a,b)
(a) Given : Mass m = 10 g = 10^{-2} kg
Final speed, v = 100 m/s
Initial speed, u = 0, Time, t = 1 second

Acceleration, $a = \frac{v - u}{t} = 100\ m/s^2$

Force, $F = ma = 10^{-2} \times 100 = 1N$

(b) Force = 2.5 N, mass of body = 0.5 kg.
Force = mass × acceleration

Acceleration $= \frac{\text{Force}}{\text{mass}} = \frac{2.5}{0.5} = 5\ m/s^2$

MULTIPLE MATCHING QUESTIONS :

1. A → (s), B → (t), C → (p), D → (q), E → (r)

2. A → (r), B → (q), C → (s), D → (p)

3. A → (q), B → (p), C → (s), D → (r, t)

PASSAGE BASED QUESTIONS :

1. (c) Pressure depends upon the length of air column.

2. (b) $P = \rho gh$

ASSERTION & REASON :

1. (a) **2.** (c) **3.** (a) **4.** (a)

INTEGER/NUMERIC TYPE QUSTIONS :

1. **2**

Here, $a_1 = 16\ m/s^2$, $m_1 = 0.5\ kg$,
$F = m_1 a_1 = 16 \times 0.5\ kg = 8\ N$

$$m_2 = \frac{F}{a_2} = \frac{8}{4} = 2\ kg\ ;\ m_1 + m_2 = 0.5 + 2 = 2.5\ kg,\ F = 8\ N;$$

$$a = \frac{F}{m_1 + m_2} = \frac{8}{2.5} = 3.2\ m/s^2 \quad \therefore \quad x = 2\ m/s^2$$

2. 3

Here, $m = \frac{20}{1000}\ kg,\ u = 300\ m/s,\ v = 0,\ s = 3\ cm = 3 \times 10^{-2}\ m$

$$\therefore\ a = \frac{v^2 - u^2}{2s} = \frac{0 - (300)^2}{2 \times 3 \times 10^{-2}} = \frac{-300 \times 300}{2 \times 3 \times 10^{-2}}$$

$$= -1.5 \times 10^6\ m/s^2$$

$$\therefore \quad F = ma = \frac{20}{1000} \times (-1.5 \times 10^6) = -3 \times 10^4\ N$$

$\therefore \quad x = 3$

3. 34.92 m/s²

Given, $m_0 = 6000\ kg,\ \frac{dm}{dt} = 16\ kg/s$, $u = 11\ km/s$
$= 11000\ m/s$, $t = 1\ min = 60\ s$, $a = ?$

$$\text{Mass left after 1 minute} = m_0 - \left(\frac{dm}{dt}\right)t$$
$$= 6000 - 16 \times 60 = 5040\ kg.$$

$$F = m\frac{du}{dt} = u\frac{dm}{dt}$$

$$\Rightarrow \quad a = \frac{du}{dt} = \frac{u(dm/dt)}{m}$$

$$\Rightarrow \quad a = \frac{1100 \times 16}{5040} = 34.92\ m/s^2$$

4. 9

Here, $P = 270\ kPa = 270 \times 10^3\ Pa \Rightarrow P = h\rho g$

$$\Rightarrow\ h = \frac{P}{\rho g} = \frac{270 \times 10^3}{10^3 \times 9.8} = 27\ m$$

5. 3 atm

Pressure at the bottom of the tank
= Atmospheric pressure + pressure due to the liquid column

$$P = P_o + h\rho g = \left(1 + \frac{h\rho g}{P_0}\right)atm$$

$$= 1 + \frac{20\rho g}{10^5} = 3\ atm$$

4 ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

1. (a) Impulse = Force × time

2. (d) Impulse = rate of change of momentum

3. (a) **4.** (c) **5.** (a) **6.** (c) **7.** (d)

8. (c) F = mg – ma when moving downward

9. (b) **10.** (b) **11.** (a) **12.** (a)

13. (b) When a body falls through a viscous medium, it attains a constant velocity called terminal velocity.

14. (a) Both friction and viscosity depend on nature of material but friction does not depend on area of contact.

15. (a) Thickness of the surface film is equal to the radius of influence.

16. (d) All the given phenomena can be explained by Bernoulli's theorem.

17. (a) Toricelli's theorem is used to find velocity of efflux of an ideal liquid through on orifice.

18. (b) Mg and N cannot form action-reaction pair as they are acting on same body.

19. (c) A pin of density greater than that of water can float on the surface of water due to surface tension.

20. (a) with increase in temperature, the viscosity of gases increases while those of liquids decreases.

21. (a) Paint gun is based on Bernoulli's theorem.

22. (b) By equation of continuity, the velocity of liquid will be more at narrower portion and less at wider portion, hence pressure will be more at the wider portion, as according to Bernoulli's theorem, pressure is more at a point where velocity is less.

23. (a) Direction of impulse is same as that of the net force.

24. (a) By Newton's third law of motion, the tension in the rope must be equal to the force applied by the monkey on the rope.

25. (a, b, d)

26. (a,c) The wall at bottom has to withstand higher pressure as compared to the top.
As force varies at the depth it produces torque about the base.

27. (a, b, d)

28. A – (r, s); B – (q, t); C – (p, q); D – (q)

29. A – (q, r); B – (s); C – (p); D – (t)

30. (b) *FBD* is of *A* and *B* are shown in figure, as $m_B > m_A$, *A* moves up and *B* moves down with same acceleration *Q*.

Physics Point

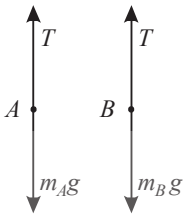
Here,

$m_B g - T = m_B a$ ...(1)

& $T - m_A g = m_A a$ ...(2)

On solving

$$a = \frac{m_B - m_A}{m_B + m_A} g = \frac{g}{5} = 2 \text{ ms}^{-2}$$



31. (a) Speed of A at $t = 1$s,

$v = u + at = 2$ ms–1

The string will become taut again when distance covered by both the blocks is equal, i.e.

$s_A = s_B$

$$2t - \frac{1}{2}gt^2 = \frac{1}{2}gt^2$$

or $t = 0.2$s.

32. (b) Let u_A and u_B be their velocities, just before the string become taut, then

$u_A = 2 - gt = 0$, $u_B = gt = 2$ ms^{-1}

Let v be their common speed just after the string becomes taut, then

impulse of A on B = – impulse of B on A

$m_A(v - 0) = -m_B(v - 2)$

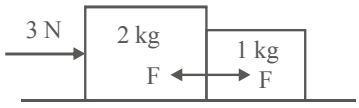
$2v = -3(v - 2)$

or $v = 0.4$ ms^{-1}

33. (a) **34.** (c) **35.** (c) **36.** (a) **37.** (a)

38. **5** Weight of body = m g = 5 N

39. **1** See fig. Let F be the force between the blocks and a their common acceleration. Then for 2 kg block,



3 – F = 2 a ...(1)

for 1 kg block, F = 1 × a = a ....(2)

∴ 3 – F = 2 F or 3 F = 3 or F = 1 newton

40. **4** The volume of liquid displaced, $v = \frac{m}{\rho}$, does not depend on a ceeleration due to grsletvity, so it remains as such.

41. **6**

Upthrust, F = vdg

$= 100 \times 4 \times 1.5 \times 10$ [∵ v = Al]

$= 600000$ dyne $\cong$ 6N

Physics Point

Chapter

2

FRICTION

INTRODUCTION

If you rub your hands together, they become warm. Why?

It is because of friction. The fine particles of our skin strike and accelerate through the mechanical movement of the hands and heat is created.

Friction is the opposing force that produced when two surfaces in contact move relative to each other. The types of surfaces also affect the force of friction. Smooth surfaces slide more easily than rough surfaces. Objects that roll have less friction than objects that slide.

Fluids such as air and water exert force of friction. You can feel air friction if you move your hands quickly. Forces of friction are very important in our everyday lives. They allow us to write, to walk or run etc. There are some disadvantages of force of friction like-wear and tear of the machinery, decreasing the efficiency of the machines as large amount of power is wasted in overcoming friction, etc.

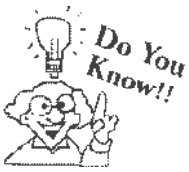
Physics Point

FRICTION

Friction is the force acting between two surfaces in contact, or the force of a medium acting on a moving object (e.g., air on aircraft) to resist the relative motion.
Frictional forces may also exist between surfaces when there is no relative motion. Frictional forces arise due to molecular interactions. Force of friction always opposes relative motion.

Causes of Friction

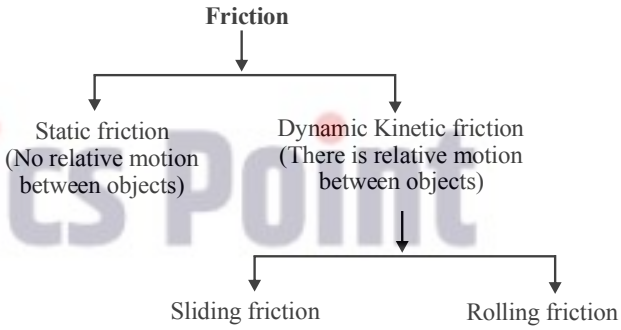
Old view : When two bodies are in contact with each other, the irregularities in the surface of one body set interlocked in the irregularities of another surface. This locking opposes the tendency of motion.
Modern view: Friction arises on account of strong atomic or molecular forces of attraction between the two surfaces at the point of actual contact.



Force of friction is not a fundamental force. There are only four fundamental forces in nature (i) Gravitational force (ii) Electromagnetic force (iii) Strong nuclear force and (iv) weak nuclear force. Electromagnetic force underlies-force of friction.

Types of Friction

Static friction : It is the frictional force which is effective before motion starts between two planes in contact with each other. It's nature is self adjusting. The numerical value of static friction is equal to external force which creates the tendency of motion of body. The maximum value of static friction is called **limiting friction.**



Physics Point

Think it Over

Static friction is a self adjusting force.

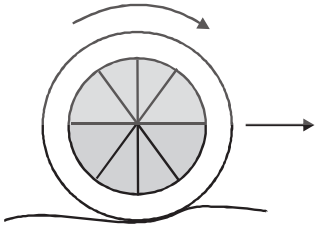
Laws of limiting friction/ Factors affecting friction

1. The magnitude of the force of limiting friction (f_L) between any two bodies in contact is directly proportional to the normal reaction (N) between them i.e., $f_L \propto N$
2. The direction of the force of limiting friction is always opposite to the direction in which one body is on the verge of moving over the other.
3. The force of limiting friction is independent of the apparent contact area, as long as normal reaction between the two bodies in contact remains the same.
4. Limiting friction between any two bodies in contact depends on the nature of material of the surfaces in contact and their roughness and smoothness.

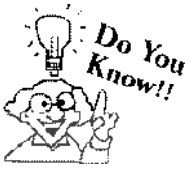
Dynamic or Kinetic friction : If the body is in motion, the friction opposing its motion is called dynamic friction. This is always slightly less than the limiting friction.

Rolling friction : When a body rolls on a surface, the resistance offered by the surface is called rolling friction. If a body rolls over the surface of another body, then both the rolling body and the surface on which it rolls are compressed by a small amount.
Cause of rolling friction :

The rolling body has to continuously detach itself from the surface on which it rolls. This is opposed by the adhesive force between the two surfaces in contact and hence a force originates which retards the rolling motion.
This retarding force is called the rolling friction. It is denoted by f_r.
For the same magnitude of normal reaction, the sliding friction is much greater than the rolling friction.



Cause of rolling friction
Fig. 2.1



Rolling friction is less for the wheel or cylinder of larger radius and more for the wheel or cylinder of smaller radius.

CONNECTING TOPIC

COEFFICIENTS OF FRICTION

The frictional coefficient describes as the ratio of the force of friction between two bodies and the normal force pressing them together.

Coefficient of static friction $\mu_s = \frac{f_L}{N}$

Coefficient of sliding or kinetic friction $\mu_k = \frac{f_k}{N}$

Coefficient of rolling friction $\mu_r = \frac{f_r}{N}$

The values of μ_s and μ_k depend on the nature of both the surfaces in contact. $\mu_s > \mu_k > \mu_r$.

The approximate value of coefficient of static friction (μ_s) and coefficient of kinetic friction (μ_k) for

		μ_s	μ_k
(i)	Rubber on concrete	1.0	0.8
(ii)	Steel on steel	0.74	0.57

Think it Over

Carts with rubber tyres are easier to fly than those with iron wheels. Why?

Graph Between Applied Force and Force of Friction

If we slowly increase the force with which we are pulling the box, graph shows that the friction force increases with our force upto a certain critical value, f_L, the box suddenly begins to move, and as soon as it starts moving, a smaller force is required to maintain its motion as in motion friction is reduced. The friction value from 0 to f_L is known as static friction, which balances the external force on the body and prevent it from sliding. The value of f_L is the maximum limit up to which the static friction acts is known as limiting friction, after which body starts sliding and friction reduces to kinetic friction.

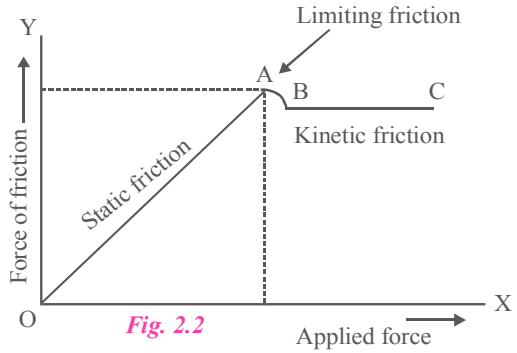


Fig. 2.2

ANGLE OF FRICTION (λ)

The angle of friction is the angle which the resultant of limiting friction f_L and normal reaction N makes with the normal reaction. It is represented by λ.

$$\tan\lambda = \frac{F_L}{N} = \frac{\mu N}{N} = \mu$$

For very-very smooth surface λ = 0

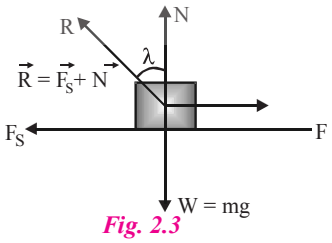


Fig. 2.3

ANGLE OF REPOSE (θ)

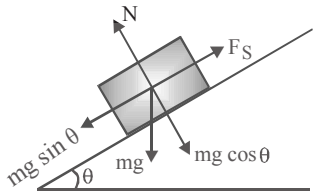
If a body is placed on an inclined plane and if its angle of inclination is gradually increases, then at some angle of inclination θ the body will just on the point to slide down. This angle is called angle of repose (θ).

$\therefore \quad F_L = mg \sin\theta$

and $N = mg \cos\theta$

So, $\frac{F_L}{N} = \tan\theta \quad \left[\because \frac{F_L}{N} = \mu\right]$

or $\mu = \tan\theta$



(a)

Relation between angle of friction (λ) and angle of repose (θ) : We know that, $\tan\lambda = \mu$ and $\mu = \tan\theta$

Hence, $\tan\lambda = \tan\theta \Rightarrow \theta = \lambda$

Thus, angle of repose = angle of friction

Pulling is Easier Than Pushing

Case of pulling : Force F is applied to pull a block of weight W. F can be resolved into two rectangular components:

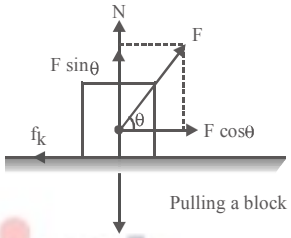
$F\cos\theta$ and $F\sin\theta$

The normal reaction $N = W - F\sin\theta$

Force of kinetic friction

$f_k = \mu_k N$

$f_k = \mu_k (W - F\sin\theta)$ ....(i)



(b)

Case of pushing :

Force F is applied to push a block

Normal reaction

$N' = W + F\sin\theta$

Force of kinetic friction

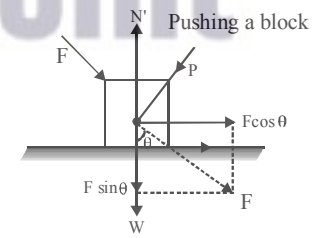
$f'_k = \mu_k N'$

or $f'_k = \mu_k (W + F\sin\theta)$ .....(ii)

By (i) and (ii)

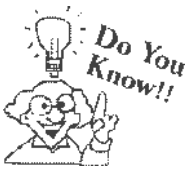
$f'_k > f_k$

The frictional force is more in the case of push. Hence it is easier to pull than to push a body.



(c)

Fig. 2.4



Material with a long angle of repose forms flatter piles than material with a high angle of repose.

Think it Over

What happens to coefficient of friction, when weight of the body is doubled?

ILLUSTRATION : 1

A block of mass 1 kg is at rest on a rough horizontal surface having coefficient of static friction 0.2 and kinetic friction 0.15, find the frictional forces if a horizontal force, (a) F = 1N (b) F = 2.5 N , is applied on the block

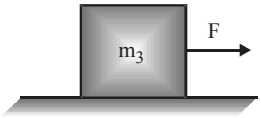


Fig. 2.5

Physics Point

SOLUTION :

Maximum force of friction or limiting friction

$f_L = 0.2 \times 1 \times 9.8\,N = 1.96\,N$

(a) For $F_{ext} = 1N$, $F_{ext} < f_L$

So, body is in rest means static friction is present and hence $f_s = F_{ext} = 1N$

(b) For $F_{ext} = 2.5\,N$ so $F_{ext} > f_L$

Now body is in moving condition

$\therefore$ Frictional force

$f_L = F_k = \mu_k N = \mu_k\, mg = 0.15 \times 1 \times 9.8 = 1.47\,N$

ILLUSTRATION : 2

A block of mass 1 kg placed on an inclined plane as shown in figure.

(a) What must be the frictional force between block and inclined plane if the block is not to slide along the inclined plane when the inclined plane is accelerating to the right at 3 m/s^2 ?

(b) What is the least value of μ can have for this to happen?

(cos 37° = 0.8 ; sin 37° = 0.6)

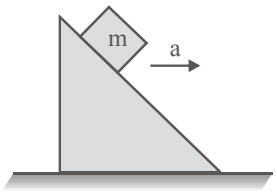


Fig. 2.6

SOLUTION :

$N = m(g\cos 37° + a\sin 37°) = 1(9.8 \times 0.8 + 3 \times 0.6)$

and $mg\sin 37° = ma\sin 37° + f$

(a) $f = mg\sin 37° - ma\sin 37°$ or,

$f = 1(9.8 \times 0.8 - 3 \times 0.8) = 5.48$

(b) $f = \mu N \quad \therefore \quad \mu = \dfrac{f}{N} = \dfrac{5.48}{9.64} = 0.57$

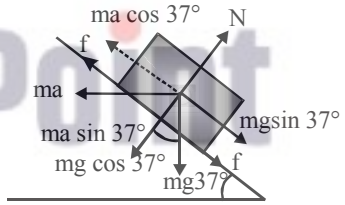


Fig. 2.7

FRICTION : A NECESSARY EVIL

Friction has advantages as well as disadvantages. In other words, friction is not desirable but without friction, we cannot think of survival, so we can say that **"friction is a necessary evil"**. In some cases friction acts as a supporting force i.e., as a friend and in some cases it acts as opposing force i.e., as a foe.

Friction as a Friend /Advantages of Friction :

(i) The force of friction helps us to move on the surface of earth. In the absence of friction, we cannot think of walking on the surface.

(ii) The force of friction between the tip of a pen and the surface of paper helps us to write on the paper. It is not possible to write on the glazed paper as there is no force of friction.

(iii) The force of friction between the tyres of a vehicle and the road helps the vehicle to stop when brake is applied. In the absence of friction, the vehicle skid off the road when brake is applied.

(iv) Moving belts remain on the rim of a wheel because of friction.

(v) The force of friction between a chalk and the blackboard helps us to write on the board.

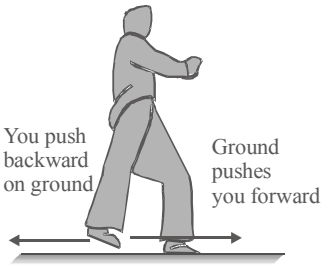


Fig. 2.8

Friction as a Foe / Disadvantages of Friction :

(i) A significant amount of energy of a moving object is wasted in the form of heat energy to overcome the force of friction.

(ii) The force of friction restricts the speed of moving vehicles like buses, trains, aeroplanes, rockets etc.

(iii) The efficiency of machines decreases due to the presence of force of friction.

(iv) The force of friction causes lot of wear and tear in the moving parts of a machine.

(v) Sometimes, a machine gets burnt due to the force of friction between different moving parts.

Think it Over

What would happen it we lived in a world where friction is nil?

INCREASING AND REDUCING FRICTION

Methods of Increasing Friction

- **Treading of tyres** is done to increase friction between the road and the tyres. Moreover, synthetic rubber is preferred over the natural rubber in the manufacture of tyres because of its larger coefficient of friction with the road.
- **Sand is thrown on tracks covered with snow.** This increases the force of friction between the wheels and the track and the driving becomes safer.
- **On a rainy day, we throw some sand on the slippery ground.** This increases the friction between our feet and the ground. This reduces the chances of slipping.

Methods of Reducing Friction

Friction can be reduced by

- polishing the surface. (but extra polishing increase friction)
- lubrication
- proper selection of material
- avoiding moisture
- streamlining the shape
- using ball bearings or roller bearings

Friction can be considerably reduced by maintaining a thin cushion of compressed air between solid surfaces in relative motion

Physics Point

Wheel Reduce Friction

When objects such as a wheel (disc or ring), sphere or a cylinder rolls over a surface, the force of friction that comes into play is called rolling friction.

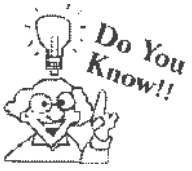
- Rolling friction is directly proportional to the normal reaction (R) and inversely proportional to the radius (r) of the rolling cylinder or wheel.

$$F_{rolling} = \mu_r \frac{R}{r}$$

μr is called coefficient of rolling friction, it would be measured in metre.

- Rolling friction is often quite small as compared to the sliding friction. That is why heavy loads are transported by placing them on carts with wheels.

Fig. 2.9



The velocity of point of contact with respect to the surface remains zero all the times although the centre of the wheel moves forward.

FLUID FRICTION (DRAG)

Fluids i.e., liquids and gases also a friction on the bodies moving through them.

For a plane to fly, level and at a steady rate, the forces acting on it must be balanced.

Lift must equal to weight and thrust must equal to drag. Drag is air resistance to the forward motion of the plane.

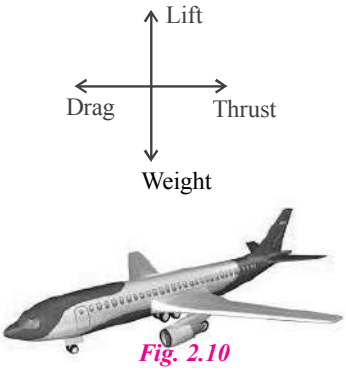


Fig. 2.10

SUMMARY

- **Friction :** It is the opposing force that produced when two surfaces in contact move relative to each other.
- **Static friction :** The friction that exists between the surfaces in contact when there is no relative motion. The maximum value of static friction is called limiting friction.

  $F_s \propto N$ or, $F_s = \mu_s N$ where μ_s = coefficient of static friction.
- **Kinetic friction :** It is the friction exprerienced by a body when it is in motion. It is less than static friction.

  $F_k \propto N$ or $F_k = \mu_k N$ where μ_k = coefficient of kinetic friction.
- **Sliding friction :** The friction that exists between two surfaces in contact when the body slides on the surface.
- **Rolling friction :** The friction that exists between two surfaces in contact when the body rolls on the surface. Its magnitude is much less than sliding friction.

  $F_r \propto N$ or $F_r = \mu_r N$ where μ_r = coefficient of rolling friction.
- **Factors that affect friction :**

  (i) The nature of the surfaces in contact and their state of roughness.

  (ii) The force of limiting friction between two surfaces in contact is directly proportional to the normal reaction between the two surface in contact.

  (iii) Friction force does not depend on the area of surfaces in contact.
- **Angle of friction :** The angle which the resultant of the limiting friction and the normal reaction makes with the normal reaction.

  Angle of friction, $\tan\theta = \mu_s$
- **Angle of repose:** It is the minimum angle that an inclined plane makes with the horizontal when a body placed on it just begins to slide down.

  Angle of repose, $\tan\phi = \mu_s$
- **Methods of increasing friction :**

  (i) Treading of tyres (ii) On a rainy day, sand is thrown on the slippery ground, etc.
- **Methods of reducing friction:**

  (i) By polishing (ii) By using wheels and ball-bearings

  (iii) By lubrication (iv) By streamlining, etc.
- **Fluid friction (Drag) :** It is the liquid or air resistance to forward motion of the body.

Physics Point

1 EXERCISE

Fill in the Blanks :

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. When two surfaces rub against each other ..... is produced.
2. The heavier the load, the ..... the frictional force.
3. Magnitude of kinetic friction ..... with increase in inclination of the inclined plane.
4. Conical shape of rockets reduce .....
5. Friction is caused by irregularities on the two surfaces in .....
6. The force required to overcome friction at the instant an object starts moving from rest is a measure of .....

True/False :

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Frictional force depends on the area of the surfaces in contact.
2. It is easier to start motion in a lighter body than a heavier body.
3. Friction is electromagnetic in nature.
4. Static friction is self-adjusting.
5. Magnitude of kinetic friction is constant.
6. The substance which reduce friction are called Turbolents

Match the Following :

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D)in Column I have to be matched with statements (p, q, r, s, t) in Column II.*

	Column I	Column II
1.	(A) Frictional force exerted by fluids	(p) heat
	(B) Increasing friction	(q) drag
	(C) Substance which reduces friction	(r) ball bearings
	(D) Friction produces	(s) lubricants
		(t) treading of tyres

Very Short Answer Questions :

DIRECTIONS : *Give answer in one word or one sentence.*

1. What is friction?
2. Why do we call friction a self adjusting force ?
3. It is easier to roll a barrel than to pull it along the road. Why?
4. Why it is difficult to move a bicycle with brakes on?
5. Why it is easy to maintain the motion then to start it?
6. Is rolling friction more than sliding friction?

Short Answer Questions :

DIRECTIONS : *Give answer in two to three sentences.*

1. Distinguish between static friction, limiting friction and kinetic friction.
2. Write any three methods of increasing friction.
3. Explain how proper inflation of tyres saves fuel?
4. You push with a 40-N horizontal force on a 4-kg mass resting on a horizontal friction force of 12 N. What is the acceleration?
5. Explain by giving suitable examples that friction is a necessary evil?
6. Write any three methods of reducing friction?

Long Answer Questions :

DIRECTIONS : *Give answer in four to five sentences.*

1. Draw the graph between friction and applied force on any object and show static friction, limiting friction and kinetic friction in graph. Using graph show that static friction is a self -adjusting force.
2. What is friction? Why it is called self adjusting force? Give some familiar methods for reducing friction.
3. Explain the terms-friction and limiting friction. State the laws of limiting friction.

Physics Point

2 EXERCISE

Text-Book Exercise :

1. Fill in the blanks:
   (a) Friction opposes the _____ between the surfaces in contact with each other.
   (b) Friction depends on the _____ of surfaces.
   (c) Friction produces _____.
   (d) Sprinkling of powder on the carrom board _____ friction.
   (e) Sliding friction is _____ than the static friction.
2. Four children were asked to arrange forces due to rolling, static and sliding frictions in a **decreasing order.** Their arrangements are given below.
   Choose the correct arrangement.
   (a) Rolling, static, sliding (b) Rolling, sliding, static
   (c) Static, sliding, rolling (d) Sliding, static, rolling
3. Alida runs her toy car on dry marble floor, wet marble floor, newspaper and towel spread on the floor. The force of friction acting on the car on different surfaces in **increasing order** will be:
   (a) wet marble floor, dry marble floor, newspaper and towel.
   (b) newspaper, towel, dry marble floor, wet marble floor.
   (c) towel, newspaper, dry marble floor, wet marble floor.
   (d) wet marble floor, dry marble floor, towel, newspaper
4. Suppose your writing desk is tilted a little. A book kept on it starts sliding down. Show the direction of frictional force acting on it.
5. You spill a bucket of soapy water on a marble floor accidently. Would it make it easier or more difficult for you to walk on the floor ? Why ?
6. Explain why sportsmen use shoes with spikes.
7. Iqbal has to push a lighter box and Seema has to push a similar heavier box on the same floor. Who will have to apply a larger force and why?
8. Explain why the sliding friction is less than the static friction.
9. Give examples to show that friction is both a friend and a foe.
10. Explain why objects moving in fluids must have special shapes.

Exemplar Questions :

1. You might have noticed that when used for a long time, slippers with rubber soles become slippery. Explain the reason.
2. The handle of a cricket bat or a badminton racquet is usually rough. Explain the reason.
3. Explain why the surface of mortar and pestle (silbatta) used for grinding is etched again after prolonged use?
4. When the cutting edge of a knife is put against a fast rotating stone to sharpen it, sparks are seen to fly. Explain the reason.
5. We have two identical metal sheets. One of them is rubbed with sand paper and the other with ordinary paper. The one rubbed with sand paper shines more than the other. Give reason.

Hots Questions :

1. A large size brake on bicycle is as effective as small one. Comment.
2. Why are wheels of automobiles made circular?
3. Proper inflation of tyres of vehicles saves fuel. Why?
4. Why frictional force gets increased when a surface is polished beyond a certain limit?

Physics Point

3 EXERCISE

Single Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. Which of the following observations shows that friction exists?
(a) When movement is decreased or prevented.
(b) When there is a constant movement.
(c) When electromagnetic charges are produced.
(d) When there is a constant increase in weight.

2. A man is walking from east to west on a level rough surface. The frictional force on the man is directed
(a) from the west to east (b) from the east to west
(c) along the north (d) along the west

3. How much is the viscous drag acting on a rocket-driven sled that is going at constant speed against a frictional force of 22000 newtons when the thrust of the engine is 31000 newtons?
(a) 8500 N (b) 9000 N
(c) 9500 N (d) 7500 N

4. Maximum value of static friction is called
(a) Limitting friction (b) Rolling friction
(c) Normal reaction (d) Coefficient of friction

5. Which of the folloiwng statements is not true?
(a) The coefficient of friction between two surfaces increases as the surface in contact are made rough
(b) The force of friction acts in a direction opposite to the applied force
(c) Rolling friction is greater than sliding friction
(d) The coefficient of friction between wood and wood is less than 1

6. When two surfaces are coated with a lubricant, then they
(a) Stick to each other (b) Slide upon each other
(c) Roll upon each other (d) None of these

7. Which one of the following is not used to reduce friction
(a) Oil (b) Ball bearing
(c) Sand (d) Graphite

8. Which activity is not based upon friction
(a) Writing (b) Speaking
(c) Hearing (d) Walking

9. A box is given a push across the floor. It comes to stop shortly. Which one of the following statement gives proper reason?
(a) Gravity is acting on the box in the direction opposite to the box's movement.
(b) Friction is acting on the box in the same direction of the box's movement.
(c) Friction is acting on the box in the direction opposite to the box's movement.
(d) The heat produced by the box's movements slows down the box.

10. On increasing the smoothness of surfaces in contact,
(a) frictional force b/w them must decrease
(b) frictional force b/w them must increase
(c) frictional force b/w them may increase or decrease
(d) frictional force does not change as it does not depend on area of contact

11. Which one is not a force at a distance?
(a) Frictional force (b) Electrostatic force
(c) Gravitational force (d) Magnetic force

12. Which one is the example of contact force :
(a) a rolling football stops
(b) a freely falling stone
(c) a magnet pulling iron nails
(d) a charged balloon sticking to a wall.

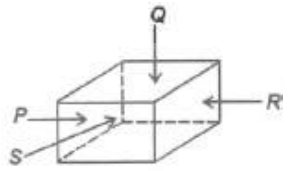
13. Whenever the surfaces in contact tend to move or move with respect to each other, the force of friction comes into play
(a) only if the objects are solid
(b) only if one of the two objects is liquid
(c) only if one of the two objects is gaseous
(d) irrespective of whether the objects are solid, liquid or gaseous

14. A toy car released with the same initial speed will travel farthest on
(a) muddy surface (c) cemented surface
(b) polished marble surface (d) brick surface

15. In a large commercial complex there are four ways to reach the main road. One of the path has loose soil, the second is laid with polished marble, the third is laid with bricks and the fourth has gravel surface. It is raining heavily and Kiran wishes to reach the main road. The path on which she is least likely to slip is
(a) loose soil (c) bricks
(b) polished marble (d) gravel

Physics Point

16. When friction is acting in the direction of P, in which direction do you think the force is applied?



(a) P (b) Q
(c) R (d) S

More than One Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Choose the correct options
(a) A force is applied to an object in the direction of its motion. The speed of object will increase
(b) If no force acts on a body it will either remain in rest or move in a straight line
(c) Friction force can change speed of an object
(d) Rolling friction is less than kinetic friction

2. Incorrect statements related to the force of friction between two bodies is/are
(a) parallel to contact surface
(b) perpendicular to contact surface
(c) inclined to contact surface
(d) a non contact force

3. A body is imparted motion from rest to move in a straight line. If it is then obstructed by an opposite force, then
(a) the body will necessarily change direction
(b) the body is sure to slow down
(c) the body will necessarily continue to move in the same direction at the same speed
(d) The body will stop after sometime

Multiple Matching Questions :

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r , s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

	Column -I		Column -II
A.	Sliding friction is smaller than	p.	heat energy
B.	Friction produces	q.	increase friction
C.	Brake pads are used to	r.	decrease friction
D.	Oil and grease are used to	s.	static friction

2.

	Column-I		Column-II
A.	Friction	p.	Reduces friction
B.	Fluid friction	q.	Opposes the motion
C.	Treaded tyres	r.	Drag
D.	Streamlining	s.	Increase friction

Passage Based Questions :

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH - I

A physicist is investigating the effect that different conditions have on the force of friction. The material used is an ordinary brick, with a mass of 1.8 kg. It is pulled across the surface of a wooden table. Friction is measured by pulling the brick with a string attached to a spring scale, calibrated in newtons (N). When the brick is pulled at constant speed, the reading on the scale is equal to the force of friction between the brick and the table top.

Experiment 1 : The brick is placed on the table in three different positions. First, it is allowed to rest on its broad face (area = 180 cm^2), then on its side (area = 130 cm^2), and finally on its end (area = 56 cm^2).

Table 1

Area (cm^2)	180	130	56
Friction (N)	7.1	7.3	7.2

Experiment 2 : A wooden block of mass 0.6 kg is made to the same dimensions as the brick, and the experiment is repeated.

Table 2

Area (cm^2)	180	130	56
Friction (N)	1.2	1.1	1.2

Experiment 3 : This time, the wooden block is loaded by adding 1.2 kg of extra mass on top of it, to give it the same weight as the brick.

Table 3

Area (cm^2)	180	130	56
Friction (N)	3.5	3.6	3.7

1. From Experiment 1, it would be reasonable to hypothesize that:
(a) the surface area of contact does not affect the amount of friction.
(b) friction is large in a brick-to-wood contact.
(c) the amount of friction depends on the way the weight of the object is distributed.
(d) heavy objects have more friction than light ones.

2. Which combination of experiments shows that the amount of friction depends on the weight of the object ?

Physics Point

(a) Experiment 1 and Experiment 2
(b) Experiment 1 and Experiment 3
(c) Experiment 2 and Experiment 3
(d) Experiment 1, Experiment 2, and Experiment 3

3. In doing Experiment 3, what was the purpose of adding enough weight to the wooden block to make its weight equal to that of the brick ?
(a) To test the hypothesis that adding weight increases friction
(b) To find the relationship between surface area of contact and friction
(c) To find out whether the density of the material influences the amount of friction
(d) To control other factors and test the effect of the nature of the materials in contact

PARAGRAPH - II

When one body rolls over the surface of another body, the resistance to its motion is called rolling friction. Rolling reduces friction. It is easier to roll than to slide a body over another.

4. Rolling friction is _____ than sliding friction.
(a) Smaller (b) Greater
(c) Equal (d) Depends on condition

5. Sliding is replaced by rolling in most machines by using
(a) Grease (b) Lubricant
(c) Ball bearing (d) Wet soil

Assertion & Reason :

DIRECTIONS : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** Aeroplanes are given streamlining to increase the speed of vehicles.
Reason : Air friction decreases due to streamlining.

2. **Assertion:** While walking on ice, one should take small steps to avoid slipping.
Reason: This is because smaller steps ensure smaller friction.

3. **Assertion:** Use of ball bearings between two moving parts of machine is a common practice.
Reason: Ball bearing reduce vibrations and provide good stability.

Integer/Numeric type Questions :

DIRECTIONS : *Following are integer based/Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

1. A body of mass 0.5 kg is kept by pressing to a vertical wall by a force of 100 N. The coefficient of friction between wall and body is 0.3. Find the frictional force

2. A body weighing 20 kg just slides down a rough inclined plane that rises 5 m in every 12 m. What is the coefficient of friction ?

3. A horizontal force of 1.2 kg is applied on a 1.5 kg block, which rests on a horizontal surface. If the coefficient of friction is 0.3, find the acceleration produced in the block.

Physics Point

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

DIRECTIONS (Qs. 1–10) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which only one is correct.*

1. Work done by a frictional force is
(a) Negative (b) Positive
(c) Zero (d) All of the above

2. If μ_s, μ_k and μ_r are coefficients of static friction, sliding friction and rolling friction, then
(a) $\mu_s < \mu_k < \mu_f$ (b) $\mu_k < \mu_r < \mu_s$
(c) $\mu_r < \mu_k < \mu_s$ (d) $\mu_r = \mu_k = \mu_s$

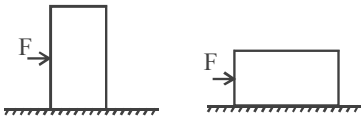
3. When a body is moving on a surface, the force of friction is called
(a) Static friction (b) Dynamic friction
(c) Limiting friction (d) Rolling friction

4. Which of the following statements about friction is true?
(a) Friction can be reduced to zero
(b) Frictional force cannot accelerate a body
(c) Frictional force is proportional to the area of contact between the two surfaces
(d) Kinetic friction is always greater than rolling friction

5. Which of the following statements is correct, when a person walks on a rough surface?
(a) The frictional force exerted by the surface keeps him moving
(b) The force which the man exerts on the floor keeps him moving
(c) The reaction of the force which the man exerts on floor keeps him moving
(d) None of these

6. A block of mass 2 kg is resting on a rough inclined plane of inclination 30°. The coefficient of friction is 0.8, the contact force between incline and the block is ($g = 10\ ms^{-2}$)
(a) 20 N (b) 10 N
(c) $10\sqrt{3}$ N (d) none of these

7. A rectangular block is placed on a rough horizontal surface in two different ways as shown, then



(i) (ii)

(a) friction will be more in case (i)
(b) friction will be more in case (ii)
(c) friction will be equal in both the cases.
(d) depends on the relations among its dimensions.

8. A coin is placed on a rotating disc and is stationary w.r.t. the disc, then the direction of friction is
(a) along the direction of motion of the coin w.r.t. ground
(b) opposite to the direction of motion of the coin w.r.t. ground
(c) towards the centre of the disc
(d) away from the centre of the disc

9. A block weighs W is held against a vertical wall by applying a horizontal force F. The minimum value of F needed to hold the block is
(a) Less than W (b) Equal to W
(c) Greater than W (d) Data is insufficient

10. The coefficient of limiting friction μ is defined as
(a) $\mu = \frac{R}{F}$ (b) $\mu = \sqrt{\frac{F}{R}}$
(c) $\mu = \frac{F}{R}$ (d) $\mu = \sqrt{\frac{R}{F}}$

DIRECTIONS (Qs. 11–13): *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which one or more may be correct.*

11. A man pulls a block heavier than himself with a light rope. The coefficient of friction is the same between the man and the ground and between the block and the ground. Then
(a) if both move, the acceleration of the man is greater than the acceleration of the block.
(b) the block will not move unless the man also moves
(c) the man can move even when the block is stationary.
(d) if the block is stationary, man cannot move

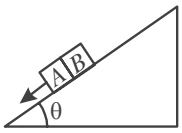
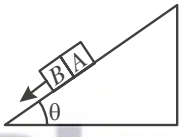
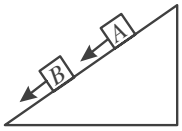
12. A man tries to remain in equilibrium by pushing with his hands and feet against two parallel walls. For equilibrium:
(a) the coefficient of friction must be the same between both walls and the man
(b) he must exert equal forces on the two walls
(c) the forces of friction at the two walls must be equal
(d) friction must be present on both walls

13. Let F, F_N and f denote the magnitudes of the contact force, normal force and the friction exerted by one surface on the other kept in contact. If none of these is zero then
(a) $F > F_N$ (b) $F > f$
(c) $F_N > f$ (d) $(F_N - f) < F < (F_N + f)$

Physics Point

DIRECTIONS (Qs. 14) : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r , s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II..*

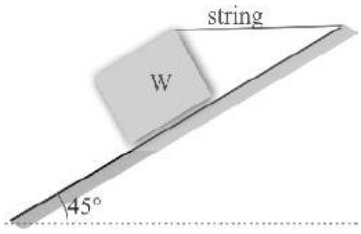
14. If μ_1 and μ_2 represent coefficients of friction between blocks *A* and inclined plane and block *B* and inclined plane respectively, then match the following:

Column I	Column II
(A) $\mu_1 = \mu_2$	(p) 
(B) $\mu_1 > \mu_2$	(q) 
(C) $\mu_1 < \mu_2$	(r) 
(D) $\mu_1 \neq \mu_2$	(s) 

DIRECTIONS (Qs. 15–17) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

A rectangular prism (*W*) weighing 150 N, is lying on an inclined plane whose inclination with the horizontal is shown in figure. The block is tied up by a horizontal string, which has a tension of 50 N.



15. The frictional force on the block is
(a) 50 N (b) 70.7 N
(c) 90.2 N (d) 100 N

16. The normal reaction of inclined plane is
(a) 70.7 N (b) 90.2 N
(c) 141.4 N (d) 200 N

17. The coefficient of friction between the surfaces of contact is
(a) 0.1 (b) 0.2
(c) 0.3 (d) 0.5

DIRECTIONS (Qs. 18–19) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.

(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.

(c) If **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

18. **Assertion :** On a rainy day, it is difficult to drive a car or bus at high speed.

Reason : The value of coefficient of friciton is lowered due to wetting of the surface.

19. **Assertion :** When a bicycle is in motion, the force of friction exerted by the ground onthe two wheels is always in forward direction.

Reason : The frictional force acts only when the bodies are in contact.

DIRECTIONS (Qs. 20 - 22) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

20. A car having a mass of 1000 kg is moving at a speed of 30 metres/sec. Brakes are applied to bring the car to rest. If the frictional force between the tyres and the road surface is 5000 newtons, then find the time taken by the car to come to rest.

21. A 100 N force acts horizontally on a block of 10 kg placed on a horizontal rough surface of coefficient of friction $\mu = 0.5$. If the acceleration due to gravity (g) is taken as 10 ms^{-2}, find the acceleration of the block (in ms^{-2}).

22. A block of mass 1 kg lies on a horizontal in a truck. The coefficient of static friction between the block and the surface is 0.6 if the acceleration of the truck is 5 m/s^2. Find the frictional force acting on the block .

Physics Point

SOLUTIONS

Brief Explanations of Selected Questions

1 EXERCISE

FILL IN THE BLANKS :

1. friction
2. greater
3. decreases
4. atmospheric friction
5. contact
6. static friction

TRUE/FALSE :

1. False
2. True
3. True
4. True
5. True
6. false

MATCH THE COLUMNS :

1. **(A) – (q), (B) – (t), (C) – (r, s), (D) – (p)**

VERY SHORT ANSWER QUESTIONS :

1. The opposing force that is set up between the surfaces of contact, when one body slides or rolls or tends to do so on the surface of another body is called friction.
2. When applied force is zero, friction is zero. As the applied force is increased, friction also increases and becomes equal to the applied force. It happens so, till the body does not start moving. For this reason, friction is called self adjusting force.
3. The rolling friction is lesser as compared to the sliding friction.
4. When brakes are on, sliding friction come into play instead of rolling friction
5. It is so because static friction is greater than kinetic friction.
6. No, rolling friction is less than sliding friction.

SHORT ANSWER QUESTIONS :

1. The force of friction which comes into play between two bodies before one body actually starts moving over the other is called static friction. The maximum force of static friction is called limiting friction.

   And the kinetic friction is the force of friction which comes into play when a body is in a state of steady motion over the surface of another body.
2. Refer to theory
3. When the tyres are properly inflated, the area of contact between the tyres and the ground is reduced which in turn reduces the rolling friction. As a result of this, there is less dissipation of energy against friction. So the automobiles cover greater distance for the same quantity of fuel consumed. Hence proper inflation of tyres leads to saving the fuel.
4. A force of 40 N acts on a 4 kg mass in horizontal direction. The opposing force is force of friction 12 N

   The net force on the mass = 40 – 12 = 28 N

   This force will produce an acceleration in the mass given by Newton's 2nd law, F = ma

   $\therefore$ acceleration a = 7 m/s^2

   Thus the mass accelerates with 7 m/s^2 in forward direction.
5. Refer to theory
6. Refer to theory

LONG ANSWER QUESTIONS :

1. Refer to theory
2. Refer to theory
3. Refer to theory

2 EXERCISE]

TEXT-BOOK EXERCISE :

1. (a) relative motion (b) nature
   (c) heat (d) reduces
   (e) smaller
2. (c) Static, sliding, rolling
3. (a) Wet marble floor, dry marble floor, newspaper and towel.
4. The direction of frictional force on the book is opposite to the direction of its motion and acts in upward direction.
5. It would be more difficult to walk on the floor because soapy water fills the floor irregularities, thus reduces the friction considerably. Feet do not make necessary grip with the floor, thus increasing the chances of falling.
6. Spikes increase friction and give tighter grip with ground. It avoids slipping of sportsmen while playing or running.

Physics Point

7. Friction is a self-adjusting force. Increase in weight will put more force on the floor surface and therefore experience more opposite force (friction). Thus Seema will have to apply larger force than Iqbal.
8. When the objects are at rest, the interlocking between the surfaces of the objects is higher then that of when object is moving. In moving position there is less interlocking between the surfaces. That's why sliding friction is less than the static friction.
9. Friction as friend:
   (i) We are able to write because of friction between ball point and paper surface.
   (ii) We are able to walk because of friction between ground and our feet.
   Friction as foe :
   (i) Machine is heated up and produce noise because of friction.
   (ii) Tyres and soles of shoes wear out because of friction.
10. When a body moves through a fluid, it experiences an opposite force which tries to oppose its motion. This frictional force exerted by fluid is called drag or fluid friction. To overcome or minimize fluid friction, the bodies are given special shape streamliner.

EXEMPLAR QUESTIONS :

1. When rubber soles are used for a long time, their surfaces become smooth. Hence, the friction between the sole and the floor decreases. Therefore, slippers become slippery.
2. To increase friction between handle of the bat and hands, to have a better grip.
3. To increase friction to make it more effective for grinding again.
4. Friction between grinding stone and the cutting edge of the knife produces heat. As the friction is very large in this case, a large amount of heat is produced and we see sparks flying.
5. The friction between sand paper and metal sheet is very large, compared to that between the ordinary paper and the metal sheet. Thus the sand paper is able to remove the outer dull layer from the metal sheet more effectively and makes it more shining.

HOTS QUESTIONS:

1. Action of brakes is based upon friction. But the friction is independent of the area of surfaces in contact so long as the normal reaction remains the same. Hence, large size brakes and normal size trakes will be equally effective if the material of brakes remains unchanged.
2. Circular wheels roll on the road and rolling friction comes into play during the motion of automobiles. Rolling friction is less than the sliding friction. It is due to this reason that wheels of automobiles are made circular.
3. When the tyre is properly inflated, the area of contact between the ryre and the ground is reduced. This reduces rolling friction. Consequently, the automobile covers greater distance for the same quantity of fuel consumed.
4. When surfaces are highly polished, the area of contact between them increases. As a result of this, a large number of atoms and molecules lying on both the surfaces start exerting strong attractive forces on each other and therefore frictional force increases.

3 EXERCISE

SINGLE OPTION CORRECT :

1. (a) When movement is decreased or prevented.
2. (b) Friction opposes the relative motion
3. (b) Viscous drag = 31000 – 22000 = 9,000N
4. (a)
5. (c) Sliding friction is greater than rolling friction.
6. (b) Surface always slide over each other.
7. (c) Sand is used to increase the friction.
8. (c)
9. (c) Friction is acting on the box in the direction opposite to the box's movement.
10. (c) On increasing smoothness, friction first decreases and then increases.
11. (a)
12. (a)
13. (d)
14. (b) In case of polished marble surface friction will be least.
15. (d)
16. (d) Friction always opposes motion, therefore it is in direction of R.

MORE THAN ONE OPTION CORRECT :

1. (a,b,c) Since the force is in the direction of motion, the speed of object will increase.
   Friction force between two surfaces tends to decrease the speed of a moving object.
2. (b,c,d)
   A force of friction is parallel to the contact surfaces and acts in a direction opposite to the direction of motion.
3. (b, d) Opposite force causes retardation.

Multiple Matching Questions :

1. (b) A → s, B → p, C → q, D → r
2. (a) A → q, B → r, C → q, D → p

Passage Based Questions :

1. (a) In spite of the fact that one surface is almost three times as great as another, there is no substantial difference in the amount of friction. The small differences are surely due to experimental variation. This is obvious when it is noted that the value obtained for the 130-cm^2 surface is a little larger than that for the 180-cm^2 surface. (2) is wrong because there is no comparison with other readings to decide what constitutes large friction. (3) is wrong because the experiment did not vary weight distribution. (4) is wrong because the same object was used throughout.
2. (c) In these two experiments, both the surface area of contact and the kind of materials in contact are the same, and the only difference is in the weight. The other three choices all include Experiment 1, in which a different kind of material is in contact with the surface, and this might be the reason for the difference in results.
3. (d) With the weight added, all other variables are controlled and the only difference between the brick and the wooden block, as far as contact with the table top is concerned, is in the nature of the material. The other choices are wrong because the experiment makes no comparison of different weights, surface areas, or densities.
4. (a)
5. (c) Ball bearing reduces friction.

Assertion & Reason :

1. (a) Aeroplanes are given streamlining to increase the speed of vehicles as air friction decreases due to streamlining.
2. (a)
3. (c)

Integer/Numeric type Qustions :

1. **5**

   For the given condition, static friction,

   = applied force = weight of body = $0.5 \times 10 = 5$ N

2. **0.458**

   Here $\sin\theta = \frac{5}{12} = 0.4167$

   $\Rightarrow \theta = 24.626°$; $\mu = \tan\theta = \tan 24.626° = 0.458$

3. **5**

   Here, $F = 1.2$ kgwt $= 1.2 \times 9.8$ N, $m = 1.5$ kg,

   $\mu = 0.3$, $a = ?$, $f = \mu R = \mu mg = 0.3 \times 1.5 \times 9.8$

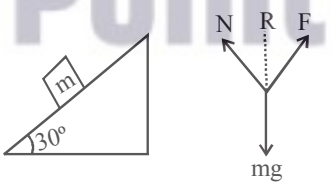
   Net force $= F - f = 1.2 \times 9.8 - 0.3 \times 1.5 \times 9.8$

   $= 9.8 \times 0.75$;

   $a = \frac{\text{net force}}{\text{mass}} = \frac{9.8 \times 0.75}{1.5} = 5\ \text{m/s}^2$

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

1. (d) Work done by friction can be positive, negative and zero depending upon the situation.
2. (c)
3. (b)
4. (d)
5. (c)
6. (a) As the block is at rest, the net contact force on the block i.e. resultant of friction and normal reaction must balance the weight of the block. Hence R = mg = 20N

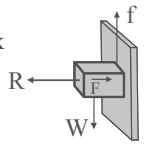


7. (c) Friction does not depend on the area of contact.
8. (c) Friction provides centripetal force to the coin, hence acts towards the centre of the disc.
9. (c) Here applied horizontal force F acts as normal reaction.

   For holding the block

   Force of friction = Weight of block

   $f = W \Rightarrow \mu R = W \Rightarrow \mu F = W$

   $\Rightarrow F = \frac{W}{\mu}$

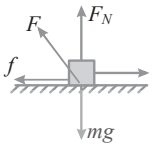
   As $\mu < 1$ $\therefore F > W$
10. (c) Coefficient of limiting friction, $\mu = \frac{F}{R}$

    where F is the force of friction and

    R is the normal reaction
11. (a, b, c)
12. (b, c, d)

Physics Point

13. (a, c, d)



As $F = \sqrt{F_N^2 + f^2}$, so

$F > F_N$ and $F > f$.

Clearly $(F_N - f) < F < (F_N + f)$

14. (A) $\rightarrow$ (p, q); (B) $\rightarrow$ (p, s); (C) $\rightarrow$ (q, r); (D) $\rightarrow$ (p, q, r, s)

15. (b)

16. (c)

17. (d)

18. (a) On a rainy day, the roads are wet, wetting of roads lowers the coefficient of friction, thus chances of skidding increases.

19. (d)

20. **6.** $v = u - at \Rightarrow t = \frac{u}{a}$ [As $v = 0$]

$$t = \frac{u \times m}{F} = \frac{30 \times 1000}{5000} = 6\,\text{sec}$$

21. **5** Acceleration,

$$a = \frac{F - \mu R}{m} = \frac{100 - 0.5 \times (10 \times 10)}{10} = 5\,\text{ms}^{-2}$$

22. **6** Maximum friction = $\mu g = 0.6 \times 10 = 6\ \text{m/s}^2$
But psuedo force = $1 \times 5 = 5$N
So required force is only 5N although max. friction available is 6N.

Physics Point

Chapter

3

SOUND

INTRODUCTION

Sound can be produced only by a vibrating body. Apart from motion in a straight line, motion in a circular path or motion in a parabolic path, we have a different type of motion in which the particle moves back and forth, to and fro, from side to side, in and out or up and down. The particle in all these cases is said to be vibrating. Vibratory motion is commonly observed in a ringing bell, in a string on a guitar, in lips on the mouth-piece of a trumpet, in the vocal cords of our larynx when we speak or sing, etc. When they vibrate in air, they make the air molecules, touch to vibrate in the same way and these vibrations spread out in all directions. These vibrations get weaker as time passes as they loose energy in the form of heat. But if these vibrations were to reach our ear, they would be transmitted to a part of our brain and we would hear sound. We cannot hear sound in vacuum, as sound cannot travels through vacuum. Sound requires a material medium a solid, a liquid or a gas to vibrate.

Physics Point

OSCILLATIONS OR VIBRATIONS

An oscillation or vibration is a special type of periodic motion in which a particle moves to and fro about a fixed point called mean position of particle. In oscillatory motion, there is always a mean position about which the particle can oscillate. At mean position, the net force acting on the particle is always zero. If particle is displaced from its mean position, due to this displacement some forces appear on it which tend the particle to move towards the mean position. This force is termed as the **restoring force**.

PERIODIC MOTION

A motion that repeats itself after a certain time is called **periodic motion**. For example, the motion of a swing, the motion of a particle on a circular path, etc. The time after which the motion repeats is called its **time-period**, generally represented by T.
An oscillatory motion is always periodic but a periodic mation is not necessarily always oscillatory.

SOUND IS PRODUCED BY A VIBRATING BODY

When the vibrations made in a medium reaches to our ears, we hear **sound**. Sound is a form of energy which produces sense of hearing. When a drum player slaps a drum it vibrates and sound is produced. Sound is produced for the time the vibration is active. Production of sound stops as the vibrations die out. The nature of sound produced depends on the nature of vibrating body.
When the prongs of a tuning fork are made to vibrate in air, the air particles in some regions will be momentarily bunched up (compressions), and in other regions in between, they will be momentarily spread out (rarefactions). Vibrations made up of compressions and rarefactions spread from the tuning fork throughout the air, and a sound wave is produced.

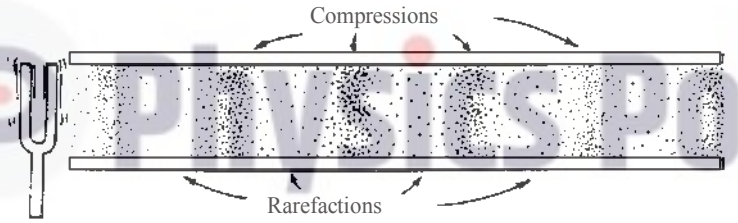
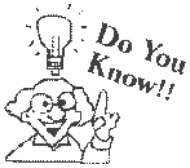


Fig. 3.1 : *Compressions and rarefactions travel (both at the same speed and in the same direction) from the tuning fork through the air in the tube.*

SOUND PRODUCED BY HUMANS

In humans sound is produced by the larynx or voice box situated at the upper end of the windpipe. Two vocal cords are stretched across the voice box or larynx and leaves a narrow slit between them. When the lungs force air through the slit the vocal cords vibrate producing sound.



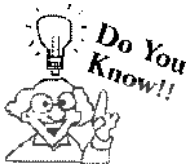
An oscillation is not a wave. Wave implies the transfer of energy through successive vibrations of the particles of the medium.

Think it Over

Does a vibrating body always produce sound.

WAVE AND WAVE MOTION

A wave is defined as "*a disturbance created in a medium which propagates in all directions, from the point of generation, without actual translatory motion of particles of the medium*", and the propagation of the wave is called the '*wave motion*'.
If you drop a stone into a calm pond, waves will travel outward in expanding circles. Energy is carried by the wave, travelling from one place to another.
When you speak, wave motion through the air travels across the room at about 340 m/s, the air itself doesn't travel across the room at this speed. In these examples, when the wave motion ceases, the water and the air return to their initial positions. It is characteristic of wave motion that the medium transporting the wave returns to its initial condition after the disturbance has passed.



- *Wave motion is possible only in a medium having the property of elasticity and inertia. In a wave motion, the wave propagates but the particles of medium don't move themselves.*
- *In a wave motion transfer of energy (not the matter) takes place from one point of the medium to the other.*

FREQUENCY, TIME PERIOD, AMPLITUDE AND VELOCITY OF A WAVE

Frequency : The number of oscillations produced in a medium per unit time is called frequency or the number of compressions and rarefactions (taken together) passing through a point in a unit time is called frequency.
The frequency is represented by 'n' or 'f'. The SI unit of frequency is hertz (symbol Hz) where 1 Hz is one oscillation per second.

Time period : The time taken by one oscillation to cross a point, is called time period or the time taken by two consecutive compressions or rarefactions to cross a point is called time period. This period is represented by the letter T.

$$Time\ period\ (T) = \frac{1}{frequency\ (n)}$$

Its SI unit is second (s).

Amplitude : The magnitude of the maximum displacement of vibrating particles of the medium on either side of their mean position is called amplitude. or The extent to which the medium is compressed, when a sound wave passes through it, is called amplitude.
It is represented by the letter A. Its SI unit is metre.

Wave speed : The speed of periodic wave motion is related to the frequency and wavelength of the waves.

Wavelength (λ) : It is the distance covered by a wave during the time in which a particle of the medium completes one vibration.

Physics Point

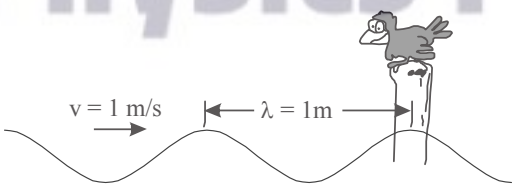
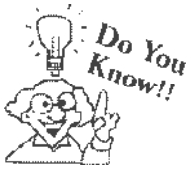


Fig. 3.2

In one time period (T), a wave advances by a distance equal to one wavelength. Thus if 'v' is the velocity of the given wave, it is given by

$$v = \frac{\lambda}{T}. \quad \text{or} \quad v = n\lambda \qquad (\because\ n = \frac{1}{T})$$

Thus, *velocity of wave propagation = frequency × wavelength.*



When a wave travels from one medium to other, its wavelength as well as velocity may change but frequency does not change.

ILLUSTRATION : 1

An electric razor completes 60 cycles every second. What is
(a) its frequency and (b) its time period?

SOLUTION :

(a) 60 cycles per second or 60 Hz ; frequency is the cycle per second.

(b) $\text{Time period} = \frac{1}{n} = 1/60$ second.

ILLUSTRATION : 2

If a train of freight cars, each 10 m long, rolls at the rate of three cars each second, what is the speed of the train?

SOLUTION :

We can see this in two ways.

(i) According to the definition of speed, $v = d/t = 3 \times 10$ m/1 s = 30 m/s, since 30 m of train passes you in 1 s.

(ii) If we compare our train to wave motion, where wavelength corresponds to 10 m and frequency is 3 Hz, then Speed = frequency × wavelength = 3 Hz × 10 m = 30 m/s

ILLUSTRATION : 3

If a water wave oscillates up and down three times each second and the distance between wave crests is 2 m,

(a) what is its frequency? (b) what is its wavelength? (c) what is its wave speed?

SOLUTION :

(a) As we know, the frequency is the no. of oscillations per second. Hence n = 3 Hz;

(b) wavelength is the distance between two consecutive crests or troughs. $\lambda = 2$ m;

(c) Wave speed = frequency × wavelength = 3/s × 2 m = 6 m/s.

CONNECTING TOPIC

MECHANICAL AND ELECTROMAGNETIC WAVES

Mechanical waves require material medium for their propagation. For example : sound waves, waves in stretched string, etc.
Electromagnetic waves do not require material medium for their propagation. For example: light wave, X-rays, etc.
There are two types of mechanical waves (i) Transverse wave (ii) Longitudinal wave.

Physics Point

Transverse and Longitudinal Waves

Fasten one end of a Slinky to a wall and hold the free end in your hand. If you shake the free end up and down, you will produce vibrations that are at right angles to the direction of wave travel. The right-angled, or sideways, motion is called *transverse motion*. This type of wave is called a **transverse wave**. Waves in the stretched strings of musical instruments and upon the surfaces of liquids are transverse waves. We will see later that electromagnetic waves, some of which are radio waves and light waves, are also transverse waves.

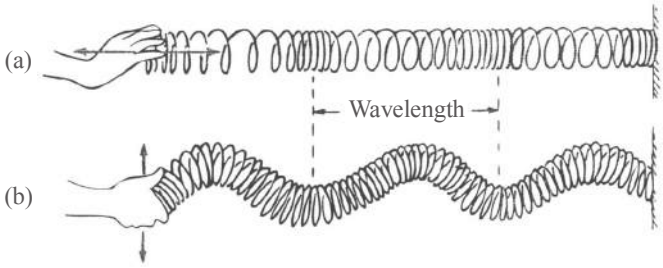
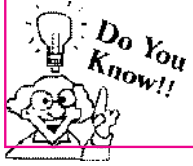


Fig. 3. 3 : *Both waves transfer energy from left to right.*
(a) When the end of the Slinky is pushed and pulled rapidly along its length, a longitudinal wave is produced. (b) When its end is shaken up and down
(or side to side), a transverse wave is produced.

A **longitudinal wave** is one in which the direction of wave travel is along the direction in which the source vibrates. You produce a longitudinal wave with your Slinky when you shake it back and forth along the Slinky's axis [Figure]. The vibrations are then parallel to the direction of energy transfer. Part of the Slinky is compressed, and a wave of *compression* travels along it. In between successive compressions is a stretched region, called a *rarefaction*. Both compressions and rarefactions travel in the same direction along the Slinky. Together they make up the longitudinal wave.



Transverse waves cannot be formed in gases only formed in solids and liquids whereas longitudinal waves formed in solids, liquid and gases.

TRANSMISSION OF SOUND/ SOUND NEEDS A MEDIUM FOR PROPAGATION

Mostly sound transmits through air but it can transmit through any elastic substance (an elastic substance is like a spring and can transmit energy with little loss. For example, steel is elastic but lead is not. Actually, air is a poor conductor of sound compared with solids and liquids.

If a person scratches one end of a long rail, the sound produced would almost instantaneously be heard by another person holding his ear to the rail at the other end. The same sound travelling through air would take longer (nearly 14 times more time!) to be heard over the same distance.

When swimming, have a friend at a distance, click two rocks together beneath the surface of water while you are submerged. Observe how well water conducts the sound.

If the two divers under water are stationed at two ends of a sufficiently long metal rod, and one of them taps the rod at his end, the other diver would find that he is able to hear the sound earlier if he holds his ear to the rod. This shows that sound travels faster in solids than in liquids.

Consider two divers under water, separated by a considerable distance. If one of them produces a sound, the other can hear it after a certain time. Separated by the same distance, if these two persons are above water, and if one produces a sound, the other would take a little more time to hear it than the time taken under water. This indicates that sound travels faster in liquids than in gases or air.

Thus *sound travels fastest in solids, less in liquids and the least in air or gases i.e.,* $V_{solid} > V_{liquid} > V_{gas}$.

The velocity of sound is about 5100 m/s in iron, about 1500 m/s in water and about 330 m/s in air.

Think it Over

Two astronauts on the surface of the moon cannot talk to each other why?

CHECK Point

What is the approximate distance of a thunderstorm, when you note a 3-s delay between the flash of lightning and the sound of thunder?

SOLUTION

Assuming the speed of sound in air is about 340 m/s, in 3 s it will travel 340 m/s × 3s = 1020 m.
There is no appreciable time delay for the flash of light, so the storm is slightly more than 1 km away.

CONNECTING TOPIC

SPEED OF LONGITUDINAL (SOUND) WAVES

According to Newton's formula,

Velocity of longitudinal wave in medium, $V_{medium} = \sqrt{\frac{E}{\rho}}$

where, E = elastic coefficient of medium and
ρ = density of medium

(a) For solid medium : $v_{solid} = \sqrt{\frac{Y}{\rho}}$ (E = Y = Young's modulus)

Velocity of sound in iron is 5150 ms^{-1} (approx)

(b) For liquid medium : $v_{liquid} = \sqrt{\frac{B}{\rho}}$

here E = B, (Bulk modulus)
For water v_{Water} = 1450 m/s

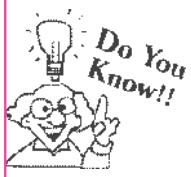
(c) For gas medium : The formula for velocity of sound in air was first obtained by Newton. He assumed that sound propagates through air temperature remains constant. (i.e. the process is isothermal)
So, isothermal elasticity = P

$\therefore \quad v_{air} = \sqrt{(P/\rho)}$

At NTP for air, $P = 1.01 \times 10^5$ N/m^2 and $\rho = 1.3$ kg/m^3

So, $v_{air} = \sqrt{\frac{1.01 \times 10^5}{1.3}} = 279$ m/s

However, the experimental value of sound in air is 332 m/s which is much higher than given by Newton's formula



- *Speed of sound is affected by temperature. It is directly proportional to the square root of the temperature.*
- *Speed of sound depends on the density of the medium. It is inversely proportional to the square root of density.*

ILLUSTRATION : 4

If the density of oxygen is 16 times that of hydrogen, what will be the corresponding ratio of their velocities of sound waves?

SOLUTION :

As we know, velocity of sound $v_{med} \propto \frac{1}{\sqrt{\rho}}$

$\therefore \quad \frac{v_{Oxygen}}{v_{Hydrogen}} = \sqrt{\frac{\rho_H}{\rho_0}} = \sqrt{\frac{1}{16}} = \frac{1}{4} = 1:4$

Physics Point

INFRASONIC, AUDIBLE AND ULTRASONIC SOUND

Sounds can be classified in three groups according to their range of frequencies.

Infrasonic sound : Longitudinal waves having frequencies below 20 Hz are called infrasonic sound. They cannot be heard by human beings. They are produced during earthquakes. Infrasonic sound can be heard by snakes.

Audible sound : Longitudinal waves having frequencies lying between 20-20,000 Hz are called audible sound. Human ears can detect only this range of frequencies.

Ultrasonic sound : Longitudinal waves having frequencies above 20,000 Hz are called ultrasonic sound. They are produced and heard by bats. Dog can hear ultrasonics.

Applications of Ultrasonic Sound

Ultrasonic sound have a large range of application. Some of them are :

(i) to detect fine internal cracks in metal .

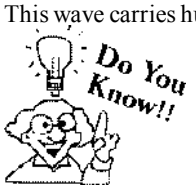
(ii) for determining the depth of the sea, lakes etc.

(iii) to clean clothes, fine machinery parts etc.

(iv) Ultrasonic waves can be used to kill smaller animals like rates, fish, frogs etc.

If the speed of the body in air is greater than the speed of the sound, then it is called **supersonic speed**. Such a body with supersonic speed leaves behind a conical region of disturbance which spreads continuously, such a disturbance is called a **shock waves**.

This wave carries huge energy. If it strikes a building, then the building may be damage.



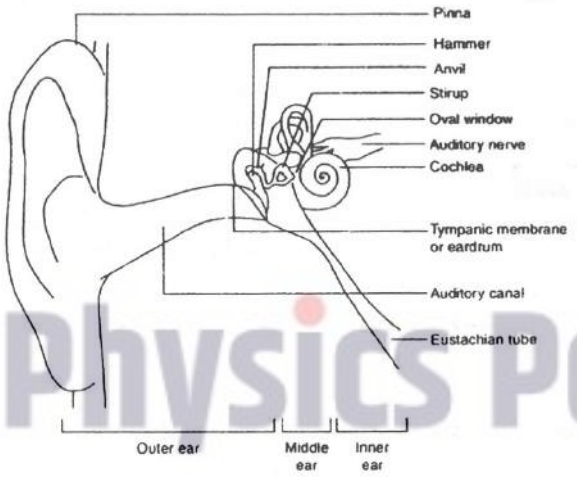
The ultrasound equipment familiar to us for investigating and tracking many medical problems works at frequencies greater than 20,000Hz i.e., ultrasonics.

THE HUMAN EAR

It is a highly sensitive part of the human body which enables us to hear a sound. It converts the pressure variations in air with audible frequencies into electric signals which travel to the brain via the auditory nerve.
The human ear has three main parts. Their auditory functions are as follows:

Outer Ear

The outer ear is called 'pinna'. It collects the sound from the surrounding. The collected sound passes through the auditory canal. At the end of the auditory canal there is a thin membrane called the ear drum or tympanic membrane. When compression of the medium produced due to vibration of the object reaches the ear drum, the pressure on the outside of the membrane increases and forces the eardrum inward. Similarly, the eardrum moves outward when a rarefaction reaches. In this way the ear drum vibrates.



Physics Point

Fig. 3.4 : *Auditory parts of the human ear.*

Middle Ear

The vibrations are amplified several times by three bones (the hammer, anvil and stirrup) in the middle ear which act as leavers. The middle ear transmits the amplified pressure variations received from the sound wave to the inner ear.

Inner Ear

In the inner ear, the pressure variations are turned into electrical signals by the cochlea. These electrical signals are sent to the brain via the auditory nerve, and the brain interprets them as sound.

REFLECTION OF SOUND - ECHO AND REVERBERATIONS

Sound reflects from a smooth surface in the same way that light does – the angle of incidence is equal to the angle of reflection. We call the reflection of sound an **echo**. The fraction of sound energy reflected from a surface is large if the surface is rigid and smooth, but it is less if the surface is soft and irregular. The sound energy that is not reflected is transmitted or absorbed. Sometimes, when sound reflects from the walls, ceiling, and floor of a room, the surfaces are too reflective and the sound becomes garbled. This is due to multiple reflections called **reverberations**. On the other hand, if the reflective surfaces are too absorbent, the sound level is low and the room may sound dull and lifeless. Reflected sound in a room makes it sound lively and full, as you have probably experienced while singing in the shower. In the design of an auditorium or concert hall, a balance must be found between reverberation and absorption.

Conditions for the Formation of Echoes

(i) The minumum distance between the source of sound and the reflecting body should be 17 m.
(ii) The wavelength of sound should be less than the height of the reflecting body.
(iii) The intensity of sound should be sufficient so that it can be heard after reflection.
(iv) Extended surfaces or obstacle of large size reflect sound waves. These surfaces need not be smooth or polished.

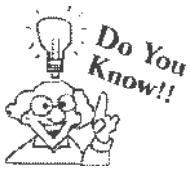
CHARACTERISTICS OF SOUND

The three characteristics of sounds are

(i) Loudness : It is the characteristic of a sound which distinguishes a feeble sound from a loud sound of the same frequency.

Factors affecting the loudness of sound

1. Loudness increases with the amplitude of vibrating body.
2. Loudness increases with the increase in surface area of vibrating bodies.
3. Loudness decreases with the increase in distance from the source of sound.



The loudness that we sense is related to the intensity of sound. Our perception of loudness is better co-related with the sound level measured in decible (dB). When the intensity increases 10 times the level increases by 10 dB

(ii) Pitch : It is the effect produced in the ear due to the sound of some particular frequency. Pitch depends upon the frequency of a vibrating body i.e., the higher the pitch, the more is the frequency and the lower the pitch, the less is the frequency. The voice of woman is more shrill than the voice of a man. The shrill sound is called high pitch sound, whereas soft or less shrill sound is called low pitch sound.

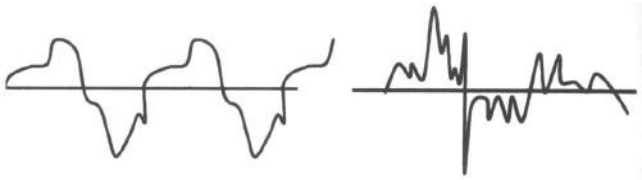
Factors affecting the pitch of sound

1. It depends upon the frequency of a vibrating body. Higher frequency produces shrill sound and lower frequency produces bass or flat sound.
2. Small lengths of vibrating air columns produce high pitched sound and vice versa.
3. Pitch of sound increases with the decrease in thickness or the length of vibrating wires.

(iii) Quality : The property due to which two notes of same pitch and loudness produced by two different vibrating bodies can be distinguished, is called quality or timbre of sound.

MUSICAL SOUND AND NOISE

The sound that produces a pleasing effect on our ears is called music or musical sound ; whereas sound that produces an unpleasant or irritating effect on our ears is called noise.



(a) Music *(b) Noise*

Fig. 3.5

Difference between musical sound and noise

	Musical sound		Noise
1.	It has a pleasant effect on the ears	1.	It has unpleasant effect on the ears
2.	Made by regular and periodic vibrations	2.	Made by irregular and non-periodic vibrations
3.	Has a definite frequency	3.	Does not have a definite frequency
4.	It is produced by musical instruments like-sitar, violin, ektara etc.	4.	It is produced by machines in a factory, moving buses, cars and trains, etc.
5.	Has a regular wave form	5.	Has an irregular wave form

NOISE POLLUTION

A sound of about 140 decibels and above can cause noise pollution. Noise pollution may cause many serious health hazards. Some of these are given below :

- It causes nervous tension and blood pressure. It can even cause heart attacks.
- It may cause partial or permanent hearing loss.
- It may cause skin diseases specially skin cancer.
- It also causes lack of concentration.

Think it Over

NO HORN PLEASE

Think methods of reducing noise pollution.

CONNECTING TOPIC

BEATS

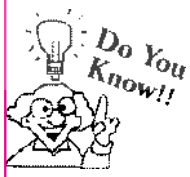
When two tones of slightly different frequencies are sounded together, a fluctuation in the loudness of the combined sounds is heard; the sound is loud, then faint, then loud, then faint, and so on. This periodic variation in the loudness of sound is called beats. Number of beats heard per second is equal to the difference between the frequencies of the two sources.

DOPPLER EFFECT

When a source of sound is moving towards us or away from us then we observe different pitches of the sound produced by it. This change in the frequency (or pitch) of the sound produced by a source due to relative motion between the source and observer is known as **Doppler Effect,** after the Austrian physicist and mathematician christian Johann Doppler.

The Doppler effect is evident when you hear the changing pitch of an ambulance or fire-engine siren. When the siren is approaching you, the crests of the sound waves encounter your ear more frequently, and the pitch is higher than normal. And when the siren passes you and moves away, the crests of the waves encounter your ear less frequently and you hear a drop in pitch.

Fig. 3.6 : *The pitch of sound increases when the source moves towards you, and it decreases when the source moves away*



- *Doppler effect is used in SONAR (Sound Navigator And Ranging) detect Sub-marines under the sea water.*
- *Doppler effect won't be observed, if the source of sound moves towards the observer with velocity more than the velocity of sound.*

SUMMARY

- **Oscillations or vibrations :** An oscillation or vibration is a special type of periodic motion in which a particle moves to and fro about a fixed point called mean position of particle.
- **Periodic motion :** A motion that repeats itself after a certain time is called **periodic motion**.
- **Sound :** Sound is a form of energy which produces sense of hearing. It can be produced by vibrating bodies.
- **Wave and wave motion :** A wave is defined as "a disturbance created in a medium which propagates in all directions, from the point of generation, without actual translatory motion of particles of the medium", and the propagation of the wave is called the 'wave motion'.
- **Amplitude :** The term amplitude refers to the distance from the midpoint to the crest (or to the trough) of the wave.
- **Frequency :** The number of the vibrations that occur in a unit time is called the frequency of the periodic motion.
- **Time period :** The time to complete one oscillation or vibration is called time-period.

$$\text{Time period} = \frac{1}{\text{Frequency}} \quad \text{or} \quad \text{Frequency} = \frac{1}{\text{Time period}}$$

- **Wave speed :** The distance by which the wave advances in one second is called the wave speed. Wave speed = frequency × wavelength.
- **Mechanical and electromagnetic waves :** A wave which required a material medium for its propagation is termed as mechanical wave and a wave which doesn't require any material medium for its propagation is termed as electromagnetic wave.
- **Transverse and longitudinal waves :** The wave in which the particles of medium vibrate in a direction perpendicular to the direction of wave motion is called transverse wave.

  The wave in which the particles of medium vibrate in a direction parallel to the wave motion is called longitudinal wave.
- **Audible, infrasonic and ultrasonic sound :** The sound ranging from 20 Hz to 20,000 Hz (or 20 kHz) is called audible sound; the sound beyond 20,000 Hz is called ultrasonic and the sound below 20Hz is called infrasonic sound.
- **Echo and reverberation :** The reflection of sound is called echo and the multiple reflection of sound is called reverberation.
- **Loudness :** Loudness is the characteristic of a sound which distinguishes a feeble sound from a loud sound of the same frequency.
- **Pitch :** Pitch is the effect produced in the ear due to the sound of some particular frequency. Pitch depends upon the frequency of a vibrating body
- **Quality or Timbre :** It is the property due to which two notes of same pitch and loudness produced by two different vibrating bodies can be distinguish.
- **Musical sound and noise :** The sound that produces a pleasing effect on our ears is called music; whereas sound that produces an unpleasant or irritating effect on our ears is called noise.
- **Beats :** When two sources of sound produce sound of different frequencies, a fluctuation in the loudness of the combined sounds is heard, which is called beats.
- **Doppler effect :** The change in the frequency (or pitch) of the sound produced by a source due to relative motion between the source and observer is known as Doppler effect.

Physics Point

1 EXERCISE

Fill in the Blanks :

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. Sound is a form of _____.
2. The speed of sound in air is _____.
3. Musical sound has a _____ effect on ears.
4. The S.I. unit of frequency is _____.
5. Loudness does not change with change in _____.
6. Jet planes which move with speeds greater than the speed of sound are called _____.
7. The audible frequency range of the sound for human beings is _____.

True/False :

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Frequency = $\frac{1}{\text{Time period}}$
2. The speed of sound in air is maximum.
3. All inaudible sounds produce frequencies less than 20 Hz.
4. Sound travels faster in gases than compared to solids and liquids.
5. The sounds having frequency less than 20 Hz are called ultrasonics.
6. The velocity of sound is affected by the density of the solid.
7. Velocity of wave = frequency × wavelength

Match the Following :

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D)in Column I have to be matched with statements (p, q, r, s, t) in Column II.*

1.

Column I	Column II
(A) Faster transmission of sound	(p) > 20 kHz
(B) Slower transmission of sound	(q) 20 Hz – 20 kHz
(C) Ultrasonic range	(r) Rarer medium
(D) Audible range	(s) Denser medium

2.

Column I	Column II
(A) Speed of sound	(p) metre
(B) Frequency	(q) having low density of the particles
(C) Amplitude	(r) s^{-1}
(D) Wavelength	(s) m/s
(E) Rarefaction	(t) Hz

Very Short Answer Questions :

DIRECTIONS : *Give answer in one word or one sentence.*

1. How does the speed of sound in water compare with the speed of sound in air?
2. If we double the frequency of a vibrating object, what happens to its period?
3. Does sound travel faster in warm air or in cold air?
4. Suppose a sound wave and an electromagnetic wave have the same frequency. Which has the longer wavelength?
5. Among solids, liquids and gases, in which medium is the velocity of sound the maximum and in which medium is the velocity of sound the minimum?
6. Define amplitude of a vibrating body.
7. What do you mean by audible sound.

Short Answer Questions :

DIRECTIONS : *Give answer in two to three sentences.*

1. Sound from source A has twice the frequency of sound from Source B. Compare the wavelengths of sound from the two sources.
2. A cat can hear sound frequencies up to 70,000 Hz. Bats send and receive ultrahigh –frequency squeaks up to 120,000 Hz. Which hears sound of shorter wavelengths, cats or bats?
3. Write the factors affecting loudness of sound.
4. At the stands of a race track, you notice smoke from the starter's gun before you hear its fire. Explain.
5. Distinguish between ultrasonics and infrasonics.
6. Why is the moon described as a "silent planet"?
7. On a keyboard, you strike middle C, whose frequency is 256 Hz.
   (a) What is the period of one vibration of this tone?
   (b) As the sound leaves the instrument at a speed of 340 m/s, what is its wavelength in air?

Long Answer Questions :

DIRECTIONS : *Give answer in four to five sentences.*

1. In reference to a wave motion, define the terms.
   (i) amplitude (ii) time period (iii) frequency (iv) wavelength
   (v) wave speed.
2. Describe an experiment to show that vibrating bodies produce sound.

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2 EXERCISE

Text-Book Exercise :

Choose the correct answer.

1. Sound can travel through

(a) gases only (b) solids only

(c) liquids only (d) solids, liquids and gases.

2. Voice of which of the following is likely to have minimum frequency?

(a) Baby girl (b) Baby boy

(c) A man (d) A woman

3. In the following statements, tick "T" against those which are true, and 'F' against those which are false.

(a) Sound cannot travel in vacuum. (T/F)

(b) The number of oscillations per second of a vibrating object is called its time period. (T/F)

(c) If the amplitude of vibration is large, sound is feeble. (T/F)

(d) For human ears, the audible range is 20 Hz to 20,000 Hz. (T/F)

(e) The lower the frequency of vibration, the higher is the pitch. (T/F)

(f) Unwanted or unpleasant sound is termed as music. (T/F)

(g) Noise pollution may cause partial hearing impairment. (T/F)

4. Fill in the blanks with suitable words.

(a) Time taken by an object to complete one oscillation is called _____.

(b) Loudness is determind by the _____ of vibration.

(c) The unit of frequency is _____

(d) Unwanted sound is called _____

(e) Shrillness of a sound is determined by the _____ of vibration.

5. A pendulum oscillates 40 times in 4 seconds. Find its time period and frequency.

6. The sound from a mosquito is produced when it vibrates its wings at an average rate of 500 vibrations per second. What is the time period of the vibrations?

7. Identify the part which vibrates to produce sound in the following instruments.

(a) Dholak (b) Sitar (c) Flute

8. What is the difference between noise and music? Can music become noise sometimes?

9. List sources of noise pollution in your surroundings.

10. Explain in what way noise pollution is harmful to human.

11. Your parents are going to buy a house. They have been offered one on the roadside and another three lanes away from the roadside. Which house would you suggest your parents should buy? Explain your answer.

12. Sketch larynx and explain its function in your own words.

13. Lightning and thunder take place in the sky at the same time and at the same distance from us. Lightning is seen earlier and thunder is heard later. Can you explain why?

Exemplar Questions :

1. We have learnt that vibration is necessary for producing sound. Explain why the sound produced by every vibrating body cannot be heard by us?

2. Suppose a stick is struck against a frying pan in vacuum. Will the frying pan vibrate? Will we be able to hear the sound? Explain.

3. Two astronauts are floating close to each other in space. Can they talk to each other without using any special device? Give reasons.

4. How is sound produced and how is it transmitted and heard by us?

5. The townhall building is situated close to Boojho's house. There is a clock on the top of the townhall building which rings the bell every hour. Boojho has noticed that the sound of the clock appears to be much clearer at night. Explain.

Hots Questions :

1. If the frequency of sound is doubled, what change will occur in its speed? What change will occur in its wavelength?

2. An astronaut is approaching the moon. He sends out a radio signal of frequency 5000MHz and the frequency of echo is different from that of the original frequency by 100kHz. Find his velocity of approach with respect to the moon.

Physics Point

3 EXERCISE

Single Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. The greater the surface area of the vibrating body, the _____ is the loudness of sound.
(a) lesser (b) greater
(c) same (d) none of these

2. The characteristic of a musical sound by which a loud sound can be distinguished from a faint sound even though both have the same pitch is
(a) loundness (b) pitch
(c) quality (d) none of these

3. A shrill sound has a _____ pitch and a dull sound has a _____ pitch.
(a) high, low (b) low, high
(c) low, low (d) high, high

4. If you go on increasing the stretching force on a wire in a guitar, its frequency.
(a) increases (b) decreases
(c) remains unchanged (d) none of these

5. A vibrating body:
(a) will always produce sound
(b) may or may not produce sound
(c) will produce sound which depends upon frequency
(d) None of the above

6. A body travelling with a speed of more than the velocity of sound in air is said to travel with
(a) supersonic speed (b) hypersonic speed
(c) ultrasonic speed (d) infrasonic speed

7. When a sound wave goes from one medium to another, the quantity that remains unchanged is
(a) Frequency (b) Amplitude
(c) Wavelength (d) Speed

8. In ordinary talk, the amplitude of vibration is approximately
(a) 10^{-12} m (b) 10^{-11} m
(c) 10^{-8} m (d) 10^{-7} m

9. The wavelength of ultrasonics in air is of the order of
(a) 10^{2} m (b) 10^{1} m
(c) 10^{-2} m (d) 10^{0} m

10. The speed of sound in a perfectly rigid rod is
(a) Infinite (b) Zero
(c) 332 m/s (d) 3×10^{8} m/s

11. Phon is unit of
(a) Wavelength (b) Loudness
(c) Frequency (d) Intensity

12. Ultrasonics are used in sonar with greater advantage, because ultrasonics
(a) Can be easily produced
(b) Are electromagnetic waves
(c) Have short wavelength
(d) Have low frequency

13. Which of the following statements is true?
(a) Sound travels faster in iron than in water.
(b) Sound can travel through inert gases.
(c) Sound travels in the form of compressions and rarefactions in air.
(d) All the above

14. Which of the following statements is incorrect?
(a) Sound travels faster in summer than in winter.
(b) Sound travels in a straight line
(c) Sound travels faster in vacuum than in air.
(d) Sound travels in the form of longitudinal mechanical waves

15. Which of the following statemnets are correct?
(i) Sound is produced by vibrations.
(ii) Sound requires a medium for propagation.
(iii) Light and sound both require a medium for propagation.
(iv) Sound travels slower than light.
(a) i & ii only (b) i, ii & iii only
(c) ii, iii & iv only (d) i, ii & iv only

16. In order to reduce the loudness of a sound we have to
(a) decrease its frequency of vibration of the sound.
(b) increase its frequency of vibration of the sound
(c) decrease its amplitude or vibration of the sound
(d) increase its amplitude of vibration of the sound

17. The loudness of sound is determined by the
(a) amplitude of vibration
(b) ratio of amplitude and frequency of vibration
(c) frequency of vibration
(d) product of amplitude and frequency of vibration

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More than One Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Which of the following frequencies are not audible.
(a) 15 Hz (b) 30,000 Hz
(c) 25,000 Hz (d) 25,00 Hz

2. Which of the following statements is/are correct?
(a) Changes in air temperature have no effect on the speed of sound.
(b) Changes in air pressure have no effect on the speed of sound.
(c) The speed of sound in water is higher than in air
(d) The speed of light in water is lesser than in air.

3. You can predict the approaching train that is not in line of sight by
(a) listening the sound of horn of engine through air
(b) listening the sound of engine through rail track.
(c) one can't predict the approaching train
(d) None of these

Multiple Matching Questions :

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and five or six statements (p, q, r , s...) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

Column I	*Column II*
(A) Audible	(p) Pitch
(B) Amplitude	(q) Vaccum
(C) Sitar	(r) That we can hear
(D) Frequency	(s) Loudness
(E) Sound cannot travel through	(t) Musical instrument

Passage Based Questions :

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH -1

Sound travels at different speeds in different substances. Speed of sound varies with factors such as temperature, nature of material, physical state of substance etc. Speed of sound in air is about 330 m/s.

1. Sound cannot travel through
(a) solids (b) liquids
(c) gases (d) vacuum

2. Speed of sound in air at room temperature is
(a) 330 m/s (b) 346 m/s
(c) 360 m/s (d) 342 m/s

Assertion & Reason :

DIRECTIONS : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** Every vibrating body is a source of sound.
Reason : All sounds are audible.

2. **Assertion :** Two persons on the surface of the moon cannot talk to each other.
Reason : There is no atmosphere.

3. **Assertion :** In oscillatory motion, displacement of a body from equilibrium can be represented by sine or cosine function.
Reason : The body oscillates to and fro about its mean position.

Integer/Numeric type Questions :

RECTIONS : *Following are integer based/Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

1. A person fires a gun infront of a building 167 m away. If the speed of sound is 334 m s^{-1}. Calculate the time after which he hears an echo.

2. An oceanic depth-sounding vessel surveys the ocean bottom with ultrasonic waves that travel 1530 m/s in sea water. How deep is the water directly below the vessel if the time delay of the echo to the ocean floor and back is 6 s?

3. A ship sends a signal and receives it back from the bottom of the sea after 6 s. What is the depth of the sea at that place? (speed of sound in sea water is 1333 ms^{-1})

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4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

DIRECTIONS (Qs. 1–14) : *The following questions has four choices (a), (b), (c) and (d) out of which only one is correct. You have to choose the correct option.*

1. A source of wave produces 3 crests and 3 troughs in 2 ms, the frequency of the wave is:
(a) 1.5 ms (b) 3 ms
(c) 1 ms (d) 0.67 ms

2. When the pressure of a gas is changed, then:
(a) the density of the gas also changes
(b) the ratio of the pressure to the density remains unaffected
(c) the velocity of the sound remains unaffected
(d) the value of y changes

3. A wave of frequency 1000 Hz travels between X and Y, a distance of 600 m in 2 seconds. The number of wavelengths there in distance XY:
(a) 3.3 (b) 300
(c) 180 (d) 2000

4. Echo is a type of
(a) reflected sound
(b) refracted sound
(c) neither reflected sound nor refracted sound
(d) none of these

5. A device which is used to find the depth of sea is called:
(a) RADAR (b) SONAR
(c) ECHO (d) none of these

6. What will be the wave velocity, if the radar gives 54 waves per min and wavelength of the given wave is 10 m?
(a) $4\ ms^{-1}$ (b) $6\ ms^{-1}$
(c) $9\ ms^{-1}$ (d) $5\ ms^{-1}$

7. The special technique used in ships to calculate the depth of ocean beds is
(a) LASER (b) SONAR
(c) sonic boom (d) reverberation

8. The velocity of ultrasonic sound in water is $1400\ ms^{-1}$. The depth of the ocean as detected by SONAR, if the time taken to receive the reflected wave is $\frac{3}{2}$ second .
(a) 21 km (b) 10.5 km
(c) 105 m (d) 1500 m

9. If the direction of the vibration of particles is parallel to the direction of the propagation of wave, then the wave is a
(a) transverse wave (b) longitudinal wave
(c) electromagnetic wave (d) All the above

10. The wavelength of infrasonics in air is of the order of
(a) 10^0 m (b) 10^1 m
(c) 10^{-1} m (d) 10^{-2} m

11. A source of sound is moving with a uniform speed along a circle. The frequency of sound as heard by listener stationed at the centre of the path
(a) Increases
(b) Decreases
(c) Remains the same
(d) May increase and decrease alternately

12. If wind blows from a stationary sounding object to a stationary listener, then the apparent frequency n' and actual frequency n are related as
(a) $n' \geq n$ (b) $n' < n$
(c) $n' = n$ (d) $n' > n$

13. Two musical notes P and Q have amplitude 0.5 cm and 0.8 cm respectively. The loudness of musical note P is :
(a) more than Q (b) equal to Q
(c) less than Q (d) none of the above

14. An electric bell is fitted in a vessel, connected to a vacuum pump. The bell is switched on. The air is gradually withdrawn from the vessel, when the bell is working. The loudness of sound of the bell will:
(a) increase when air is withdrawn
(b) decrease when air is withdrawn
(c) does not change when air is withdrawn
(d) none of the above.

DIRECTIONS (Qs. 15–16): *The following questions has four choices (a), (b), (c) and (d) out of which more than one are correct. You have to choose the correct option.*

15. Choose the correct statements (s) from the following?
(a) Mechanical wave needs medium for their propagation.
(b) Sound cannot travel through vacuum.
(c) Mechanical waves transport energy form one place to another
(d) Sound waves are non mechanical waves.

16. Transverse mechanical wave can travel in
(a) iron rod (b) hydrogen gas
(c) water (d) stretched string

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DIRECTIONS (Qs. 17-19) : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

17.

Column I	Column II
(A) Wavelength	(p) Sensitive to ultrasonic
(B) Bats	(q) Distance between two consecutive crest
(C) Noise	(r) Reflection of sound
(D) Aerophone	(s) Non–periodic vibrations
	(t) Distance between two consecutive compressions

18.

Column I	Column II
(A) Mechanical waves	(p) Disturbance for short time
(B) Pulse	(q) Independent of amplitude of vibrations
(C) Velocity of sound in air	(r) SONAR
(D) Tracking of fish in ocean	(s) Require a material medium

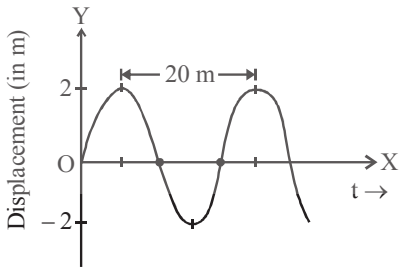
19.

Column I	Column II
(A) Sound	(p) Frequency
(B) SONAR	(q) Mechanical wave
(C) Reflection of sound	(r) Finding depth of the sea
(D) Pitch	(s) Echo

DIRECTIONS (Qs. 20–22) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH - 1

A mechanical wave is propagating in a material medium. The graph shown demonstrates the displacement curve of the wave at any time *t*.



20. What is the amplitude ?
(a) 2m (b) 20m (c) 10m (d) 5m

21. What is the wavelength of the wave ?
(a) 10m (b) 2m (c) 20m (d) 5m

22. If wave propagates with a velocity 340 ms^{-1}, find the frequency
(a) 15 Hz (b) 20 Hz (c) 17 Hz (d) 10 Hz

DIRECTIONS (Qs. 23–26) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

23. **Assertion :** Ultrasonic waves are longitudinal waves of frequency greater than 20, 000 Hz.
Reason : The maximum frequency of audible sound waves is 20, 0000 Hz.

24. **Assertion :** Infrasonic waves have largest wavelength
Reason : Velocity of sound in a material remaining same they will have largest wave length, because their frequency ranges between 0– 20 Hz.

25. **Assertion :** The flash of lighting is seen at once, but crack and thunder is heard sometimes latter
Reason : The light traels at a speed of 300,000 km/s, whereas sound travels 332 m/s

26. **Assertion :** Transverse waves can travel through the solids
Reason : Solids are mor elastic than liquids and gases.

DIRECTIONS (Qs. 27 – 30) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

27. Shruti hammers on a block of wood when she is 85 m from a large brick wall. Each time she hits the block, she hears an echo 0.5 s later. With this information, she finds the speed of sound 170 x. Find the value of x

28. A man fired a bullet against a wall and hears an echo after 2 s. He walks 80 m towards the wall and fired bullet, such that he hears echo after 1s. Find the distance from wall to the second fired place.

29. An ultrasonic source emits sound of frequency 220 kHz in air. If this sound meets a water surface, what is the wavelength of the reflected sound.
(At the atmospheric temperature, speed of sound in air $= 352\ m\ s^{-1}$ andin water = 1. 496 ms^{-1})

30. Imagine an old hermit type who lives in the mountains. Just before going to sleep, he yells "WAKE UP," and the sound echoes off the nearest mountain and returns 8 hours later. How far (in macrometer) away is that mountain?

Physics Point

SOLUTIONS

Brief Explanations of Selected Questions

1 EXERCISE

FILL IN THE BLANKS :

1. energy
2. 330 m/s
3. pleasant
4. Hertz
5. frequency
6. supersonic jets
7. 20 Hz to 20 kHz

TRUE/FALSE :

1. True
2. False
3. False
4. False
5. False
6. True
7. True

MATCH THE COLUMNS :

1. A - s; B - r; C - p; D - q
2. A - (s); B - (r, t); C - (p); D - (p); E - (q)

VERY SHORT ANSWER QUESTIONS :

1. The speed of sound in water is four times of the speed of sound in air.
2. Doubling the frequency reduces period to half.
3. Sound travels faster in warm air.
4. As the speed of sound waves is less than the speed of electromagnetic waves, wavelength of electromagnetic wave will be longer.
5. Maximum –solids

   Minimum– gases
6. The maximum displacement of the vibrating particle from mean position.
7. The frequency range of sound 20 Hz to 20 kHz that humans can hear.

SHORT ANSWER QUESTIONS :

1. Frequency and wavelength of a wave are related as, $\nu = \frac{v}{\lambda}$

   where, ν is the frequency of wave.

   λ is the wavelength of wave.

   v is the speed of wave.

   According to this relation, source A will have wavelengths half of source B.
2. Bats hear sound of shorter wavelengths compared to the cats as bats send and receive frequencies higher than the cats. Higher frequencies mean lower wavelength. Then, bats hear sound of shorter wavelengths compared to the cats.
3. Refer to theory
4. This is due to the fact that speed of light is greater than the speed of sound.
5. Refer to theory
6. As moon has no atmosphere, sound waves cannot propagate on the moon. Sound waves being pressure waves requires the presence of medium.
7. (a) $\text{Period (T)} = \frac{1}{\text{frequency}} = \frac{1}{256\ \text{Hz}} = 0.0039$ second

   (b) $\text{Wavelength } (\lambda) = \frac{\text{speed of sound in air}}{\text{frequency}} = \frac{340\ \text{m/s}}{256\ \text{s}^{-1}} = 1.328$ metre.

LONG ANSWER QUESTIONS :

1. Refer to theory
2. (i) Suspend a pendulum from a retort stand.

   (ii) Fix a tuning fork to a stand.

   (iii) Vibrate with rubber hammer.

   (iv) Make the bob of pendulum in contact with the fork

2 EXERCISE

TEXT-BOOK EXERCISE :

1. (d) solids, liquids and gases
2. (c) a man
3. (a) T (b) F
   (c) F (d) T
   (d) T (e) F
   (f) F (g) T
4. (a) time period (b) amplitude
   (c) Hertz (Hz) (d) noise
   (e) frequency
5. Given, number of oscillations = 40

   Time taken = 4s

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$$\text{Frequency} = \frac{\text{Number of oscillations}}{\text{Total time taken}} = \frac{40}{4} = 10 \text{ Hz}$$

$$\text{Time Period} = \frac{1}{\text{Frequency of oscillations}} = \frac{1}{10} = 0.1\text{s}$$

6. Given, frequency of vibrations = 500 Hz

$$\text{Time period} = \frac{1}{\text{Frequency of vibrations}} = \frac{1}{500} = 0.002 \text{ s}$$

7. (a) Dholak - Stretched membrane
(b) Sitar - Stretched string
(c) Flute - Air - column vibrations

8. The sound which is pleasing to the ear is called music. For example . the sound produced by flutes, pianos etc. The sound which is unpleasing to the ear is called noise. For example - sound produced by hornes of buses, electric generator etc.

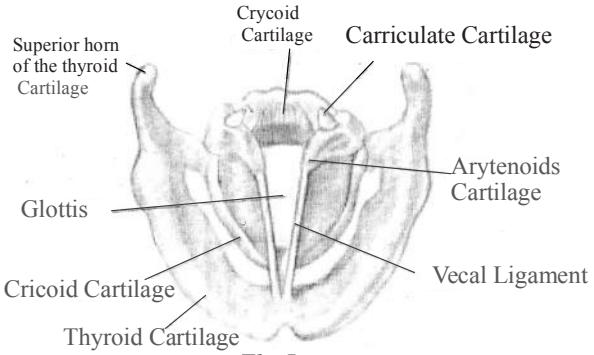
If a musical sound becomes too loud, it will not be pleasent to hear. It would not remain melodius, rather it will become noise.

9. There are many sources that causes noise pollution in our surrounding as
(i) hornes of buses, cars and trucks
(ii) kitchen appliances such as grinder
(iii) running of machines
(iv) television running at high volume

10. Noise pollution is harmful to humans in many ways as
(i) lack of sleep (ii) hearing loss
(iii) severe headache (iv) hypertension

11. I will suggest my parents to buy the house three lanes away from the roadside because there will be more noise produced by transportation of vehicles, in the house along the roadside. It may cause trouble to the residents. The intensity of the noise decreases with the distance between the source and the listener.

12. Inside the larynx, there are two vocal cords. There are a small gap between them. This small gap allows air to pass through. When we speak, air is forced into this small gap by the lungs, the vocal cords vibrate, producing sound. Muscles attached to the vocal cords can make the cords tight or loose.. When the vocal cords are tight and thin, the quality of voice is different from the when they are loose and thick.



The Larynx

13. The speed of light is more than the speed of sound. So, when lightning and thunder take place in the sky at the same time and at the same distance from us. Lightning is seen earlier than thunder.

EXEMPLAR QUESTIONS :

1. If the sound produced by a vibrating body is in the audible range. the sound produced will be heard by us otherwise we will not be able to hear the sound even though the body is vibrating.

2. The frying pan will vibrate. We will not be able to hear the sound of vibration because sound cannot travel in vacuum.

3. No. In space there is vacuum and sound cannot travel in vacuum.

4. Explain how a vibrating body produces sound and how it travels through the air and is heard by us by our ears.

5. The noise level is quite low at night. Therefore the sound of the clock appears much clearer at night than in the day.

HOTS QUESTIONS:

1. Speed will remain unchanged. Wavelength will be halved. It is due to the fact that the speed of sound depends on the medium characteristics such as temperature, humidity, etc. and not on the frequency.

2. $\frac{\Delta v}{v} = \frac{2n}{c}$

$$v = \frac{\Delta v}{2n} c$$

$$= \frac{100 \times 10^3 \times 3 \times 10^8}{2 \times 5000 \times 10^6} = 3 \text{ km/s}$$

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3 EXERCISE

SINGLE OPTION CORRECT :

1. **(b)** Loudness will be greater if surface area will be greater.
2. (a)
3. (a)
4. (b) Not produce sound if frequency is less than 20 Hz or more than 20 kHz.
5. (c)
6. (a)
7. (a)
8. (c)
9. (c)
10. (a)
11. (b)
12. (c)
13. (d) $v_{solid} > v_{liquid} > v_{gas}$
14. (c)
15. (d) Speed of sound in air $v_{air} = 332$ m/s
    $v_{light} = 3 \times 10^8$ m/s
16. (c)
17. (a) Loudness increases with the amplitude of vibrating body.

MORE THAN ONE OPTION CORRECT :

1. (a, b, c) Audible frequencies = 20 Hz to 20,000 Hz
2. (a, c, d)
3. (a, b)

MULTIPLE MATCHING QUESTIONS :

1. (A) – (r); (B) – (s); (C) – (t); (D) – (p) ; (E) – (q)

PASSAGE BASED QUESTIONS :

1. (d) Sound requires material medium to travel.
2. (a)

ASSERTION & REASON :

1. (c) Sound audible if frequencies lie between 20 Hz to 20 kHz
2. (c) **3.** (b)

INTEGER/NUMERIC TYPE QUSTIONS :

1. **1** Here, $d = 167$ m, $v = 334$ m s^{-1}, $t = ?$

   we know, $t = \frac{2d}{v} = \frac{2 \times 167}{334} = 1.0$ s

2. The round trip is 6 s, meaning 3 s down and 3 s up. Then by the relation $d = vt$

   the distance travelled by the ultrasonic waves is

   $d = 1530\,(m/s) \times 3\,(s) = 4590$ m

3. **4** Let the depth of the sea be 'd'

   Time interval before the echo is heard = 6 s,

   Speed of sound = 1333 m s^{-1}

   Distance travelled by sound = 2 d

   2d = speed × time

   $\Rightarrow$ $2d = 1333 \times 6$

   The depth of the sea $\cong$ 4 km

4 EXERCISE

1. (a) Frequency is the number of oscillation per unit time.
2. (b)
3. (d) $v = n\lambda \;\therefore\; \lambda = \frac{v}{n}$
4. (a)
5. (b)
6. (c)
7. (b)
8. (b) Here, 2d = speed × time
9. (b)
10. (b)
11. (c)
12. (c) As both source and observer are stationary
13. (c)
14. (b) Sounds require material medium to propagate.
15. (a, b, c)
16. (a , c, d)
17. A - (q, t); B - (p); C - (s); D - (r)
18. A - s; B - p; C - q; D - r
19. A - q; B - r; C - s; D - p
20. (a) Maximum displacement gives the amplitude.
21. (c) Distance between two consecutive crests or troughs gives the wavelength.

Physics Point

22. (c) $v = 340\ ms^{-1}, \lambda = 20\ m$

$$\text{Using } v = \nu\lambda, \text{ we get } \nu = \frac{v}{\lambda} = \frac{340}{20} = 17\ Hz$$

23. (a) Audible range of sound frequency 20 Hz to 20 kHz. Above 20 kHz ultrasonic and below 20 Hz infrasonic.

24. (a)

25. (a)

26. (b)

27. **2**

The distance covered (travelled) by the sound wave in 0.5 second is $2 \times 85 = 170$ metre.

$\therefore$ Speed of sound = distance travelled by the sound waves in one second

$= 2 \times 170$ (metre/s)

$= 340$ (metre/s)

$\therefore$ Speed of sound = 340 m/s. $\therefore$ x = 2

28. 160 m

29 1.6×10^{-3} m

30. **5**

Delay time of an echo = 8 hours = 8×3600 (s)

Speed of the sound = 340 (m/s).

Thus, the total distance travelled by sound waves

= delay time × speed of sound

$= (8 \times 3600\ s) \times (340\ m/s)$

$= 8 \times 3600 \times 340$ metre

$= 9.79 \times 10^6$ metre.

Since, during an echo, a wave has to go to the mountain and come back to the hermit, therefore, the distance between mountain and hermit is

$$\frac{9.79 \times 10^6}{2} \text{ metre} \cong 5 \times 10^6 \text{ m}$$

Physics Point

Chapter

4

CHEMICAL EFFECTS OF ELECTRIC CURRENT

INTRODUCTION

In present day, it is difficult to imagine life without electricity. Electricity has become inevitable in every walk of life. Be it medical field, agriculture, communication and media, transport or computers, almost every field depends heavily on electricity. So, this branch of physics is very important to us.

Electricity creates as a result of somewhat called charge. If electricity is produced as a result of charges at rest, the electricity is termed as static electricity and if electricity is produced as a result of charges in motion, the electricity is called current electricity. The materials which allow electric current to pass through them are good conductors of electricity. And the materials, which do not allow electric current to pass through them are poor conductors of electricity. When electric current passes through some conducting fluids, chemical action takes place at the electrodes, This effect is known as chemical effects of electric current. The liquid which allows the current to pass through them and dissociates into ions on passing current through them are called electrolytes and the process is called electrolysis.

CELLS, EMF AND INTERNAL RESISTANCE

Electrochemical Cell : *An electrochemical cell is a device which by converting chemical energy into electrical energy maintains the flow of charge or an electron in a circuit.* It usually consists of two electrodes of different materials and an electrolyte. The electrode at higher potential is called **anode** and the one at lower potential is **cathode**.

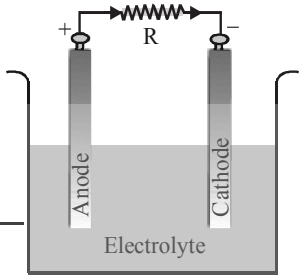
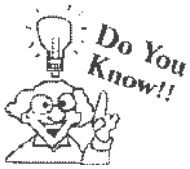


Fig. 4.1 Cell



The charge on an electron is 1.6 × 10–19 C, which is negative.

Electromotive Force (EMF) : *The emf of a cell is defined as work done by cell in moving a unit positive charge in the whole circuit including the cell.*

(1) EMF E = W/q; **SI unit** is joule/coulomb or volt.

(2) EMF is the maximum potential difference between the two electrodes of the cell when no current is drawn from the cell.
Also, it is the potential difference between the terminals of a cell in an open circuit.

(3) EMF is the characteristic property of cell and depends on the nature of electrodes and electrolyte used in cell.

(4) EMF is independent of quantity of electrolyte and size of electrodes.

Internal Resistance of Cell : *The opposition offered by the electrolyte of the cell to the flow of electric current through it is called the internal resistance of the cell.*

The internal resistance of cell (r) depends on the following factors.

(1) Distance between electrodes : Larger is the separation between electrodes more is the length of electrolyte through which ions have to move, so more is internal resistance ($r \propto d$).

(2) Conductivity or nature of electrolyte ($r \propto 1/\sigma$)

(3) Concentration of electrolyte ($r \propto c$)

(4) Temperature of electrolyte ($r \propto 1/T$)

(5) Nature and area of electrodes (A) dipped in electrolyte ($r \propto 1/A$)

Terminal Potential Difference : *The potential difference between the two electrodes of a cell in a closed circuit i.e., when current is being drawn from the cell is called terminal potential difference.*

(a) When cell is discharging : When cell is discharging current inside the cell is from cathode to anode.

Current $I = \dfrac{E}{r+R}$ or $E = IR + Ir = V + Ir$ or $V = E - Ir$

When current is drawn from the cell potential difference is less than emf of cell. Greater is the current drawn from the cell smaller is the terminal voltage. When a large current is drawn from a cell its terminal voltage is reduced.

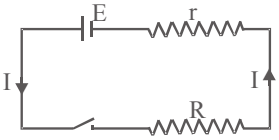


Fig. 4.2

(b) When cell is charging : When cell is charging current inside the cell is from anode to cathode.

Current $I = \dfrac{V-E}{r}$ or $V = E + Ir$

During charging terminal potential difference is greater than emf of cell.

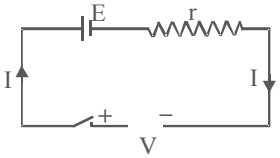


Fig. 4.3

(c) When cell is in open circuit :

In open circuit, $R = \infty \;\therefore\; I = \dfrac{E}{R+r} = 0$ so, $V = E$

In open circuit terminal potential difference is equal to emf and is the maximum potential difference which a cell can provide.

(d) When cell is short circuited :

In short circuit, R = 0 so, $I = \dfrac{E}{R+r} = \dfrac{E}{r}$ and $V = IR = 0$

In short circuit current from cell is maximum and terminal potential difference is zero.

Here, E = emf of a cell; V = terminal potential difference, I = electric current; r = internal esistance of cell; R = resistance.

Physics Point

DO LIQUIDS CONDUCT ELECTRICITY

Some liquids like tap water, lemon juice, etc. allow electric current to pass through them and some like distilled water, vegetable oils, etc. do not allow electric current.

The liquids that allow electric current to pass through are called **good conductors** and that do not allow electric current are called **poor conductors** of electricity.

The liquids which allow the current to pass through them and dissociate into ions on passing current through them are called electrolytes. e.g., solutions of salts, acids and bases in water. etc.

Those liquids which do not allow current to pass through them are called insulators (e.g. vegetable oils, distilled water etc.)

Solutions of cane sugar, glycerine, alcohol etc. are examples of non-electrolytes.

The process of decomposition of electrolytic solution into ions on passing the current through it is called electrolysis.

Practical applications of electrolysis are electrotyping, extraction of metals from the ores, purification of metals, manufacture of chemicals, production of O_2 and H_2, medical applications and electroplating.

ELECTROLYSIS

Most liquids that conduct electricity are solutions of acids, bases and salts.

Arrhenius explained the process of electrolysis by theory of ionic dissociation. When an electrolyte is dissolved in a liquid then some molecules of electrolyte dissociate into oppositely charged ions. This dissociation is reversible. When no current is passed through the solution the ions move randomly and the solution is electrically neutral. When an electric current is passed then the anions move towards anode and cations towards cathode under the influence of potential difference.

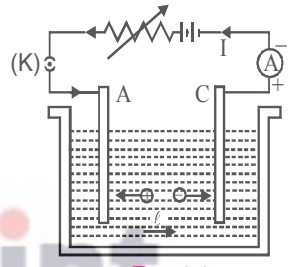


Fig. 4.4

On reaching electrode they give up their charge and become neutral. Then they appear as gas molecules or are deposited as thin layer on the electrode. The motion of ions to respective electrodes is equivalent to current flowing from anode +ve terminal to cathode –ve terminal.

Copper Voltameter : It consists of a glass vessel containing aqueous solution of $CuSO_4$ as electrolyte and two Cu plates which work as electrodes.

$CuSO_4$ in water dissociates as

$CuSO_4 \rightarrow Cu^{++} + SO_4^{--}$

On passing current through $CuSO_4$ Cu ions drift towards cathode and are neutralized by electrons flowing in from negative terminal of battery.

At cathode : $Cu^{++} + 2e^- \rightarrow Cu$. These copper atoms are deposited on cathode. The SO_4^{--} ions move towards anode, loose their two electrons and become neutral. These combine with Cu atoms from anode to form $CuSO_4$ which is dissolved in solution.

At anode : $Cu + SO_4^{--} \rightarrow CuSO_4 + 2e^-$.

Cu is lost from anode and deposited on cathode. The Cu^{++} and SO_4^{--} ions carry current from anode to cathode in the electrolyte. In external circuit the current is due to electrons.

The concentration of $CuSO_4$ remains constant.

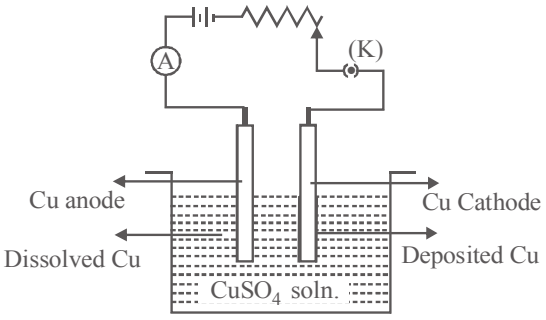


Fig. 4.5

Electroplating

It is a *process of depositing a thin layer of one metal over another metal by the method of electrolysis.* The articles of cheap metals are coated with precious metals like silver and gold to make their look more attractive. The article to be electroplated is made the cathode and the metal to be deposited is made the anode. A soluble salt of the precious metal is taken as the electrolyte. (If gold is to be coated then auric chloride is used as electrolyte).

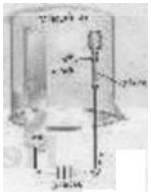


Fig. 4.6

CONNECTING TOPIC

FARADAY'S LAWS OF ELECTROLYSIS

First law : *The mass of a substance deposited or liberated at an electrode is directly proportional to the quantity of charge passed through the electrolyte.*

i.e., $m \propto q$ or $m = Zq = ZI\,t$

where, **Z is electrochemical equivalent (ECE)** of the substance.

If q = 1C then m = Z.

The ECE of a substance is the mass of substance deposited at an electrode when one coulomb of charge is passed through the electrolyte.

The **S.I. unit** of Z is kg/C

If ρ is the density of deposited material and A is area of deposition then the thickness of layer deposited is

$$y = \frac{m}{\rho A} = \frac{ZIt}{\rho A}$$

Second law : *When same charge is passed through different electrolytes, the mass of substance deposited or liberated are directly proportional to the chemical equivalents.*

i.e. $\frac{m_1}{m_2} = \frac{E_1}{E_2}$.

Chemical equivalent : *The ratio of atomic weight to valency.*

From faraday's Ist and IInd law for same charge q.

$$\frac{m_1}{m_2} = \frac{Z_1}{Z_2} = \frac{E_1}{E_2} \text{ or } \frac{E_1}{Z_1} = \frac{E_2}{Z_2} = \ldots\ldots\ldots = constant$$

In case of electrolysis the ratio of chemical equivalent and electrochemical equivalent is constant and same for all electrolytes or it is independent of nature of electrolyte.

From first law, m = ZQ if m = E and Q = F then, E = ZF or $\frac{E}{Z} = F$ then E/Z is the charge required to liberate 1g equivalent of substance through electrolysis. This quantity of charge is **one faraday**.

Faraday is charge on 1 g equivalent ions so, if p is the valency and N is Avogadro's number then

F = charge on an ion × no. of ions in 1 g equivalent

$$= (p \times e) \times \left(\frac{N}{p}\right) = Ne$$

$$F = 6.023 \times 10^{23} \times 1.6 \times 10^{-19} = 96487C \approx 96500\ C$$

In terms of faraday's first law it can be written as

$$m = Zq = \frac{E}{q}\ Q = E\left(\frac{Q}{F}\right)$$

$$= \left(\frac{Q}{F}\right) = \frac{M}{p}\frac{Q}{F} = \frac{\text{atomic mass}}{\text{valency}} \times \text{charge in faraday}$$

ILLUSTRATION : 1

Ag and Cu voltameter are connected in series with a 12.0 V battery of negligible internal resistance. 0.806 g of Ag is deposited in half an hour in silver voltameter. Calculate magnitude of current flowing in circuit. [mass of Cu deposited in same time $Z_{Ag} = 1.12 \times 10^{-8}$ kg/C and $Z_{cu} = 6.6 \times 10^{-7}$ kg/C].

SOLUTION :

$m_{Ag} = Z_{Ag}\,It$

or $I = \frac{m_{Ag}}{Z_{Ag}t} = \frac{0.806 \times 10^{-3}}{1.12 \times 10^{-8} \times 1800} = 39.98\,A$

$m_{Cu} = \frac{Z_{Cu}}{Z_{Ag}} \times m_{Ag} = \frac{6.6 \times 10^{-7}}{1.12 \times 10^{-8}} \times 0.806 \times 10^{-3} = 4.75 \times 10^{-2}$ kg

ILLUSTRATION : 2

A metal plate of area 250 cm^2 is to be coated on both sides by Cu. How long will it take to deposit Cu 0.01 cm in thickness if a current of 1.5 A is used? ECE of Cu = 0.00033 g/C and density of Cu = 9 g/cm^3.

SOLUTION :

Mass of Cu to be deposited = volume × density = total area × thickness × density = 2 × 250 × 0.01 × 9 = 45 g

$t = \frac{m}{ZI} = \frac{45}{0.00033 \times 1.5} = 90909.09$ sec. = 25.25 hours.

PRIMARY AND SECONDARY CELL

(1) **Primary cell :** The cell in which electrical energy is produced due to chemical energy. In the primary cell, chemical reaction is irreversible. This cell cannot be recharged. Examples of primary cells are Voltaic cell, Daniel cell, Leclanche cell and Dry cell etc.

(2) **Secondary cell :** A secondary cell is that cell in which the electrical energy is first stored up as chemical energy and when the current is taken from the cell, the chemical energy is reconverted into electrical energy. In the secondary cell chemical reactions are reversible. The secondary cells are also called storage cells or accumulator. The commonly used secondary cell is lead accumulator.

Defects in a Primary Cell

In voltaic cell main defects are

Local action : It arises due to the presence of impurities of iron, carbon etc. on the surface of commercial Zn rod used as an electrode. The particles of these impurities and Zn in contact with sulphuric acid form minute voltaic cells in which small local electric currents are set up resulting in the wastage of Zn even when the cell is not sending the external current.

Removal : By amalgamating Zn rod with mercury (i.e. the surface of Zn is coated with Hg.)

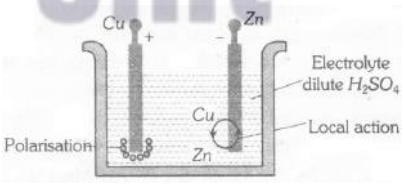


Fig. 4.7

ELECTRIC CURRENT AND RESISTANCE

When two bodies at different potentials are connected by a conducting wire, the charge flows from one body to another until the potentials of both the bodies become equal.

The quantity of electric charge flowing through a conductor in one second is called ***electric current****.*

i.e., current (I) $= \frac{\text{charge } (q)}{\text{time } (t)} = \frac{ne}{t}$

where, e = charge of electron and n = 0, 1, 2, 3 ..... (integer)

Its **S.I. unit** is ampere (A) or coulomb/second (Cs^{-1})

Resistance *is the obstruction offered to the flow of current*

According to **Ohm's law** at constant temperature, the current (I) flowing through a conductor is directly proportional to the potential difference (V) across the conductor.

i.e., $I \propto V$ or, $I = \frac{V}{R}$ or, $V = RI$

where R is a constant called the resistance of the conductor.

Its **S.I. unit** is volt/ampere or ohm (Ω).

Resistance of a conductor (R) ∝ length (l) of a conductor and $\propto \frac{1}{\text{A(area of cross-section of conductor)}}$

Resistance, $R = \rho\frac{\ell}{A}$ where ρ is called the resistivity of the material.

ELECTRIC CIRCUIT

An electric circuit is the path along which an electric current flows. There must be no gap in a circuit. It should be continuous. A circuit contains a source of electricity like a cell to supply energy, a switch to connect or disconnect the bulb from the electric sources when desired, a conducting wire to connect all the devices and a load like a bulb or any electrical appliance.

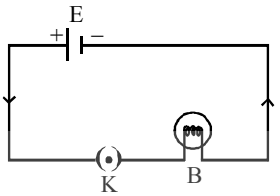


Fig. 4.8 Electric circuit diagram

To understand and study in detail the electrical connections made between various electrical components, a schematic diagram is often used. Such a schematic representation of an electric circuit on paper showing the symbols for components used is known as a 'circuit diagram'

Electrical Component	Symbol
Resistance	
Cell (source of electricity)	
A battery (combination of two or more cells)	
Plug key (switch) in closed condition	
Plug key in open condition	
Tap key (switch) in open condition	
Tap key in closed condition	
Bulb	
Ammeter (electric current measuring device)	

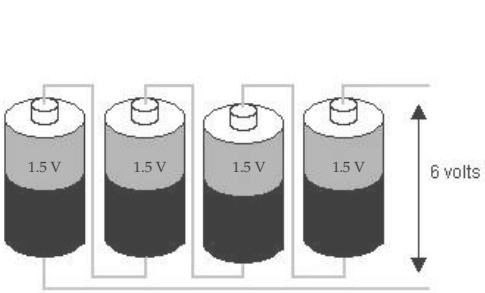
PhysicsPoint

Fig. 4.9

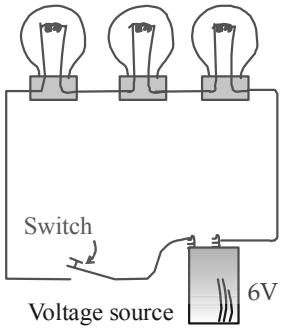
Most circuits have more than one device that receives electric energy. These devices are commonly connected in a circuit in one of two ways, in *series* or in *parallel*. When connected in series, they form a single pathway for electron flow between the terminals in the battery, generator, or wall outlet (which is simply an extension of these terminals). When connected in parallel, they form branches, each of which is a separate path for the flow of electrons. Both series and parallel connections have their own distinctive characteristics.

Series Circuits

A circuit in which loads (such as bulbs fans etc.) are connected such that positive terminal (+) of one load is connected to the negative terminal (–) of the next, the positive terminal of the second load is connected to the negative terminal of the third and so on such that same current passes through each load is known as series circuit. A simple series circuit is shown in Fig.
Three bulbs are connected in series with a battery. Electrons that make up the current leave the negative terminal of the battery, pass through each of the bulbs, and then return to the positive terminal of the battery.



(a)



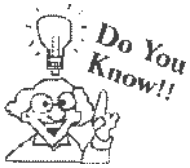
(b)

Fig. 4.10 : *(a) A simple series circuit. (b) The 6-V battery provides 2V across each lamp*

The following points explain the characteristics of a series circuit.

1. Electric current has a single pathway through the circuit. This means that the current passing through the resistance of each electrical device along the pathway is the same.

2. This current is resisted by the resistance of the first device, the resistance of the second, and that of the third also, so the total resistance to current in the circuit is the sum of the individual resistances along the circuit path.
3. The current in the circuit is numerically equal to the voltage supplied by the source divided by the total resistance of the circuit. This is in accorance with Ohm's law.
4. The total voltage impressed across a series circuit divides among the individual electrical devices in the circuit so that the sum of the "voltage drops" across the resistance of each individual device is equal to the total voltage supplied by the source. This characteristic follows from the fact that the amount of energy given to the total current is equal to the sum of energies given to each device.
5. The voltage drop across each device is proportional to its resistance. This follows from the fact that more energy is dissipated when a current passes through a large resistance than when the same current passes through a small resistance.



Equivalent resistance of some resistances connected in series is always greater than the greatest of individual resistance. Potential difference across any resistor is directly proportional to the resistance of that resistor.

Think it Over

Three bulbs of 30W, 60W, and 100W are connected to the same source of electricity in series. Which bulb will glow more?

CHECK Point

1. **What happens to current in other lamps if one lamp in a series circuit burns out?**
2. **What happens to the light intensity of each lamp in a series circuit when more lamps are added to the circuit?**

SOLUTION

1. If one of the lamp filaments burns out, the path connecting the terminals of the voltage source breaks and current ceases. All lamps go out.
2. Adding more lamps in a series circuit produces a greater circuit resistance. This decreases the current in the circuit and therefore, in each lamp, which causes dimming of the lamps. Energy is divided among more lamps, so the voltage drop across each lamp is less..

Physics Point

ILLUSTRATION : 3

A cell of emf 1.5V and internal resitance 1.0 Ω is connected to two resistors of 4.0 Ω and 20.0 Ω in series as shown in the Fig. Calculate the:

(a) current in the circuit.
(b) potential difference across the 4.0 ohm resistor.
(c) voltage drop when the current is flowing.
(d) potential difference across the cell.

SOLUTION :

(a) Total resistance = $4.0 + 20.0 + 1.0 = 25.0\,\Omega$

$$\therefore \text{ Current } I = \frac{V}{R} = \frac{1.5}{25.0} = \frac{15}{250} = \frac{3}{50} = 0.06\,\text{A}$$

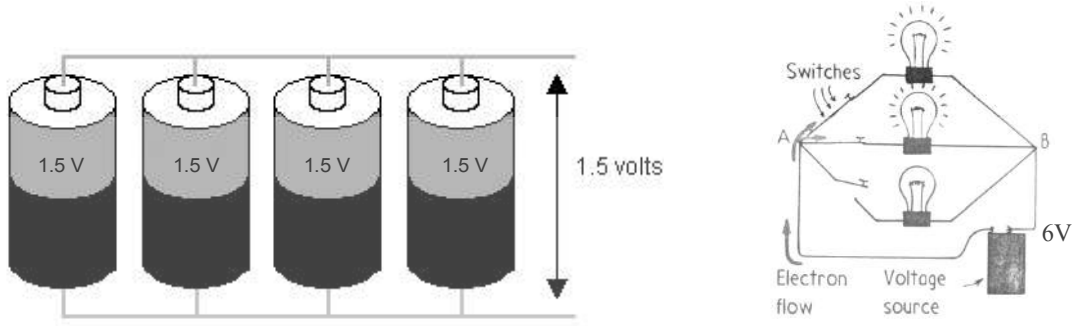
(b) Potential difference across $4\,\Omega = V \times R = 0.06 \times 4 = 0.24$ volts.

(c) Voltage drop $= 1 \times r = 0.06 \times 1 = 0.06$ volts.

(d) Potential difference across the cell, $V = \varepsilon - 1r = 1.5 - 0.06 = 1.44$ volts

Parallel Circuits

A circuit is said to be parallel if different components are individually connected to the battery so that they form different branches in circuit. In each branch, the current flowing might be same or different depending upon the resistance to the flow of current that each branch offers.



(a) (b)

Fig. 4.11 : (a) A simple parallel circuit. (b) A 6-V battery provides 6V across each lamp.

From the figure it can be seen that each bulb is connected to both the terminals of battery independently so that even if one bulb is removed or if fuses, other bulbs are not affected. This is the reason why electric appliances at homes and offices are connected in parallel so that they can be independently switched off and on.

The following points explain characteristics of a parallel circuit.

1. Each device connects the same two points, A and B, of the circuit. The voltage is therefore the same across each device.
2. The total current in the circuit divides among the parallel branches. Since the voltage across each branch is the same, the amount of current in each branch is inversely proportional to the resistance of the branch.
3. The total current in the circuit equals the sum of the currents in its parallel branches.
4. As the number of parallel branches is increased, the overall resistance of the circuit is *decreased*. Overall resistance is lowered with each added path between any two points of the circuit. This means the overall resistance of the circuit is less than the resistance of any one of the branches.

The equivalent resistance in a parallel combination is always less than the value of least individual resistance

CHECK Point

1. **What happens to the current in other lamps if one of the lamps in a parallel circuit burns out?**
2. **What happens to the light intensity of each lamp in a parallel circuit when more lamps are added in parallel to the circuit?**

SOLUTION

1. If one lamp burns out, the other lamps will be unaffected. The current in each branch, according to Ohm's law, is equal to voltage/resistance, and since neither voltage nor resistance is affected in the other branches, the current in those branches is unaffected. The total current in the overall circuit (the current through the battery), however, is decreased by an amount equal to the current drawn by the lamp before it burned out. But the current in any other single branch is unchanged.
2. The light intensity for each lamp is unchanged as other lamps are introduced (or removed). Only the total resistance and total current in the total circuit changes, which is to say that the current in the battery changes. (There is resistance in a battery also, which we assume is negligible here.) As lamps are introduced, more paths are available between the battery terminals, which effectively decreases total circuit resistance. The decreased resistance is accompanied by an increased current, the same increase that feeds energy to the lamps as they are introduced. Although changes of resistance and current occur for the circuit as a whole, no changes occur in any individual branch in the circuit.

ILLUSTRATION : 4

In figure 4.12 shown, calculate the:

(a) value of combined resistances of 40 Ω and *R*, using the readings of the two meters.

(b) value of *R*.

(c) current flowing through *R*.

SOLUTION :

(a) By Ohm's law, Combined resistance,

$$R' = \frac{V}{I} = \frac{4.0}{0.4} = 10\,\Omega$$

(b) Let R' be the equivalent resistance. Then,

$$\frac{1}{40} + \frac{1}{R} = \frac{1}{R'} \quad \text{or} \quad \frac{1}{40} + \frac{1}{R} = \frac{1}{10}$$

$$\text{or} \quad \frac{1}{R} = \frac{1}{10} - \frac{1}{40} \quad \text{or} \quad \frac{1}{R} = \frac{4-1}{40} = \frac{3}{40}$$

$$\text{or} \quad R = \frac{40}{3} = 13.3\,\Omega$$

(c) Current flowing through R.

$$I' = \frac{V}{R} = \frac{4}{13.3} = \frac{40}{133} = 0.3\text{A}$$

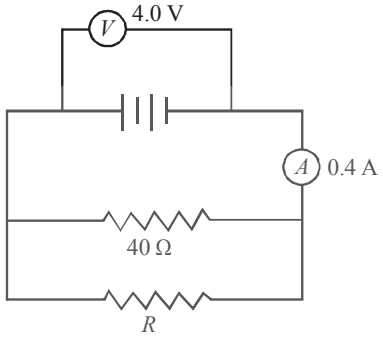


Fig. 4.12

CONNECTING TOPIC

DOMESTIC CIRCUITS AND OVERLOADING

Electricity is usually fed into a home by way of two wires called *lines*. These lines are very low in resistance and are connected to wall outlets in each room–sometimes through two or more separate circuits. An electric potential of about 110 to 120 volts is applied across these lines by a transformer in the neighborhood. (A transformer is a device that steps down the higher voltage supplied by the power utility). As more devices are connected to a circuit, more pathways for current result. This lowers the combined resistance of the circuit. Therefore, more current exists in the circuit, which is sometimes a problem. Circuits that carry more than a safe amount of current are said to be *overloaded*.

We can see how overloading occurs in figure. The supply line is connected to a toaster that draws 8 A, a heater that draws 10 A, and a lamp that draws 2 A. When only the toaster is operating and drawing 8 A, the total line current is 8 A. When the heater is also operating, the total line current increases to 18 A (8 A to the toaster plus 10 A to the heater). If you turn on the lamp, the line current increases to 20 A. Connecting additional devices increases the current still more. Connecting too many devices into the same circuit results in overheating the wires, which can cause a fire.

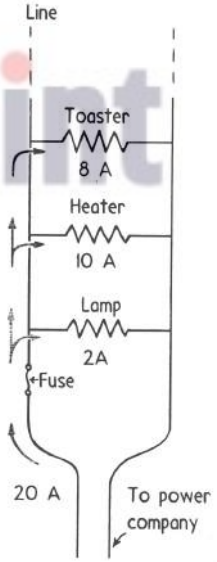


Fig. 4.13 : *Circuit diagram for appliances connected to a household circuit.*

SAFETY FUSES

Electric fuse is the device used in the household electric wiring that protects appliances from high current. Fuse wire is connected between the mains and leads of the primary circuit of an electric appliance. When excess amount of electricity passes through the wire, the fuse wire gets heated and the heat produced fuses or melts the wire breaking the power supply to the circuit of the appliance. Thus, the electric appliance is protected from the passage of high electric current which destroys the appliance.

If the fuse is rated at 20 A, it will pass 20 A, but no more. A current above 20 A will melt the fuse, which "blows out" and breaks the circuit. Before a blown fuse is replaced, the cause of overloading should be determined and remedied. Sometimes insulation that separates the wires in a circuit wears away and allows the wires to touch. This greatly reduces the resistance in the circuit and is called a *short circuit*.

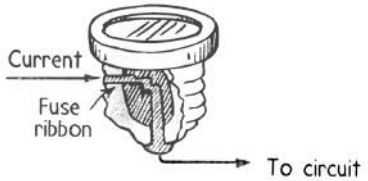


Fig. 4.14: *A safety fuse*

HEATING EFFECT OF ELECTRIC CURRENT

Heating effect is one of the most important effects of electric current. When an electrical conductor is connected to a source of electricity, heat is produced in it. That is, electrical energy is transformed into heat energy. This is known as the heating effect of electric current.

When a solid electrical conductor like a metallic wire is connected to the terminals of a battery, electric current, i.e., flow of charge, takes place through the conductor by way of the motion of free electrons present in it from one end to the other end. Due to the collision of free electrons in the conductor with its atoms or molecules, their kinetic energy increases and this increase in the kinetic energy is exhibited in the form of heat. Thus, we can say the more the electrical resistance of a conductor, the more is the heat produced.

Heat produced in a resistor is directly proportional to square of current and also to the time for which current passes through it.

Heat produced in time t in a resistor R through which a current I is passing is given by

$$H = I^2 R\, t = V I\, t$$

This is also called **Joule's heating law**.

ELECTRIC POWER

The moving charges in an electric current do work. This work, for example, can heat a circuit or turn a motor. The rate at which work is done – that is the rate at which electric energy is converted into another form, such as mechanical energy, heat, or light – is called electric power. Electric power is equal to the product of current and voltage.

Mathematically, Power = current × voltage

$$P = VI = I^2 R$$

Where, I = current, R = resistance, V = potential difference

If the voltage is expressed in volts and the current in amperes, then the power is expressed in watts. So, in units form,

Watt = ampere × volt

If a lamp rated at 120 watts operates on a 120-volt line, you can figure that it will draw a current of 1 ampere (120 watt = 1 ampere × 120 volt). A 60-watt lamp draws ½ ampere on a 120-volt line. This relationship becomes a practical matter when you wish to know the cost of electrical energy, which is usually a small fraction of a dollar per kilowatt-hour, depending on the locality. A kilowatt is 1000 watts, and a kilowatt-hour represents the amount of energy consumed in 1 hour at the rate of 1 kilowatt. Therefore, in a locality where electric energy costs ₹2.5 per kilowatt-hour, a 100-watt electric light bulb can operate for 10 hours at a cost of ₹2.5. A toaster or iron, which draws much more current and therefore, much more energy, costs about ten times as much to operate.

Practical Unit of Electrical Energy (Board of Trade unit B.O.T. U)

The amount of electrical energy used daily in our household is quite large and a special unit has to be used to measure it. This unit is **kilowatt hour** (kW h). If 1000 J of energy per second is used continuously for 1 hour, the energy consumed is 1 kWh.

$$1\ \text{kWh} = 1000\ \text{W} \times 1\text{h}$$

$$= 1000 \times 60 \times 60\ \text{W s} = 3.6 \times 10^6\ \text{J}$$

$$\therefore \quad 1\text{kWh} = 3.6\ \text{M J}$$

The device which measures the electrical energy being consumed in a household is called kWh metre, and 1 kWh is referred to as 1 unit of electrical energy.

SUMMARY

- **Electric cell :** An electric cell is a device which converts chemical energy into electric energy.
- **Electro-motive force (emf) of a cell :** The energy given by a cell in flowing unit positive charge throughout the circuit completely one time is equal to the emf of a cell.

  $\text{Emf of a cell, } E = \frac{W}{q}$
- **Terminal potential difference :** The energy given by a cell in flowing a unit positive charge through the outer circuit from one terminal to the other terminal of the cell.
- **Internal resistance of a cell :** The obstruction offered by the electrolyte of a cell in the path of electric current is called internal resistance of the cell.
- **Chemical effects of electric current :** Chemical action due to the passage of electric current through some conducting fluids. The conducting fluids are called **electrolytes** and the process is called electrolysis.
- **Electroplating :** The process of coating an object that conduct electricity with another metal.
- **Faraday's first law of electrolysis :** The mass of the substance liberated at each electrode is directly proportional to the total charge passed through the electrolyte.

  i.e., $W \propto Q$ or $W = ZIt$

  where, Z = electrochemical equivalent of the substance deposited on the electrode.
- **Faraday's second law of electrolysis :** The mass of each substance liberated at the electrodes in electrolysis by a given amount of charge is proportional to the chemical equivalent of the substance

  i.e., $W \propto E$ or $\frac{W_1}{W_2} = \frac{E_1}{E_2}$

Physics Point

- **Electric current :** It is the charge flowing through a given cross-section per unit time. It is given by $I = \frac{Q}{t} = \frac{ne}{t}$
- **Quantization of charge :** Charge on any object can be integer multiple of a smaller charge (e),

  $Q = \pm ne$ where $n = 1, 2, 3, ...$
- **Ohm's Law :** "Under given physical conditions the current (I) produced in the conductor is proportional to the applied potential difference across the conductor". i.e., $V \propto I$ or $V = RI$
- **Resistance :** The property of a conductor due to which it resists electric current to pass through itself.
- **Electric circuit :** An electric circuit is the path along which an electric current flows. There must be no gap in a circuit. It should be continuous.
- **Series circuits :** A circuit in which loads (such as bulbs) are connected such that positive terminal (+) of one load is connected to the negative terminal (–) of the next, the positive terminal of the second load is connected to the negative terminal of the third and so on such that same current passes through each load is known as series circuit.
- **Parallel circuits :** A circuit is said to be parallel if different components are individually connected to the battery so that they form different branches in circuit. In each branch, the current flowing might be same or different depending upon the resistance to the flow of current that each branch offers.
- **Overloading :** Circuits that carry more than a safe amount of current are said to be overloaded.
- **Joule's heating law :** Heat produced in time t in a conductor of resistance R through which a current I is passing is given by $H = I^2Rt = VIt$
- **Electric power :** The rate at which work is done – that is the rate at which electric energy is converted into another form, such as mechanical energy, heat, or light – is called electric power. Electric power is equal to the product of current and voltage. Power = current × voltage

1 EXERCISE

Fill in the Blanks :

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. In charging a battery of motor-car, the _____ effect of electric current is used.
2. The electrical process of coating inexpensive conductor with a metal is called _____.
3. The decomposition of an electrolyte when electricity is passed through it is called _____.
4. In _____ conduction is due to the motion of free electrons.
5. A cell converts chemical energy into _____.

True/False :

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. All liquids conduct electricity.
2. Good conductors of electricity allow electric current to pass through them.
3. During electrolysis negative terminal used is called anode.
4. Pure water can be used as an electrolyte in the process of electrolysis.
5. During electrolysis cations move towards cathode.

Match the Following :

DIRECTIONS : *Question contain statements given in two columns which have to be matched. Statements in column I have to be matched with terms given in column II.*

1.

Column-I	Column-II
(A) Good conductor	(p) cathode
(B) Bad conductor	(q) metals
(C) Negative terminal	(r) salts
(D) Positive terminal	(s) wood
(E) Electrolyte	(t) anode

2.

Column-I	Column-II
(A) Flow of charge per unit time	(p) good conductor
(B) Pure water	(q) liquid that conducts electricity
(C) Materials which allow electricity	(r) current
(D) Electrolyte	(s) bad conductor

Very Short Answer Questions :

DIRECTIONS : *Give answer in one word or one sentence.*

1. Why a small quantity of sulphuric acid is added to water for its electrolysis?
2. What is electroplating?
3. What is an electrolyte?
4. Define electric current.
5. What is electrolysis ?
6. Why distilled water not conduct electricity?
7. Write any two practical applications of electrolysis.

Short Answer Questions :

DIRECTIONS : *Give answer in two to three sentences.*

1. Classify the following materials as good or bad conductor of electricity.
   Air, pure water, lemon juice, milk, tap water, vegetable oil and honey.
2. Distinguish between the flow of electric current through metal conductor and electrolytes?
3. Explain the application of electrolysis.
4. Define electric current. Write the unit of electric current.
5. Does electric charge flow across a circuit or through a circuit? Does voltage flow across a circuit or is it impressed across a circuit? Explain.
6. How much energy is given to each coulomb of charge passing through a 6-V battery?

Long Answer Questions :

DIRECTIONS : *Give answer in four to five sentences.*

1. Define :
   (i) Electrochemical cell.
   (ii) Electromotive force.
   (iii) Internal resistance of a cell.
   (iv) Terminal potential difference
2. Explain the electrolysis of water.
3. Write an activity to show the chemical effect of electric current

Physics Point

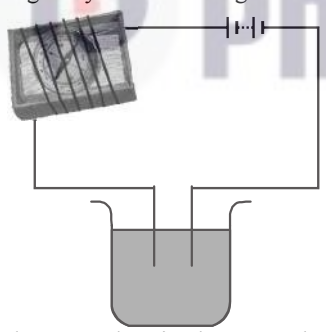
2 EXERCISE

Text-Book Exercise :

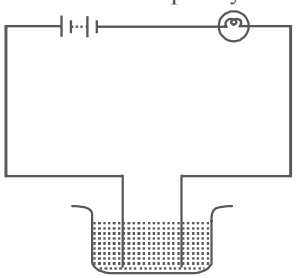
1. Fill in the blanks.
(a) Most liquids that conduct electricity are solutions of _____,_____ and _____.
(b) The passage of an electric current through a solution causes _____ effects.
(c) If you pass current through copper sulphate solution, copper gets deposited on the plate connected to the _____ terminal of the battery.
(d) The process of depositing a layer of any desired metal on another material by means of electricity is called _____.

2. When the free ends of a tester are dipped into a solution, the magnetic needle shows deflection. Can you explain the reason?

3. Name three liquids, which when tested in the manner shown in Fig. may cause the magnetic needle to deflect.



4. The bulb does not glow in the setup shown in Fig. List the possible reason. Explain your answer.



5. A tester is used to check the conduction of electricity through two liquids. labelled A and B. It is found that the bulb of the tester glows brightly for liquid A while it glows very dimly for liquid B. You would conclude that
(i) liquid A is a better conductor than liquid B.
(ii) liquid B is a better conductor than liquid A.
(iii) both liquids are equally conducting.
(iv) conducting properties of liquid cannot be compared in this manner.

6. Does pure water conduct electricity? If not, what can we do to make it conducting?

7. In case of a fire, before the firemen use the water hoses, they shut off the main electrical supply for the area. Explain why they do this.

8. A child staying in a coastal region tests the drinking water and also the sea water with his tester. He finds that the compass needle deflects more in the case of seawater. Can you explain the reason?

9. Is it safe for the electrician to carry out electrical repairs outdoors during heavy downpour ? Explain.

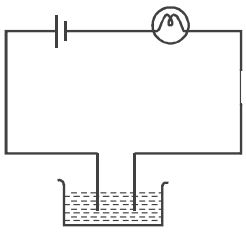
10. Paheli had heard that rainwater is as good as distilled water. So she collected some rainwater in a clean glass tumbler and tested it using a tester. To her surprise she found that the compass needle showed deflection. What could be the reasons?

11. Prepare a list of objects around you that are electroplated.

12. The process that you saw in **Activity 14.7** is used for purification of copper. A thin plate of pure copper and a thick rod of impure copper are used as electrodes. Copper from impure rod is sought to be transfered to the thin copper plate. Which electrode should be attached to the positive terminal of the battery and why ?

Exemplar Questions :

1. Boojho made the circuit given in Fig. and observed that the bulb did not glow. On paheli's suggestion he added one more cell in the circuit. The bulb now glows. Explain

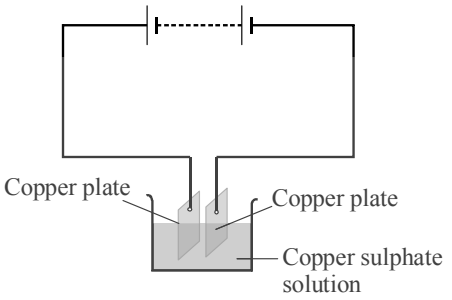


2. Paheli wants to deposit silver on an iron spoon. She took silver nitrate ($AgNO_3$) solution in a beaker and setup a simple circuit for electroplating. Which terminal of the battery should the spoon be connected to? What material should the other electrode be made of?

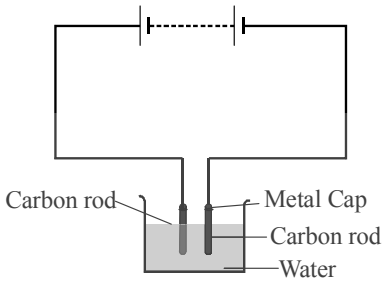
3. Why is tin electroplated on iron to make cans used for storing food?

4. In the circuit given as Fig. Boojho observed that copper is deposited onthe electrode connected to the negative terminal of the battery. Paheli tried to repeat the same experiment. But she could find only one copper plate. Therefore she took a carbon rod as negative electrode. Will

copper be still deposited on the carbon rod? Explain your answer.



5. Boojho made the circuit shown in fig. He wanted to observe what happens when an electric current is passed through water. But he forgot to add a few drops of lemon juice to water. Will it make any difference to his observations? Explain.



Hots Questions :

1. What causes electric shock – current or voltage?
2. What does it mean to say that your car has a 12-volt battery?
3. We use D.C. source not A.C. source in electroplating. Why?

3 EXERCISE

Single Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. The electrode connected to the positive terminal of the battery is called
(a) anode (b) cathode
(c) electrode (d) None of these

2. The electrode connected to the negative terminal of the battery is called
(a) electrode (b) anode
(c) cathode (d) None of these

3. In the process of electrolysis, the current is carried out inside the electrolyte by
(a) electrons
(b) atoms
(c) positive and negative ions
(d) All the above.

4. The electrochemical equivalent of a material in an electrolyte depends on
(a) the nature of the material
(b) the current through the electrolyte
(c) the amount of charge passed through electrolyte
(d) the amount of material present in electrolyte.

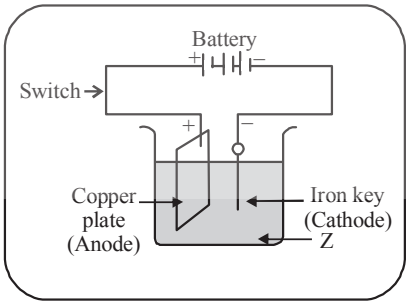
5. The process of electrolysis is used in _____.
(a) gold covering (b) metallurgy
(c) electric printing (d) All the above

6. An electric current can produce
(a) heating effect only.
(b) chemical effect only.
(c) magnetic effect only
(d) chemical, heating, and magnetic effects.

7. When electric current is passed through a conducting solution, there is a change of colour of the solution. This indicates
(a) the chemical effect of current
(b) the heating effect of current
(c) the magnetic effect of current
(d) the lightning effect of current

8. Which of the following metals is used in electroplating to make objects appear shining?
(a) iron (b) chromium
(b) copper (d) aluminium

9. Observe the following figure.



Identify the electrolyte Z in the given figure.
(a) Silver nitrate (b) Zinc sulphate
(c) Copper sulphate (d) Potassium sulphate

More than One Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. The mass of ions deposited during a given interval of time in the proces of electrolysis does not depend on the
   (a) current (b) reistance
   (c) temperature (d) electric power
2. For electroplating a spoon, it is placed in the voltameter at
   (a) the position of anode
   (b) the position of cathode
   (c) exactly in the middle of anode and the cathode
   (d) anywhere in the electrolyte
3. Electroplating helps
   (a) fine finish to the surface
   (b) shining appearance
   (c) metals to become hard
   (d) protecting metal against corrosion

Multiple Matching Questions :

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and five or six statements (p, q, r, s...) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

Column I	*Column II*
(A) Ability of substance to carry current	(p) Very low voltage
(B) LED requires	(q) Hydrogen gas escapes
(C) In electrolysis of NaCl at cathode	(r) Electrical conductivity
(D) In electrolysis of NaCl at anode	(s) Chlorine gas escapes.

Passage Based Questions :

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Pure water is a poor conductor of electricity. But the water that we use in our house is not pure water. Generally it contains a lot of impurities most of which are usually dissolved salts.

1. If we add some soluble metallic salt to water then
   (a) electrical conductivity decreases
   (b) no effect occurs
   (c) electrical conductivity increases
   (d) None of these
2. Lemon juice contains an acid which helps in producing electric current is
   (a) citric acid (b) nitric acid
   (c) hydrochloric acid (d) oxalic acid

Assertion & Reason :

DIRECTIONS : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** Current can produce or speed up chemical change, this ability of current is called chemical effect of electric current.
   Reason : Soution of cane sugar allows electric current to pass through.
2. **Assertion :** In electrolysis of copper sulphate solution, copper sulphate dissociates into copper ions and sulphate ions
   Reason : The copper ions move towards the anode.
3. **Assertion :** The method of coating one metal with another using an electric current is called electroplating.
   Reason : Steel is first electroplated with copper and is then coated with chromium.
4. **Assertion:** To recover gold and other valuable metals from the circuits of computers, mobiles, deplating is done.
   Reason: The process of deplating is similar to the process of electroplating
5. **Assertion:** Chromium plating is very popular in the industry.
   Reason: Chromium plated objects have a good lustrous shine and they are scratch and corrosion resistant.

Integer/Numeric type Questions :

RECTIONS : *Following are integer based/Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

1. During the elecrolysis proces x A electric current flows through a copper sulphate solution for 4 minutes and 16×10^{20} per minute number of copper atoms deposited at the cathode. Find the value of x.
2. The current flowing in a copper voltameter is 1.6 A. The number of Cu^{++} ions deposited at the cathode per minute are $x \times 10^{20}$. Find the value of x.

Physics Point

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

DIRECTIONS (Qs. 1 - 16) : *The following questions has four choices (a), (b), (c) and (d) out of which only one is correct. You have to choose the correct alternative.*

1. Emf is most closely related to
(a) mechanical force (b) potential difference
(c) electric field (d) electric current

2. Faraday's laws of electrolysis are related to
(a) the atomic number of positive ion
(b) the equivalent weight of electrolyte
(c) the atomic number of negative ion
(d) the velocity of positive ion

3. According to Ohm's law, under given physical conditions
(a) $V = \frac{I}{R}$ (b) $V = \frac{R}{I}$
(c) $V = R^2I$ (d) $V = RI$

4. If E be chemical equivalent of an element and Z is its electrochemical equivalent, then E/Z is measured in
(a) farad (b) newton
(c) coulomb (d) faraday

5. A silver and a zinc voltameter are connected in series and a current I is passed through them for a time t, liberating W grams of zinc. The weight of silver deposited is nearly
(a) 1.7 W gram (b) 2.4 W gram
(c) 3.5 W gram (d) 1.2 W gram

6. What determines the e.m.f. between the two metals placed in an electrolyte?
(a) relative position of metals in the electrochemical series
(b) distance between them
(c) strength of electrolyte
(d) nature of electrolyte

7. Faraday's laws are consequence of conservation of
(a) energy (b) electric field
(c) charge (d) magnetic field

8. According to Faraday's law of electrolysis, the amount of deposition is proportional to
(a) 1/time for which current passes
(b) electrochemical equivalent of the substance
(c) 1/current
(d) 1/electrochemical equivalent

9. The current inside a copper voltameter
(a) is half the outside value
(b) is the same as the outside value
(c) is twice the outside value
(d) depends on the concentration of $CuSO_4$.

10. In electrolysis, the amount of mass deposited or liberated at an electrode is directly proportional to
(a) amount of charge
(b) square of current
(c) concentration of electrolyte
(d) square of electric charge

11. Of the following, the one that does not make use of chemical effect of electric current is
(a) electroplating
(b) electrotyping
(c) thermoelectric refrigerator
(d) voltaic cells

12. How much current should be passed through acidified water for 100s to liberate 0.224 litre of H_2.
(a) 22.4 A (b) 19.3 A
(c) 9.65 A (d) 1 A

13. For goldplating on a copper chain, the substance required in the form of solution is
(a) copper sulphate (b) copper chloride
(c) potassium cyanide (d) potassium aurocyanide

14. On passing the current in wter voltameter, hydrogen
(a) is liberated at anode (b) is liberated at cathode
(c) is not liberated (d) remains in the solution

15. The resistance of a cell does not depend on
(a) current drawn from the cell
(b) temperature of electrolyte
(c) concentration of electrolyte
(d) the e.m. f of the cell

16. Faraday's 2nd law states that mass deposited on the electrode is directly proportional to
(a) atomic mass (b) atomic mass × Velocity
(c) atomic mass/ Valency (d) valency

DIRECTIONS (Qs. 17 - 19): *The following questions has four choices (a), (b), (c) and (d) out of which more than one is correct. You have to choose the correct alternatives.*

17. A can as shown here, used for storing soft drinks or food items is usually electroplated with tin because

(a) tin is less reactive than the base metal with which the can is made
(b) tin is cheap
(c) tin is stronger and shiny in appearance
(d) tin is lighter than other metals

Physics Point

18. X is a good conductor of electricity. Which of the following could be X?
(a) Solid sodium chloride
(b) Human blood
(c) Distilled water
(d) Liquid oxygen

19. In an electrolysis experiment, a current i passes through two different cells in series, one containing a solution of $CuSO_4$ and the other a solution of $AgNO_3$. The rate of increase of the weight of the cathodes in the two cells will not be
(a) in the ratio of the densities of Cu and Ag
(b) in the ratio of the atomic weight of Cu and Ag
(c) in the ratio of half the atomic weight of Cu to the atomic weight of Ag
(d) in the ratio of half the atomic weight of Cu to half the atomic weight of Ag

DIRECTIONS (Qs. 20) : *Following question has four statements (A, B, C and D) given in Column I and five statements (p, q, r , s and t) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

20.

Column I		Column II	
(A)	Graphite	(p)	Electrolyte
(B)	Rubber	(q)	Citric acid
(C)	Salt Solution	(r)	A form of carbon and a good conductor of electricity
(D)	Lemon	(s)	Insulator

DIRECTIONS (Qs. 21–22) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Two tungston lamps with resistances R_1 and R_2 respectively at full incandescence are connected first in parallel and then in series, in a lighting circuit of negligible internal resistance. It is given that: $R_1 > R_2$.

21. Which lamp will glow more brightly when they are connected in parallel?
(a) Bulb having lower resistance
(b) Bulb having higher resistance
(c) Both the bulbs
(d) None of the two bulbs

22. If the lamp of resistance R_1 now burns out, how will the illumination produced change?
(a) Net illumination will increase
(b) Net illumination will decrease
(c) Net illumination will remain same
(d) Net illumination will reduced to zero

DIRECTIONS (Qs. 23–24) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.

(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.

(c) If **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

23. **Assertion :** In an electrolyte, the positive ions move from left to right and the negative ions from right to left, so there is no net current flows in an electrolyte.
Reason : The current flows from cathode to anode in an electrolyte.

24. **Assertion :** Leclanche cell is used when constant supply of electric current is not required.
Reason : The e.m.f of a Leclanche cell falls if it is used continuously.

DIRECTIONS (Qs. 25-27) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

25. In producing chlorine by electrolysis 100 kW power at 125 V is being consumed. $4.4x \times 10^{-3}$ kg chlorine per minute is liberated? Find the value of x. (E.C.E. of chlorine is 0.367×10^{-6} kg /C)

26. In an electroplating experiment, m g of silver is deposited when 4 A of current flows for 2 minutes. The amount in g of silver deposited by 6 A of current for 40 seconds is m/x. Find the valur of x.

27. A steady current of x A is maintained for 45 minutes. During this time it deposits 4.572 g of zinc at the cathode of voltameter. Find the value of x. E.C.E. of zinc is 3.387×10^{-4} g/C.

Physics Point

SOLUTIONS

Brief Explanations of Selected Questions

1 EXERCISE

FILL IN THE BLANKS :

1. chemical
2. electroplating
3. electrolysis
4. solids
5. electrical energy

TRUE/FALSE :

1. False
2. True
3. False
4. False
5. True

MATCH THE COLUMNS :

1. A – (q), B – (s), C – (p), D – (t), E – (r),
2. A – (r), B – (s), C – (p), D – (q)

VERY SHORT ANSWER QUESTIONS :

1. Adding sulphuric acid to water make it conducting. Pure water is poor conductor of electricity.
2. Electroplating is the process of coating a thin layer of one metal over another metal by electrolysis.
3. Liquids that conduct electricity.
4. Electric current is the charge flowing per unit time.
5. Electrolysis is the process of decomposition of electrolyte solution into ions on passing current through it.
6. Distilled water do not allow current to pass through them.
7. Electrotyping and electroplating.

SHORT ANSWER QUESTIONS :

1.

Good conductor of electricity	Bad conductor of electricity
Lemon juice	Air
Tap water	Pure water
	Milk
	Vegetable oil and Honey

2. Free electrons conduct electricity in metal conductor whereas –(ve) and +(ve) ions conduct electricity in electrolytes.
3. Iron is coated with nickel or chromium to prevent it from rusting.
   Low cost metals can be covered with gold.
   Extraction of metals by electrolysis.
4. The rate of flow of charge is called electric current.

   Electric current $I = \frac{q}{t}$

   Its S.I. unit is ampere (A) or coulomb sec^{-1}.
5. Electric charges flow through a circuit just like the molecules of water flow through a pipe if there is a pressure difference between its ends.
   On the other hand, voltage doesn't flow across a circuit but it is just impressed across a circuit. Voltage doesn't go anywhere in a circuit just like pressure.
6. We have,

$$1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$$

   Thus, 6 joules of energy is given to each coulomb of charge passing through a 6–V battery.

LONG ANSWER QUESTIONS :

1. Refer to theory
2. Refer to theory
3. Refer to theory

Physics Point

2 EXERCISE

TEXT-BOOK EXERCISE :

1. (a) acids, bases, salts (b) Chemical
   (c) negative (d) electroplating
2. When free ends of a tester are dipped into solution and the magnetic needle shows deflection, it means that the solution is a good conductor of electricity and it is allowing electric current to pass through it and thus making the circuit complete, which causes the deflection of magnetic needle.
3. (i) Salt water
   (ii) Lemon juice
   (iii) Vinegar
4. The possible reasons are :
   (i) the liquid is poor conductor of electricity.
   (ii) the bulb is fused
   (iii) the connections are loose.
5. (i) liquid A is a better conductor than liquid B.
6. Pure water does not conduct electricity. We can make it conducting by adding common salt or lemon juice.
7. Water may conduct electricity. In case of fire if the electric supply for the area is not shut off the water is poured over electric appliances. Which may harm the firemen. So, in case of fire, before the firemen use the water holes, they shut off the electric supply for the area.

8. The sea water and drinking water both contains some impurities in form of salt or acid dissolved in them. The concentration of salt is much more in sea water as compare to the drinking water. The presence of excess of salt in sea water makes it better conductor of electricity than drinking water. So, the child finds that the compasss needle deflects more in the case of sea water.
9. No, it is not safe for the electrician to carry out electrical repairs outdoor during heavy downpour because rain water contains impurities in form of salts. So, it can conduct electricity. The electricity may shocks while working outdoors during rain.
10. Rainwater contains some impurities in the form of either salt or acid due to increased level of air pollution, which makes the rainwater a good conductor of electricity. So. Paheli found the compass needle showing deflection on testing rain water with a tester.
11. Electroplated objects in our surrounding are:
    (i) Chromium plated automobiles parts such as carriage, engine parts, wheel rim etc.
    (ii) Tin plated iron cans, used for storing food.
    (iii) Gold, silver plated artificial jwellary.
    (iv) Chromium plated kitchen, bathroom fixtures, such as showers, tapes, etc.
12. Copper ion (Cu^{++}) is a positively charged ion. It is attracted towards the plate which is connected to the negative terminal of the battery. As copper from impure rod is sought to be transfered to the thin copper plate, so, this thin copper plate must be connected to the negative terminal of the battery. Thus, the impure copper rod is connected to the positive terminal of the battery.

EXEMPLAR QUESTIONS :

1. Addition of another cell increased the current through the bulb sufficiently to make it glow.
2. The spoon should be connected to the negative terminal of the battery. The other electrode should be made of silver.
3. Tin is less reactive than iron. Tin coating prevents food from coming in contact with iron and thus prevents it from getting spoiled.
4. Yes, copper from the copper sulphate solution will be deposited on the carbon rod. Copper from the copper plate will be dissolved into the copper sulphate solution for electroplating.
5. If the water is distilled water and lemon juice is not added, no current will pass through the circuit. If the water taken is salty, then a feeble current will pass through the circuit and bubbles will be seen on the negative electrode.

HOTS QUESTIONS:

1. Electric shock occurs when current is produced in the body, but the current is caused by an impressed voltage.
2. Car has a 12-volt battery means that one of the battery terminals is 12 V higher in potential than the other one. It also means that, when a circuit is connected between these terminals, each coulomb of charge in the resulting will be given 12 J of energy as it passes through the battery.
3. When we use A.C. no deposit on electrodes will occur, as ions will be moving in opposite directions alternately with the frequency of A.C.

3 EXERCISE

SINGLE OPTION CORRECT :

1. (a) Anode connected to the positive terminal of the battery.
2. (c) Cathode connected to the negative terminal of the battery.
3. (c)
4. (a)
5. (d) Electrolysis is used in electroplating, electrotyping i.e. electric printing and metallurgy i.e., in extraction of metals from ores.
6. (d)
7. (a)
8. (c) Shining of chromium is maximum among iron, chromium copper and aluminium.
9. (c) Electrolyte is copper sulphate

MORE THAN ONE OPTION CORRECT :

1. (b, c, d) $m \propto Q \Rightarrow m \propto it$
2. (b) Positive ions deposited on cathode.
3. (a, b, d) Electroplating only provides a thin deposite on a metal on the surface which in no way can give hardness to the metal.

MULTIPLE MATCHING QUESTIONS :

1. **A - (r), B-(p), C- (q), D - (s)**

PASSAGE BASED QUESTIONS :

1. (c) Salts help dissociate into ions hence increases electrical conductivity.
2. (a)

ASSERTION & REASON :

1. (c) Cane sugar solution do not dissociates into ions hance do not allow electric current.
2. (c)
3. (b)
4. (c) The process deplating is opposite to electroplating, in this process the object to be deplated is used as the anode and the recovered metal is deposited on a cathode.

Physics Point

5. (a) Chromium plating is very popular in industry as chrome plate objects have a good lustrous shine and they are scratch and corrossion resistant.

INTEGER/NUMERIC TYPE QUSTIONS :

1. **4** Current $I = \frac{q}{t} = \frac{ne}{t}$

2. **3** Charge $Q = It = 1.6 \times 60 = 96\,C$

Let n be the number of Cu^{+2} ions, then

$$ne = Q \Rightarrow n = \frac{Q}{e} = \frac{96}{2 \times 1.6 \times 10^{-19}} = 3 \times 10^{20}$$

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

1. (b) Both emf and potential difference are measured in volt.

2. (b)

3. (d) $V = RI$

4. (a) farad

5. (c) $m_{Ag}/m_{Zn} = E_{Ag}/E_{Zn} = 108/31$

or $m_{Ag} = m_{Zn} \times 108/31 = W \times 108/31$

6. (d)

7. (a) Faraday's laws are based on the conversion of energy.

8. (b) The amount of decomposition (i.e. mass of the substance liberated during electrolysis) is proportional to electrochemical equivalent of the substance.

9. (b) Current inside a copper voltameter is same as that of outside.

10. (a) $m = ZIt = Zq$ where I is the current & q is the amount of charge.

11. (c)

12. (b)

13. (d)

14. (b)

15. (d) The resistance of the cell is independent of emf.

16. (c) m = zq, z = atomic mass/valency

17. (b, c, d)

18. (b, c, d)

19. (a, b, d)

20. A-(r), B-(s), C-(p), D-(q)

21. (a) When the lamps are connected in parallel, then potential difference V across each lamp will be same and will be equal to potential necessary for full brightness of each bulb. Because illumination produced by a lamp is proportional to electric power consumed in it, and power consumed,

$$P_1 = \frac{V^2}{R_1} < \frac{V^2}{R_2} = P_2$$

Hence, illumination produced by 2nd bulb will be higher than produced by lst bulb, i.e., bulb having lower resistance will shine more brightly.

22. (b) When R_1 burns out, then power is dissipated in R_2 only. Because internal resistance is quite low in lighting circuit, potential difference is still equal to V, hence, power dissipated in 2nd lamp, i.e.,

$$\frac{V^2}{R_2} < \left(\frac{V^2}{R_1} + \frac{V^2}{R_2}\right)$$

i.e., net power consumed initially. In other words, net illumination will now decrease.

23. (d)

24. (a)

25. **4** $I = \frac{P}{V} = \frac{100 \times 10^3}{125} A = \frac{10^5}{60} A$

$E.C.E. = 0.367 \times 10^{-6}\,kg\,C^{-1}$

Charge per minute

$$= (I \times 60)\,C = \frac{10^5 \times 60}{125} C = \frac{6 \times 10^6}{125} C$$

$$\therefore \text{ Mass liberated } = \frac{6 \times 10^6}{125} \times 0.367 \times 10^{-6}$$

$$= \frac{6 \times 1000 \times 0.367 \times 10^{-3}}{125} = 17.616 \times 10^{-3}\,kg$$

$\therefore\ x = 4$

26. **2** Mass of substance deposited

$m = ZI\,t = Z \times 4 \times (2 \times 60) = 480\,Z$ and

$m' = Z \times 6 \times 40 = 240\,Z$ or $m' = m/2$.

27. **5** Electrochemical equivalent,

$$Z = \frac{m}{It} = \frac{4.572}{x \times 45 \times 60} = 3.387 \times 10^{-4}\,g/C$$

$\therefore\ x = 5A$

Physics Point

Chapter

5

SOME NATURAL PHENOMENA

INTRODUCTION

Lightning, earthquake, cyclones, thunderstorms etc. are some destructive natural phenomena. In this chapter we will discuss about two destructive natural phenomena such as lightning and earthquake.

Lightning occurs when the charges move from thundercloud to the earth or move from cloud to cloud. Everything around us is made up of atoms. Atoms are made up of electrons, protons and neutrons. Electrons have a negative charge and protons have a positive charge. Neutrons are neutral. Friction between the water molecules in thunder clouds and air molecules produces static electric charges.

The earth's crust is made up of seven large and many smaller plates. These plates are constantly trying to move relative to each other. Suddenly shifting of these plates causing earthquake.

Understanding earthquakes is obviously of major importance to society.

Recently in Nepal earthquake, intensity measured 7.9 on the richter scale killed thousands of people and damage property on a huge scale.

Physics Point

ELECTRIC CHARGE

The word electric charge was derived from Greek word elektron, meaning amber. It was known to the ancient Greeks as long ago as 600 B.C. that amber rubbed with wool, acquires property of attracting light objects. It has now concluded that there are two kinds of electric charges; positive charge and negative charge. The experiments lead to the fundamental results that (i) like charges repel, (ii) unlike charges attract.

American scientist Benjamin Firanklin named the two kinds of charges as positive and negative

Where does Charge come from?

The process of acquiring charge consists of transferring something from one body to another, so that one body has an excess and the other a deficiency of that something. It was not until the end of nineteenth century that this "something" was found to consist of very small, negatively charged particles, known today as **electron** discovered by Sir J.J. Thomson.

Types of charges-positive and negative charges: To give a body an excess negative charge, we may add a number of electrons. And to give excess of positive charge, we may remove the electrons from the body.

Methods of Charging

1. **By rubbing:** Static electricity builds when two different non-metal materials rub together. Rubbing or friction makes electrons move. This gives one material a positive charge and the other a negative charge. The charges stay, or remain static, on the surfaces of the materials, until they have a pathway along which they can flow suddenly, or discharge.

   The energy of rubbing or friction gives extra energy to electrons. This allows some of them to break free from their nuclei and wander off on their own. It is known as "separating charge". Some electrons pass or transfer from one material to the other.

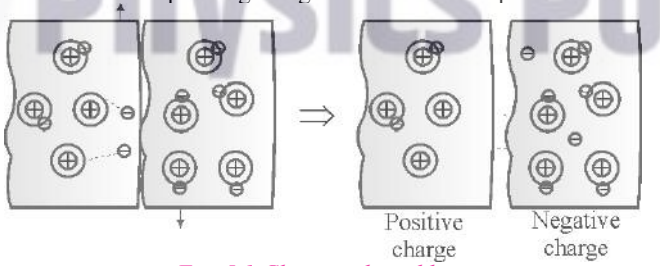
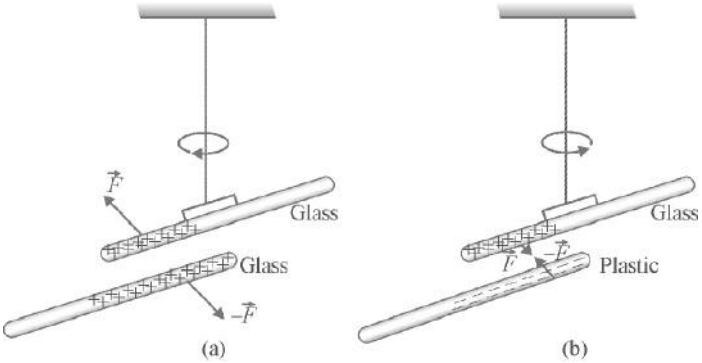


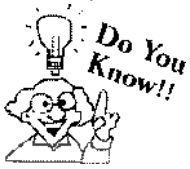
Fig. 5.1 Charging by rubbing



(a) Two charged rods of the same signs repel each other
(b) Two charged rods of opposite signs attract each other

Fig. 5.2

When glass rod is rubbed with silk, it aquires positive charge and by convention silk will aquires some amount of negative charge. Similarly when a plastic rod rubbed with fur it acquires negative charge, and the fur itself is found to acquire a positive charge. Moreover, if the rod and fur are brought into contact with one another, the charge is found to disappear from both. Similar observations are true for the glass rod and silk cloth.



If an electrically charged comb is brought near normal flow of water from a tap, the flow gets slightly diverted towards the comb

Fig. 5.3

2. **By conduction (by touch without rubbing):**
Because of having excess free electrons in metals they can be charged by conduction. When two conductors, one charged and other uncharged bring in contact, the same type of charge will appear on both the conductors. Charge on any conductor is proportional to its size.

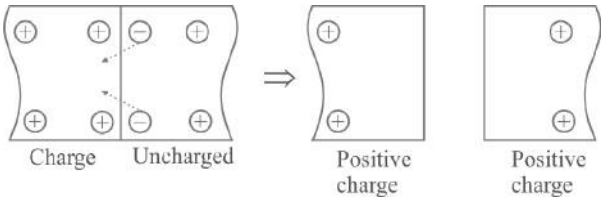


Fig. 5.4 Charging by conduction

3. **By induction (without touch):** If a charged body is brought near an uncharged body, then neutral body becomes oppositely charged. By induction method, we can charge any type of material body. From the figure one can understand the steps follow in the charging of the body by induction.

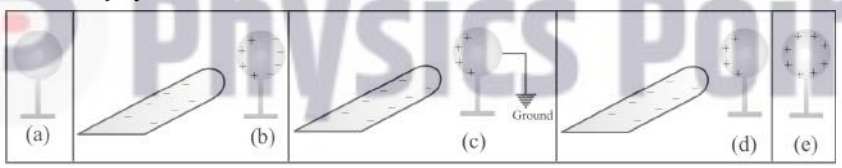


Fig. 5.5 Charging by ionduction

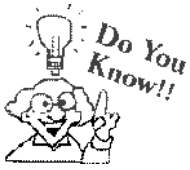
The magnitude of induced charge depends on the material of the body being charged. If q is the inducing charge and q' is the induced charge, then

$$|q'| = q\left(1 - \frac{1}{k}\right)$$

For metals $k = \infty$, $q' = q$, and for non-metals $k < \infty$, $\therefore\ q' < q$

Properties of Charge

(i) Charge always be associated with mass.
(ii) It can be transferred from one body to another.
(iii) Charge is conserved. It can neither be created nor be destroyed.
(iv) Charge is quantised. That is, any body can have charge in integral multiple of smallest charge called electronic charge or $q = \pm ne$, where $n = 1, 2, 3, \ldots\ldots$, $e = 1.6 \times 10^{-19}$ C.
(v) Charge is relativistically invariant. That is, $q_{rest} = q_{motion}$.
(vi) Moving charge produces magnetic field in addition to electric field.
(vii) Accelerated charge radiates energy.



Charge supplied to an insulator is not distributed over its entire surface and remains stationary at the supplied position on the insulator.

Think it Over

Does motion of a body affect its charge?

GOLD LEAF ELECTROSCOPE

It is used to detect the charge on the body. It consists of a gold leaf attached to the brass strip which is suspended with the help of a brass rod in a glass jar (see figure).

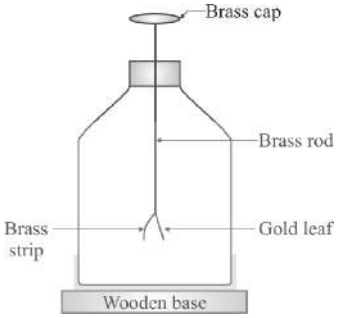


Fig. 5.6 Gold leaf electroscope

Uses of Gold Leaf Electroscope

1. **To detect the charge :** Bring the body near the brass cap of the electroscope. If the gold leaf diverges outward, the body is electrically charged. However if no divergence takes place, then body has no charge.
2. **Identification of charge :**

(a) **By conduction :** First of all, charge the electroscope positively. Then touch the body under consideration to the brass cap of the electroscope. If the divergence of the gold leaf increases then the body is positively charged. However if divergence of gold leaf decreases then body will be negatively charged.

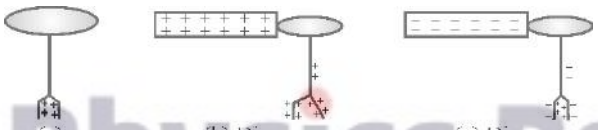


Fig. 5.7

When positively charged body touches the brass cap of the electroscope, the positive charge on the leaf will increase and hence divergence of it increases. But when negatively charged body touches the brass cap of the electroscope, the positive charge on the leaf will decrease and hence divergence of it decreases.

(b) **By induction** : First charge the electroscope positively. Then bring the body under consideration near the brass cap of the electroscope.

If the divergence of the gold leaf increases, then the object is positively charged. However if divergence of the gold leaf decreases then the object is negatively charged.

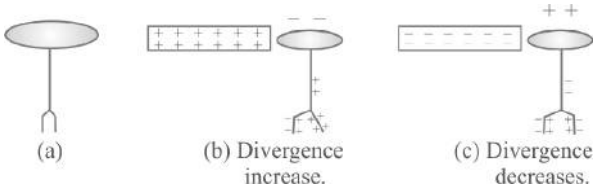


Fig. 5.8

When positively charged body brings near the brass cap of the electroscope, the negative charge induces on the brass cap and positive charge on the gold leaf and hence divergence of the leaf will increase. However when negatively charged body brings near the brass cap, the positive charge induces on the brass cap and negative charge on gold leaf and hence divergence of the leaf will decrease.

Think it Over

If you walk across a rug and scuff electrons from your feet, are you positively or negatively charged ?

CHECK Point

(i) What is the causes of charging?
(ii) Can an insulator be charged by conduction?

SOLUTION

(i) The actual transfer of electrons from one body to the other is the cause of charging.
(ii) No, charging by conduction is possible in conductor only, insulator can be charged by friction or induction?

ILLUSTRATION : 1

A glass rod rubbed with silk is brought close to two uncharged metallic spheres in contact with each other, inducing charges on them as shown in *fig. 5.9*.
Describe what happens when

(i) the spheres are slightly separated, and

(ii) the glass rod is subsequently removed, and finally

(iii) the sphere are separated far apart.

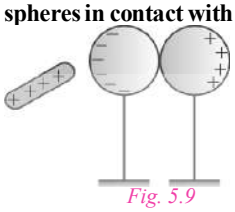


Fig. 5.9

SOLUTION :

(i) Little change in the distribution of charges.

(ii) The charges on the sphere are redistributed; positive and negative charges will face each other.

(iii) Charge on each sphere will be uniformly distributed.

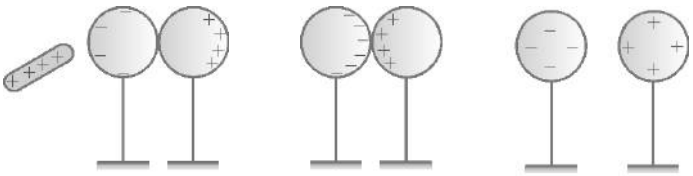


Fig. 5.10

ILLUSTRATION : 2

The diagram shows a gold coated pith-ball suspended between two plates and closer to the plate *A*.

(i) Plates *A* and *B* are connected to the positive and negative poles of a high tension battery. What happens to the pith-ball ? Give reason.

(ii) What would happen if *B* is earthed ? Give reasons.

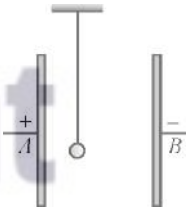


Fig. 5.11

SOLUTION :

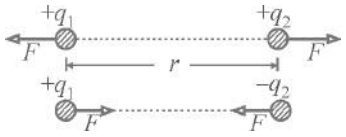
(i) The opposite charges are induced on both sides of the ball. On being close to plate *A*, the ball experiences a net force towards this plate, and so string becomes slent from the vertical.

(ii) When plate *B* is earthed, it becomes neutral. The opposite charges are induced on the both sides of the ball. Now plate *A* exerts net attractive force on the ball. The ball will touch the plate *A* and becomes positively charged due to conduction. Now plate *A* repels the ball. The ball moves to mean position, but due to inertia, it crosses the mean position and then touches the plate *B*. There it becomes neutral. The ball swing back and repeats its motion till entire charge of plate *A* flows into the earth.

CONNECTING TOPIC

COULOMB'S LAW

The force between two point charges at rest is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. Thus, if two point charges q_1, q_2 are separated by a distance r in free space, the magnitude of the force (F) between them is given by



$$F = k\frac{q_1 q_2}{r^2},$$

Fig. 5.12

where k is a constant. For historical reason and so simplifies many other formulas in electricity and magnetism, the constant k is usually written $\frac{1}{4\pi \in_0}$.

Thus Coulomb's law can be written as

$$F = \frac{1}{4\pi \in_0}\frac{|q_1||q_2|}{r^2} \qquad \ldots(1)$$

If the particles repel each other, the force on each particle is directed away from the other particle. If the particles attract each other, the force on each particle is directed toward the other particle.

Coulomb's law has proved its validity by experimental tests; no exceptions to it have ever been found. It holds even within the atom, correctly describing the force between the positively charged nucleus and each of the negatively charged electrons. This law also correctly accounts for the forces that bind atoms together to form molecules, and for the forces that bind atoms and molecules together to form solids and liquids.

More about Coulomb's Law

(i) The force between any two charges is independent of the presence of other charges.
(ii) Coulomb's law holds for point charges (whose dimensions) are small compared to their separation.
(iii) Coulomb's law holds for charges at rest or nearly at rest.
(iv) Coulomb's law holds over wide range from atomic distances (10^{-15} m) to many kilometers.
(v) In the CGS system the constant $k = 1$, without unit. The unit of charge is stat coulomb or the esu (electro static unit). The conversion factor $1C = 3 \times 10^9$ esu. Thus

$$\therefore \qquad F = \frac{q_1 q_2}{r^2}. \quad \text{(in CGS system of units)}$$

(vi) **In SI system of unit:** In SI system $k = \frac{1}{4\pi \epsilon_0}$, where ϵ_0 is called permittivity of free space. The introduction of $\left(\frac{1}{4\pi \epsilon_0}\right)$ will simplify some formulas to be encountered later. Thus coulomb's law is usually written as

$$F = \frac{1}{4\pi \epsilon_0}\frac{q_1 q_2}{r^2}$$

with $\frac{1}{4\pi \epsilon_0} = 9 \times 10^9 \ \text{Nm}^2/\text{C}^2$ and $\epsilon_0 = 8.854 \times 10^{-12} \frac{\text{C}^2}{\text{N-m}^2}$.

Physics Point

ILLUSTRATION : 3

Two equally charged identical metal spheres *A* and *B* repel each other with a force 2.0×10^{-5}N. Another identical uncharged sphere C is touched to A and then placed at the mid point between *A* and *B*. What is the net electric force on C?

SOLUTION :

Suppose charge of each sphere is q, the force between spheres A and B for separation r,

$$F = 2.0 \times 10^{-5} = \frac{1}{4\pi \epsilon_0}\frac{q^2}{r^2} \qquad \ldots(i)$$

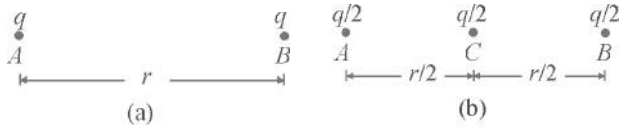


Fig. 5.13

When uncharged sphere C is touched to the sphere A, the charge on each one becomes $q/2$. Thus force between A and C

$$F_{AC} = \frac{1}{4\pi \epsilon_0}\frac{(q/2)(q/2)}{(r/2)^2} = F,$$

and force between B and C,

$$F_{BC} = \frac{1}{4\pi \epsilon_0}\frac{\left(\frac{q}{2}\right)q}{\left(\frac{r}{2}\right)^2} = 2F.$$

Thus the net force on the sphere $C = 2F - F = F = 2.0 \times 10^{-5}$ N from C to A.

EARTHING OR GROUNDING

We know that sea is the very large reservoir of water; from which if few buckets of water is taken out, the level of water in sea will remain almost same, practically same. On the same way earth can be regarded as a large reservoir of oppositely charged particles; electrons and protons, on a whole, is electrically neutral. By any means, if we take out or add some electrons to the earth, its charge will remain almost zero, practically zero. Thus the earth is regarded as a large capacitor with zero potential under all practical situations. Any body connected to earth becomes its part and hence of zero potential.

(i) When a positively charged body is connected to the earth, the electrons start flowing from the earth till the positive charge of the body becomes zero, and hence potential of the body V becomes zero.

(ii) When a negatively charged body is connected to earth, the electrons from the body start flowing to the earth, till the body becomes neutral and hence its potential becomes zero.

LIGHTNING AND LIGHTNING CONDUCTOR

The occurance of lightning depends on the atmospheric conditions. It needs a weather in which moisture-laden warm air near the earth rises rapidly. As the moist air rises, it collides with the other drops of moisture and air molecules and so lose or gain electric charges by friction. Usually, the moisture drops become positive and the air molecules negative. When moist air becomes cold enough, it condenses to form a cloud. The lower part of the cloud usually becomes negative and upper most part of the cloud becomes positive. The sudden movements in the cloud cause this charge to discharge in a flash of lightning to another cloud or the earth. When such a charged cloud moves over a tall building, the positive charge will induce over it. Since this induce charge is of very high order, so the building experiences a bursting force and hence cracks will develope in it. The building can be saved from destruction by using lightning conductor.

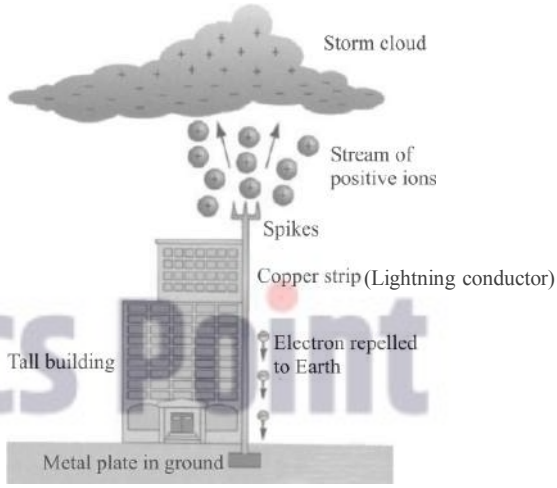


Fig. 5.14

A lightning conductor is made of copper and has sharp pointed edges. It is connected to the earth by the metal conductor running down the building and terminating in a buried metal plate. In the presence of lightning conductor, most of the charge will induce on it, which soonly move to the earth without harming the building.

Lightning Safety Precautions

(a) Outside the home

(i) Do not stand underneath a natural lightning rod such as a tall, isolated tree.

(ii) Avoid projecting above the surrounding landscape as you would do if you were standing on a hilltop, in an open field, on the beach or fishing from a small boat.

(iii) Get out of and away from open water.

(iv) Get away from tractors and other metal farm equipment.

(v) Get off of and away from motorcycles, scooters, golf carts and bicycles. Put down golf clubs.

(vi) Stay away from wire fences, clotheslines, metal pipes, rails and other metallic paths which could carry lightning to you from some distance away.

(vii) Avoid standing in small isolated sheds or other small structures in open area.

(b) Inside the home

(i) Unplugging the telephone and unnecessary appliances.

(ii) Avoiding running water.

(iii) Turning off the air conditioner. Power surges cause costly damages.

(iv) Listening to the news for updated weather reports.

CONNECTING TOPIC

ELECTRIC FIELD

The charge and its influence can only be seen when we bring another charge (test charge) in the vicinity of the first charge. It means there is something but not visible around every charge, in which other charges experience force. This something is known as electric field. Electric field is a vector field. The electric field strength, is usually called electric field at any point is the force experiences by unit test charge at that point. If $\vec{F}$ is the force acts on test charge q_0, then the electric field

$$\vec{E} = \frac{\vec{F}}{q_0}.$$

The direction of field $\vec{E}$ is that of the force $\vec{F}$ acts on the positive test charge.
The SI unit of electric field is newton per coulomb (N/C). Also 1 N/C = 1 V/m

Electric Field Lines (EFL)

A very nice way to visualise electric field, is the lines of force, now usually called **electric field lines**. The idea of lines of force was introduced by Micheal Faraday. These are the imaginary lines, but can be visualised by the motion of the test charge.

Properties of electric lines of field

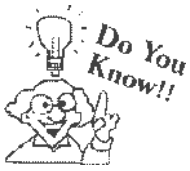
(i) Every line of field is a continuous and smooth curve originating from a positive charge and ending on a negative charge.
(ii) The tangent to a line of field to any point gives the direction of $\vec{E}$ at that point.
(iii) They do not path but leave or end on a charged conductor normally when the charges on the conductor are in equilibrium.
(iv) Lines of fields are never intersect. If it happens then we say that at the point of intersection the electric intensity is zero, otherwise it would have to be tangential to two different curves at the same instant which is not possible.
(v) The number per unit area crossing a surface at right angle to the field direction at every point is proportional to the electric intensity. Hence lines of field are closely spaced where the intensity is large and are widely separated where the intensity is small.

WHY DO EARTHQUAKES OCCUR?

There are three layers of earth-crust (outermost), mantle (middle) and core (innermost). The earth's crust is not a solid stable mass but is made of seven large and many smaller plates that floats on the viscous mantle. These plates are constantly trying to move relative to each other. As a result, massive pressure builds up between them, which can be released when the plates suddenly shift, causing an earthquake. *An earthquake is a sudden shaking or trembling of the earth which lasts for a very short time*. So far, it is not possible to make an exact prediction of when and where an earthquake will take place. However scientists can determine the probabilities of an earthquake and predict the regions where they likeli to occur. With the aid of a worldwide network of **seismographs**, which are used to measure the earth's movement, Scientists try to detect and interpret the signs.

Earthquakes can cause floods, landslides and tsunamis.

The power of an earthquake is expressed in terms of a magnitude on a scale called **the Richter Scale**. Earthquakes of magnitude higher than 7 on the richter scale are really destructive.



- *The National Earthquake Information Centre (NEIC) records an average of 20,000 earthquakes every year (about 50 a day) around the world.*
- *Alaska is the most earthquake prone state in the world. It experiences a magnitude of 7.0 earthquake every year and a magnitude 8.0 or greater earthquake approximately once every 14 years.*

Precautions against Earthquakes

1. If you are at home
(i) Take shelter under a table and stay there till shaking stops.
(ii) Stay away from tall and heavy objects that may fall on you.
(iii) If you are in bed, do not get up. Protect your head with a pillow.

2. If you are at outdoors
(i) Find a clear spot, away from buildings, trees and overhead power lines.
(ii) If you are in a car or a bus, do not come out. Ask the driver to drive slowly to a clear spot, do not come out till tremors stop.

Physics Point

SUMMARY

- An object is said to be neutral when it contains the same number of positive and negative charges.
- There are two kinds of charges – positive charge and negative charge.
- Like charges repel and unlike charges attract each other.
- The electrical charges produced by rubbing are called static charges.
- Contact and induction are other ways of charging.
- An electroscope may be used to detect whether a body is charged or not.
- When charges move, they constitute an electric current.
- The process of transfer of charge from a charged object to the earth is called earthing.
- The process of electric discharge between clouds and the earth or between different clouds causes lightning.
- Lightning strike could destroy life and property.
- Lightning conductors can protect buildings from the effects of lightning.
- An earthquake is a sudden shaking or trembling of the earth.
- Earthquake is caused by a disturbance deep inside the earth's crust.
- Earthquakes tend to occur at the boundaries of earth's plates. These boundaries are known as fault zones.
- Destructive energy of an earthquake is measured on the Richter scale. The earthquake measuring 7 or more on Richter scale can cause severe damage to life and property.
- We should take necessary precautions to protect ourselves from lightning and earthquakes.

Physics Point

1 EXERCISE

Fill in the Blanks :

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. An object is said to be _____ when it contains the same number of positive and negative charges.
2. The process of electric discharge between different clouds causes _____.
3. The boundaries of earth's plate where earthquake tend to occur are called _____.
4. Destructive energy of an earthquake is measured on the _____.

True/False :

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Like charges repel and unlike charges attract each other.
2. Lightning is caused due to movement of earth's plates.
3. An electroscope can detect seismic waves.
4. Earthquake is caused by a disturbance deep inside the earth's crust.

Match the Columns :

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D)in Column I have to be matched with statements (p, q, r, s, t) in Column II.*

1.

Column I	Column II
(A) Negatively charged particle	(p) Electric discharge
(B) Positively charged particle	(q) Flow of charge
(C) Cause of lightning	(r) Electron
(D) Electric current	(s) Proton

2.

Column I	Column II
(A) Earthquake	(p) Golden leaves
(B) Lightning	(q) Seismograph
(C) Electroscope	(r) Lightning rod
(D) Rubbing	(r) Static charges

Very Short Answer Questions :

DIRECTIONS : *Give answer in one word or one sentence.*

1. What is the cause of earthquake?
2. When is a body charged negatively?
3. How does the charge of one electron compare with that of another electron?
4. What is the use of lightning rod?

Short Answer Questions :

DIRECTIONS : *Give answer in two to three sentences.*

1. Write safety precautions against lightning.
   (i) outside the home (ii) inside the home
2. Explain charging by rubbing.
3. Write safety precautions against earthquake.
4. How is the power of an earthquake is estimated? At what strength it becomes destructive?

Long Answer Questions :

DIRECTIONS : *Give answer in four to five sentences.*

1. Describe an experiment to prove that on electrification, both kinds of charges are produced simultaneously.
2. Explain the properties of electric charges.
3. (a) What is lightning conductor?
   (b) How it protects us from lightning?

Physics Point

2 EXERCISE

Text-Book Exercise :

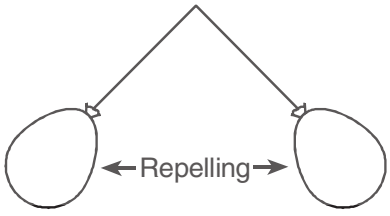
1. Which of the following cannot be charged easily by friction?
   (a) A plastic scale (b) A copper rod
   (c) An inflated ballon (d) A woollen cloth
2. When a glass rod is rubbed with a piece of silk cloth the rod
   (a) and the cloth both acquire positive charge.
   (b) becomes positively charged while the cloth has a negative charge.
   (c) and the cloth both acquire negative charge.
   (d) becomes negatively charged while the cloth has a positive charge.
3. Write T against true and F against false in the following statements.
   (a) Like charges attract each other (T/F)
   (b) A charged glass rod attract a charged plastic straw (T/F)
   (c) Lightning conductor cannot protect a building from lightning (T/F)
   (d) Earthquakes can be predicted in advance (T/F)
4. Sometimes, a cracking sound is heard while taking off a sweater during winters, Explain.
5. Explain why a charged body loses its charge if we touch it with our hand.
6. Name the scale on which the destructive energy of an earthquake is measured. An earthquake measures 3 on this scale. Would it be recorded by a seismograph? Is it likely to cause much damage?
7. Suggest three measures to protect ourselves from lightning.
8. Explain why a charged balloon is repelled by another charged balloon whereas an uncharged balloon is attracted by another charged balloon?
9. Describe with the help of a diagram an instrument which can be used to detect a charged body.
10. List three states in India where earthquakes are more likely to strike.
11. Suppose you are outside your home and an earthquake strikes. What precaution would you take to protect yourself?
12. The weather department has predicted that a thunderstorm is likely to occur on a certain day. Suppose you have to go out on that day. Would you carry an umbrella? Explain.

Exemplar Questions :

1. During the construction of a building the lightning conductor was left hanging in the air by mistake. Would the lightning conductor be still effective? Explain.
2. You might have observed on a dry day that when you touch the screen of a television or computer monitor (with picture tube), you get a slight shock. Why does it happen?
3. The strips of an electroscope diverge when a charged body is brought in contact with the metal clip. Now the clip is touched gently by our hand. What will happen to the strips? Explain.
4. Explain why it is safer to use a wireless telephone instead of a landline telephone during lightning.
5. If the metal clip used in the electroscope is replaced by an ebonite rod and a charged body is brought in contact with it, will there be any effect on the aluminium strips? Explain.

Hots Questions :

1. When combing your hair, you scuff electrons from your hair on to the comb. Is your hair then positively or negatively charged? How about the comb?
2. The five thousand billion freely moving electrons in a penny repel one another. Why don't they fly out of the penny?
3. A student attached two balloons to equal lengths of string and tied them to the same point. The student observed that the balloons repelled each other, as shown in the diagram below.



In terms of electrical charges, explain why the balloons repelled each other.

Physics Point

3 EXERCISE

Single Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. The earth's plate responsible for causing earthquakes is
(a) the crust of the earth
(b) the mantle of the earth
(c) the inner core of the earth
(d) the outer core of the earth

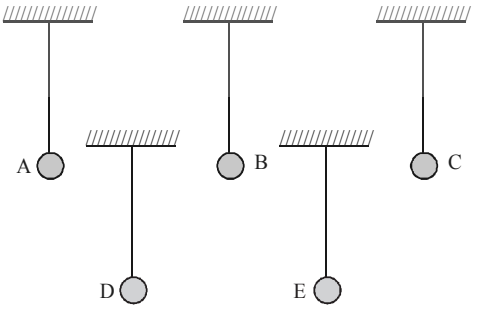
2. If a body is charged by rubbing it, its weight
(a) remains precisely constant
(b) increases slightly
(c) decreases slightly
(d) may increase slightly or may decrease slightly

3. If a body is positively charged, then it has
(a) excess of electrons
(b) excess of protons
(c) deficiency of electrons
(d) deficiency of neutrons

4. Electric current is to be passed from one body to another. For this purpose the two bodies must be joined by
(a) cotton thread (b) copper wire
(c) plastic string (d) rubber band

5. An electroscope is a device which is used to find if an object is
(a) charged (b) free of cracks
(c) magnetic (d) hot

6. Five styrofoam balls are suspended from insulating threads. Several experiments are performed on the balls and the following observations are made
(i) ball A repels C and attracts B
(ii) ball D attracts B and has no effect on E
(iii) a negatively charged rod attracts both A and E.
An electrically neutral styrofoam ball gets attracted if placed nearby a charged body due to induced charge. What are the charges, if any, on each ball ?



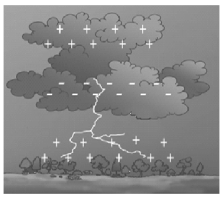
	A	B	C	D	E
(a)	+	–	+	0	+
(b)	+	–	+	+	0
(c)	+	–	+	0	0
(d)	–	+	–	0	0

7. Where are the more earthquake occur
(a) Under the sea
(b) Under the land
(c) Equal in both sea and land
(d) Can't be predicted

8. Shock wave of earthquakes are called
(a) Seismic waves
(b) Spectro waves
(c) Transverse waves
(d) Longitudinal waves

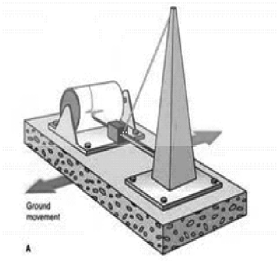
9. Five balls numbered 1 to 5 are suspended using separate threads. Pairs (1, 2), (2, 4), (4, 1) show electrostatic attraction, while pairs (2, 3) and (4, 5) show repulsion. Therefore ball 1 must be :
(a) positively charged (b) negatively charged
(c) neutral (d) made of metal

10. What does the below shown figure leads to?



(a) lighting
(b) rain
(c) flood
(d) lightning, thunder, rain

11. What is the name of instrument shown in the following image?



(a) Sesmograph (b) Seizemograph
(c) Seismograh (d) Seismograph

Physics Point

More than One Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. A lightning conductor installed in a building
(a) does not allow the lightning to fall on the building
(b) protects from the lightning
(c) forces the lightning to fall in an area where there are no building
(d) conducts electric charge to the ground when lightning strikes the building.

2. When a glass rod is rubbed with silk cloth
(a) silk gets positively charged
(b) glass rod gets negatively charged
(c) silk gets negatively charged
(d) glass rod gets positively charged

3. Which of the following can be charged by friction, if held by hand?
(a) plastic scale (b) copper rod
(c) inflated balloon (d) woolen cloth

Multiple Matching Questions :

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r , s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

	Column-I	Column-II
A.	Benjamin Franklin	(p) Measurement of intensity of earthquake
B.	Charles F. Richter	(q) Lightning is a huge electric spark
C.	Mercalli	(r) Attracting ability of amber on rubbing with fur.
D.	Thales	(s) Measurement of magnitude of earthquake

2.

	Column-I Reading on Richter scale	Column-II Effect of earth quake
A.	6 to 6.9	(p) Not felt but recorded
B.	4 to 5.9	(q) Can be destructive in small area
C.	0 to 3	(r) Total damage due to great earthquake
D.	8 and above	(s) Often felt but less damage

Passage Based Questions :

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Benjamin Franklin designed the lightning conductor. This is a thick copper strip running up the outside of a tall building. The upper end of the strip terminates at highest point of the building. The lower end is connected to a metal plate buried in moist earth.

1. Lightning conductor is made up of copper because it is
(a) good conductor of electricity
(b) bad conductor of electricity
(c) easily available
(d) None of these

2. Which of the following is not a correct measure to protect ourselves from lightning?
(a) Try to remain indoors
(b) Do not carry an umbrella during lightning
(c) Do not take shelter under a tall tree
(d) None of these

Assertion & Reason :

DIRECTIONS : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** Earthquake occurs due to the movement of tectonic plates.
Reason : When these plates move faster due to frictional force, pressure is build and results in earthquake when pressure is released.

2. **Assertion :** An electroscope can be used to find the nature of charge and body.
Reason : It is based on principle electric charge can be transferred from a charged object to another through a metal conductor.

3. **Assertion:** When a charged comb is brought near small pieces of paper, it attracts the pieces of paper.
Reason: Because the paper becomes charged.

4. **Assertion :** The electrification is due to transference of free electrons in outermost orbit of an atom.
Reason : The atom of an element is electrically neutral.

Integer/Numeric type Questions :

DIRECTIONS : *Following are integer based/Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

1. The net charge on a substance consisting of 5×10^{14} electrons is $-10x$ μC. Find the value of x.

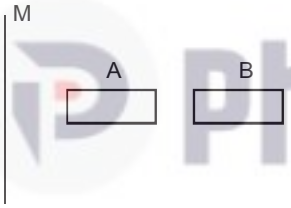
2. When a piece of polythene is rubbed with wool, a charge of 1.6×10^{-7} C is developed on polythene. The amount of mass, which is transferred to polythene is $3x \times 10^{-19}$ kg. Find the value of x.

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

DIRECTIONS (Qs. 1–9) : *The following questions has four choices (a), (b), (c) and (d) out of which only one is correct. You have to choose the correct option.*

1. One metallic sphere A is given positive charge whereas another identical metallic sphere B of exactly same mass as of A is given equal amount of negative charge. Then
(a) mass of A and mass of B still remain equal
(b) mass of A increases
(c) mass of B decreases
(d) mass of B increases

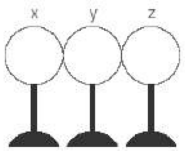
2. A large nonconducting sheet M is given a uniform charge density. Two uncharged small metal rods A and B are placed near the sheet as shown in figure. Then

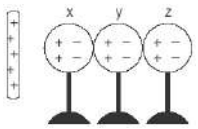


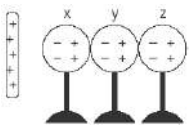
(a) M attracts A (b) M attracts B
(c) A attracts B (d) All of the above

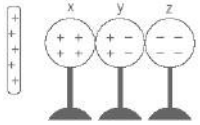
3. Two identical metal spheres A and B are supported on insulating stands and placed in contact. What kind of charges will A and B develop when a negatively charged ebonite rod is brought near A?
(a) A will have a positive charge and B will have a negative charge
(b) A will have a negative charge and B will have a positive charge
(c) Both A and B will have positive charges
(d) Both A and B will have negative charges

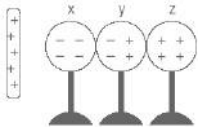
4. The diagram below shows three neutral metal spheres, x, y, and z, in contact and on insulating stands. Which diagram best represents the charge distribution on the spheres when a positively charged rod is brought near sphere x, but does not touch it?



(a) 

(b) 

(c) 

(d) 

5. When a body is charged by induction, then the body
(a) becomes neutral
(b) does not lose any charge
(c) loses whole of the charge on it
(d) loses part of the charge on it

6. On charging by conduction, mass of a body may
(a) increase (b) decreases
(c) increase or decrease (d) none of these

7. When a neutral metal sphere is charged by contact with a positively charged glass rod, the sphere
(a) loses electrons (b) gains electrons
(c) loses protons (d) gains protons

8. A clyindrical conductor is placed near another positively charged conductor. The net charge acquired by the cylindrical conductor will be
(a) positive only
(b) negative only
(c) zero
(d) either positive or negative

9. A positive point charge Q is brought near an isolated metal cube then
(a) the cube becomes negatively charged.
(b) the cube becomes positively charged.
(c) the interior becomes positively charged and the surface becomes negatively charged.
(d) the interior remains charge free and the surface gets nonuniform charge distribution.

DIRECTIONS (Qs. 10–11): *The following questions has four choices (a), (b), (c) and (d) out of which more than one is correct. You have to choose the correct options.*

10. Among two discs A and B, first have radius 10 cm and charge 10^{-6} μC and second have radius 30 cm and charge 10^{-5}C. When they are touched, then
(a) $q_A = 2.75\,\mu C$, $q_B = 3.15\,\mu C$
(b) $q_A = 1.09\,\mu C$, $q_B = 1.53\,\mu C$
(c) $q_A = q_B = 5.5\,\mu C$
(d) $q_A + q_B = 11\,\mu C$

11. Coulomb's law correctly describes the electric force that
(a) binds the electrons of an atom to its nucleus
(b) binds the protons and neutrons in the nucleus of an atom
(c) binds atoms together to form molecules
(d) binds atoms and molecules together to form solids

DIRECTIONS (Qs. 12) : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

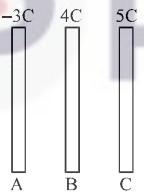
12.

Column I	Column II
(A) Loss of electrons by a body leads to	(p) Electroscope
(B) Material having large number of free electrons	(q) Lightning conductor
(C) Device used for arresting lightning	(r) Conductor
(D) Device used for detecting static electric charge	(s) Positive electrification
	(t) Periscope

DIRECTIONS (Qs. 13–15) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Three large plates A, B and C are placed parallel to each other and charges are given as shown.



13. The charge that appears on the left surface of plate B is:
(a) 5 C (b) 6 C
(c) 3 C (d) –3 C

14. The charge on inner surface of plate C, if plate B is earthed,
(a) 5 C (b) 6 C
(c) 3 C (d) –3 C

15. The charge on left surface of B, if B and C both are earthed,
(a) 5 C (b) 6 C
(c) 3 C (d) –3 C

DIRECTIONS (Qs. 16–19) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

16. **Assertion:** An insulator does not conduct electricity usually.
Reason: The number of electrons in an insulator is very small in comparison to that in a conductor.

17. **Assertion:** Some charge is put at the centre of a conducting sphere. It will move to the surface of the sphere.
Reason: Conducting sphere has no free electrons at the centre.

18. **Assertion:** The lightening conductor at the top of high building has sharp pointed ends. It is used to prevent the cracks in the building.
Reason: The charge density at sharp ends becomes very much higher than the building.

19. **Assertion:** The tyres of aircraft are slightly conducting.
Reason: If a conductor is connected to ground, the extra charge induced on conductor will flow to ground.

DIRECTIONS (Qs. 20 - 21) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

20. A polythene piece rubbed with wool is found to have a negative charge of 3.2×10^{-7} C. The no. of electrons transferred is $x \times 10^{12}$. Find the value of x.

21. The electrostatic force of repulsion between two equal charged ions is 3.7×10^{-9} N, when they are separated by a distance of 5 Å . How many electrons are numbering from each ion.

Physics Point

SOLUTIONS

Brief Explanations of Selected Questions

1 EXERCISE

FILL IN THE BLANKS :

1. neutral
2. lightning
3. fault zone
4. richter scale

TRUE/FALSE :

1. True
2. False
3. False
4. True

MATCH THE COLUMNS :

1. A – (r); B – (s); C – (p); D – (q)
2. A – (q); B – (r); C – (p); D – (s)

VERY SHORT ANSWER QUESTIONS :

1. The cause of earthquake is the movement of earth's plate.
2. When electrons are gained.
3. The charge on every electron is same. In other words, all electrons are similar in charge.
4. It is metallic rod installed in the building roof to protect it from the effect of lightning.

SHORT ANSWER QUESTIONS :

1. Safety precautions against lightning
   (i) Outside the home
   – Avoid standing underneath a natural lightning rod such as a tall, isolated tree.
   – Avoid standing in small isolated sheds or other small structures in open area.
   (i) Inside the home
   – Unplugging the telephone and other electric appliances.
   – Avoiding running water.
2. When a plastic rod is rubbed with fur, it acquires negative charge and for acquires positive charge. The energy of rubbing or friction makes electrons move.
3. Safety precautions against earthquake
   – Find a clear spot, away from building, trees and overhead power lines.
   – If you are at home take shelter under a table and stay there till shaking stops.
4. The power of earthquake is measured in terms of richter scale. Really destructive earthquake has magnitude higher than about '7' on the richter scale.

LONG ANSWER QUESTIONS :

1. Fit a cat's skin cap over an ebonite rod. Rub the rod with the cap so that both are charged. When we verify for charge on both cat's skin and ebonite, the total charge is proved as zero. By removing ebonite rod from cat's skin and check for the presence of charge on either bodies, it is proved that both got oppositely charged and the magnitudes of charge on both are equal.
2. (i) Two charges – positive and negative.
   (ii) Charge is conserved.
   (iii) Charge is quantized.
   (iv) Net charge always reside on the outer surface of a conductor.
   (v) Charge density is more on the surface of a conductor at parts of higher curvatures.
3. Refer to theory.

Physics Point

2 EXERCISE

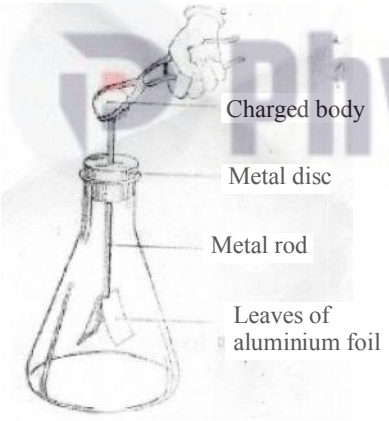
TEXT-BOOK EXERCISE :

1. (b) A copper plate
2. (b) The rod becomes positively charged while the cloth has a negatively charged.
3. (a) F (b) T
   (c) F (d) F
4. Objects can be charged by rubbing with each other. While taking off sweater during winters it comes in contact with the surface of inner clothes. Due to rubbing, the sweater gets charged. Thus while taking off the sweater during winters it produces electric sparks with crackling sound.
5. When we touch a charged body the excess charge gets transfer to the ground through our body. Thus the charged body loses the charge and becomes neutral.
6. The destructive energy of an earthquake is measured on Richter scale. The earthquake measuring 3 on Richter scale, may be recorded by a seismograph and it is not likely to cause much damage. The earthquake measuring 7 or more on the Richter scale cause severe damage to life and property.
7. Safety Measures to protect from lightning.
   (i) Do not touch any electrical wires, telephone cables, metal pipes etc.
   (ii) Do not bath in running water. This may cause an electric shock.

(iii) If you are travelling by car or by bus, close the windows of the car or bus immediately.

8. Like charges repel and unlike charges attract each other. The nature of charges present on the surface of the balloons are similar so they repel each other. When an uncharged balloon is brought near a charged balloon the uncharged balloon acquires charges on its surface which is opposite nature in relation to a charged body. Since the uncharged balloon is attracted by the charged balloon.

9. A device which can be used to detect whether an object is carrying charge or not, is known as electroscope.
It consists of a metal rod. At one end of the rod, two leaves of aluminium foil are fixed and at the another end, there is a metal disc. The leaves of aluminium foil are placed inside conical flask and the flask is corked to isolate the leaves from air.



When the metal disc is touched with a charged body, the aluminium strips move away from each other. This happens because some of the charges of the body transfered to the strip through the metal rod. This method of charging a body is called charging by conduction. The nature of charges on both the leaves and the charged body are similar. Hence, both the leaves of the aluminium foil will move away from each other. If the body was not charged, then the leaves of the foil would remain as they were before. They would not repel each other.

10. Three States of India where earthquakes are more likely to strike are :
(i) Jammu and kashmir
(ii) Gujrat
(iii) Rajasthan

11. The precautions, we would take to protect ourselves are
(i) We would find a clear spot, away from buildings, trees and overhead power lines. Drop to the ground.
(ii) If we are in car or a bus, we would not come out. In moving vehicle, we would ask the driver to drive slowly to a clear spot and wait there inside the vehicle till the tremors stop.

12. No, we would avoid to carry an umbrella in a thunderstorm because lightning has great affinity to strike at any available metal object in the open. During thunderstorm, which are accompanied with lightning, electric discharge from the clouds can travel through the metallic rod of the umbrella. This may give an electric shock to the person who is carrying it. Hence, it is not safe to carry an umbrella during thunderstorm.

EXEMPLAR QUESTIONS :

1. No, it will not be effective. Since lightning conductor was not connected properly to the earth, therefore, the charge will not pass through to the earth.

2. Electric charge gets accumulated on the screen. On touching the screen the charge discharges through our body. Thus, we get a slight shock.

3. The charge that was in the electroscope strips will get discharged through our hand. The strips will come back to the original state.

4. Lightning is an electrical discharge. During lightning atmospheric electric charge may discharge through landline telephone wires and may become dangerous. Therefore it is safer to use a wireless telephone instead of a landline telephone during lightning.

5. The aluminium strips will not show any repulsion. The charged body will not transfer any charge to the ebonite rod as ebonite rod is an insulator. As a result there will be no charge on the aluminium strips and no repulsion will occur.

HOTS QUESTIONS:

1. When an electron leaves an atom, an equal amount of positive charge as the charge on an electron is produced on the atom. Therefore, when we comb our hair, they become positively charged and the comb becomes negatively charged as electrons scuff from our hair on to the comb.

2. The five thousand billion freely moving electrons in a penny repel one another but at the same time they are attracted by positively charged nuclei of the atoms of the penny. The net force of attraction exceeds the net force of repulsion in a penny. Therefore, electrons don't fly out of the penny.

3. Same charges repel each other.

PhysicsPoint

3 EXERCISE

SINGLE OPTION CORRECT :

1. (a) Crust is the outermost layer of the earth.
2. (d) **3.** (c)
4. (b) Conduction possible in conductor only.
5. (c) **6.** (c) **7.** (a) **8.** (a) **9.** (c)
10. (a) The figure shows the accumulation of charges, this leads to lightning followed by thunder and rain.
11. (a) The name of the instrument is seismograph.

MORE THAN ONE OPTION CORRECT :

1. (b, d) Conducts electric charge to the ground.
2. (c, d)
3. (a, c, d) Copper rod is a conductor.

MULTIPLE MATCHING QUESTIONS :

1. A → (q), B → (s), C → (p), D → (r)
2. A → (q), B → (s), C → (p), D → (r)

PASSAGE BASED QUESTIONS :

1. (a) **2.** (d)

ASSERTION & REASON :

1. (a) Earthquake occurs due to the movement of tectonic plates, pressure builds up. When pressure is released, it results in earthquake.
2. (a) An electroscope can be used to find the nature of charge and to measure the charge on a body.
3. (c) There is redistribution of charge but the net charge remains zero.
4. (b) Atoms contain equal no. of electrons and protons.

INTEGER/NUMERIC TYPE QUSTIONS :

1. **8** The charge of one electron is -1.6×10^{-19}C. So net charge on a substance consisting of 5×10^{14} electrons is

$$5 \times 10^{14} \times (-1.6 \times 10^{-19}\text{C}) = -8\times10^{-5}\,\text{C} = -80\mu\text{C}.$$

2. **3** No. of electrons transferred, $n = \frac{q}{e}$

$$\text{Mass transferred} = m_e \times n = m_e \times \left(\frac{q}{e}\right)$$

$$= 9.1\times10^{-31} \times \left(\frac{1.6\times10^{-7}}{1.6\times10^{-19}}\right)$$

$$\cong 9\times10^{-19}\ \text{kg}$$

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

1. (d) Because of excess of electron mass of *B* increases.
2. (d) **3.** (a) **4.** (d) **5.** (b)
6. (c) Mass increases if gains electrons and decreases if loose electrons.
7. (a) **8.** (c) **9.** (d)
10. (c, d) The charge on disc A is 10^{-6} μC. The charge on disc B is 10×10^{-6} μC. The total charge on both = 11 μC. When touched, this charge will be distributed equally i.e. 5.5 μC on each disc.
11. (a, c, d) Nuclear force binds the protons and neutrons in the nucleus of an atom.
12. A – (s), B – (r), (C) – (q), (D) – (p)
13. (b) **14.** (a) **15.** (c)
16. (c) The number of electrons in insulator is of the same order as that in a conductor. But the number of free electrons is very small in an insulator. This is basic difference between a conductor and an insulator.
17. (a) **18.** (a) **19.** (b)
20. **2** Here, $e = -1.6\times10^{-19}$ C, $Q = -3.2\times10^{-7}$ C;

$$Q = ne \quad \therefore \quad n = \frac{Q}{e} = 2\times10^{12}$$

21. **2** According to Coulomb's law, $F = \frac{kq_1q_2}{r^2} = \frac{k(ne)^2}{r^2}$

$$\Rightarrow \quad 3.7\times10^{-9} = \frac{9\times10^9\times(n\times1.6\times10^{-19})^2}{(5\times10^{-10})^2} \quad \therefore n = 2$$

Chapter

6

LIGHT

INTRODUCTION

Light is the only thing we can really see. We probably learn more about the world around us from our sense of sight than from any of our other senses. Light is electromagnetic radiation. The human eye can detect light wavelengths between about 380 and 780 nm. The primary source of light is the sun. Other common sources are flames, white hot filaments in light bulbs and glowing gases in glass tubes. Light is a form of radiant energy. It does not require any material medium to propagate. It can travel through vacuum at a speed of 3 × 108 ms–1. Light travels from the source in straight lines. This is known as rectilinear propagation. The speed of light changes when it goes from one medium to another medium.

Physics Point

WHAT MAKES THINGS VISIBLE?

We see things when send out light. We cannot see objects in the dark. Our eyes alone cannot see any object. It is only when light from an object enters our eyes we see the object. Light affects the eye to produce the sensation of vision. The light may have been emitted or reflected by the object.

Light behaves as a stream of photons when it interacts with photographic film or other detectors, and it behaves as a wave in travelling from a source to the place where it is detected.

LUMINOUS AND NON-LUMINOUS OBJECTS

Luminous objects are those which emit its own light e.g., sun, glowworm, burning candle, electric lights, etc. Luminous objects can be natural or artificial.
Non-luminous objects do not give out its own light but are visible only when light from a luminous object falls on it e.g., moon, earth, table, paper, etc.

Think it Over

Light rays are invisible unless they shine directly in our eyes. From a space ship, the "sky" looks black except where light hits something . Can you explain why a search light beam is often visible from the side.

TRANSPARENT, TRANSLUCENT AND OPAQUE MATERIALS

Transparent materials are those which allow most of light to pass through them.
Example : Glass, water, air, etc.
Translucent materials allow only a part of light to pass through it. We cannot see distinctly through them. *Example* : Greased paper, paraffin wax, etc.
Opaque materials do not allow any light to pass through it. They reflect or absorb all the light that falls on them. *Example* : Books, desk, stone, rubber, trees, etc.

A shadow is formed when rays of light are stopped by an opaque object.

Think it Over

Scientists sometimes refer to "invisible light". What other forms of energy are like light but not visible to the human eye ?

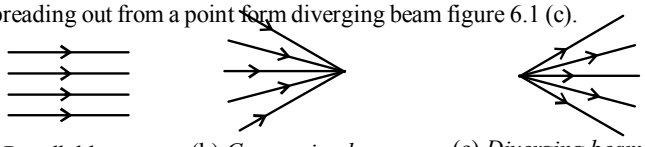
RAY AND BEAM OF LIGHT

A ray of light is represented by a straight line with an arrow head . The arrow head gives the direction of propagation of light.

Beam of light : A bundle of light rays is called a beam of light.

Parallel, Converging and Diverging Beam of Light

Parallel beam : Light from distant source gives a parallel beam of light. Rays stay at the same distance apart in parallel beam of light figure 6.1 (a).
Converging beam : Rays of light meeting at a point form converging beam figure 6.1 (b).
Diverging beam : Rays of light spreading out from a point form diverging beam figure 6.1 (c).



(a) *Parallel beam* (b) *Converging beam* (c) *Diverging beam*

Fig. 6.1

REFLECTION OF LIGHT

When light hits an opaque material, the light may be absorbed by the material and converted into heat energy. If light is not absorbed, it is bounced back or reflected at the surface of material i.*e.,* *Turning back of light in the same medium is called reflection of light.*

Laws of Reflection

1. The angle of incidence '*i*' is equal to the angle of reflection '*r*' i.e., ∠i = ∠r
2. At the point of incidence, the incident ray, the normal to the surface and the reflected ray all lie in the same plane.

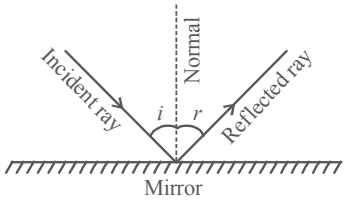


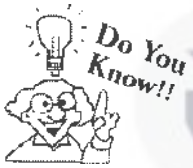
Fig. 6.2

Regular and Diffused Reflection

When light is incident on a smooth surface it is reflected in the first medium. This reflection on a smooth surface is called **regular reflection.** When light is incident on a rough surface, it is reflected in many directions. This is called **diffused reflection.**

(a) Regular reflection *(b) Diffused reflection*

Fig. 6.3



There is no surface that will reflect 100% of the light incident upon it.

Physics Point

IMAGE FORMED BY A PLANE MIRROR

A plane mirror is made from glass with a layer of silvering at the back. A polished shiny metal can also be used as a mirror. The formation of image by a plane mirror is due to the reflection of light.

(i) When rays of light from a light source falls on you, the light will be reflected into the mirror.

(ii) An image will be formed in the mirror and the mirror reflects the image into your eyes. Thus, we can see the image in the mirror.

If you place a candle in front of a mirror, rays of light radiate from the flame in all directions. Figure shows only four of the infinite number of rays leaving one of the infinite number of points on the candle. When these rays meet the mirror, they reflect at angles equal to their angles of incidence. The rays diverge from the flame. Note that they also diverge when reflecting from the mirror. These divergent rays appear to emanate from behind the mirror (dashed lines). You see an image of the candle at this point. The light rays do not actually come from this point, so the image is called a *virtual image*. The image is as far behind the mirror as the object is in front of the mirror, for example, the size of your image is the same as the size you are in front —as long as the mirror is flat.

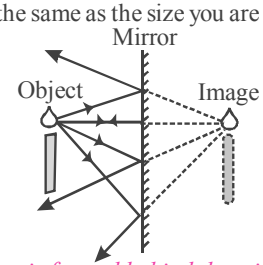


Fig. 6.4 : *A virtual image is formed behind the mirror and is located at the position where the extended reflected rays (dashed lines) converge*

Only part of light that strikes a surface is reflected. For example, on a surface of clear glass and for normal incidence only about 4 percent is reflected from the surface. On a clear and polished aluminium and silver surface however, about 90 per cent of the incident light is reflected.

Real and Virtual Image

An '**image**' is defined as the impression of an object carried over and formed by light reflected from it.

Real image

1. When the rays of light actually meet, the image so formed is known as real image.
2. A real image can be caught on a screen since it is formed by actual meeting of rays.
3. A real image is always inverted.
4. A real image is formed by a convergent reflected beam.
5. In ray diagrams, for real image, the rays are represented by full lines.

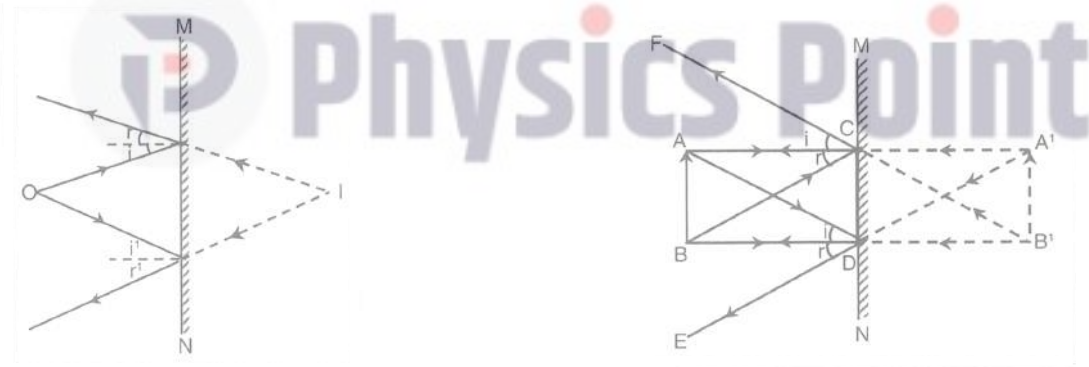
Virtual image

1. When the rays of light appear to meet, the image so formed is known as virtual image.
2. A virtual image cannot be caught on a screen since it is formed by meeting of imaginary rays.
3. A virtual image is always erect.
4. A virtual image is formed by a divergent reflected beam.
5. In ray diagrams, for virtual image, the rays are generally represented by dotted lines.

Characteristics of Images Formed by a Plane Mirror

The image formed by a plane mirror is

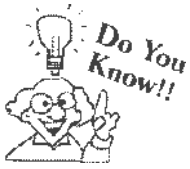
(i) virtual (the image cannot be formed on a screen)
(ii) upright
(iii) *laterally inverted* (the left side of an image is formed by the right side of an object) and vice-versa
(iv) the same size as the object
(v) the same distance behind the mirror as the object is in front of the mirror.



(a) Reflection of a point object in a plane mirror

(b) Reflection of an extended object in a plane mirror

Fig. 6.5



- *A person needs a plane mirror of minimum half of his height to see his full image.*
- *A person standing in the middle of room can see complete wall behind him if the mirror in front of him is* $\frac{1}{3}$*rd of height of wall.*
- *If an object moves towards (or away from) a plane mirror at a speed v, the image will also approach (or recede) at the same speed. v, i.e. the speed of image relative to object will be* $v - (-v) = 2v$.

Think it Over

Standard two plane mirrors to form a shape V. Put a coin in the V. How many images can you see ? What is the effect of changing the angle between the mirrors? When is the number of images infinite (more than you can count) ?

Uses of Plane Mirrors

(i) Plane mirrors are primarily used as looking glasses.
(ii) Since, a combination of mirrors can produce *multiple images,* they are used to provide false dimensions in showrooms.

(iii) They are also used as reflectors in solar cookers.

(iv) Plane mirrors are used in the construction of a periscope

Activity

To make a simple kaleidoscope or a simple periscope using plane mirrors and cardboard tubes.

- Tape three mirrors together to form a triangle.
- Insert the triangle in one end of a tube.
- Cover that end with wax paper and drop bits of coloured paper inside the triangle.
- Cover the top end except for a viewing hole.
- Shake to get changing patterns.

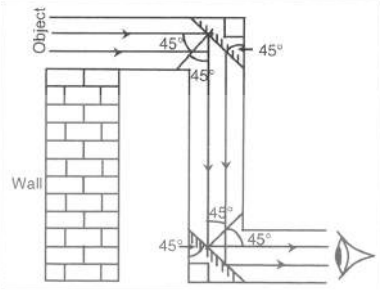


Fig. 6.6 Periscope

CHECK Point

1. **If you wish to take a picture of your image while standing 5 m in front of a plane mirror, for what distance should you set your camera to provide the sharpest focus?**
2. **Why is it more dangerous to drive a car on a rainy night ?**

SOLUTION

1. You should set your camera for 10 m; the situation is equivalent to you standing 5 m in front of an open window and viewing your twin standing 5 m in back of the window.
2. Because the road surface is more mirrored when it is wet, beams from your headlights mostly reflect ahead instead of back to you by diffuse reflection. This makes the road more difficult to see. Furthermore, headlights from oncoming cars reflect from the wet surface full force into your eyes. Glare is much more intense from a mirrored surface.

Physics Point

CONNECTING TOPIC

REFLECTION AT CURVED SURFACES (SPHERICAL MIRRORS)

A highly polished curved surface whose reflecting surface is a cut part of a hollow sphere of a glass or any polished metal is called spherical mirror. Spherical mirrors are of two types:

Concave Mirrors

Imagine a **sphere** of **hollow** glass. If we cut out a spherical cap and polished it with silver on the outside, we have a **concave mirror** if we look at it from the hollow side. These mirrors, which are referred to as **convergent** mirrors, concentrate the light rays, causing them to arrive parallel to the main axis onto a point known as the **focal point**. Concave mirrors form **real images** that can be **projected** onto a screen if the object is farther away than the focal point. The image obtained is large if formed near the focal point or small if formed far away from the focal point. In both cases, the image is **reversed**. If we place the object closer than the focal point, the image is formed upright and large but virtual (i.e., it cannot be projected).

Uses: As a shaving mirror, reflector, by dentists and E.N.T. specialists to view the interior portions of a body clearly.

Convex Mirrors

If we polished the **inner surface** of a concave mirror with silver and look at it toward the **outward bulge**, we have a **convex** mirror. Mirrors of this type are also called **divergent** mirrors because the light beams that reach their surface and are **parallel** to their main axis are diverted in such a way that they **separate**, but their **extensions** come back together again in a point known as the **focal point**. The images produced by a convex mirror are always **virtual, upright**, and **small**.

Uses: As a side view mirror in vehicles, in ATM centres, etc.

TERMS RELATED TO SPHERICAL MIRROR

Centre of curvature (C) **:** It is the centre of sphere of which the mirror is a part.

Radius of curvature (R) **:** It is the radius of the sphere of which the mirror is a part.

Pole (P) **:** It is the geometrical centre of the spherical reflecting surface.

Principal axis : It is the straight line joining the centre of curvature to the pole.

Focus (F) **:** When a narrow beam of rays of light, parallel to the principal axis and close to it (know as paraxial rays), is incident on the surface of a mirror, the reflected beam is found to converge (concave mirror) or appear to diverge (convex mirror) from a point principal axis. This point is called focus.

Focal length (f) : It is the distance between the pole and the principal focus. For spherical mirrors, $f = R/2$.

Sign Convention

(The Cartesian Sign convention)

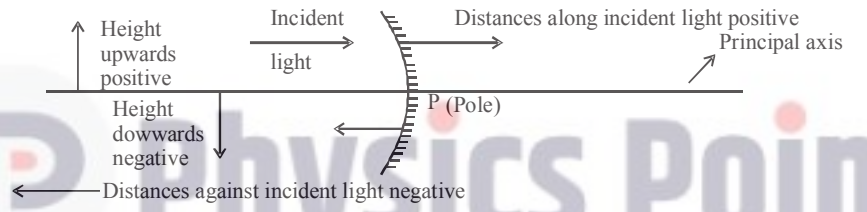
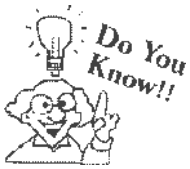


Fig. 6.7

(i) All distances are measured from the pole of the mirror.

(ii) The distances measured in the same direction as the incident light are taken as positive and those measured in the direction opposite to the direction of incident light are taken as negative.

(iii) The heights measured upwards and perpendicular to the principal axis are taken as positive. The heights measured downwards are taken as negative.



- *Focal length of concave mirror is always negative.*
- *Focal length of convex mirror is always positive.*
- *Focal length of a mirror depends only on the curvature of the mirror* $\left(f = \frac{R}{2}\right)$. *It does not depend on the material of the mirror or on the wavelength of incident light.*

Rules for Ray Diagram

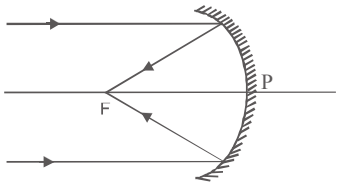
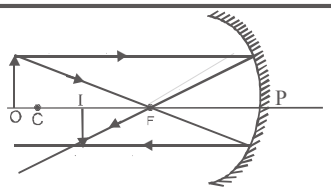
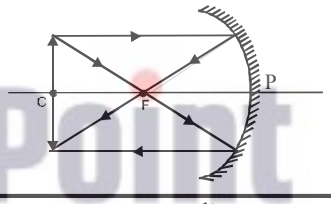
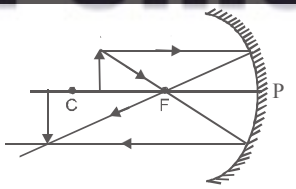
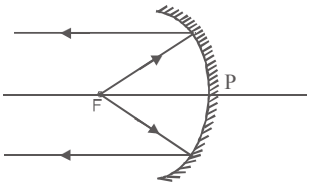
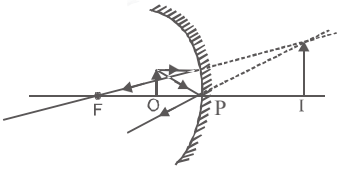
(i) A ray, parallel to the principle axis will after reflection, pass through the focus.

(ii) When a ray falls in the direction of centre of curvature of mirror then it reflects back along the same path.

(iii) A ray passing through the focus is reflected parallel to the principal axis.

CONNECTING TOPIC

IMAGE FORMED BY THE CONCAVE MIRROR

Position of object	Position of image	Nature	Ray diagram
At infinity	At the focus	Real, inverted & diminished	
Between infinity & centre of curvature	Between focus & centre of curvature	Real, inverted & small in size	
At centre of curvature	At centre of curvature	Real, inverted and of the same size	
Between focus & centre of curvature	Beyond centre of curvature	Real, inverted and enlarged	
At focus	At infinity	Real, inverted and very large	
Between Focus & Pole	Behind the mirror	Erect, virtual & enlarged	

Physics Point

IMAGE FORMED BY CONVEX MIRROR

A convex mirror forms only virtual images for all positions of the real object. The image is always virtual, erect, smaller than the object and is located between the pole and the focus. The image becomes smaller and moves closer to the focus as the object is moved away from the mirror.

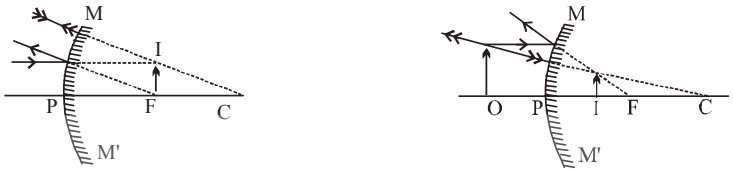


Fig 6.8

The virtual image is diminished in size and upright, relative to the object. A convex mirror form a virtual image of the object, no matter where in front of the mirror the object is placed.

MIRROR FORMULA

If an object is placed at a distance u from the pole of a mirror and its image is formed at a distance v (from the pole) then, focal length (f) of mirror is related as

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$$

MAGNIFICATION

If a thin object linear size O situated vertically on the axis of a mirror at a distance u from the pole and its image of size I is formed at a distance v (from the pole), magnification is defined as

$$m=\left[\frac{I}{O}\right]=-\left[\frac{v}{u}\right]$$

- (+ve means erect image)
- (–ve means inverted image)
- (|m| >1 means large image)
- (|m| < 1 means small image)

Here –ve magnification implies that image is inverted with respect to object while +ve magnification means that image is erect with respect to object

ILLUSTRATION : 1

A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00 m from this mirror, find the position, nature and size of the image.

SOLUTION :

Radius of curvature, $R=+3.00\ m$; Object-distance, $u=-5.00$ m; Image-distance, $v=?$ Height of the image, $h'=?$

Focal length, $f=R/2=+\frac{3.00m}{2}=+1.50m$

Since $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ or $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$

$$\Rightarrow \frac{1}{v}=\frac{1}{1.50}-\frac{1}{(-5.00)}=\frac{1}{1.50}+\frac{1}{5.00}=\frac{5.00+1.50}{7.50}$$

or $v=\frac{+7.50}{6.50}=+1.15m$

The image is 1.15m at the back of the mirror.

Magnification, $m=\frac{h'}{h}=-\frac{v}{u}=-\frac{1.15\text{m}}{-5.00\text{m}}=+0.23$

The image is virtual, erect and smaller in size by a factor of 0.23.

ILLUSTRATION : 2

An object, 4.0 cm in size, is placed at 25.0 cm in front of a concave mirror of focal length 15.0 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? Find the nature and the size of the image.

SOLUTION :

Object-size, $h = +4.0$ cm; Object-distance, $u = -25.0$ cm;
Focal length, $f = -15.0$ cm;
Image-distance, $v = ?$ Image-size, $h' = ?$

From $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ or $\frac{1}{v}=\frac{1}{f}-\frac{1}{u}=\frac{1}{-15.0}-\frac{1}{-25.0}=-\frac{1}{15.0}+\frac{1}{25.0}$

or $\frac{1}{v}=\frac{-5.0+3.0}{75.0}=\frac{-2.0}{75.0}$ or $v=-37.5$ cm.

The screen should be placed at 37.5 cm. from the mirror. The image is real.

Also, magnification, $m=\frac{h'}{h}=-\frac{v}{u}$ or $h'=-\frac{vh}{u}=\frac{(-37.5\text{cm})\ (+4.0\text{cm})}{(-25.0\text{cm})}$

Height of the image, $h' = -6.0$ cm.
The image is inverted and enlarged.

REFRACTION OF LIGHT

The bending of the light ray from its path in passing from one medium to the other medium is called refraction of light.

If the refracted ray bends towards the normal relative to the incident ray (Passing obliquely), then the second medium is said to be denser than the first medium. But if the refracted ray bends away from the normal, then the second medium is said to be rarer than the first medium.

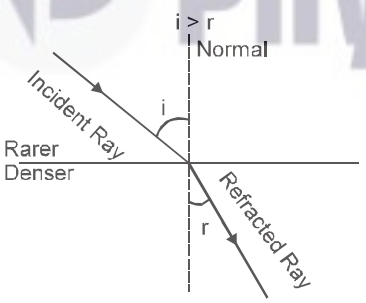


Fig. 6.9 (a)

Separating Plane

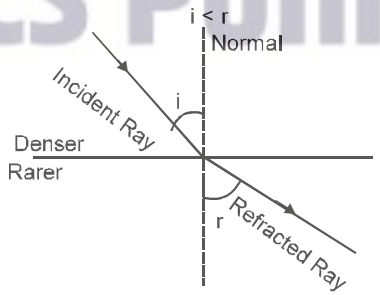


Fig. 6.9 (b)

If a ray of light passing normally i.e., at right angles from one medium to another optical medium then it does not bend or deviate from its path.

Cause of refraction of light: Refraction of light takes place due to change in the speed of light as it enters from one medium to another medium.

Refraction causes many illusions. One of them is the **apparent bending of a stick that is partially submerged in water**. The submerged part appears closer to the surface than it actually is. The same is true when you look at a fish in water. The fish appears nearer to the surface and closer than it really is (Fig. 1.36). If we look straight down into water, an object submerged 4 meters beneath the surface appears to be only 3 meters deep. Because of refraction, submerged objects appear to be magnified.

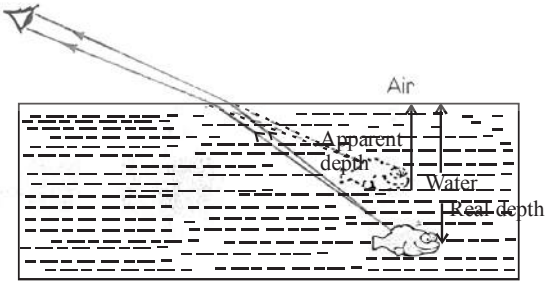


Fig.6.10 A submerged object appears to be nearer to the surface than it actually is

Atmospheric Refraction

Refraction occurs in the earth's atmosphere. Whenever we watch a sunset, we see the sun for several minutes after it has sunk below the horizon (Fig. 1.36). The earth's atmosphere is thin at the top and dense at the bottom. Because light travels faster in thin air than in dense air, parts of the wavefronts of sunlight at high altitude travel faster than parts closer to the ground. Light rays bend. The density of the atmosphere changes gradually, so light rays bend gradually and follow a curved path. So we gain additional minutes of daylight each day. Furthermore, when the sun (or moon) is near the horizon, the rays from the lower edge are bent more than the rays from the upper edge. This shortens the vertical diameter, causing the sun to appear elliptical figure).

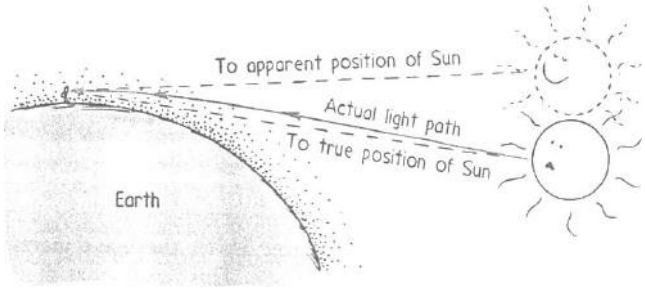


Fig. 6.11. When the sun is near the horizon it appears to be higher in the sky.

CHECK Point

If, while standing on the bank of a stream, you wished to spear a fish swimming in the water out in front of you, would you aim above, below, or directly at the observed fish to make a direct hit? If you decided instead to zap the fish with a laser, would you aim above, below, or directly at the observed fish? Defend your answer.

SOLUTION

When you try to hit the fish with a spear, you need to aim below as the fish is actually at a lower depth than that observed by you from outside the water due to refraction of light. When you aim with a laser light then also you should aim much below as the path of laser will change as it enters in water. Since it is going from rarer to denser medium, it bends towards the normal and deviates from the original path.

Laws of Refraction

There is two laws of refraction

1. The incident ray, the refracted ray, and the normal to the refracting surface at the point of incidence are in the same plane.
2. The ratio of *sine* of angle of incidence to the *sine* of angle of refraction is constant for a pair of media i.e. $\frac{\sin i}{\sin r} = \text{constant } ({}_1u_2)$

   Where ${}_1\mu_2$ is the refractive index of medium 2 w.r.t. medium 1. This law is also known as **snell's law.**

REFRACTIVE INDEX

Light travels through a vacuum at a speed $c = 3.00 \times 10^8$ m/s. It can also travel through many materials, such as air, water and glass. Atoms in the material absorb, reemit and scatter the light, however. Therefore, light travels through the material at a speed that is less than c, the actual speed depending on the nature of the material.

To describe the extent to which the speed of light in a material medium differs from that in a vacuum, we use a parameter called the index of refraction (or refractive index).

Absolute Refractive Index

It is defined as *the ratio of speed of light in free space c to that in a given medium v.*

i.e. μ or $n = \frac{c}{v}$ ...(1)

Also, μ or $n = \frac{\sin i}{\sin r}$ (incident ray in vacuum or air)

It is a scalar and has no units and dimensions.

As in vacuum or free space, speed of light of all wavelengths is maximum and equal to c, so, for all wavelengths the refractive index of free space is minimum and is $\mu = \frac{c}{v} = \frac{c}{c} = 1$

For a given light, denser is the medium, lesser will be the speed of light and so greater will be the refractive index, e.g. as $v_{glass} < v_{water}$, $\mu_G > \mu_w$

i.e. for a given light refractive index depends on nature of medium [i.e., $\mu \propto (1/v)$]s

For a given medium (other than free-space), the speed of light of different wavelengths is different,i.e., $v \propto \lambda$ and $\mu = (c/v)$, $\mu \propto (\lambda)$ i.e. greater the wavelength of light lesser will be the refractive index e.g. $\lambda_R > \lambda_B$, so in water or glass $\mu_R < \mu_B$, i.e., for a given medium (other than free space) refractive index depends on wavelength of light.

As for light in free space $c = f\lambda_0$ and in a medium $v = f\lambda$,

$$\mu = \frac{c}{v} = \frac{\lambda_0}{\lambda} \quad \text{...(2)}$$

i.e., for a given light and medium refractive index is equal to the ratio of wavelength of light in free space to that in the medium. Refractive index decreases with the increase in temperature.

Relative Refractive Index

When light passes from one medium to the other, the refractive index of medium 2 relative to 1 is written as ${}_1\mu_2$ and is defined as

$${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{(c/v_2)}{(c/v_1)} = \frac{v_1}{v_2} \quad \text{...(3)}$$

While using the concept of relative μ, it must be kept in mind that :

${}_2\mu_1 = \frac{\mu_1}{\mu_2} = \frac{v_2}{v_1}$ So that, $({}_1\mu_2)\,({}_2\mu_1) = \frac{v_1}{v_2} \times \frac{v_2}{v_1} = 1$

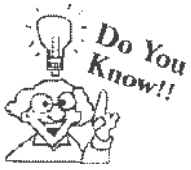
i.e., $${}_1\mu_2 = \frac{1}{{}_2\mu_1} \quad \text{....(4)}$$

Usually 'μ' is used for relative refractive index and it implies the refractive index of denser medium relative to rarer one,

i.e., $\mu = \frac{\mu_D}{\mu_R} = \frac{v_R}{v_D} > 1$

In lens theory μ is used for the refractive index of material of lens relative to the medium,

i.e., $\mu = \frac{(\mu)_{Lens}}{(\mu)_{Medium}}$ and can be greater than, less than or equal to unity.



- *A medium is said to be denser, if the wave velocity in it is smaller.*
- *Frequency (and hence colour) and phase do not change while wavelength and velocity changes when light passes from one medium to another. .*

CHECK Point

If the speed of light were the same in all media, would refraction still occur when light passes from one medium to another ?

SOLUTION

No. We can notice many interesting events occurring due to refraction of light in nature. For example, when a straight object like pencil is kept partly immersed in water in a glass tumbler, the part of the pencil immersed in water appears to be bent and thicker when viewed from sides.

Physics Point

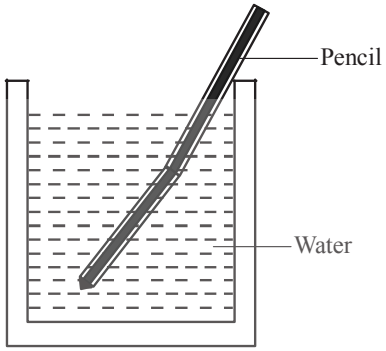


Fig. 6.12

Similarly, the body of a swimmer inside water appears to be inflated.

Place a coin in a bucket full of water. The coin appears slightly above its real position due to refraction of light..

ILLUSTRATION : 3

One light wave is incident upon a plate of refractive index μ. Find the incident angle *i*, for which refractive and reflective waves are mutually perpendicular.

SOLUTION :

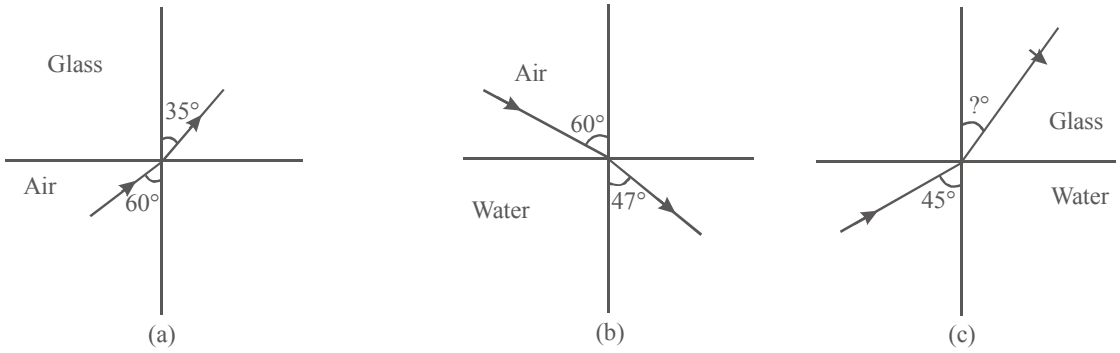
According to snell's laws, $\frac{\sin i}{\sin r} = \mu$

Angle between refractive and reflective waves $= 180^o - (i + r) = 90^o \Rightarrow i + r = 90^o \Rightarrow r = 90° - i$

$$\therefore \mu = \frac{\sin i}{\sin(90^o - i)} = \frac{\sin i}{\cos i} = \tan i \Rightarrow i = \tan^{-1}(\mu)$$

ILLUSTRATION : 4

Figures (a) and (b) show refraction of a ray in air incident at 60° with the normal to a glass-air and water-air interface, respectively. Predict the angle of refraction in glass the angle of incidence in water is 45° with the normal to a water-glass interface [Fig. (c)].



SOLUTION : *Fig. 6.12 (a)*

For glass-air interface, i = 60°, r = 35°

According to snell's law, $n_{ga} = \frac{\sin i}{\sin r} = \frac{\sin 60°}{\sin 35°} = \frac{0.866}{0.573} = 1.51$

For water-air interface, i = 60°, r = 41°

$$n_{wa} = \frac{\sin i}{\sin r} = \frac{\sin 60°}{\sin 47°} = \frac{0.866}{0.656} = 1.32$$

For water - glass interface, i = 45°, r = ?

$$n_{gw} = \frac{\sin i}{\sin r}, \quad \frac{n_{ga}}{n_{wa}} = \frac{\sin 45°}{\sin r}, \quad \frac{1.51}{1.32} = \frac{0.707}{\sin r}$$

$$\therefore \sin r = \frac{0.707 \times 1.32}{1.51} = 0.6181 \quad \therefore r = 38°$$

TOTAL INTERNAL REFLECTION

The phenomenon of reflection of total light when the light traveling from an optically denser medium to a rarer medium strikes the interface at an angle greater than the critical angle is called total internal reflection.

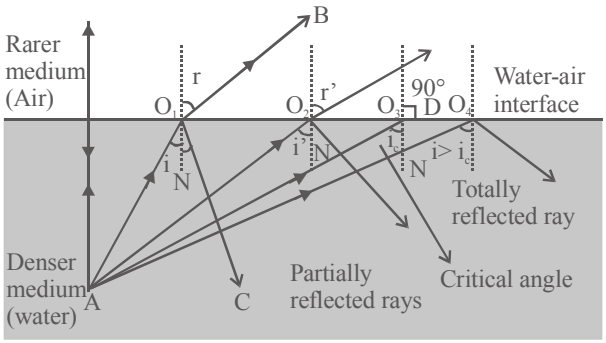


Fig. 6.13

Conditions for Total Internal Reflection

(i) The ray of light must travel from denser to rarer medium.

(ii) The angle of incidence must be greater than critical angle

Critical Angle

The critical angle for the given pair of media is defined as the angle of incidence in the denser medium corresponding to which the angle of refraction is 90° in the rarer medium.

According to Snell's law, $n_{12} = \frac{\sin i}{\sin r}$ when $i = i_c$, $r = 90°$ $\therefore n_{12} = \frac{\sin i_c}{\sin 90°} = \sin i_c$ $\therefore n_{12} = \frac{1}{\sin i_c}$

LENS

A lens is a piece of transparent material with two refracting surfaces such that at least one is curved and refractive index of used material is different from that of the surroundings.

Convex lens: A thin spherical lens with refractive index greater than that of surrounding behaves as a convergent or convex lens i.e. converges parallel rays. Its central (i.e. paraxial) portion is thicker than marginal one.

Convex lens: If the central portion of a lens (with $\mu_L > \mu_M$) is thinner than marginal, it diverges parallel rays and behaves as a divergent or a concave lens.

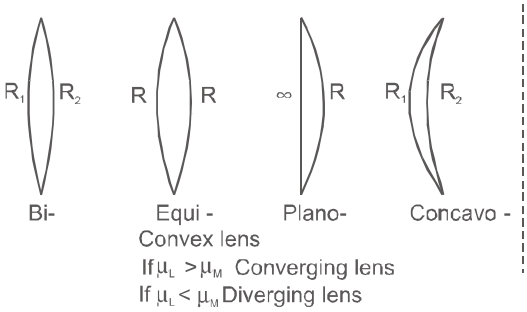


Fig. 6.13 (a)

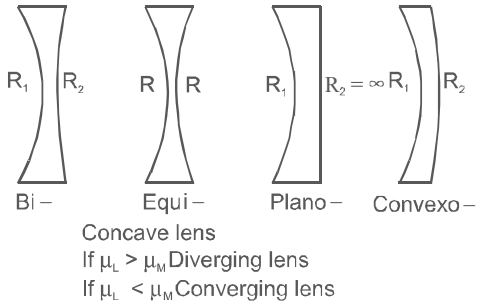


Fig. 6.13 (b)

Optical centre (*O*) - It is a point for a given lens through which any ray passes undeviated.

Principal axis (C_1C_2) - It is a line passing through optical centre and perpendicular to the lens. The centre of curvature of curved surface always lie on the principal axis (as in a sphere is always perpendicular to surface)

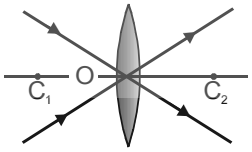


Fig. 6.14 (a)

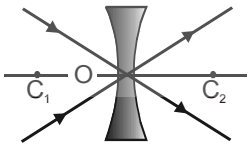


Fig. 6.14 (b)

Principal focus - A lens has two surfaces and hence two focal points first focal point is an object on the principal axis for which image is at infinity while second focal point is an image point on the principal axis for which object is at infinity.

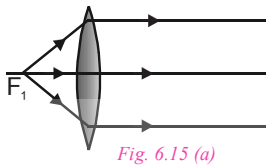


Fig. 6.15 (a)

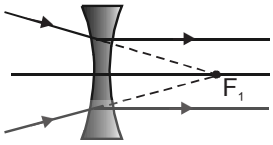


Fig. 6.15 (b)

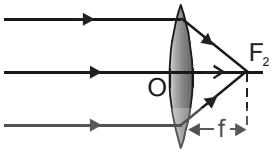


Fig. 6.15 (c)

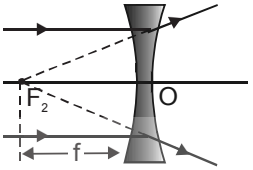


Fig. 6.15 (d)

Focal length (*f*) - It is defined as the distance between optical centre of a lens and the point where the parallel beam of light converges or appear to converge i.e., focus.

Aperture - In reference to lens, aperture means to effective diameter of its light transmitting area so that brightness i.e. intensity of image formed by a lens which depends on the light passing through the lens will depend on the square of aperture.

i.e. $I \propto (\text{aperture})^2$

Sign-Convention

1. Whenever and where possible, rays of light are taken to travel from left to right.
2. Transverse distances are measured from optical centre and are taken to be positive while those below it negative.
3. Longitudinal distances are measured from optical centre and are taken to be positive if in the direction of light propagation and negative if opposite to it e.g., according to our convention the sign of R_1, R_2 and f are given.

$R_1(= OC_1)$ = Positive
$R_2(= OC_2)$ = Negative
f (= OF) = Positive

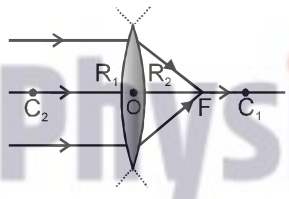


Fig. 6.16 (a)

$R_1(= OC_1)$ = Negative
$R_2(= OC_2)$ = Positive
f (= OF) = Negative

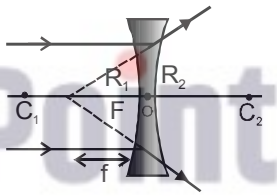


Fig. 6.16 (b)

While using the sign convention it must be kept in mind that

(i) to calculate an unknown quantity the known quantities are substituted with sign in a given formula.

(ii) in the result, sign must be interpreted as there are number of sign conventions and same sign has different meaning in different conventions.

Rules for Image Formation

In order locate the image formed by a lens graphically following rules are adopted -

1. A ray passing through optical centre proceeds undeviated through the lens. (by definition of optical centre).

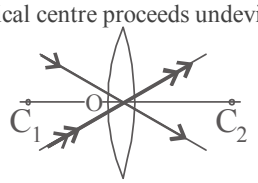


Fig. 6.17 (a)

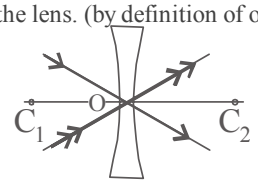
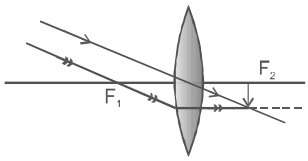
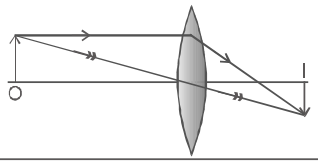
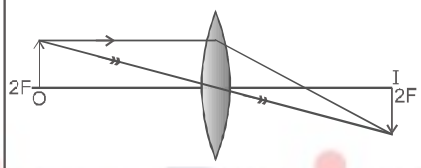
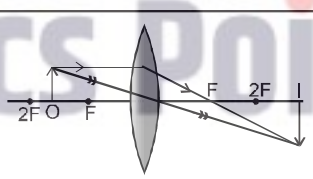
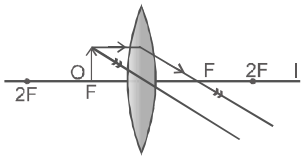
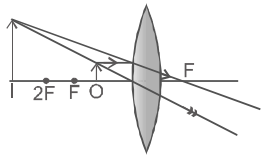


Fig. 6.17 (b)

2. A ray passing through first focus or directed towards it, after refraction from the lens becomes parallel to the principal axis. (by definition of F_1)
3. A ray passing parallel to the principal axis after refraction through the lens passes or appear to pass through F_2 (by definition of F_2).
4. Only two rays from the same point of an object are needed for image formation and the point where the rays after refraction through the lens intersect or appear to intersect is the image of the object. If they actually intersect each other the image is real and if they appear to intersect the image is said to be virtual.

Image Formation by a Lens

(a) For convergent or Convex Lens

Position of object	Details of Image	Figure
At infinity	Real, inverted, Diminished (m<<–1) At F	
Between ∞ and 2F	Real, inverted, Diminished (m<–1) Between F and 2F	
At 2F	Real, inverted, Equal m = –1 At 2F	
Between 2F and F	Real, Inverted, Enlarged (m > –1) Between 2F and ∞	
At F	Real, Inverted, Enlarged (m >>–1) At infinity	
Between Focus & Pole	Virtual, Erect, Enlarged (m > + 1) Between ∞ and object on same side	

(b) For Divergent or Concave lens

1. If object is at infinity image will be formed at focus on the same side of the lens as the object, virtual, erect and point sized.
2. If object is in front of lens, anywhere between the optical centre and infinity image will be formed between focus and the optical centre, on the same side of the lens, highly diminished, virtual and erect.

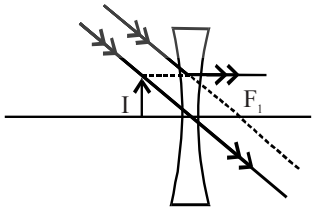


Fig. 6.18 (a)

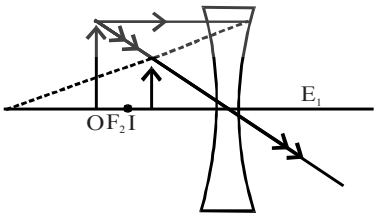


Fig. 6.18 (b)

LENS FORMULA

If an object is placed at a distance u from the optical centre of a lens and its image is formed at a distance v (from the optical centre) and focal length of this lens is f then

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

This is called lens formula.

Power of a Lens

It is the reciprocal of focal length 'f' (in metre) of a lens.

$P=\frac{1}{f(\text{in } m)}$. The unit of power is diopter (D).

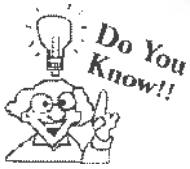
MAGNIFICATION OF A LENS

If a thin object linear size O situated vertically on the axis of a lens at a distance u from the optical centre and its image of size I is formed at a distance v (from the optical centre) then, magnification 'm' is defined as

$$m=\left[\frac{I}{O}\right]=\left[\frac{v}{u}\right]$$

- → (+ve erect image)
- → (–ve inverted image)
- → (|m| >1 large image)
- → (|m| < 1 Small image)

Here, –ve magnification implies that image is inverted with respect to object while+ive magnification means that image is erect with respect to object



The image produced by a concave lens is always virtual and smaller in size.When a convex lens produces real image, m is negative and when image formed is virtual, m is positive.

ILLUSTRATION : 5

Two converging lenses with focal lengths 15 cm and 25cm are placed 18cm apart. An object is located 8.0 cm to the left of the 15cm focal length lens. Where is the final image formed ?

SOLUTION :

Find the image location for the first lens using the lens formula, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$

$$\frac{1}{v_1}=\frac{1}{f_1}-\frac{1}{u_1}=\frac{1}{15\text{cm}}-\frac{1}{8.0\text{cm}} \qquad \text{which gives } v_1=-17\text{cm}$$

This image forms the object of the second lens located 17 cm + 18 cm = 35 cm away. Then for the second lens

$$\frac{1}{v_2}=\frac{1}{f_2}-\frac{1}{u_2}=\frac{1}{25\text{ cm}}-\frac{1}{35\text{ m}} \qquad \text{which gives } v_2=87.5\text{ cm}$$

The final image lies 87.5 cm to the right of the second lens (25 cm) lens.

ILLUSTRATION : 6

A converging lens is used to read the small print. The lens is held 9.0 cm from the print and produces a magnitification of +2.5. What is the focal length of the lens ?

Physics Point

SOLUTION :

The fine print serves as the object for the lens $u = 9.0$ cm. The image distance is then

$$v = -mu = -(2.5\text{ cm})(9.0\text{ cm}) = -22\text{ cm}$$

The thin lens equation gives $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{1}{9.0\text{ cm}} + \frac{1}{(-22\text{ cm})}$

so $f = +15$ cm.

DISPERSION OF LIGHT

The phenomenon of splitting of white ray of light into component coloursVIBGYOR is known as dispersion. The pattern of colour components of light is called the spectrum of light.

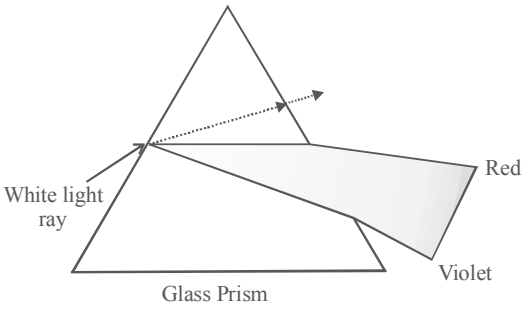


Fig. 6.19

The sequence of different colour components are, violet, indigo, blue, green, yellow, orange and red (given by the word VIBGYOR). The red light bends the least, while the violet light bends the most.

Cause of dispersion : The colour of light depends upon its wavelength. The red light has longer wavelength (700nm) as compared to the violet light (400nm).

The refractive index of material for different wavelengths is different. $\left(\mu \propto \frac{1}{\lambda}\right)$

The deviation Produced is given by $\delta = (\mu - 1)A$. since wavelength of violet is smaller than that of red light $\therefore \mu_v > \mu_r$ hence the violet light is refracted through a larger angle than the red light.

The Rainbow

A rainbow is a spectrum of white light from the sun. This is a phenomenon due to *combined effect of dispersion, refraction and reflection of sunlight* by spherical water droplets of rain. To observe a rainbow, the observer must stand with his back towards the sun. There are two kinds of rainbows:-

(i) **Primary rainbow:-** It is formed due to two refractions and one total internal reflection of the light incident on the water droplet. Sunlight is first refracted as it enters a raindrop which cause different colours of light to separate. Different colours of light are bent through different angles. These components of light strike the inner surface of the water drop and get internally reflected. The reflected light is refracted again as it comes out of the drop. Thus the observer sees a rainbow with red colour on the top and violet on the bottom.

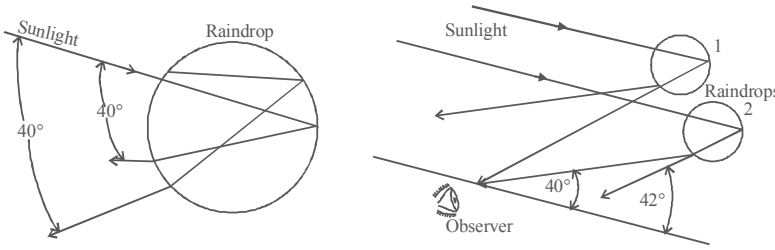


Fig. 6.20

(ii) **Secondary rainbow:-** It is formed due to two refractions and two total internal reflection of light incident on the water droplet. It is due to four - step process. The intensity of light is reduced at the second reflection and hence the secondary rainbow is fainter than the primary rainbow.

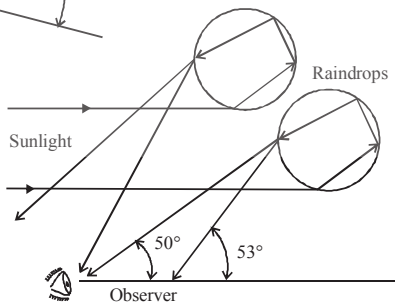


Fig. 6.21

Scattering of Light

As sunlight travels through the earth's atmosphere, it gets scattered by the small particles in the atmosphere.
According to Rayleigh law, the amount of scattering is inversely proportional to the fourth power of the wavelength.

i.e., scattering $\propto \left(\frac{1}{\lambda^4}\right)$.

Examples of Scattering of Light

(i) **Blue colour of Sky:-** Among the primary colours blue colour has a shorter wavelength than red and green colour therefore blue colour is scattered strongly. Hence the bluish colour predominates in a clear sky.

(ii) **White colour of clouds:-** Clouds contain large dust particles, water droplets or ice particles. These large sized Particles donot obey Rayleigh law of scattering. All wavelengths are scattered nearly equally. Hence clouds are generally white.

(iii) **Sun looks reddish at the sunset or sunrise :-** At sunset or sunrise, the sun's rays have to pass through a larger distance in the atmosphere. Most of the blue and other shorter wavelengths are scattered. The least scattered light i.e. red reaching our eyes, therefore the sun looks reddish.

THE HUMAN EYE

The human eye is the organ which gives us the sense of sight, allowing us to learn more about the surrounding world than we do with any of the other four senses. We use our eyes in almost every activity we perform, whether reading, working, watching television, writing a letter, driving a car, and in countless other ways. Most people probably would agree that sight is the sense they value more than all the rest.

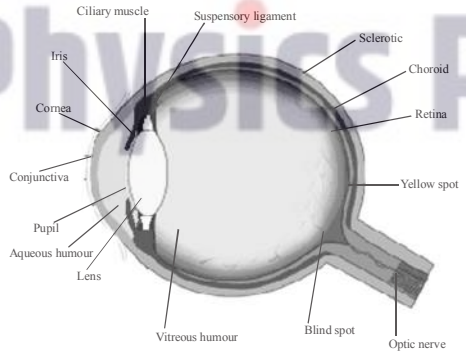


Fig. 6.22 Human eye

The eye allows us to see and interpret the shapes, colors, and dimensions of objects in the world by processing the light they reflect or emit. The eye is able to see in bright light or in dim light, but it cannot see objects when light is absent. The diameter of human eye is about 2.3 cm.
The structure and function of its important parts are described below.

(i) **Retina :** It is a light sensitive screen inside the eye on which image is formed. It contains rods and cones.

(ii) **Cornea :** It is a thin membrane which covers the eye ball. It acts like a lens which refracts the light entering the eye.

(iii) **Aqueous humour :** It is fluid which fills the space between cornea and eye lens.

(iv) **Eye lens :** It is a Convex lens made of transparent and flexible jelly like material. Its curvature can be adjusted with the help of ciliary muscles.

(v) **Pupil :** It is a hole in the middle of iris through which light enters the eye. It appears black because light falling on it goes into the eye and does not come back.

(vi) **Ciliary muscles :** These are the muscles which are attached to eye lens and can modify the shape of eye lens which leads to the variation in focal lengths.

(vii) **Iris :** It controls the amount of light entering the eye by changing the size of pupil.

(viii) **Optical nerve :** These are the nerves which take the image to the brain in the form of electrical signals.

The ability of the eye lens to change its shape to focus near and distant objects clearly is called power of accommodation.

Persistence of vision: *The image of any object seen persists on the retina for $\frac{1}{10}$ second even after the removal of the object. This continuance of sensation of eye is called persistence of vision. This property is used in cinematography.*

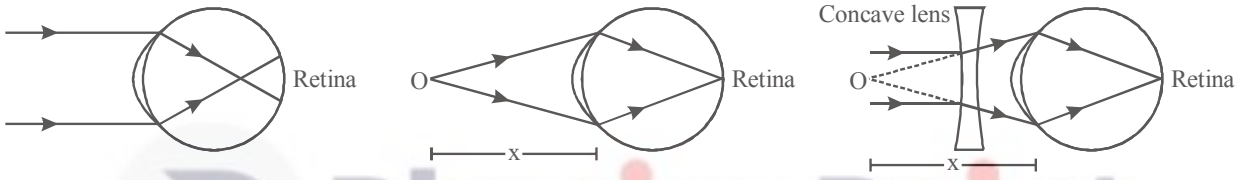
DEFECTS OF VISION AND THEIR CORRECTION

Myopia or Short-Sightedness

If the eyeball is too long or the lens too spherical, the image of distant objects is brought to a focus in front of the retina is out of focus again before the light strikes the retina. Nearby objects can be seen more easily.

A person with myopic eye can see nearby objects clearly but cannot see far off objects distinctly. Eyeglass with concave lens corrects this problem by diverging the light rays before they enter the eye. Myopia most commonly develops in childhood or early teens (between 8 and 14). The risk of developing myopia is increased if there is a family history of it. There may also be a link between myopia and prolonged close-up work, such as reading or sitting close temporary short-sightedness, called pseudomyopia, can be caused by a number of diseases or certain drugs. For example, myopia may be the first sign of type-2 (non insulin-dependent) diabetes. Symptoms of pseudomyopia usually clear up if the underlying cause is treated to the television, although there is little scientific evidence for this.

Remeady: This defect can be corrected by using a concave lens of suitable focal length. A concave lens diverges the rays coming from the object so that they get focused at the retina.



(a) Myopic eye (b) Far point of a myopic eye (c) Corrected myopic eye

Fig. 6.23

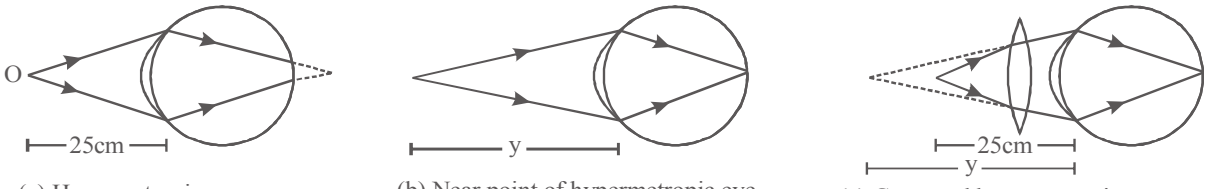
Let a person can see an object at a maximum distance x *m* (i.e. far point is x). Thus, if the eye is to see a distant object clearly, the concave lens should form the virtual image of this distant object at a distance x. Thus, the required focal length of the lens is $f = -x$ and power of lens $P = \frac{1}{f} = -\frac{1}{x}$.

Hypermetropia or Farsightedness

If the eyeball is too short or the lens too flat or inflexible, the light rays entering the eye–particularly those from nearby–objects will not be brought to a focs by the time they strike the retina.

A person with hypermetropic eye can see far off objects clearly but cannot see nearby objects clearly.

Remeady: Eyeglass with convex lens is used to rectify this problem. Squinting, eye rubbing, lack of interest in school, and difficulty in reading are often seen in children with hypermetropia.



(a) Hypermetropic eye (b) Near point of hypermetropic eye (c) Corrected hypermetropic eye

Fig. 6.24

SUMMARY

- **Light :** It is a form of energy which makes us the sense of vision.
- **Reflection of light :** When a ray of light travelling from one medium to another, bounces back in the same medium then this phenomenon is called reflection.
- **Law of reflection :**
  1. The angle of incidence '*i*' is equal to the angle of reflection '*r*'.
  2. At the point of incidence, the incident rays, the normal to the surface and the reflected ray all lie in the same plane.
- **Regular reflection :** When light is incident on a smooth surface, it is reflected parallaly in the first medium. This reflection on a smooth surface is called regular reflection.
- **Diffuse reflection :** When light is incident on a rough surface, it is reflected in many directions. This is called diffuse reflection.
- **Real image :** When the rays of light actually meet, the image so formed is known as real image. It is always inverted .
- **Virtual image :** When the rays of light appear to meet, the image so formed is known as virtual image. It is always erect.
- **Concave mirror :** If the reflection takes place from the inner surface of a spherical mirror, then the mirror is called concave mirror.
- **Convex mirror :** If the outer surface of the spherical mirror acts as a reflector then the mirror is called convex mirror.
- **Focus of a mirror :** When a narrow beam of rays of light, parallel to the principal axis and close to it (known as paraxial rays), is incident on the surface of a mirror, the reflected beam is found to converge (concave mirror) or appear to diverge (convex mirror) from a point on principal axis. This point is called focus.
- **Mirror formula :** If an object is placed at a distance *u* from the pole of a mirror and its image is formed at a distance *v* (from the pole) then, $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$
- **Refraction :** When light passes from one medium to another, we call the process refraction.
- **Refractive index :** Refractive index of a medium is defined as the ratio of the velocity of light in the vacuum to the velocity of light in the medium. That is , $\mu=\frac{c}{v}$
- **Snell's law :** For any two media and for light of a given wavelength, the ratio of the *sine* of the angle of incidence to the sine of the angle of refraction is a constant i.e., $\mu=\frac{\sin i}{\sin r}$
- **Lens :** A lens is a piece of transparent material with two refracting surfaces such that atleast one is curved and refractive index of used material is different from that of the surroundings.
- **Lens formula :** If an object is placed at a distance u from the optical centre of a lens and its images is formed at a distance *v* (from the optical centre) and focal length of this length is f then $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$
- **Power of a lens** $P=\frac{1}{f(\text{in metre})}$
- **Total internal reflection :** When a ray of light passes from denser medium to rarer medium and if the incident angle is greater than critical angle then the ray of light gets reflected back to the originating medium.
- **Magnification:** $M=\frac{v(\text{image distance or image height})}{u(\text{object distance or object height})}$
- **Dispersions :** The splitting of white light into its seven constituent colours (VIBGYOR) on passing through a prism.
- **Myopia or short sightedness :** Person suffering this defect can see nearby objects clearly but cannot see distant objects clearly. To overcome this defect a concave lens is used.
- **Hypermetropia or long sightedness :** Person suffering this defect can see distant objects clearly but cannot see nearby objects clearly. To overcome this defect a convex lens is used.

Physics Point

1 EXERCISE

Fill in the Blanks :

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. The turning back of light in the same medium is called _____ of light.
2. Objects that emit their light are called _____ objects.
3. Materials that do not allow any light to pass through it are called _____ materials.
4. The splitting of white light into its constituent colours is called _____ of light.
5. A rainbow is formed due to _____ of sunlight by water droplets.
6. Shortsightedness can be removed by using _____ lenses.
7. Irregular reflection.....laws of reflection.

True/False :

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Luminous objects emit light on their own.
2. Moon is a non luminous object.
3. Light cannot travel through vacuum.
4. In a plane mirror the image formed is real.
5. Speed of light ray slows down when it travels from air to water.
6. White light is composed of seven colours.
7. Real image is always inverted.

Match the Columns :

DIRECTIONS : *Question contain statements given in two columns which have to be matched. Statements in column I have to be matched with terms given in column II.*

1.

Column -A	Column - B
(A) A material that reflects all light	(p) Transparent
(B) A material that transmits most of the light	(q) Translucent
(C) A material that transmits some light	(r) Opaque
(D) Image formation in a mirror	(s) Regular reflection

2.

Column-I	Column-II
(A) Smooth surface	(p) Upright image
(B) Uneven surface	(q) Regular reflection
(C) Spectrum	(r) Diffused reflection
(D) Erect	(s) Band of colours

Very Short Answer Questions :

DIRECTIONS : *Give answer in one word or one sentence.*

1. The angle between incident ray and reflected ray is 30°. What is the value of angle of incidence?
2. Distinguish between luminous and non-luminous objects.
3. What is the scattering of light ?
4. What do you mean by the spectrum of sunlight ?
5. What is the order of colours in the spectrum of sunlight obtained by a prism ?
6. What is the speed of light in vacuum ?
7. Write laws of reflection of light.

Short Answer Questions :

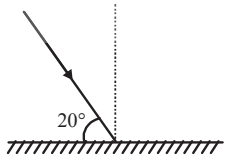
DIRECTIONS : *Give answer in two to three sentences.*

1. What is dispersion of light? Explain.
2. A laser bean consists of light of only single colour. Will a laser bean incident on glass prism produce a spectrum?
3. Why is it important to take care of our eyes? Mention any two activities that may cause damage to our eyes.
4. Explain the function of Ciliary muscles.
5. Does the law of reflection hold for curved mirrors? Explain.
6. What do you mean by the angle of the prism?
7. What type of lens is used to correct hypernetropia?

Long Answer Questions :

DIRECTIONS : *Give answer in four to five sentences.*

1. Describe an experiment to verify law of reflection.
2. Draw a labelled diagram to show different parts of the human eye. What are the main function of iris, pupil and cornea?
3. What are the defects of eye? Bring out the differences between myopia and hypermetropia.
4. Find the angle through which the reflected ray gets rotated when the mirror is rotated by an angle of 60°.
5. An incident ray strikes a plane mirror at an angle of 20° with respect to horizontal surface as shown. What is the change in the angle of reflection, if the incident ray moves towards normal by 1°?



6. If you take a photograph of your image in a plane mirror, how many meters away should you set your focus if you are 2 m in front of the mirror?

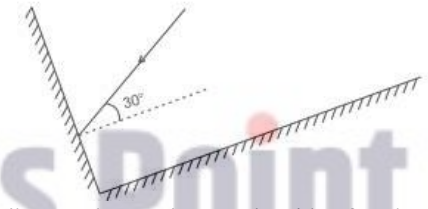
2 EXERCISE

Text-Book Exercise :

1. Suppose you are in a dark room. Can you see objects in the room? Can you see objects outside the room. Explain.
2. Differentiate between regular and diffused reflection. Does diffused reflection mean the failure of the laws of reflection?
3. Mention against each of the following whether regular or diffused reflection will take place when a beam of light strikes. Justify your answer in each case.
   (a) Polished wooden table
   (b) Chalk powder
   (c) Cardboard surface
   (d) Marble floor with water spread over it
   (e) Mirror
   (f) Piece of paper
4. State the laws of reflection.
5. Describe an activity to show that the incident ray, the reflected ray and the normal at the point of incidence lie in the same plane.
6. Fill in the blanks in the following :
   (a) A person 1 m in front of a plane mirror seems to be _____ m from his image.
   (b) If you touch your _____ ear with right hand in front of a plane mirror it will be seen in the mirror that your right ear is touched with _____
   (c) The size of the pupil becomes _____ when you see in dim light.
   (d) Night birds have _____ cones than rods in their eyes.

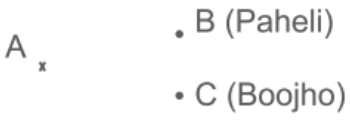
Choose the correct option in Questions 7 – 8

7. Angle of incidence is equal to the angle of reflection
   (a) always
   (b) sometimes
   (c) under special conditions
   (d) never
8. Image formed by a plane mirror is
   (a) virtual, behind the mirror and enlarged
   (b) virtual, behind the mirror and of the same size as the object
   (c) real, at the surface of the mirror and enlarged
   (d) real, behind the mirror and of the same size as the object.
9. Describe the construction of a klaleidoscope.
10. Draw a labelled sketch of the human eye.
11. Gurmit wanted to perform Activity 16.8 using a laser torch. Her teacher advised her not to do so. Can you explain the basis of the teacher's advise?
12. Explain how you can take care of your eyes.
13. What is the angle of incidence of a ray if the reflected ray is at an angle of 90° to the incident ray?
14. How many images of a candle will be formed if it is placed between two parallel plane mirrors separated by 40 cm?
15. Two mirrors meet at right angles. A ray of light is incident on one at an angle of 30° as shown in Fig. Draw the reflected ray from the second mirror.



16. Boojho stands at A just on the side of a plane mirror as shown in Fig. Can he see himself in the mirror? Also can he see the image of objects situated at P, Q and R?

17. (a) Find out the position of the image of an object situated at A in the plane mirror.
    (b) Can Paheli at B see this image?
    (c) Can Boojho at C see this image?
    (d) When Paheli moves from B to C, where does the image of A move?

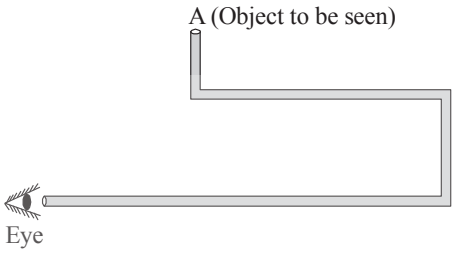


Exemplar Questions :

1. What happens to light when it gets dispersed? Give an example.
2. Eyes of the nocturnal birds have large cornea and a large pupil. How does this structure help them?
3. What kind of lens is there in our eyes? Where does it form the image of an object?
4. Boojho planned an activity to observe an object A through pipes as shown in Fig so that he could see objects which he

Physics Point

could not directly see.

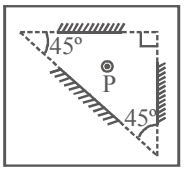


(a) How many mirrors should he use to see the objects?
(b) Indicate the positions of the mirrors in the figure.
(c) What must be the angle with respect to the incident light at which he should place the mirrors?
(d) Indicate the direction of rays in the figure.
(e) If any of the mirrors is removed, will he be able to see the objects?

5. How is the phenomenon of reflection used in making a kaleidoscope? What are the applications of a kaleidoscope?

Hots Questions :

1. Three plane mirrors are mounted on three walls forming an isosceles right triangle as shown in the figure. How many images are formed in all? Draw a diagram and indicate the positions of the images.



2. You can get a sunburn on a cloudy day, but you cannot get a sunburn even on a sunny day if you are behind glass. Explain.

3 EXERCISE

Physics Point

Single Option Correct :

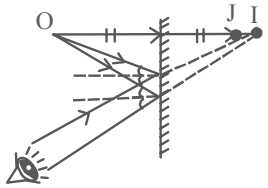
DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. We can see a non-luminous object when light
(a) emitted by the object falls on the eye
(b) is reflected from the object towards our eye
(c) completely passes through the object
(d) gets completely absorbed by the object

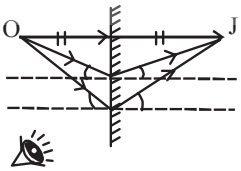
2. A ray of light is incident on a plane mirror at an angle of incidence of 30°. The deviation produced by the mirror is
(a) 30° (b) 60°
(c) 90° (d) 120°

3. Identify the ray diagram that shows the formation of an image by a plane mirror.

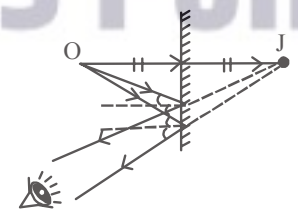
(a)



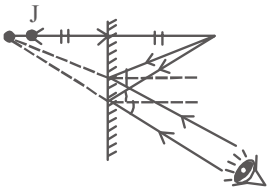
(b)



(c)



(d)

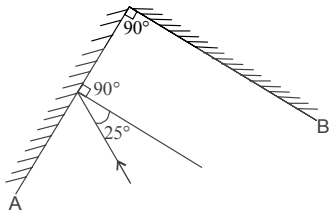


4. Which of the following part protects the eye and gives it shape?
(a) choroid (b) sclera
(c) yellow spot (d) ciliary muscles

5. In lateral inversion
(a) right side of the object will be right side of the image.
(b) left side of the object will be left side of the image.
(c) upside of the object will be down side of the object.
(d) right side of the object will be left side of the image.

6. An ideal mirror
(a) absorbs all the amount of light incident on it
(b) refracts all the light
(c) reflects all the light
(d) none of the above

7. Two mirrors A and B are placed at right angles to each other as shown in Fig.



A ray of light incident of mirror A at an angle of 25° falls on mirror B after reflection. The angle of reflection for the ray reflected from mirror B would be
(a) 25° (b) 50°
(c) 65° (d) 115°

8. Internal reflections of light is prevented in human eye by
(a) iris (b) pupil
(c) choroid (d) blind spot

9. Power of accommodation of eye implies
(a) control intensity
(b) prevent internal reflection of light
(c) change of focal length of eye lens
(d) all the above

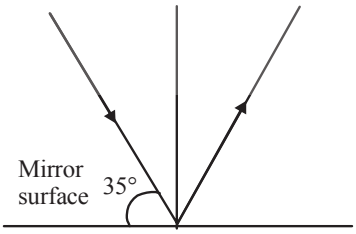
10. A ray of light is incident on a plane mirror and the angle of incidence is 25°. What is the angle of reflection?
(a) 0 (b) 50°
(c) 90° (d) 25°

11. A ray of light is incident on a plane mirror and the angle of reflection is 50°. Calculate the angle between the incident ray and the reflected ray.
(a) 50° (b) 25°
(c) 90° (d) 100°

12. If you can't quite see all your face in a pocket mirror, to do so you'll need to
(a) hold it closer (b) hold it farther away
(c) get a bigger mirror (d) none of these

13. When a light ray is reflected repeatedly by a set of parallel plane mirrors, the intensity of light rays decreases after some reflections. This is because of
(a) poor reflection from mirrors
(b) absorption of some amount of light by mirrors
(c) dispersion of light when the rays travel through the atmosphere
(d) scattering of light by the mirrors

14. Find the angle of incidence and angle of reflection from the diagram.



(a) 45°, 40° (b) 55°, 55°
(c) 60°, 60° (d) 30°, 30°

15. Rahul is observing his image in a plane mirror. The distance between the mirror and his image is 3 m. If he moves 1 m towards the mirror, then the distance between Rahul and his image will be:
(a) 2m (b) 6m
(c) 4m (d) 8m

More than One Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. The mirrors that cannot be used in search light are
(a) Convex (b) Plane
(c) Concave (d) Cylindrical

2. Choose the correct options ?
(a) When light passes through prism, it is dispersed because speeds are different for different colours
(b) Concave mirror is used by dental surgeon.
(c) Convex mirror is used by dental surgeon.
(d) Convex mirror is used as a shaving mirror

3. Choose the correct options
(a) The persistence of the eye is only for 1/10th of a second.
(b) The outer layer of the eye is called sclerotic
(c) The outer layer of the eye is called cornea
(d) The least distance of distinct vision for a normal human eye is infinite

4. Choose the correct options
(a) The part which protects the human eye is called cornea
(b) The 'pupil' in human eye can be dilated by iris
(c) Nocturnal animals like owl & bat have retina with large number of rods
(d) Image is formed on the pupil of the eye

Multiple Matching Questions :

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and five or six statements (p, q, r , s...) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

Column-I	Column-II
(A) Sclera	(p) opening in the iris through which light enters
(B) Cornea	(q) gives colour to the eye
(C) Iris	(r) outermost tough covering
(D) Pupil	(s) transparent outer layer that refracts light

2.

Column I	Column II
(A) Plane mirror	(p) Point image
(B) Parallel beam	(q) Convex lens
(C) Microscope	(r) Refractive index

(D) Optical density (s) Lateral inversion
(E) Periscope (t) Upright image
(u) Plane mirror

Passage Based Questions :

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

A light ray makes an angle of reflection 60º, when it reflects from a plane reflecting sheet.

1. The galancing angle of reflection will be
(a) 60º (b) 30º (c) 45º (d) 90º

2. The angle of incidence will be
(a) 60º (b) 30º (c) 45º (d) 90º

3. The angle of deviation will be
(a) 60º (b) 30º (c) 45º (d) 90º

Assertion & Reason :

DIRECTIONS : *Each of these questions contains an Assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** Virtual image can't be seen by human eye.
Reason : Virtual image is formed by diverging rays.

2. **Assertion :** When we see an object, the image formed on the retina is real and inverted.
Reason : If the magnification of a system is less than one, then the image formed is inverted.

3. **Assertion :** A ray incident along normal to the mirror retraces its path.
Reason : In reflection, angle of incidence is always equal to angle of reflection.

4. **Assertion :** A small area on the retina of the eye where no visual image can be formed is called the blind spot.
Reason : At the junction of the optic nerve and the retina, there are no sensory cells, so no vision is possible at that spot.

Integer/Numeric type Questions :

Directions : Following are integer based/Numeric based questions. Each question, when worked out will result in one integer or numeric value.

1. A ray of light incident on a plane mirror, makes an angle of 82° with the normal. Find the angle of reflection.

2. Two plane mirrors are inclined to each other such that a ray of light incident on the first mirror and parallel to the second is reflected from the second mirror parallel to the first mirror. The angle between the two mirrors (20x)°. Find the value of x.

3. An equilateral prism produces a minimum deviation of 30°. The angle of incidence is (9x)°. Find the value of x.

4 ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

DIRECTIONS (Qs. 1-9) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. V_v, V_R, V_G are the velocities of a violet, red and green light respectively passing through a prism after the dispersion of white light. Which among the following is a correct relation?
(a) $V_V = V_R = V_G$ (b) $V_V > V_R > V_G$
(c) $V_V < V_G < R_R$ (d) $V_V < V_R < V_G$

2. A convex lens forms a virtual image of the object placed
(a) between the lens and its focus
(b) on the focus of the lens
(c) between f and $2f$
(d) at infinity

3. In a convex lens, we get virtual image when the object is.....
(a) between F and $2F$ (b) beyond $2F$
(c) between F and optic centre
(d) None of these

4. The object or image distance is taken as positive
(a) if the length is measured opposite to the direction of the incident ray
(b) if the length is measured in the direction of the incident ray
(c) if the length is measured opposite to the direction of the refracted ray
(d) none of these

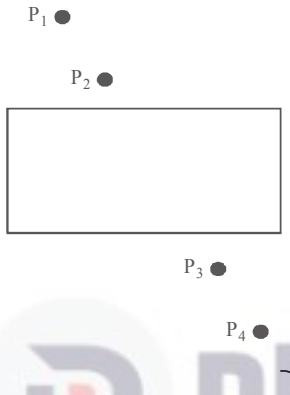
5. In a periscope, the reflecting mirrors will be
(a) perpendicular to each other
(b) parallel to each other
(c) at an angle of 45º
(d) at an angle of 60º

6. The point where the rays from a point object meet after refraction through a lens is called the
(a) focus (b) centre of curvature
(c) optic centre (d) image point

7. The sky is blue because air molecules in the sky act as tiny
   (a) mirrors that reflect primarily blue light
   (b) scatterers of high-frequency light
   (c) diffractors of high-frequency light
   (d) prisms

8. Lenses work because, in different materials, light has different
   (a) wavelengths (b) frequencies
   (c) speed (d) none of these

9. In the glass slab experiment shown, four students A, B, C and D did the following :



A : kept the eyes far from the glass slab while placing both the pins P_3 and P_4.
B : kept the eyes close from the glass slab while placing both the pins P_3 and P_4.
C : kept the eyes close to the glass slab while placing pin P_3 and far from the slab while placing pin P_4.
D : kept the eyes far to the glass slab while placing pin P_3 and close to the slab while placing pin P_4.
The correct procedure is that of student –
   (a) A (b) B
   (c) C (d) D

DIRECTIONS (Qs. 10-17) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

10. When a ray of light enters a lens then choose the incorrect statements.
   (a) Wavelength decreases
   (b) Wavelength increases
   (c) Frequency decreases
   (d) Frequency increases

11. Choose the correct statements
   (a) Light from sun takes nearly eight minutes 20 seconds to come to earth.
   (b) For a convex lens, if the object is placed between the focus and optical centre then the image formed will be magnified
   (c) For a convex lens, if the object is placed between the focus and optical centre then the image formed will be diminished
   (d) Cinematography makes use of persistence of vision.

12. Choose the incorrect statements related to the light incident on a boundary separating two media ?
   (a) It bends away from the normal in all cases
   (b) It always bends towards the normal
   (c) It does not bend when it is incident normal to the boundary
   (d) It bends away from the normal when the light passes from rarer to denser medium

13. Which of the following statements are correct?
   (a) Light is a wave motion.
   (b) Velocity of light is greater than the velocity of sound.
   (c) Gradual decrease in the size of moon during its phases is called waning.
   (d) Total solar eclipse can be seen from penumbra.

14. Choose the correct options ?
   (a) At the focus an object be placed so that a real and inverted image of very large size is obtained by using a convex lens.
   (b) The quantity of light entering the eye is controlled by Iris.
   (c) The unit of power of a lens is Dioptre.
   (d) The quantity of light entering the eye is controlled by pupil.

15. Choose the correct options ?
   (a) An object is 5 cm high and is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is equal to the radius of curvature. The size of the image will be 4 cm.
   (b) An object is placed between two plane mirrors mutually perpendicular to each other the number of images formed is 2.
   (c) An object is 5 cm high and is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is equal to the radius of curvature. The size of the image will be 5 cm.
   (b) An object is placed between two plane mirrors mutually perpendicular to each other the number of images formed is 3

16. The refractive index of medium B with respect to medium A is 1.6 then choose the incorrect options
   (a) B is denser with respect to A
   (b) A is denser with respect to B
   (c) A and B are equally denser
   (d) Both A and B are rarer

17. The lower part of a convex lens is blackened then the image formed will be
   (a) incomplete (b) complete
   (c) of lower intensity (d) of higher intensity

Physics Point

DIRECTIONS (Qs. 18-19) : *Following question has four statements (A, B, C and D) given in Column I and five statements (p, q, r , s and t) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

18.

Column I	Column II
(A) Virtual image	(p) Scattering
(B) Headlight	(q) Dispersion
(C) Splitting of white light	(r) Real image
(D) Blue ocean	(s) Concave mirror
(E) Image on retina	(t) Convex mirror

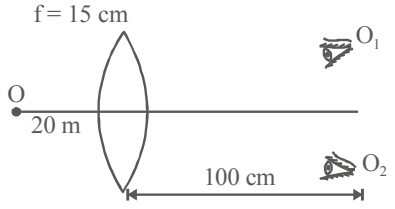
19.

Column I	Column II
(A) Optical fibre	(p) Concave lens
(B) Converging lens	(q) Transparent
(C) Diverging lens	(r) Convex lens
(D) Material allows light to pass	(s) Tanslucent
(E) Butter paper	(t) Total internal reflection
	(u) To correct eye defect

DIRECTIONS (Qs. 20–28) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH-I

Figure shows a convex lens of focal length 15 cm. A point object is placed on the principal axis of lens at a distance 20 cm from it as shown. On the other side of lens two observer eyes O_1 and O_2 are situated at a distance 100 cm from the lens at some distance above and below the principal axis.



Activity I: Now, half position of lens below principal axis is painted black.

Activity II: After this, lens is cut along its horizontal diameter and upper part of it is raised up slightly in vertical direction.

20. In initial setup before the activities which of the following statement is correct?

(a) Observer O_1 will see a real image at 60 cm from the lens but observer O_2 will not be able to see it

(b) Observer O_2 will see a real image at 60 cm from the lens but observer O_1 will not be able to see it

(c) Both the observers will see a real image at 60 cm from lens irrespective the positions of O_1 and O_2

(d) Both the observers may or may not be able to see the image at 60 cm from lens depending on the positions of O_1 and O_2

21. After activity - I, which of the following observer will not be able to see the image of object, if before this activity both were seeing the image

(a) O_1 (b) O_2

(c) both O_1 & O_2 (d) neither for O_1 nor for O_2

22. After activity -I, for which observer the intensity of image will be reduced to half.

(a) for O_1 (b) for O_2

(c) both for O_1 & O_2 (d) neither for O_1 nor for O_2

PARAGRAPH-II

Experiments are done to test the optical properties of lenses immersed in media having different indices of refraction.

Experiment 1 : A lens made of flint glass index of refraction 1.720 is tested. A beam of parallel light rays is sent into the lens, and the distance from the lens to the point of convergence of the beam is measured. This is the focal length of the lens. This focal length is measured with the lens immersed in media of various indices of refraction.

Medium	Index of refraction	Focal length (cm)
Air	1	8
Folinol	1.24	13
Water	1.33	20
11 % Sugar solution	1.5	39
Carbon disulfide	1.62	95

*Rays do not converge at all.

Experiment 2 : Another lens is tested. It is made of the same kind of glass as in Experiment 1. but this lens is thicker, more strongly curved.

Medium	Index of refraction	Focal length (cm)
Air	1	5
Folinol	1.24	8
Water	1.33	12
11 % Sugar solution	1.5	24
Carbon disulfide	1.62	60
Methylene iodide	1.74	*

Experiment 3 : A lens made of a new plastic is then tested. This lens is identical in size and shape to the glass lens in Experiment 2.

Medium	Index of refraction	Focal length (cm)
Air	1	13
Folinol	1.24	34
Water	1.33	360
11 % Sugar solution	1.5	*
Carbon disulfide	1.62	*
Methylene iodide	1.74	*

Physics Point

23. The index of refraction column is the same in all three experiments because
(a) all three lenses have the same basic properties.
(b) the same liquids are used in all three experiments.
(c) the temperatures at which the experiments are performed are carefully controlled.
(d) the color of the light source is not allowed to change from one experiment to another.

24. As the index of refraction of the medium increases, what happens to the rays of light emerging from the lens?
(a) They converge more strongly in all cases.
(b) They converge more strongly on leaving the glass lenses, but not the plastic lens.
(c) They converge less strongly in all cases.
(d) They converge less strongly on leaving the plastic lens, but not the glass lens.

25. Making a lens thicker and more strongly curved
(a) shortens the focal length
(b) increases the focal length
(c) increases the index of refraction
(d) decreases the index of refraction

26. In Experiment 3, why do the rays not come to a focus at all when they pass through the lens into certain materials?
(a) The index of refraction of each of those materials is greater than that of the lens.
(b) The curvature of the lens is not great enough.
(c) Chemical reactions turn some of those materials opaque.
(d) In some materials, the light rays are unable to bend as they pass out of the lens.

27. Measurements of the kind made in these experiments would not be useful in efforts to find
(a) the index of refraction of a liquid.
(b) the way a prism in a fluid would bend light rays.
(c) the concentration of a sugar solution.
(d) the chemical composition of an unknown liquid.

28. The index of refraction of the plastic lens in Experiment 3 must be –
(a) less than 1.33 (b) between 1.33 and 1.50.
(c) more than 1.33 (d) more than 1.50.

DIRECTIONS (Qs. 29–33) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

29. **Assertion:** Rainbow is an example of the dispersion of sunlight by the water droplets.
Reason : Light of shorter wavelength is scattered much more than light of larger wavelength.

30. **Assertion :** Different colours travel with different speed in vacuum.
Reason : Wavelength of light depends on refractive index of medium.

31. **Assertion :** The air bubble shines in water.
Reason : Air bubble in water shines due to refraction of light.

32. **Assertion :** Optical fibres are used to transmit light without any appreciable loss in its intensity over distance of several kilometers.
Reason : Optical fibres are very thick and all the light is passed through it without any loss.

33. **Assertion :** Red light travels faster in glass than green light.
Reason : The refractive index of glass is less for red light than for green light.

DIRECTIONS (Qs. 34-36) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

34. A convex lens of focal length 0.5 and concave lens of focal length 1 m are combined. What is the power of the combination of two lenses.

35. The velocity of light in air is 3×10^8 ms^{-1} and in a liquid is 2.5×10^8 ms^{-1}. If the ray of light passes from liquid to air, the value of critical angle is (19x)°. Find the value of x.

36. A rod of length 10 cm lies along the principal axis of a concave mirror of focal length 10 cm in such a way that its end closer to the pole is 20 cm away from the mirror. Find the length of the image.

Physics Point

SOLUTIONS

Brief Explanations of Selected Questions

1 EXERCISE

FILL IN THE BLANKS :

1. reflection **2.** luminous **3.** opaque
4. dispersion **5.** refraction **6.** concave
7. obeys

TRUE/FALSE :

1. True **2.** True **3.** False **4.** False
5. True **6.** True **7.** True

MATCH THE COLUMNS :

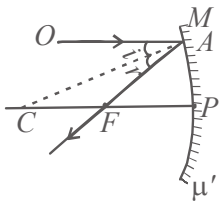
1. A – (r), B – (p), C – (q), D – (s)
2. A – (q), B – (r), C – (s), D – (p)

VERY SHORT ANSWER QUESTIONS :

1. $(90° - 30°) = 60°$
2. Luminous objects emit their light.
Non-luminous objects that do not emit their light.
3. Refer to theory
4. Refer to theory
5. VIBGYOR
6. 3×10^8 m/s
7. Laws of reflection of light:
(i) The incident ray, the reflected ray and the normal all three lie in the same plane
(ii) The angle of incidence (i) = angle of reflection (r)

SHORT ANSWER QUESTIONS :

5. Yes, the law of reflection holds good for curved mirror.
Consider, a concave mirror MM', P, F, C are respectively the pole, focus and center of curvature of the mirror. If a ray of light OA parallel to principal axis is incident on the mirror at A, then the reflected ray AF will pass through the focus. Here, C is the normal at the point of incidence. Measurement of $\angle OAC$ is equal to $\angle FAC$. So angle of incidence $(\angle OAC)$ is equal to angle of reflection $(\angle FAC)$.



LONG ANSWER QUESTIONS :

4. 120°. **5.** 1° **6.** 4 cm

2 EXERCISE

TEXT-BOOK EXERCISE :

1. When we are in a dark room, we cannot see the objects because there is no light in the dark room. We may see an object only when light from an object enters our eyes. Outside the dark room, we can easily see the objects, due to either reflected light from the surface of illuminated objects or direct light from luminous objects such as sun, candle etc.

2.

	Regular reflection	Diffused reflection
(i)	When all the parallel ray reflected from a plane surface are parallel, the reflection is known as regular reflection.	When all the parallel says reflected from a plane surface are not parallel, the reflection is known as diffused or irregular reflection.
(ii)	Images are formed by regular reflection	Images are not formed by diffused reflection.
(iii)	Reflection from a smooth surface like that of a mirror is called regular reflection.	Reflection from a rough surface like that of a cardboard is called diffused reflection. It is caused by the irregularities in the reflecting surface

3. (a) Polished wooden table : Regular reflection
Regular reflection will take place from polished wooden table because it has a smooth surface.
(b) Chalk powder : Diffused reflection
Chalk powder is spread on a surface is an example of irregular surface, so diffused reflection will take place.

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(c) Cardboard surface: Diffused reflection

Cardboard surface is an irregular surface. So reflection will be diffused reflection.

(d) Marble floor with water spread over it : Regular reflection. From marble floor with water spread over it will be regular reflection because it is a smooth surface.

(e) Mirror : Regular reflection

Mirror is a smooth surface, so the reflection will be regular reflection.

(f) Piece of paper : Diffused reflection

Surface of piece of paper is irregular. So, the reflection will be diffused reflection.

4. Laws of reflection :

(i) The angle of incident is always equal to the angle of reflection.

(ii) The incidence ray, the rormal at the point of incidence and the reflected ray all lie in the same plane.

5. Activity :

Place a plane mirror on the table. Take a paper sheet and make a small hole in its centre. Make sure that light in the room is not bright. Hold the sheet normal to the table. Take another sheet and place it on the table in contact with the vertical mirror. Draw a normal line on the second sheet from the mirror. Now light a torch on the mirror through the small hole such that the ray of light falls on the normal at the bottom of the mirror. When the ray from this hole is incident on the mirror, it gets reflected in a certain direction. We can easily observe the incident ray, reflected ray and the normal on the mirror at the point of incidence on the sheet placed on the table. This activity shows that the incident ray, the reflected ray and the normal at the point of incidence lie in the same plane.

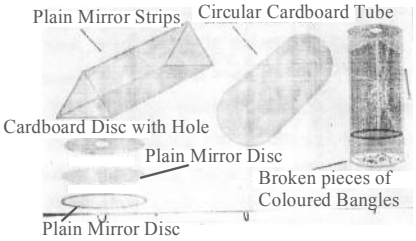
6. (a) 2 (b) left, left hand

(c) large (d) less

7. (a) Always

8. (b) virtual, behind the mirror and of the same size as the object

9. A kaleidoscope, is made up of three rectangular mirror strips about 15 cm long and 4 cm wide each. These mirrors are joined together to form a prism. This prism is fixed into a circular cardboard tube. The circular cardboard tube should be slightly longer than the prism. The circular tube is now closed at one end with a cardboard disc. This disc has a hole in it through which we can see. At the other end of the circular tube, a plane glass plate is fixed. It is important that this glass plate touches the prism mirrors. On this glass plate, several small and broken pieces of coloured glass are placed. This end is now closed by a round glass plate allow enough space for the coloured glass pieces to move.



10. Human eye :

11. The intensity of laser light is very high. It can cause damage to the retina and lead to blindness. Hence, it is advisable not to look at the laser beam directly.

12. We can take care of our eyes in following ways:

(i) Clean our eyes with cold water if dust particles or small insects enter in the eye.

(ii) Do not rub the eyes.

(iii) Avoid direct exposure of sunlight to the eye.

(iv) Avoid reading in dim light or very bright light.

(v) Visit an eye specialist regularly.

13. According to the law of reflection

The angle of incidence $\angle i$ = angle of reflection $\angle r$

Here, $\angle i + \angle r = 90°$

$\therefore \angle i + \angle i = 90°$

$2\angle i = 90°$

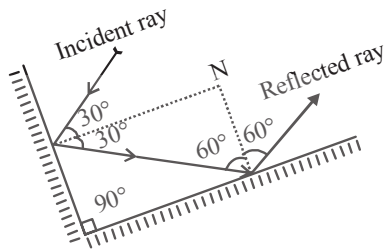
$\angle i = 45°$

Hence, angle of incidence $\angle i = 45°$

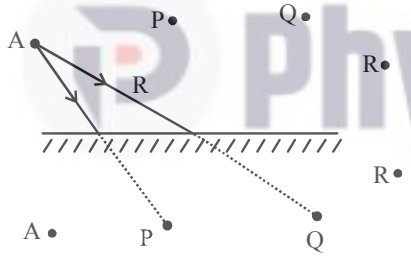
14. If a candle is placed between two parallel plane mirrors, we will see infinite no of images.

Physics Point

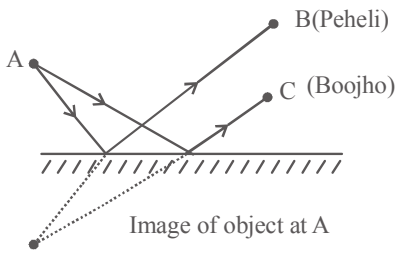
15.



16. Boojho is not standing in front of plane mirror, So, the incident ray, reflected ray and the normal drawn at the point of incidence to the reflecting surface does not lie in the same plane, therefore he cannot see his image. We can see the images of objects situated P at and Q only because incedent ray, reflected ray and the normal drawn at the point of incidence to the reflecting surface lie in the same plane. Incident ray from R will not reflected to reach point A, hence it will not be seen by Boojho.



17. (a)



A virtual and leteral image of an object situated at A, will be formed, behind the mirror surface. The image will be exactly at the same distance, as the distance of real object at position A.

(b) Yes, Paheli at B can see the image

(c) Yes, Boojho at C can see the image

(d) Image of the object at A will not move. It will remain at the same position when Paheli moves form B to C.

EXEMPLAR QUESTIONS :

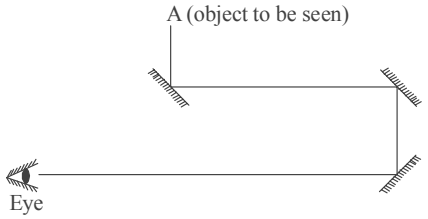
1. Light is split into its constituent colours. Rainbow is an example.

2. A large pupil and large cornea allows more light to enter their eyes and they can see objects even in faint light.

3. The type of lens in our eyes is convex. It forms image on the retina.

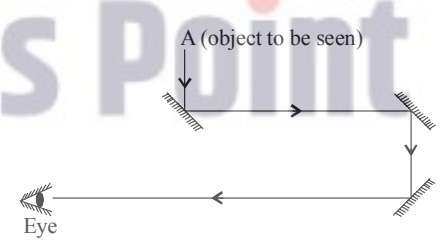
4. (a) Three

(b)



(c) 45°

(d)



(d) No, he will not be able to see the objects.

5. The kaleidoscope gives a number of images formed by reflection from the mirrors inclined to one another. Designers and artists use kaleidoscope to get ideas for new patterns to design wallpapers, jewellery and fabrics.

HOTS QUESTIONS:

1. (i) Find the number of images formed when two plane mirrors are placed at some angle in each case.

(ii) Add all the images excluding the images that have overlapped.

(iii) Number of images formed $= \frac{360°}{\theta} - 1$

2. Sunburn is caused by the ultraviolet radiation coming from sun. Clouds are semi-transparent to the ultraviolet radiation and hence, part of the radiation penetrates clouds and reaches human skin. This causes sunburn. In contrast to the clouds, window glass is opaque to the ultraviolet

Physics Point

radiation and thus, absorbs it. No ultraviolet radiation thus, penetrates glass window and a person sitting behind the window cannot get sunburn.

3 EXERCISE

SINGLE OPTION CORRECT :

1. (b) We see an object, when objects reflect light and reaches our eyes.

2. (d) **3.** (c) **4.** (b)

5. (d) Ideal mirror reflects all the incident light without absorption.

6. (c) **7.** (c) **8.** (c) **9.** (c) **10.** (d)

11. (d) According to law of reflection $\angle i = \angle r$

12. (b) **13.** (b) **14.** (b)

15. (c) Distance between Rahul and his image will be 4m.

MORE THAN ONE OPTION CORRECT :

1. (a, b, d) Concave mirrors are used in search lights.

2. (a, b)

(a) As speeds are different for different colours, hence when light passes through prism it is dispersed.

(b) As concave mirror produces enlarged image of an object if it is between focus and pole of mirror. Hence the mirror used by dental surgeon is concave.

3. (a, b)

(a) It is a phenomenon where the brain continues to sense the image even after the object has been removed. This lasts for 1/10th of a second.

(b) The front of eye forms a transparent curved part called cornea.

4. (a, b, c)

(a) The front of eye forms a transparent curved part called cornea.

(b) Iris contains muscles which dilate the pupil.

(c) The nocturnal animals need more light to see at night. The large cornea and pupil allow more light into their eyes.

MULTIPLE MATCHING QUESTIONS :

1. (d) A – (r), B – (s), C – (q), D – (p)

2. A – (s, t); B – (p); C – (q); D – (r); E – (u)

PASSAGE BASED QUESTIONS :

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

ASSERTION & REASON :

1. (d) We can see vertual image but cannot take on screen.

2. (c) **3.** (a)

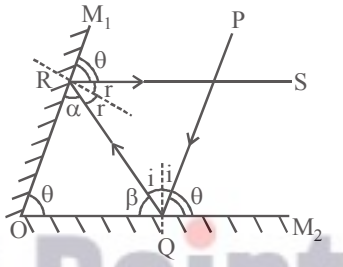
4. (a) A small area on the retina of the eye where no visual image can be formed is called blind spot as the junction of the optic nerve and the retina, there are no sensory cells.

INTEGER/NUMERIC TYPE QUSTIONS :

1. **8** Angle of incidence = 90° – 82° = 8°

And angle of incidence = angle of reflection = 8°

2. **3** Let θ be the angle between the two mirrors.



$PQ \,||\, M_1O$ and $RS \,||\, OM_2$

$\because\ r + \theta = \frac{\pi}{2}$ and $r + \alpha = \frac{\pi}{2} \Rightarrow \alpha = \theta$ and Similarly $\beta = \theta$

Hence In ΔROQ, $3\theta = 180°$

$\theta = 60°$ $\therefore\ x = 3$

3. **5** $\delta_{min} = 2i - A \Rightarrow i = \frac{30 + 60}{2} = 45°$ $\therefore\ x = 5$

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

1. (a)

2. (a) A convex lens forms virtual image only when object is in between the lens and its focus.

3. (c) **4.** (b) **5.** (c) **6.** (a)

7. (b) Scattering $\propto \frac{1}{\lambda^4}$

8. (b) **8.** (c)

9. (a) Correct procedure is that of student A.

10. (b, c, d)

$v = n\lambda$

When ray of light enter the lens v decreases but n

remains constant.

[Where v = velocity, n = frequency & λ = wavelength]

11. (a, b, d)

(a) Light from sun takes nearly eight minutes 20 seconds to come to earth.

(b) The image formed by a convex lens when the object is placed between the focus and the optical centre is virtual and magnified.

(d) Cinematography makes use of persistence of vision. Persistence of vision is the ability of an eye to continue to see the image of an object for a very short duration even after the removal of the object.

12. (a, b, d)

Ray incident normally on separation of medium goes undeviated in other medium.

13. (a, b, c)

Total solar eclipse cannot be seen from penumbra. Only partial solar eclipse can be seen from it.

14. (a, b, c)

(a) By using a convex lens the object will form a real and inverted image of very large size when it is placed at the focus.

(b) Iris control the quantity of light entering the eye.

(c) The unit of power of lens is dioptre.

15. (c, d)

(a) Given : Height of object = 5 cm

Object distance = R (radius of curvature)

When the object is at the centre of curvature then the image is formed at centre of curvature & is of the same height as that of the object.

(b) Let the number of images formed when object is placed between the plane mirrors is n. Let θ is the angle between the two mirrors.

Here $\theta = 90°$

$\because \frac{360}{\theta} = \frac{360}{90°} = 4$ even number

$\therefore$ Number of images, $n = \frac{360}{\theta} - 1 = 4 - 1 = 3$

16. (b, c, d)

The refractive index of medium B with respect to medium A is 1.6

$\because$ It is greater than one.

$\therefore$ B is denser with respect to A

17. (b, c)

If the lower part of a convex lens is blackened then complete image will be formed but of lower intensity.

18. A – s, t; B – s; C – q; D – p; E – r

19. A – t; B – r, u; C – p, u; D – q; E – s

20. **(d)** **21.** **(a)** **22.** **(d)** **23.** **(b)**

24. **(c)** **25.** **(a)** **26.** **(a)** **27.** **(d)**

28. **(b)**

(i) The index of refraction is a property of the liquid used. (A) is wrong because the index of refraction of the liquid has nothing to do with the lens. (C) and (D) are wrong because the experimental design says nothing about temperature or color of light.

(ii) All three data tables show an increase in focal length as the index of refraction of the medium increases. This means that the rays converge further from the lens.

(iii) Comparing the results of Experiments 1 and 2 shows that the focal length of the thicker lens was always less than that of the thinner one given the same medium.

(iv) As the index of refraction of the medium increases in Experiments 1 and 2, the rays converge ever further from the lens; when the index of refraction is more than 1.720, they do not converge at all. (B) is wrong because in other media the rays do converge. (C) is wrong because there is no evidence for any chemical reactions. (D) is wrong because there is no reason to believe the rays do not bend; they bend the wrong way.

(v) There is no reason to believe that knowledge of index of refraction would lead to knowledge of chemical composition. (A) is wrong because there is a clear correlation between focal length of the lens and the index of refraction of the liquid. (B) is wrong because knowledge of the behavior of light passing through a lens can be used in determining how it would act in passing through a prism. (C) is wrong because index of refraction could depend on the concentration of a sugar solution; in fact, it is so used.

(vi) The experiment shows that the rays will converge only if the index of refraction of the lens is greater than that of the medium. Thus, the index of refraction of the lens must be greater than 1.33. If it were greater than 1.50, however, there would be convergence when the lens is in the 11 % sugar solution, so it must be between 1.33 and 1.50.

Physics Point

29. (b) **30.** (b) **31.** (a) **32.** (a)

33. (c)

34. **1** Here, $f_1 = 0.5\ m_1,\ f_2 = -1m$

Power of combination

$$p = p_1 + p_2 = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{0.5} + \frac{1}{(-1)}$$

$$= 2 - 1 = 1\ D$$

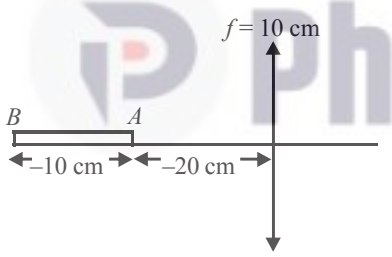
35. **3** $c = 3 \times 10^8\ ms^{-1},\ v = 2.5 \times 10^8 ms^{-1}.$

$$\mu = \frac{c}{v} = \frac{3\times10^8}{2.5\times10^8} = 1.2$$

$$\text{As, } \sin c = \frac{1}{\mu} = \frac{1}{1.2} = 0.8333$$

$$\sin c \approx \sin 57^\circ \Rightarrow c = 57^\circ \therefore x = 3$$

36. **5**



The focal length of the mirror

$$-\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

For A end of the rod the image distance

When $u_1 = -20$ cm

$$\Rightarrow \frac{-1}{10} = \frac{1}{v_1} - \frac{1}{20}$$

$$\frac{1}{v_1} = \frac{-1}{10} + \frac{1}{20} = \frac{-2+1}{20}$$

$v_1 = -20$ cm

For when $u_2 = -30$ cm

$$\frac{1}{f} = \frac{1}{v_2} - \frac{1}{30}$$

$$\frac{1}{v_2} = \frac{-1}{10} + \frac{1}{30} = \frac{-30+10}{300} = \frac{-20}{300}$$

$v_2 = -15$ cm

$L = v_2 - v_1 = -15 - (-20)$

$L = 5$ cm

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Chapter

7

STARS AND THE SOLAR SYSTEM

INTRODUCTION

The vast unbounded but finite surrounding space is called universe. The stars, planets, satellites, asteroids, comets, meteors etc. are called **celestial objects** are the components of solar system. The apparent motion of the stars in the sky is due to the rotation of the earth on its own axis. Star like objects which do not twinkle are planets.

Many of the planets have satellites called moons. The earth has one moon. The moon, the brightest object in the night sky produces no light of its own and shines only by reflecting the rays of the sun.

Physics Point

THE MOON

Every night the size of the bright part of the moon changes. The day on which the whole disc of the moon is visible is known as the **full moon** day. Thereafter, the bright portion of the moon reduces and on the fifteenth day the moon is not visible. This day is known as the **new moon day**. Two or three days after this, we see only a part of the moon. This is called the **Crescent moon**. Gradually, the shape of the bright portion of the moon becomes bigger and bigger, within a week we see half of the moon. This is called the **first quarter**. When we see more than half of the moon, it is called the **Gibbous moon**. On the fifteenth day once again we see the full moon.

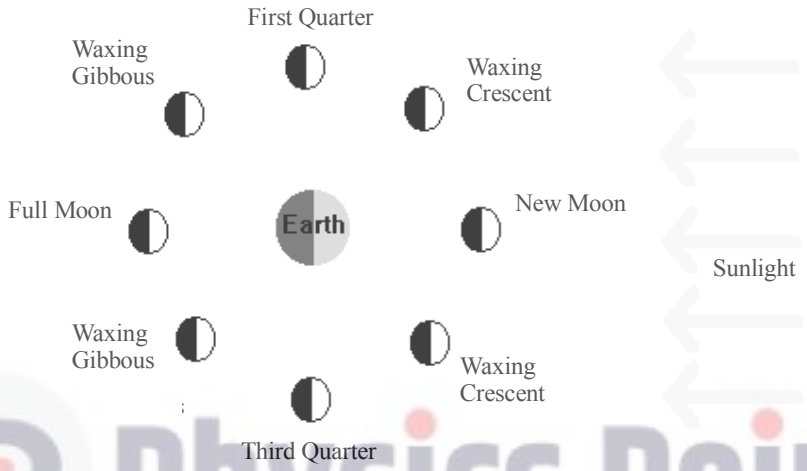


Fig. 7.1 Phases of the moon

The various shapes of the bright part of the moon as seen from the earth during a month are called **phases en of the moon**.

The time period between one full moon to the next full moon is slightly longer than 29 days.

The Moon's Surface

The surface of the moon is dusty and barren. It has many craters of different sizes, large number of steep and high mountains.

The moon has no atmosphere (so we cannot hear any sound) and it has no water hence no life exist on the moon.

CONNECTING TOPIC

BIG BANG THEORY

The whole of the matter of the universe was concentrated in a very dense and hot fire ball about 20 billion years ago. An explosion occurred. The matter was broken into pieces in the form of stars and galaxies. The faster moving galaxies have gone farther than the slower ones. A galaxy situated at 20 billion light years is the boundary of universe.

One light-year $= 300{,}000 \times 365 \times 24 \times 60 \times 60$ km

$= 9460000000000$ kilometres

$= 9.46 \times 10^{12}$ kilometres

Astronomers estimated that almost between 12 and 14 billion years ago Big-Bang occurred. On the basis of the measurements made on the Cosmic Microwave Background Radiation (CMBR) the age of the universe is supposed to be 13.7 billion years and our solar system is supposed to be 4.5 billion years old.

Hubble's Law

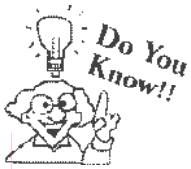
Edwin P. Hubble an American astronomer who gave first evidence of the big-bang theory in 1925 explained that the universe has a diameter of 205 billion light years and is composed of several galaxies. According to Hubble's law - the dominant motion in the universe in the smooth expansion.

Recessional velocity = Hubble's constant × distance

Physics Point

GALAXY

A galaxy is a cluster of millions of stars along with hydrogen gas and dust. There are millions of galaxies in the universe. In fact, galaxies are the building bricks of the universe. The name of our galaxy is the milky way. The milky way is one of the millions of galaxies which exist in the universe. It contains about 100 billion stars. The view of milky way galaxy looks like a disc of stars. The sun and the planets of the solar system belong to the milky way galaxy.



Milky way and Andromeda are spiral galaxies. The mass of milky way galaxy is 150 solar masses (i.e. 3 × 10^{41} kg).

THE STARS

The stars are made up of hot gases, mainly of hydrogen and helium. Stars emit their own light. The sun is also a star.
The distance between the sun and the earth is about 150 million kilometres. The light reaches from the sun to the earth in about 8.3 minutes. The next nearest star from the earth is about 4.3 light-years away from it known as **Alpha Centauri**. The brightest star **Sirus** is about 8.7 light-years away from the earth. A spinning neutron star emits radiowaves and is commonly known as a **pulsar.** The stars appear to move from east to west as the earth rotates from west to east on its axis. The pole star which is situated close to the axis of rotation of the earth does not appear to move.

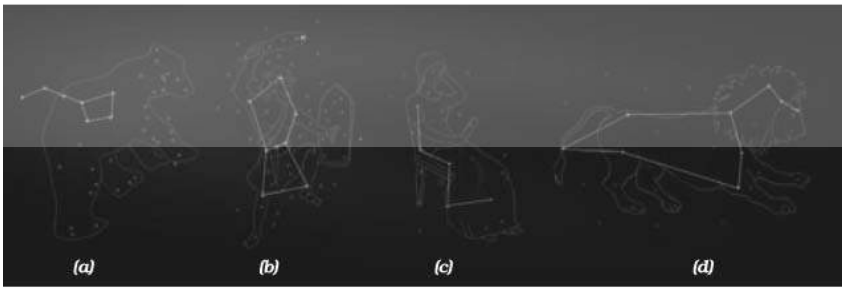
CONNECTING TOPIC

LIFE CYCLE OF A STAR

Stars are born in nebulae. A nebula is a dust in the space and cloud of gases. These clouds of gas and dust forms protostars under gravitational forces. Then these stars form sequence stars, by undergoing further collapse. Colour of a star can depend on its temperature.
As they grow old, stars expand. When the core runs out of hydrogen and helium, then the core contracts. The outer layers expand, become less bright and cool. This is known as red giant. Then they will eventually collapse and explode to become a black dwarf star, neutron star or black hole.
White Dwarf : It is a small and hot star which is the last stage in the life cycle of a star. Its mass is similar to that of the sun but only 1% of Sun's diameter, which is approx. the diameter of the Earth.
Supernova : This stage shows the death of a star and results in the star which obtains its brightness of 100 million Suns for a short time.
Neutron Stars : These type of stars are mainly composed of neutrons and are produced by the explosion of supernova, forcing the protons and electrons to combine to form a neutron star.
Black Holes : These are formed from massive stars when they reach the end of their life time. Its gravity is so high that it prevents even the light to radiate into space. The density of a matter inside a black hole cannot be measured.

CONSTELLATIONS

The stars which appear in the form of closed groups and form some recognizable shapes and patterns are known as constellations. Some of easily recognizable constellations are Ursa Major (or Great Bear), Ursa Minor or laghu Saptarishi, Orion and Cassiopeia.



(a) Great Bear (b) Orion (c) Cassiopeia (d) Leo Major

Fig. 7.2

One of the most famous constellations which you can see in the night sky is Ursa Major. It is, also known as the Big Dipper, the Great Bear or the Saptarishi. It is because the Ursa Major constellation consists of seven bright stars which are arranged in a pattern resembling somewhat a big bear. Orion is one of the well-known and most impressive constellations. Orion is also known as 'Hunter'. The Indian name of Orion is 'Kalpurush'. The Orion constellation consists of seven bright stars (and several faint stars). The three middle stars represent the belt of the hunter. You can easily locate this constellation in the sky during winter. During winter it can be seen in the sky in the late evenings. The star sirius is the brightest star in the sky is located closed to orion cassiopeia is another prominent constellation in the northern sky looks like a distorted letter W or M is visible during winter in the early part of the night.

THE SOLAR SYSTEM

The Sun

The sun, the eight planets and other celestial objects that revolve around the sun form the solar system. It includes also comets, asteroids and meteors.

The Sun is the centre of the solar system, it is believed that Sun was born about 5 million years ago. The Sun is the main source of all energy on the earth and on all other planets.

The Sun is composed of mainly hydrogen gas (93%), helium (5%) and heavier elements (2%).

THE PLANETS

The names of eight planets in the sequence of their distance from the sun is Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. Pluto is no more considered as a planet. In 2006 scientists decided that Pluto is too small to be called a planet. It is now called a dwarf planet'.

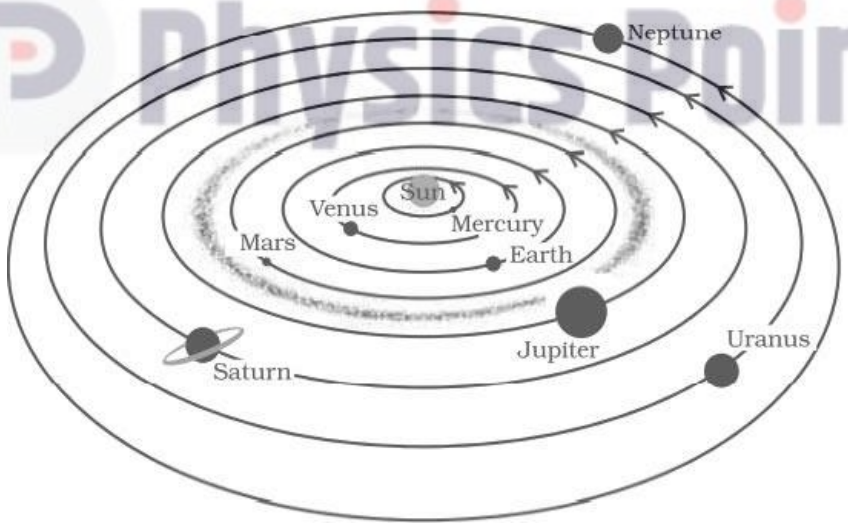


Fig. 7.3 The solar system

The planets look like stars, but they do not have light of their own and twinkle like a star. A planet has a definite path called an **orbit** in which it revolves around the sun.

The time taken by a planet to complete one revolution is called its period of revolution. And to complete one rotation on its own axis is called period of rotation.

Mercury (Budh)

- Diameter: 4,879 km
- Mass: 3.30×10^{23} kg
- Orbit distance: 57,909,227 km (0.39 AU)
- Surface temperature: –173°C to 427°C
- Mercury does not have any moons or satellite.
- It is the smallest planet in the solar system.

Venus (Shukra)

- Diameter: 12,104 km
- Mass: 4.87×10^{24} kg
- Orbit distance: 108,209,475 km (0.73 AU)
- Orbit period: 225 days
- Surface temperature: 462°C
- Venus does not have any moons or satellite.
- Venus is made up of a central iron core, rocky mantle and silicate crust.
- Sometimes Venus appears in the eastern sky before sunrise and sometimes it appears in the western sky after sunset. Therefore, it is often called a morning or an evening star.
- Venus is the brightest planet.

Earth (Prithvi)

- Diameter: 12,756 km
- Mass: 5.97×10^{24} kg
- Moons: 1
- Orbit distance: 149,598,262 km (1 AU)
- Orbit period: 365.26 days
- Surface temperature: –88°C to 58°C
- Earth has a powerful magnetic field.
- It is the densest planet in the solar system.
- It is the only planet in the solar system that has life. Because of right distance from the sun so right temperature range, the presence of water and suitable atmosphere and a blanket of ozone.
- Earth has been called the blue planet due to the abundant water on its surface.
- The reason of day and night on the earth is the rotation of the earth about its imaginary axis. The portion of the earth facing the sun at any time has day and the portion facing away has night.
- The different seasons are caused by the tilt of the earth's axis and the revolution of the earth around the sun.

Physics Point

Mars (Mangal)

- Diameter: 6,792 km
- Polar diameter: 6,752 km
- Mass: 6.42×10^{23} kg
- Moons: 2 (Phobos & Deimos)
- Orbit distance: 227,943,824 km (1.52 AU)
- Orbit period: 687 days (1.9 years)
- Temperature: –153°C to 20°C
- Mars and Earth have almost the same landmass.
- It has the largest dust storms in the solar system.
- Mars is known as the red planet.

Jupiter (Brihaspati)

- Diameter: 142,984 km
- Polar distance: 133,709 km
- Mass: 1.90×10^{27} kg
- Moons: 67 (Io, Europa, Ganymede, Callisto etc.)
- Rings: 4
- Orbit distance: 778,340,821 km (5.20 AU)
- Orbit period: 4,333 days (11.9 years)
- Temperature: –148°C
- It has the shortest day of all the planets.
- Jupiter is the fourth brightest object in the solar system as it is visible to the naked eye from Earth.
- Interior part is made of rock, metal and hydrogen compounds.
- Jupiter's moon Ganymede is the largest moon in the solar system.
- It is the biggest planet in the solar system.

Saturn (Shani)

- Diameter: 120,536 km
- Polar diameter: 108,728 km
- Mass: 5.68×10^{26} kg
- Moons: 62 (Titan, Enceladus, Lapetus, Rhea, etc.)
- Rings: 30 + (7 Groups)
- Its beautiful rings make it unique in the solar system.
- Orbit distance: 1,426,666,422 km (9.54 AU)
- Orbit period: 10,756 days (29.5 years)
- Temperature: –178°C
- One can see Saturn with the naked eye. It is yellowish in colour.
- Saturn is the flattest planet.
- It is the least dense among all the planets.
- Its density is less than that of water.

Uranus

- Diameter: 51,118 km
- Polar diameter: 49,946 km
- Mass: 8.68×10^{25} kg
- Moons: 27 (Miranda, Titania, Ariel, Umbriel & Oberon)
- Rings: 13
- Orbit distance: 2,870,658,186 km (19.19 AU)
- Orbit period: 30,687 days (84.0 years)
- Temperature: –216°C
- Uranus is referred to as an "ice giant" planet.
- Uranus has two sets of very thin dark coloured rings.
- Uranus is the coldest planet in the solar system.
- The most remarkable feature of uranus is that it has highly tilted rotational axis.

Physics Point

Neptune

- Diameter: 49,528 km
- Polar diameter: 48,682 km
- Mass: 1.02×10^{26} kg
- Moons: 14 (Triton)
- Rings: 5
- Orbit distance: 4,498,396,441 km (30.10 AU)
- Orbit periods 60,190 days (164.8 years)
- Temperature –214°C
- Neptune spins on its axis very rapidly.
- Neptune is the densest giant planet.

Inner planets are called as terrestial planets (Mercury, Venus, Earth & Mars). And **outer planets** are called as Gas giant planets (Jupiter, Saturn, Uranus & Neptune)

Dwarf Planets

Pluto

- Diameter: 2,372 km
- Mass: 1.31×10^{22} kg
- Orbit distance: 5,874,000,000 km (39.26 AU)
- Orbit period: 246.0 years
- Temperature: –229°C
- Moons: 5

Physics Point

Ceres

- Diameter: 950 km
- Mass: 8.96×10^{20} kg
- Orbit distance: 413,700,000 km (2.8 AU)
- Orbit period: 1,680 days (4.6 years)
- Temperature: –105°C
- Moons: None

SOME OTHER MEMBERS OF THE SOLAR SYSTEM

Asteroids

There is a large gap in between the orbits of the Mars and Jupiter. This gap is occupied by a large number of small bodies that revolve around the sun. These are called asteroids (meaning star like) or minor planets. The **largest asteroid** has a diameter of 1000 km while smallest of them may be only one kilometre across.

Comets

Apart from planets and asteroids there are some other heavenly (or celestial) bodies which revolve around the sun in highly elliptical orbits. These are comets. Comets are very small sized celestial bodies. They become visible from the earth only when they come close to the sun. They are characterised with a small head followed with a long tail. The length of the tail of a comet grows in size as it approaches the sun. The tail disappears again when the comet moves away from the sun. However, the tail of a comet is always directed away from the sun. Many comets are known to appear again and again after a definite period of time.

Halley's comet, appears after nearly 76 years. Halley's comet was last seen in early 1986

Meteors and Meteorites

Meteors are very small stone-like objects that are revolving around the sun. Their existence becomes known only when some of them enter by chance into the earth's atmosphere. When a meteor enters the atmosphere of the earth, it gets heated due to the friction of air. The heat produced is so high that the meteor begins to glow and evaporates within a short-time. The path of the meteor, therefore, appears as a streak of light in the night sky. The meteors are commonly known as shooting stars although they are not stars.

Some meteors are large and so they can reach the earth before they evaporate completely. The body that reaches the earth is called **meteorites**

Meteorites help scientists in investigating the nature of the material from which the solar system was formed.

Meteor showers - The swarms of meteors seen when the earth crosses the tail of a comet.

SATELLITE

A natural satellite is a heavenly (or celestial) body that revolves around another heavenly body. The earth has only natural satellite, the moon. Some planets, like the Jupiter, Saturn and Neptune, has more than one natural satellites or moons.

Artificial Satellite

The satellites like Aryabhata or INSAT 3B are examples of man-made or artificial satellite. The artificial satellites also revolve around the earth like its natural satellite, the moon. However, they are much closer to the earth than the moon. Russia was the first to send a artificial satellite around the earth. This was followed by America and other countries including China and India. Aryabhata, Bhaskar, Apple, IRS, Kalpana-I, EDUSAT INSAT I, II and 3B are some artificial satellites sent around the earth by India.

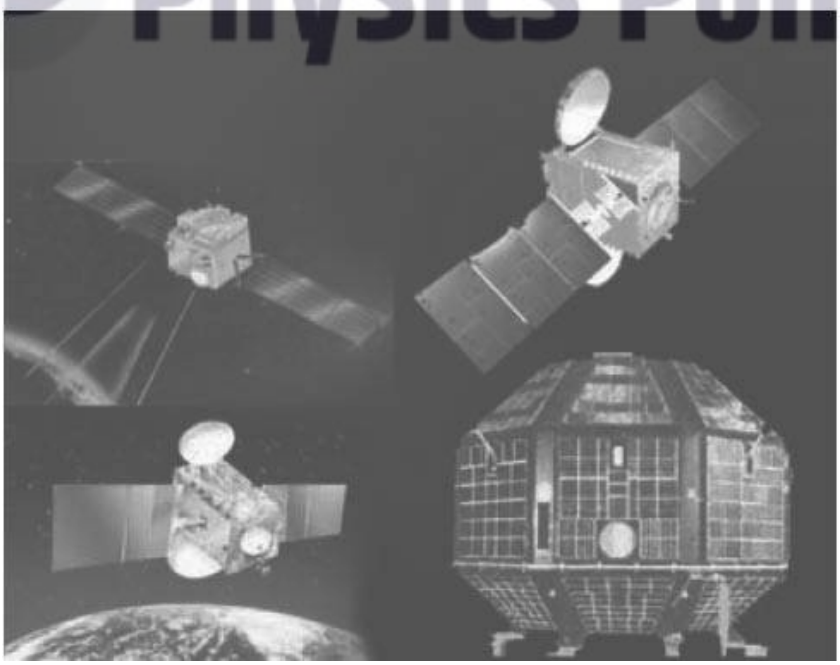


Fig. 7.4 Some Indian Satellites

Artificial satellite are used for forecasting weather, transmitting television and radio signals. They are also used for telecommunication and remote sensing (collecting information from a distance) technology is used to collect information about weather, agriculture, land and ocean features including movement of fishes in oceans, etc.

CONNECTING TOPIC

LUNAR AND SOLAR ECLIPSE

Lunar Eclipse

A lunar eclipse happens when the Earth is in between the Sun and the Moon. Lunar eclipses can only happen when there is a full moon. As the Moon's orbit takes it behind the Earth, a shadow crosses the face of the full Moon. The shadow does not always cover the entire Moon in a total eclipse.

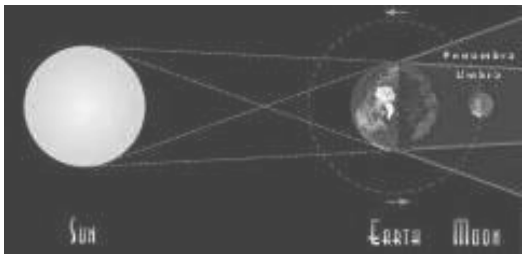


Fig. 7.5 Lunar eclips

There are also partial and penumbral lunar eclipses. There are two or three lunar eclipses each year. If you hear about a lunar eclipse, feel free to look up. They are safe to look at.

- *The longest duration for a lunar eclipse is 106 minutes.*
- *The longest duration for a solar eclipse is 7.5 minutes.*

Solar Eclipse

Solar eclipses are more spectacular than lunar eclipses, but much more dangerous for your eyes. Never look directly at a solar eclipse. Solar eclipses happen when the Moon passes between the Sun and the Earth. The Moon casts a shadow over a portion of the planet, leaving that area in darkness.

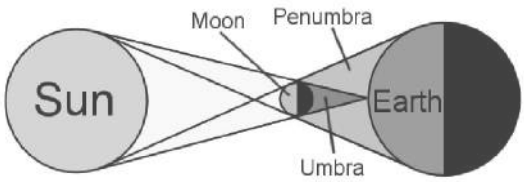


Fig. 7.6 Solar eclips

If you were watching from space, you could see the shadow pass over the surface. You would also notice that the Moon's shadow only covers a part of the planet because the Earth is much larger than the Moon. A lunar eclipse can put the entire surface of the Moon in darkness.

SUMMARY

- The phases of the moon i.e., full moon, new moon, crescent moon, gibbous moon etc. occur because we can see only that part of the moon which reflects the light of the Sun towards us.
- The surface of the moon is dusty and barren. It has no atmosphere.
- Stars are celestial bodies that emit light of their own. Our sun is also a star.
- It is convenient to express distances of stars in light years. The brightest star sirus is about 8.7 light-years away from the earth.
- Stars appear to move from east to west.
- The pole star appears to be stationary from the Earth, because it is situated close to the direction of the axis of rotation of the Earth.
- Constellations like ursa major, orion, Cassiopeia etc are groups of stars that appear to form recognisable shapes.
- The solar system consists of the sun, eight planets and a host of asteroids, comets and meteors.
- The planets in order from the Sun, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.
- Asteroids - a large number of small objects that revolve around the sun in between the orbits of Mars and Jupiter.
- Comets are the members of our solar system revolve around the sun in highly elliptical orbits. A comet appears generally as a bright head with a long tail.
- Meteor is a small object that occasionally enters the earth's atmosphere.
- Venus is the brightest planet in the night sky
- Mars is called as a red planet
- Jupiter is the largest planet of the solar system.
- A body revolving around another body is called a satellite
- Moon is the natural satellite of the Earth. Some planets also have natural satellites.
- The artificial satellites revolve around the Earth. They are much closer than the moon.
- Aryabhatta was the first Indian satellite.
- Artificial satellites are used for weather forecasting, long distance communication and remote sensing.
- Lunar eclipse – when the earth is in between the sun and the moon.
- Solar eclipse – when the moon is in between the sun and the earth.

Physics Point

1 EXERCISE

Fill in the Blanks :

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. The distance between the sun and the earth is about _____ million kilometres.
2. The planet nearest to the sun is _____.
3. The Indian name of the Orion constellation is _____.
4. _____ planet changes colour in different seasons.
5. Venus is surrounded in clouds of _____, which hide the surface.
6. The Sun is made up of 70% _____, 28% of _____ and 2% of heavier elements.

True/False :

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. The stars appear to move from east to west.
2. Earth is situated in the galaxy -Milky Way.
3. Cassiopeia is known as hunter.
4. Orion constellation consists of seven bright stars, the three middle stars represent the belt of the hunter.
5. The stars twinkle while the planets do not.
6. The stars are much bigger in size than the planets.

Match the Following :

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D)in Column I have to be matched with statements (p, q, r, s, t) in Column II.*

1. Match the column -I with column -II.

A.	Mercury	(p)	rotates on its sides
B.	Uranus	(q)	red planet
C.	Saturn	(r)	closest planet
D.	Mars	(s)	it has a ring system

2. Match the column I with the column -II

	Column-I		**Column-II**
A.	hottest planet	(p)	Jupiter
B.	Coldest planet	(q)	Mars
C.	Largest planet	(r)	Mercury
D.	Red planet	(s)	Pluto

Very Short Answer Questions :

DIRECTIONS : *Give answer in one word or one sentence.*

1. Why do we not see the stars during the day?
2. Why does a pole star appear stationary ?
3. Why do the planets not collide while revolving around the sun ?
4. Why does the moon changes its shape every day ?
5. The tail of a comet is directed away from the sun. Why ?
6. Which comet can be seen after every 76 years?
7. Name the stars in which constellation form the shape of a hunting man.

Short Answer Questions :

DIRECTIONS : *Give answer in two to three sentences.*

1. What makes the Earth unique?
2. Why are there New and Full Moons?
3. What is the difference between meteors and meteorites
4. Why is Mercury very hot during the day and very cold at night?
5. Both galaxies and constellations are group of stars. Give difference between them.
6. Why does the sun have spots?

Long Answer Questions :

DIRECTIONS : *Give answer in four to five sentences.*

1. Suppose the moon emits light of its own. Would it still have phases? Justify your answer.
2. Explain with a diagram how you can locate pole star with the help of the constellation great bear (Ursa major)
3. (a) What are planets? State the physical conditions of different planets

   (b) How is a planet different from a star?
4. Why do stars appear to be permanent to us even though these are born, grow and then die?

Physics Point

2 EXERCISE

Text-Book Exercise :

Choose the correct answer in Questions 1-3 :

1. Which of the following is NOT a member of the solar system?
(a) An asteroid (b) A satellite
(c) A constellation (d) A comet

2. Which of the following is NOT a planet of the sun?
(a) Sirius (b) Mercury
(c) Saturn (d) Earth

3. Phases of the moon occur because
(a) we can see only that part of the moon which reflects light towards us.
(b) our distance from the moon keeps changing.
(c) the shadow of the Earth covers only a part of moon's surface.
(d) the thickness of the moon's atmosphere is not constant.

4. Fill in the blanks:
(a) The planet which is farthest from the Sun is _____ .
(b) The planet which appears reddish in colour is _____ .
(c) A group of stars that appear to form a pattern in the sky is known as a _____ .
(d) A celestial body that revolves around a planet is known as _____.
(e) Shooting stars are actually not _____.
(f) Asteroids are found between the orbits of _____ and _____ .

5. Mark the following statements as true (T) or false (F):
(a) Pole Star is a member of the solar system.
(b) Mercury is the smallest planet of the solar system.
(c) Uranus is the farthest planet in the solar system.
(d) INSAT is an artificial satellite.
(e) There are nine planets in the solar system.
(f) Constellation Orion can be seen only with a telescope.

6. Match items in **column A** with one or more items in **column B**:

Column A	**Column B**
(i) Inner planets	(a) Saturn
(ii) Outer planets	(b) Pole Star
(iii) Constellation	(c) Great Bear
(iv) Satellite of the Earth	(d) Moon
	(e) Earth
	(f) Orion
	(g) Mars

7. In which part of the sky can you find Venus if it is visible as an evening star?

8. Name the largest planet of the solar system.

9. What is a constellation? Name any two constellations.

10. Draw sketches to show the relative positions of prominent stars in
(a) Ursa Major and (b) Orion

11. Name two objects other than planets which are members of the solar system.

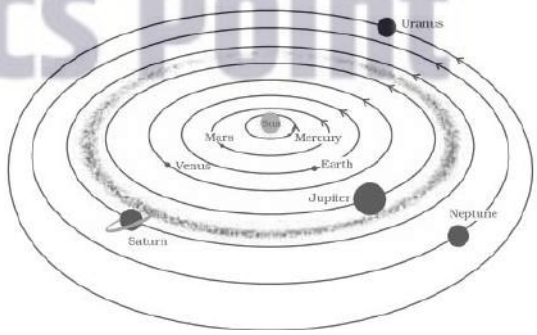
12. Explain how you can locate the Pole Star with the help of Ursa Major.

13. Do all the stars in the sky move? Explain.

14. Why is the distance between stars expressed in light years? What do you understand by the statement that a star is eight light years away from the Earth?

15. The radius of Jupiter is 11 times the radius of the Earth. Calculate the ratio of the volumes of Jupiter and the Earth. How many Earths can Jupiter accomodate?

16. Boojho made the following sketch (Shown in Figure) of the solar system. Is the sketch correct? If not, correct it.



Exemplar Questions :

1. A star is ten light years away from the earth. Suppose it brightens up suddenly today. After how much time shall we see this change?

2. Meteors are not visible during the daytime. Explain the reason.

3. Why does the moon change its shape daily?

4. Paheli saw the moon through a glass window at 8:00 p.m. She marked the position of the moon on the glass pane. She got up at 4 a.m. in the morning. Will the moon be visible at the same position?

Hots Questions :

1. Why is moon not suitable as a communication satellite?

2. On earth, the sun rises in the east and sets in the west will it be the same on Venus?

3. Since your birth, how many times have you gone around the Sun?

Physics Point

3 EXERCISE

Single Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. There are millions of celestial bodies in the solar system. The small celestial bodies which revolve between the orbit of Mars and Jupiter are called asteroid. What is the name of the largest asteroid?
(a) Vesta (b) Pallas
(c) Ceres (d) Hygeia

2. The first artificial satellite launched by India is
(a) Aryabhata (b) Rohini
(c) Bhaskara (d) Apple

3. Who gave the first evidence of the big-bang theory?
(a) Edwin Hubble (b) Albert Einstein
(c) S Chandrasekhar (d) Stephen Hawking

4. An exploding star may be called –
(a) Nova (b) Supernova
(c) Protostar (d) Neutron star

5. Which of the following is a star?
(a) Alpha Centuari (b) Deimos
(c) Orion (d) Phobos

6. How many prominent stars are there in the constellation Great Bear ?
(a) 6 (b) 8
(c) 7 (d) 5

7. Suppose a new planet is discovered between Uranus and Neptune. Its time period would be
(a) less than that of Neptune
(b) more than that of Neptune
(c) equal to that of Neptune or Uranus.
(d) less than that of Uranus.

More than One Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Life is possible on the planet Earth because
(a) it is at a right distance from the Sun
(b) it has air and water, essential for life
(c) it has right temperature
(d) it is brightest and coldest planet in our solar system.

2. The change in seasons is brought on the earth because it is
(a) inclined at an angle of 23.5° with vertical
(b) not always at the same distance from the Sun
(c) ordered by the almighty God
(d) earth revolves around its own axis

3. In which of the following activities are Indian Remote Sensing (IRS) satellites used?
(a) Assessment of crop productivity
(b) Locating groundwater resources
(c) Mineral exploration
(d) Telecommunications

Multiple Matching Questions :

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r , s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

Column I	Column -II
(A) A collection of billions of stars	(p) Constellation
(B) A collection of billions of stars to which our Sun belongs	(q) Pole star
(C) A star at the tip of the handle of Ursa Minor	(r) Galaxy
(D) A group of few stars resembling to some familiar animal or an object	(s) Milky way

2.

Column I	Column -II
(A) The planet that revolves around the Sun from east to west	(p) Jupiter
(B) The planet looks most like the Moon	(q) Mars
(C) The planet spins so fast that a day lasts only just 10 days.	(r) Mercury
(D) The planet looks reddish	(s) Venus

Passage Based Questions :

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH -1

The Sun is the centre of the solar system, it is believed that Sun was born about 5 million years ago. The Sun is the nearest star to the earth. The Sun is the main source of all energy on the earth.

- Sunlight takes 8 mins 20 sec to reach us.
- The Sun's diameter is about 1,392,000 km, which is 100 times bigger than the earth.
- The Sun is 400 times farther away from us than the Moon.
- The temperature at the surface of the Sun is 5,500°C.
- The temperature at the core is 15 million °C.
- Gravitational pull of the sun is 28 times the gravity of the earth.

Physics Point

- The Sun is composed of mainly hydrogen gas (93%), helium (5%) and heavier elements (2%).
- The surface layer is called photosphere, surrounding the photosphere is an unseen layer of gas called the chromosphere.

1. The main source of Sun energy is
   (a) presence of dense mass of rocks and metals.
   (b) presence of hydrogen gases
   (c) presence of high gravitational pull.
   (d) All of the above
2. If gravitational pull of the Sun is x the gravitational out of the earth will be
   (a) 47x (b) x/2.8
   (c) 6x (d) x/84
3. If the light travelling at 3×10^5 km/s reaches the earth in 8.3 minutes, the distance of the Sun from the earth is
   (a) 150 million km (b) 15 million km
   (c) 300 million km (d) 200 million km

PARAGRAPH-2

Meteors are very small stone-like objects that are revolving around the sun. Their existence becomes known only when some of them enter by chance into the earth's atmosphere. When a meteor enters the atmosphere of the earth, it gets heated due to the friction of air. The heat produced is so high that the meteor begins to glow and evaporates within a short-time. The path of the meteor, therefore, appears as a streak of light in the night sky. The meteors are commonly known as shooting stars although they are not stars.

4. The meteors are also called as
   (a) shooting stars (b) falling stars
   (c) vanishing stars (d) All of these
5. The unburnt piece of meteor that reaches the earth is called
   (a) meteor stump (b) unburnt meteor
   (c) meteorite (d) All of these
6. The meteor begins to glow due to
   (a) its own light
   (b) heat produced by friction of air
   (c) due to sunlight
   (d) None of these

Assertion & Reason :

DIRECTIONS : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** The main fuel of the Sun is hydrogen gas.
   Reason : Hydrogen atoms under enormous pressure and temperature fuse to form helium gas with the liberation of enormous amount of energy.
2. **Assertion :** Solar eclipse lasts at some particular place for very short time.
   Reason : The shadow caused by the moon on the surface of earth is very small on account of its smaller size.
3. **Assertion :** Pole stars appears stationary in the sky, unlike all other stars.
   Reason : Pole stars is located vertically above the north pole of the earth and hence, does not appear to move.

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

DIRECTIONS (Qs. 1–7) : *The following questions has four choices (a), (b), (c) and (d) out of which only one is correct. You have to choose the correct option.*

1. How long does it take light from the sun to reach to the earth (approximately) ?
   (a) 2 min (b) 4 min
   (c) 8 min (d) 16 min
2. The energy produced in a star is due to the
   (a) burning of carbon and oxygen
   (b) fission of radioactive metals
   (c) fusion of hydrogen gas
   (d) None of the above
3. The age of universe is believed to be –
   (a) 1 billion years
   (b) 10 billion years
   (c) 10-20 billion years
   (d) 1000 billion years
4. The tail of a comet is directed away from the sun because:
   (a) as the comet rotates around the sun, the lighter mass of the comet is pushed away due to the centrifugal force alone
   (b) as the comet rotates, the lighter mass of the comet is attracted by some stars situated in the direction of its tail
   (c) the radiation emitted by the sun exerts a radial pressure on the comet throwing its tail away from the sun
   (d) the tail of the comet always exists in the same orientation

5. A 'black hole' is a body in space which does not allow any radiation to come out. This property is due to its:
(a) very small size (b) very large size
(c) very high density (d) very low density

6. A solar eclipse is caused when the
(a) sun comes between the earth and the moon
(b) moon comes between the sun and the earth
(c) earth comes between the sun and the moon
(d) None of these

7. There are various stages of the life of the stars. During these phases, the stars undergo various changes in its feature. The second stage of the life of the star is called:
(a) Shooting star (b) White dwarf
(c) Protostar (d) Black hole

DIRECTIONS (Qs. 8–9): *The following questions has four choices (a), (b), (c) and (d) out of which more than one is correct. You have to choose the correct options.*

8. Which of the following statements are correct about solar eclipse?
(a) Lasts for five to ten minutes
(b) Caused on the new moon day
(c) Caused on the full moon night.
(d) Shadow of moon falls on the earth.

9. Which of the following statements are true ?
(a) Inner planets are called as terrestial planets
(b) Outer planets are called as gas giant planet
(c) Mercury is the brightest planet
(d) The diameter of largest asteroid is 1000 km

DIRECTIONS (Qs. 10-11) : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

10.

	Column -I		Column -II
(A)	Lunar eclipse i.e., earth passes between the moon and the sun	(p)	New moon
(B)	The shape of moon that appears to be less than half illuminated by the sun	(q)	Half moon
(C)	Moon refers to the two lunar phases	(r)	Full moon
		(s)	Crescent moon

11.

	Column -I		Column -II
(A)	The southern hemisphere has longest day	(p)	21 March and 23 september
(B)	Autumn in northern hemisphere	(q)	21 June
(C)	The northern hemisphere has longest day	(r)	22 December
(D)	The duration of day and night are equal in both hemisphere	(s)	22 September

DIRECTIONS (Qs. 12–14) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

The vast collection of billions of stars along with the vast amount of hydrogen and dust in an isolated place in the universe is called galaxy.

Our Sun and all the stars that can be seen in the night sky belong to a giant family of stars. This family of stars with dust and hydrogen gas forms our galaxy, called the milky way. It contains about 100,000 million stars.

Beside our own galsxy, there are about 100 billion other galaxies scattered all over the universe and each one of them has around 100,000 million stars. The nearest galaxy visible to the naked eye is the Andromeda galaxy.

12. We live in galaxy or our home galaxy
(a) Andromeda (b) Whirlpool
(c) Milky way (d) Black eye

13. The galaxy which send out stars in all directions is
(a) elliptical galaxy (b) spiral galaxy
(c) irregular galaxy (d) barred spiral galaxy

14. Which galaxy has several arms of stars around central core and from sideway it looks like a flying saucer?
(a) elliptical galaxy (b) barred spiral galaxy
(c) irregular galaxy (d) spiral galaxy

DIRECTIONS (Qs. 15–17) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

15. **Assertion :** Stars that occur in the form of clusters or groups are called galaxies
Reason : Our sun is a middle order star in the spiral galaxy, called milky way.

16. **Assertion :** Solar eclipse lasts at some particular place for very short time.
Reason : The shadow caused by the moon on the surface of earth is very small on account of its smaller size.

17. **Assertion :** Geostationary satellites are used for remote sensing
Reason : Remote sensing satellites are employed in spying work for military purposes.

Physics Point

SOLUTIONS

Brief Explanations of Selected Questions

1 EXERCISE

FILL IN THE BLANKS :

1. 150
2. mercury
3. vyadha.
4. Mars
5. sulphuric acid.
6. hydrogen gas, helium gas

TRUE/FALSE :

1. True
2. True
3. False, the three middle stars represent the belt of hunter. Orion is known as hunter.
4. True
5. True
6. True, stars appear smaller in size because of its large distance from the earth's surface.

MATCH THE COLUMNS :

1. A → (r), B → (p), C → (s), D → (q)
2. A → (r), B → (s), C → (p), D → (q)

VERY SHORT ANSWER QUESTIONS :

1. Stars are present in the sky during day time also but they are not visible because of the bright sunlight.
2. Pole star appears stationary as it is situated in the direction of the earth's axis.
3. Planets do not collide while revolving around the sun as they repel each other.
4. We see the part of the moon from which the light of sun is reflected towards us.
5. The radiation emitted by sun exerts a radial presssure on the comet. So the tail of comet is always directed away from the sun.
6. Halley's comet appears after every 76 years.
7. Orion is called the Hunter.

SHORT ANSWER QUESTIONS :

1. The presence of water, right temperature, suitable atmosphere and a blanket of ozone make earth unique.
2. The Moon is moving around the Earth and because one side of the Moon is always in sunlight, we see different amount of light as it moves. This means that the moon seems to change shape during each month. **At New Moon**, we cannot see any of the lit half. After a week, we can see about half a Moon and **at Full Moon**, we can see the whole lit disc.
4. Being very close to the Sun, Mercury is very hot during the day (about 400°C). Due to the absence of an atmosphere, the heat is quickly lost at night, and it becomes freezing cold (about - 200°C)
5. Difference between a galaxy and constellation –
   1. A galaxy is collection of billions of stars whereas a constellation is a collection of only a very few stars.
   2. A galaxy does not form a definite pattern which resemble shape of an animal or a human being but a constellation appears to resemble an animal or human being in its shape.
   3. There are billions of galaxies in this universe but only 88 constellations are known at present.
6. Sun spots are caused by changes in the Sun's magnetic field. The number of sunspots we see varies upto 100, over an 11 year cycle.

LONG ANSWER QUESTIONS :

3. (b) Difference between star and planet

	Stars	Planets
1.	Stars have their own light.	Planets do not have their own light. They just reflect the light of the star to which they being.
2.	Stars twinkle.	Planets do not twinkle.
3.	Their number is infinite in the celestial sphere.	Their number is only eight in the solar system.
4.	The relative distance between stars remains constant.	The relative distance between the planets changes with time.
5.	A star is a huge mass of extremely hot gases and its temperature is very high.	A planet is made of rocks and metal and its temperature depends on its distance from Sun.
6.	Stars are very big in size. They appear small as they are very far off.	Planets are relatively smaller.

Physics Point

4. Stars are born inside giant dust and gas clouds called nebulae, the mass of matter becomes immensely hot and begins to give off energy as light and heat. A new star starts to shine.

During their lives, stars burn up energy, sending out light and heat. Some grow into blue giants and explode as supernovae. Other smaller stars swell up as their fuel starts to run out and become vast glowing red gaints. They then shrink into white dwarfs, as they are so small hard to detect in the sky. But the stars appear to be permanent as physical characteristics of a star like brightness, temperature, colour and size change very slowly with time as compared to our life span. it takes millions of years for a noticeable change to occur in a star whereas a man stays on earth for 70-75 years on an average. Therefore, a star appears to be permanent even though it is slowly dying.

2 EXERCISE

TEXT-BOOK EXERCISE :

1. (c) A constellation

2. (a) Sirius

3. (a) We can see only the part of the moon which reflects light towards us.

4. (a) Neptune (b) Mars
(c) constellation (d) satellite
(e) stars (f) Mars, Jupiter

5. (a) F (b) T
(c) F (d) T
(e) F (f) F

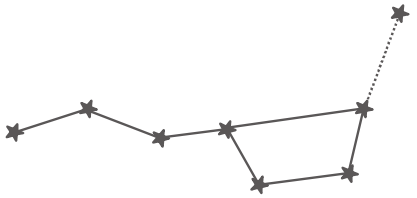
6. (i) → (e,g) (ii) → (a)
(iii) → (c,f) (iv) → (d)

7. Venus appears in the western part of the sky, it is also known as evening star.

8. Jupiter

9. A group of stars that forms recognisable pattern in the sky is called constellation.
Two constellations are Ursa Major and Orion.

10. (a)



(b) Ursa Major

Orion

11. Two members of solar system other than planets are :
(i) Asteroids (ii) Comets

12. To locate the pole star, we consider two stars at the base of the Ursa Major. Now, draw an imaginary straight line towards the northern direction connecting these two stars as shown in figure.

The imaginary line meets a star called a Pole star. The length of the imaginary line from the bowl is above five time the distance between the two bowl of the bowl.

13. No, all the stars do not move in the sky. They appear to move from east to west. It is due to rotation of Earth in which we live. The Earth moves from west to east. But Pole star do not appear to move because it is located above the axis of rotation of the Earth in the north direction. It appears to remain stationary at a point in the sky.

14. Stars are far away from each other. The distance among them is millions of kilometers. The distance between sun and Earth is 150,000,000 km. Whereas the distance of alpha centaury is 40,000,000,000,000 km. It is not convenient to show in km. So it is expressed in light year. A light year is the distance covered by light in one year. One light year is equal to 9.46×10^{12} km.
Eight light years means the distance covered by light in eight years. The statement that a star is eight light years aways from the earth means the distance between the star and the earth is eight light years i.e. a star is located $8 \times (9.46 \times 10^{12}) = 7.6 \times 10^{13}$ km away from the earth.

15. Let the radius of Earth = R

$\therefore$ Volume of Earth = $\frac{4}{3}\pi R^3$

Now , the radius of Jupiter = R^1

$\therefore$ Volume of Jupiter = $\frac{4}{3}\pi R'^3$

It is given that R' = 11 R

Thus, volume of Jupiter $\frac{4}{3}\pi(11R)^3 = \frac{4}{3}\pi(1331)R^3$

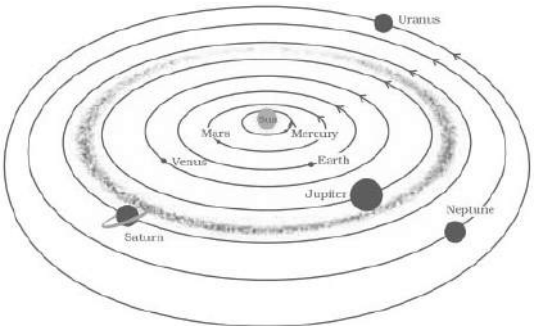
Now, the ratio of the volume of Jupiter and the Earth,

$$= \frac{\text{Volume of Jupiter}}{\text{Volume of Earth}}$$

$$= \frac{\frac{4}{3}\pi(1331)R^3}{\frac{4}{3}\pi R^3} = \frac{1331}{1} = 1331 : 1$$

So, 1331 Earth's can be accommodated in one Jupiter

16. The sketch made by Boojho is incorrect, because the correct order of the planets in order to distance from the sun is:
Mercury, Venus, Eart, Mars, Jupiter, Saturn, Uranus, Neptune.
The correct sketch is:



EXEMPLAR QUESTIONS :

1. We will see the change after 10 years.
2. The brightness of a meteor is extremely small compared to that of the sun, therefore, it is not seen during day time.
3. It changes its shape because we see only that part of the moon from which the light of the sun is reflected towards us.
4. No, because the position of the moon keeps changing during the night.

HOTS QUESTIONS:

1. Moon cannot be used for communication because
(i) it does not rotate in the equatorial plane of the earth
(ii) it is not geo-stationary and
(iii) distance between moon and earth is very large.
2. No, it will not be same on Venus because unlike the earth and most other planets Venus rotates on its axis from east to west i.e., in the opposite direction.
3. Time taken by the earth to revolve around the sun is almost $365\frac{1}{4}$ days i.e., 1 year. So, if your age is x years, you will gone around the sun x times since your birth.

3 EXERCISE

SINGLE OPTION CORRECT :

1. (c) The name of largest asteroid is Ceres.
2. (a) Aryabhata
3. (a) Edwin Hubble gave the first evidence of the big-bang theory.
4. (b) An exploding star may be called as Supernova.
5. (a) Alpha centuari is a star.
6. (a) Constellation Great Bear has six prominent stars.
7. (a) less than that of Nepture

MORE THAN ONE OPTION CORRECT :

1. (a, b, c)
2. (a, b)
3. (a, b, c) Indian Remote Sensing (IRS) satellites are used in Assessment of crop productivity, Locating groundwater resources and Mineral exploration. This system was launched in 1979 and 1981. This system is used in agriculture, water resources, forestry, ecology, geology, marine fisheries and coastal management.

MULTIPLE MATCHING QUESTIONS :

1. A → (r) ; B → (s) ; C → (q) ; D → (p)
2. A → (s) ; B → (r) ; C → (p) ; D → (q)

PASSAGE BASED QUESTIONS :

1. (b) Hydrogen atom fuses and generate Sun's energy.
2. (b) **3.** (a) **4.** (a) **5.** (c) **6.** (b)

ASSERTION & REASON :

1. (a) Nuclear fusion in sun is the main source of energy.
2. (a) **3.** (a)

4 ADVANCED EXERCISE BASED ON CONNECTING TOPICS

1. (c) Light takes about 8 minutes from the sun to reach to the earth.
2. (c)
3. (c) The age of universe is believed to be 10-20 billion years.
4. (c) The radiation emitted by sun exerts a radial presssure on the comet. So the tail of comet is always directed away from the sun.
5. (c) A black hole is a region of space from which nothing, not even light, can escape. It is the result of the deformation of spacetime caused by a very compact mass. The simplest black hole has mass but neither electric charge nor angular momentum. The mass of a black hole is finite, the reason why a black hole has infinite density is that it's mass is concentrated into a space of zero-volume. Thus, it has a very high density.
6. (c) **7.** (c)
8. (a, b, d)
9. (a, b, d)
10. A → (r); B → (s); C → (q)
11. A → (r); B → (s); C → (q); D → (p)
12. (c) A milky way is our home galaxy.
13. (a) **14.** (d) **15.** (b) **16.** (a)
17. (d) Geo-stationary satellite are the satellites which appear stationary with respect to earth.

Physics Point

Chapter

8

MEASUREMENTS

INTRODUCTION

Measurement plays an important role in Physics and in our daily life as well. Physics is said to be the science of measurement. Study of Physics is absolutely meaningless without measurement. Our day-to-day life is also full of the techniques of measurements.

When we say that the car is moving at 100 km/h, we measure the speed; when we say that the weightlifter lifts 200 kg, we measure the mass; when we say that it takes 30 minutes to reach to our school, we measure the time etc.

Imagine if nothing was measured. There would be crooked buildings, any ole shape cars, it would be like living in a crooked out of control world. We couldn't ask the required amount of rice, milk, vegetables, sugar or clothes to our shopkeepers. We couldn't ask them to give us 5 kg rice, 3 kg milk, 2 kg sugar or 2 m of shirt piece, etc. These things became possible only when the necessity of measurement was ended by developing different techniques of measurement.

Measurement of a physical quantity is expressed in terms of some standards known as units. This chapter makes an attempt to associate a physical quantity with its unit and also some techniques of measurement.

PHYSICAL QUANTITIES

Those quantities which can describe the laws of physics and possible to measure are called physical quantities.
Example : Length, mass, time, speed, velocity, acceleration, area, specific heat, etc.

Types of Physical Quantities

1. **Fundamental quantities :** The physical quantities which are *independent* are called *fundamental quantities*. The following *seven* quantities are fundamental: *Length*, *mass*, *time*, *thermodynamic temperature*, *electric current*, *luminous intensity* and *amount* of *substance*.
2. **Derived quantities :** The physical quantities which *depend* upon the fundamental quantities are called *derived quantities*. Derived physical quantities are obtained from fundamental quantities.
   Example : Area, volume, speed, acceleration, pressure, specific heat, etc.

Think it Over

Think of some quantities which are not physical.

MEASUREMENT OF A PHYSICAL QUANTITY

Measurement is a *process of comparing* an unknown physical quantity with a known physical quantity. It consists of two parts – *numerical value* and the *unit* of that quantity. Therefore, if n and u represent numerical value and the unit respectively, then measurement = nu
Example : When we measure a certain amount of sugar with the standard kilogramme and if it comes out to be four times of the kilogramme then the measurement of sugar is said to be 4 kg.

CHECK Point

If a physical quantity is five times the standard known as joule. What is its measurement?

SOLUTION

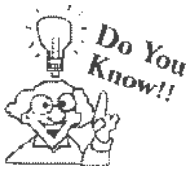
Measurement = nu
Here, $n = 5$ and u = joule
$\therefore$ Measurement = 5 joule.

Physics Point

UNIT OF A PHYSICAL QUANTITY

The unit of a physical quantity is the reference *standard* used to measure it.

For example, the unit *metre* (m) is defined as the distance travelled by light in vacuum in $\frac{1}{299,792,458}$ second. Now any length equal to this amount is said to be 1 m and thrice of this is said to be 3 m.
Example : Unit of length is metre (here 'metre' is the standard), unit of mass is kilogramme, etc.



In our country, the function of manufacturing, maintaining, monitoring and improving of the standards of measurement by the ***National physical laboratory (NPL), New Delhi.***

Properties of a Unit

The unit should
(i) be well-defined.
(ii) be of some suitable size.
(iii) be easily reproducible.
(iv) not change with time.
(v) not change with physical conditions like pressure, temperature, etc.
(vi) be of proper size.

Types of Units

1. **Fundamental units :** Units of fundamental physical quantities are called fundamental units.
   Example : *metre, kilogramme, second, kelvin, ampere, candela* and *mole*.

2. **Derived units :** Units of derived physical quantities are called derived units. Derived units are derived from fundamental units.
   Example : *Metre per second* (unit of speed), *metre per second*^{2} (unit of acceleration), *kilogramme per metre*^{3} (unit of density), etc.

Let us develop a new system of units in which force, acceleration and time be taken as the fundamental quantities and their respective units as F, A and T. What is the unit of length in this system?

CHECK Point

The unit of electric potential is joule/coulomb. Which type of units is it – fundamental or derived?

SOLUTION

It is a derived unit because it is obtained from fundamental units.

System of Units

Following are the system of units developed over a period of time.

(1) **C.G.S. System :** In this system, *length*, *mass* and *time* are measured in *centimetre* (cm) *gramme* (gm) and *second* (s) respectively.

(2) **F.P.S. System :** In this system, *length*, *mass* and *time* are measured in *foot* (ft), *pound* (lb) and *second* (s) respectively.

(3) **M.K.S. System :** In this system, *length*, *mass* and *time* are measured in *metre* (m), *kilogramme* (kg) and *second* (s) respectively.

(4) **The International System (S.I.) of Units :** To bring uniformity in measurement, the international system of units (abbreviated as S.I. system) was adopted in 1960. But the current version of S.I. was completed in 1971 by adding the *mole* as base unit for amount of substance, bringing the total number of base units to seven.

Advantage of S.I. system is that it assigns only one unit to various form of a particular physical quantity. For example, units of all kinds of energy is joule in this system but in MKS, different forms of energy has different units.

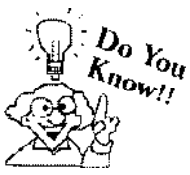
This system has seven base units and two supplementary units which are given in the following tables. It is also known as the *metric system*.

SI Fundamental or base units

S. No.	Base quantity	Base unit	Symbol
1	length	meter	m
2	mass	kilogramme	kg
3	time	second	s
4	electric current	ampere	A
5	thermodynamic temperature	kelvin	K
6	amount of substance	mole	mol
7	luminous intensity	candela	Cd

SI supplementary units

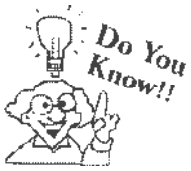
S. No.	Quantity	Unit	Symbol
1	plane angle	radian	rad
2	solid angle	steradian	sr



- *While writing the symbol of a unit, its plural form is not used, e.g. we can't write 10 kgs but we write 10 kg.*
- *Full stop or other punctuation marks should not be used within or at the end of symbols for units, e.g. we write 15 cm and not 15 c.m. or 15 cm. for a given length.*

Definitions of S.I. Units

1. **kilogramme** : 1 kilogramme is defined as the mass of a platinum – iridium cylinder kept in International Bureau of Weights and Measures at Sevre near Paris.
2. **metre :** 1 metre is the distance travelled by light in vacuum in 1/299,792,458 seconds or it is equal to 1650763.73 wavelengths, emitting from Kr^{86}.
3. **second** : 1 second is defined as the time interval in which Cesium-133 atom vibrates 9,192,631, 770 times.
4. **kelvin :** 1 Kelvin is defined as the (1/273.16) fraction of thermodynamic temperature of triple point of water.
   Triple point of water is the temperature at which ice, water and water vapour co-exist.
5. **ampere :** 1 ampere is the amount of current flowing along two parallel wires of infinite length and negligible cross-sectional area in same direction separated by a distance of 1 metre in vacuum which produces a force of 2×10^{-7} N on per unit length of the wires.
6. **candela** : 1 candela is the amount of intensity on 1/60000 m² area of blackbody in the direction perpendicular to its surface at freezing point of platinum 2042 K at pressure of 101325 N/m^2.
7. **mole :** 1 mole is the amount of a substance which has same number of elementary entities as in 12 g of carbon ($_6C^{12}$).



Other units of length are

1. *Light year = 9.46×10^{15} m*
2. *Parsec = 3.084×10^{16} m*
3. *Fermi = 10^{-15} m*
4. *Angstrom (Å) = 10^{-10} m*
5. *Astronomical unit (A.U.) = 1.496×10^{11} m*

Prefixes for S.I. Units

In physics, we have to deal from very small (micro) to very large (macro) magnitudes. To express such large and small magnitudes simultaneously we use following prefixes.

Prefixes for powers of 10

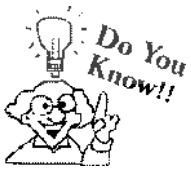
Multiple of 10	Prefix	Symbol	Sub-multiple of 10	Prefix	Symbol
10^1	Deca	da	10^{-1}	deci	d
10^2	Hecto	h	10^{-2}	centi	c
10^3	Kilo	k	10^{-3}	milli	m
10^6	Mega	M	10^{-6}	micro	μ
10^9	Giga	G	10^{-9}	nano	n
10^{12}	Tera	T	10^{-12}	pico	p
10^{15}	Peta	P	10^{-15}	femto	f
10^{18}	Exa	E	10^{-18}	atto	a

Example :

$5\ km = 5 \times 10^3 m$

$12\ \mu m = 12 \times 10^{-6} m$

$15\ pm = 15 \times 10^{15}\ m$, etc.



S. No.	Quantity	Unit
1	*Mass*	*Solar mass = 2×10^{30} kg* *Dalton = 1.66×10^{-27} kg* *Chander Shekhar limit = 1.4 times of mass of sun*
2	*Pressure*	*Pascal = 1 N/m^2* *Bar = 10^5 N/m^2*
3	*Area*	*Barn = 10^{-28} m^2*
4	*Radio-activity*	*Bequerel*
5	*Time*	*Shake = 10^{-8} sec*

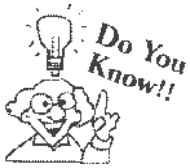
Methods of Writing Units

The following steps help in writing units of a derived physical quantity.

Step 1 : Firstly, express the given physical quantity in terms of fundamental quantities.

Step 2 : Write the units of the fundamental quantities in the system in which the unit is sought.

Step 3 : Write all the fundamental units with positive or negative powers.



- *While writing the full name of a given unit, it should not be started with capital letter even when it is named after a scientist, e.g. we can't write 2 Newton or 4 Joule or 5 Metres but we should write 2 newton or 4 joule or 5 metres.*
- *Symbol of a unit named after a scientist has capital letter, e.g. 4 N or 5 J etc.*

ILLUSTRATION : 1

Write the CGS unit of acceleration.

SOLUTION :

Step 1: We know that acceleration $= \frac{\text{velocity}}{\text{time}}$

Also, velocity $= \frac{\text{displacement}}{\text{time}}$ $\therefore$ acceleration $= \frac{\text{displacement}}{\text{time} \times \text{time}}$

Step 2 : CGS unit of displacement (length) = centimetre (cm)

CGS unit of time = second (s)

$\therefore$ C.G.S. unit of acceleration $= \frac{\text{cm}}{\text{s} \times \text{s}} = \text{cm/s}^2$ (or cms^{-2})

ILLUSTRATION : 2

Write the SI unit of density.

SOLUTION :

Step 1 : We have, density $= \frac{\text{mass}}{\text{volume}}$

Again, volume = length × breadth × height

$\therefore$ density $= \frac{\text{mass}}{\text{length} \times \text{breadth} \times \text{height}}$

Step 2 : SI unit of mass = kilogramme (kg)

SI unit of length = metre (m)

SI unit of breadth = metre (m)

SI unit of height = metre (m)

Step 3 : SI unit of density $= \frac{\text{kg}}{\text{m} \times \text{m} \times \text{m}} = \frac{\text{kg}}{\text{m}^3} = \text{kgm}^{-3}$.

MEASUREMENT OF LENGTH

The simplest instrument used in the laboratory for measuring the small lengths is metre scale. One can accurately measure only up to 1 mm with the help of a metre scale. Therefore, its least count is 1 mm.

Least count of an instrument

The minimum measurement which can be taken by an instrument is called its least count.

While taking an observation with metre scale, some important precautions must be kept in the mind to avoid certain errors which arise due to wrong use of the metre scale.

1. The metre scale should be kept along the length of the object.
   The scale should never be inclined, inclined scale gives more length.
2. The edge of the object whose length is to be measured should coincide with a fixed mark on the scale.
3. The measurement should not be taken from zero mark of the scale because the edge of the scale is generally worn out.
4. The observation should be taken keeping one eye closed and the other eye directly over the mark. Observation with an inclined eye will be wrong due to the *error of parallax*.
5. Now without distributing the metre scale and the object move your eye to the other edge of the object and again take the observation. The difference between these two observations (readings) will give the actual length of the object.

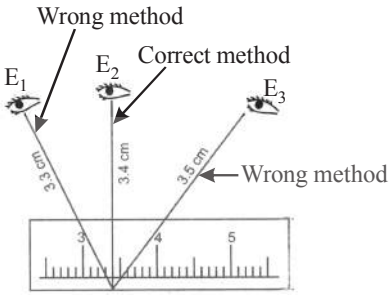


Fig. 8.1

To measure smaller length accurately up to $\left(\frac{1}{100}\right)$ th or $\left(\frac{1}{1000}\right)$ th of a centimetre, the following instruments are used in the laboratory:

1. *Vernier Callipers* 2. *Screw Gauge* 3. *Spherometer*

Vernier Callipers

A Vernier calliper is used to measure a small length like radius of a wire. The following diagram describes a Vernier calliper.

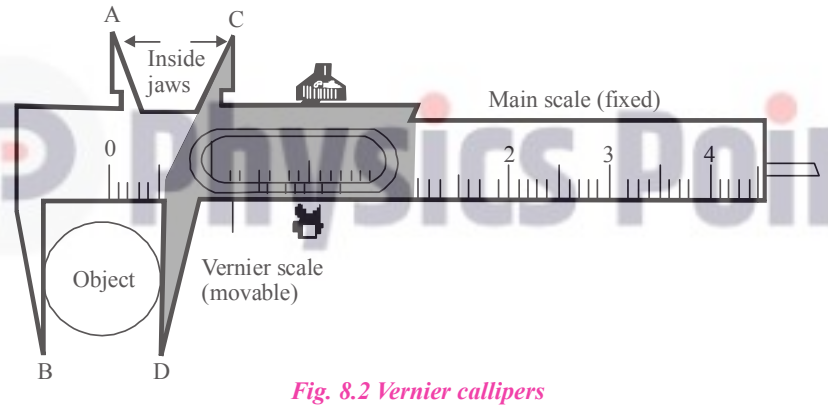


Fig. 8.2 Vernier callipers

Principle of Vernier Callipers : As shown in the figure, a Vernier calliper has two scales – (i) main scale and (ii) Vernier scale. Reading of the given measurement is taken by the following formula:

Total reading, T.R. = M.S.R. + V. S. R.

where, M.S.R. = Main scale reading and V.S.R. = Vernier scale reading

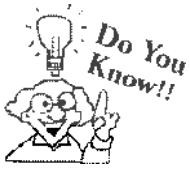
If with the body between the jaws, the zero of Vernier scale lies ahead of Nth division of main scale, then main scale reading (M.S.R.) = N

If with division of Vernier scale coincides with any division of main scale, then Vernier scale reading (V.S.R.)

= n × (L.C.) (L.C. is least count of Vernier callipers)

= n × (V.C.) (V.C. is Vernier constant of Vernier callipers)

Total reading, T.R. = M.S.R. + V.S.R. = N + n × (V.C.)



The main scale reading with which the vernier scale division coincides has no connection with reading.

Zero Error : When the jaws AB and CD are made to touch each other, and if the zero mark of Vernier scale exactly coincides with the zero mark of the main scale, then in this situation the instrument is free from any error. In other words the instrument has no zero error. However, when we use the Vernier callipers, due to the wear and tear of the jaws and there may be some manufacturing defect, when

the jaws AB and CD made to touch each other, the zero mark of the Vernier scale may not be in the same straight line with the zero mark of the main scale. This situation gives rise to an error which is called zero error. Zero error is always algebraically subtracted from the observed reading. Zero error is of two types:

1. Positive zero error, and 2. Negative zero error.

1. Positive zero error: Zero error is positive when zero of Vernier scale lies to the right of the zero of the main scale, when jaws AB and CD are made to touch each other. To find out the zero error read the main scale reading (N) on the left of the zero of the Vernier scale and note down which number of Vernier scale division (n) is coinciding with any main scale division. In Fig. 1.3 (a), we have

Main scale reading (N) = 0.0 cm

No. of Vernier scale division coinciding (n) = 3. Fig. 8.3 (b)

Zero error = 0.0 + 3 × (V.C.)

= 0.0 + 3 × 0.01 cm = + 0.03 cm

This error is algebraically subtracted from the observed reading to get the corrected reading.

Corrected reading = Observed reading – Zero error

= Observed reading – 0.03 cm.

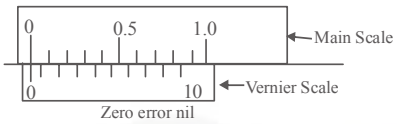


Fig. 8.3 (a)

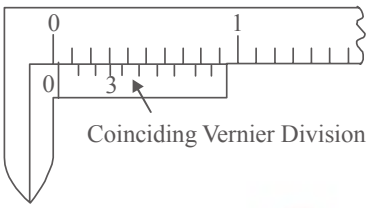


Fig. 8.3 (b)

2. Negagtive zero error: If the zero mark of the Vernier scale is slightly on the left of the zero mark on the main scale, when two jaws AB and CD are made to touch with each other, the zero error is negative. It is shown in Fig. 8.3(b)

To determine the negative zero error, again read the main scale reading (N) and note down which number of Vernier scale division (n) is coinciding with any main scale division.

In case of negative zero error, the number of Vernier scale division (n) coinciding with the main scale division is subtracted from total number of divisions on the Vernier scale and then this difference is multiplied by the Vernier constant (V.C.). In Fig. 8.3 (b), we have:

Main scale reading (N) = 0.0 cm

No. of Vernier scale division coinciding = (n) = 3 Fig. 1.3 (b)

Zero error = 0.0 cm – (10 – 3) × V.C.

= 0.0 cm – (10 – 3) × 0.01 cm = – 0.07 cm

Corrected reading = Observed reading – Zero error

= Observed reading – (– 0.07 cm)

= Observed reading + 0.07 cm.

SCREW GAUGE

It is also used to measure small length like thickness of a thin sheet or the diameter of a wire. The following diagram shows all the components of a screw gauge.

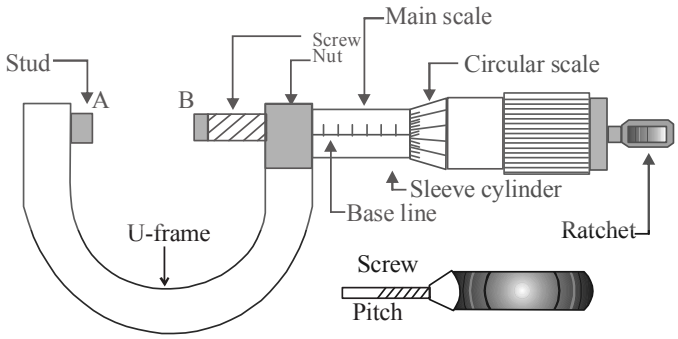


Fig. 8.4 : Screw gauge

Principle of a Screw Gauge

It works on the principle of a screw in a nut.

If with the wire between plane faces A and B, the edge of the cap lies ahead of Nth division of linear scale, then, linear scale reading (L.S.R.) = N

Let nth division of circular scale lies over reference line.

Then, circular scale reading (C.S.R.) = n × L.C. (L.C. is least count of screw gauge)

Total reading (T.R.) = L.S.R. + C.S.R. = N + n × (L.C.)

First calculate the pitch of screw gauge.

$$\text{Pitch} = \frac{\textit{distance moved by screw}}{\textit{number of rotations}}$$

Note the total number of divisions on the circular scale, then

$$\text{Least count} = \frac{\textit{pitch}}{\textit{total number of divisions on the circular scale}}$$

Zero Error : When zero of the circular scale exactly coincide with the line of graduation (reference line) when stud A and B just touch each other, the zero error and hence zero correction is nil. In case this is not so, then the instrument is said to possess a zero error. In case of screw gauge also zero error may by positive or negative zero error.

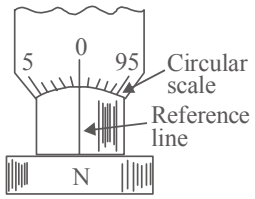


Fig. 8.5 : *(a) Screw gauge with no zero error*

Positive Zero Error : If the zero of the circular scale is below the line of graduation when stud A and B just touch each other then zero error is positive.

Now to determine the magnitude of positive zero error, take an example as shown in Fig. When the stud A just touches with B, the zero mark of the circular scale is 2 divisions below the line of graduation (reference line). Hence,

Zero error = + 2 × L.C. = + 2 × .001 cm = + .002 cm

and zero correction = –ve of zero error = – .002 cm.

Corrected reading = observed reading – 0.002 cm

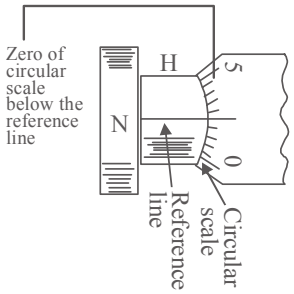


Fig. 8.5 : *(b) Screw gauge with positive zero error*

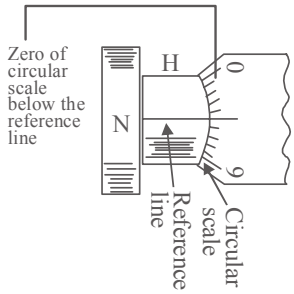


Fig. 8.5 : *(c) Screw gauge with negative zero error*

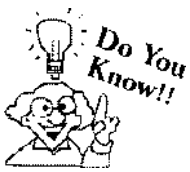
Negative Zero Error : When zero of circular scale is above the line of graduation, when stud A and B just touch each other, then zero error is negative.

In fig zero of circular scale is 3 division above the line of graduation. When stud A and B just touch each other, then

Zero erro = – 3 × L.C. = – 3 × 0.001 cm = – 0.003 cm

Zero correction = – *ve* of zero error = – [– 0.003 cm] = + 0.003 cm

Corrected reading = Observed reading + 0.003 cm.



- Absolute error (Δa) : $\Delta a_1 = a_m - a_1$
  $\Delta a_2 = a_m - a_2$

  $\Delta a_n = a_m - a_n$

$$\text{Where } a_m = \text{mean value} = \text{true}$$

$$\text{Value} = \frac{a_1 + a_2 + a_3 + ... + a_n}{n}$$

- $\text{Relative error} = \frac{\text{mean absolute error } (\Delta\bar{a})}{\text{mean value } (a_{mean})}$
- $\text{Percentage error } (\delta a) = \frac{\text{mean absolute error}}{\text{mean value}} \times 100\%$

MEASUREMENT OF AREA

Area of an object is measured by multiplying two lengths. For example, the area of a rectangular object is measured by multiplying its length and breadth. That is, *area of rectangle = length × breadth*
Area is measured in cm^2, m^2, mm^2, etc.

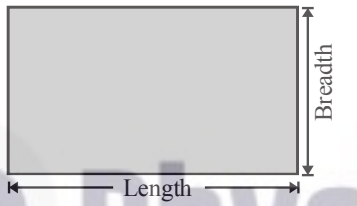


Fig. 8.6 : *A rectangle*

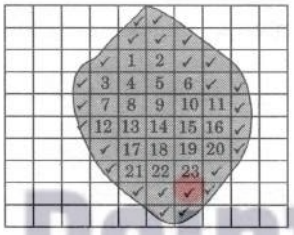


Fig. 8.7 : *Measurement of an irregular object*

The area of an irregular object can be calculated by drawing the outline of its shape on a graph paper. The number of complete squares are calculated, next the squares greater than half are also counted as a square, leaving the squares less than half. The sum of all the squares gives the area of irregular object to be that many cm^2.

MEASUREMENT OF VOLUME

Volume of an object is defined as the space occupied by that object. It is measured in m^3, cm^3, mm^3, etc. For an object having length *l*, breadth *b*, and height *h*, volume is given by

volume = $l \times b \times h$

Volume of liquids is measured by different apparatus such as *measuring jar*, *measuring flask*, *pipette*, *burette* etc.

MEASUREMENT OF MASS

The amount of matter contained in an object is known as its mass. It is measured in *gramme* (g), *kilogramme* (kg), *milligramme* (mg), etc. *Common balance*, *physical balance*, etc. are commonly used apparatus for measuring mass.

Common balance works on the principle of moments according to which a beam remains horizontal and 'balanced' when equal weights are placed at equal distances from the point of suspension, which is the middle of the beam.

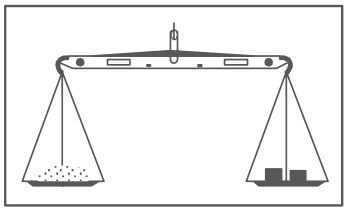


Fig. 8.8 : *Common balance*

MEASUREMENT OF TIME

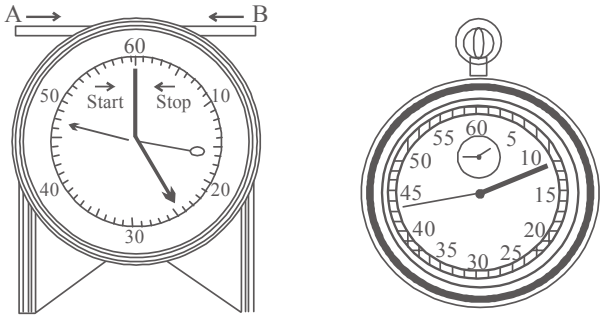
The interval between two events is known as time. It is measured in *second*, *minute*, *hour*, etc.

It is mostly measured by a *stop clock*, *a stop watch* or a *simple pendulum*.

1. **Stop clock:** Stop clock has an arangement for the start and stop of the clock. There is a rod AB projecting out of the clock both ways at its sides as shown in the Figure 8.9(a) . When the rod AB is pushed to the right, the clock starts and when it is pushed to the left, the clock stops. There is no fly back arrangement in the stop clock. While second and minute hands are fixed inside the case, a third needle operates from outside. The starting position of the second's hand is marked by the third needle which is called third hand. The least count of a stop clock is generally one second.

2. **Stop watch:** It consists of a circular dial dividing into 30 or 60 equal divisions over which a long second hand moves, as shown in the Figure 8.9(b) . Each division represents one second. Each division is further divided into 5 or 10 equal divisions to enable us to read upto 0.2 second or 0.1 second. A small minute hand moves over another circular dial, divided into 30 equal divisions. Each division represents a minute. The operation of a stop watch comprises of three stages. In the first stage, at the beginning to the event, the knob K at the top is pressed. Both the hands now begin to move simultaneously. At the end of the event, the knob is again pressed and both the hands come to rest. This is called second stage of operation. At this stage, the stop watch measures directly the desired time interval. At the third stage, the knob has to be pressed again, this brings the needles back to zero position on the scale. The watch is now ready for the new observations. The least count of the stop clock is one second and that of stop watch is 0.1 second.

   So for the accurate measurement of time intervals in a laboratory, a stop watch is preferred.



(a) (b)

Fig. 8.9

Think it Over

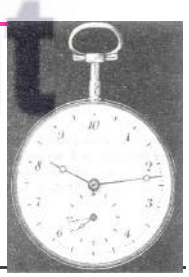


Fig. 8.10 : When the metric system was proposed in 1792, the hour was redefined to provide a 10-hour day. The idea did not catch on. The maker of this 10-hour watch wisely provided a small dial that kept conventional 12-hour time. Do the two dials indicate the same time?

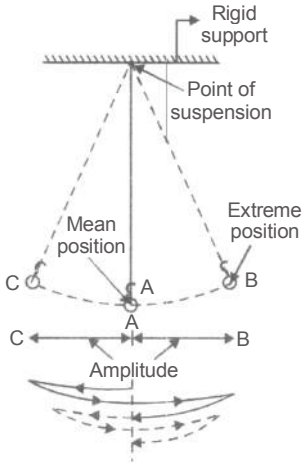
3. **Simple Pendulum :** An ideal simple pendulum consists of a heavy point mass suspended by inextensible, perfectly flexible and weightless string from rigid support. However, these conditions cannot be achieved practically. The nearest approach to the ideal simple pendulum consist of a small metallic sphere called bob suspended from a fixed support by a fine and inelastic silk or cotton thread.

   The oscillatory motion of a simple pendulum suspended from a rigid support is shown in the Figure. If the bob of simple pendulum is displaced to one extreme position B and left free, the bob returns to mean position A and goes to extreme left position C and again returns to mean position A. This completes one vibration and motion is repeated.

   The *time period T* of a simple pendulum is given by the following relation:

$$T = 2\pi\sqrt{\frac{l}{g}}$$

   where l is the length of the simple pendulum and g is the acceleration due to gravity.



SIGNIFICANT FIGURES

When we measure a physical quantity, generally the measured value does not come out to be accurate. It may contain some error. When the measured value is expressed as a number, then some digits which it contains are known reliably plus the first digit which is unreliable.

Fore example: Let us measure the length of a glass plate using a scale. Let this length lies somewhere between 2.6 and 2.7 cm say 2.63 cm. Here, digits 2 and 6 are reliable, but digit 3 is unreliable. Now, the reliable digits and first unreliable digits are known as significant figures or significant digits. Thus, the measurement 2.63 cm contains three significant figures.

These significant figures are desired when the observation of any experiment have to be recorded and then to be used in calculations. Here, the knowledge of significant figures is helpful.

Larger the number of significant figures obtained in a measurement, greater is its accuracy and vice versa.

Rules to find the number of significant figures :

Rule I : All the non-zero digits are significant, *e.g.* 1984 has 4 significant figures.

Rule II : All the zeros between two non-zero digits are significant, *e.g.* 10806 has 5 significant figures.

Rule III : All the zeros to the left of first non-zero digit are not significant, *e.g.* 00108 has 3 significant figures.

Rule IV : If the number is less than 1, zeros on the right of the decimal point but to the left of the first non-zero digit are not significant *e.g.* 0.002308 has 4 significant figures.

Rule V : The trailing zeros (zeros to the right of the last non-zero digit) in a number with a decimal point are significant, *e.g.* 01.080 has 4 significant figures.

Rule VI : When the number is expressed in exponential form, the exponential term does not affect the number of significant figures.

For example in : $x = 12.3 = 1.23 \times 10^1 = 0.123 \times 10^2 = 0.0123 \times 10^3 = 123 \times 10^{-1}$

each term has 3 significant figures only.

Think it Over

Let some length is meaured to be 1200 mm. According to rule, it should have two significant figures. But we can write 1200 mm = 1.200 mm. Then according to rule it should have four significant figures. Does the change of unit change the number of significant figures?

If a set of experimental data is specified to n significant figures, a result obtained by combining the data will also be valid to n significant figures.

ILLUSTRATION : 3

Write down the number of significant figures in the following:

(a) 165 **(b) 2.05** **(c) 34.000**
(d) 0.005 **(e) 0.02340**

SOLUTION :

(a) 3 significant figures (following rule I)
(b) 3 significant figures (following rules I & II)
(c) 5 significant figures (following rules I & V)
(d) 1 significant figure (following rules I & IV)
(e) 4 significant figures (following rules I, IV &V)

ROUNDING OFF

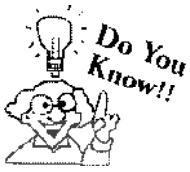
To represent the result of any computation containing more than one uncertain digits, it is rounded off to appropriate number of significant figures.

Rules for rounding off the numbers:

Rule I : If the digit to be rounded off is more than 5, then the preceding digit is increased by one *e.g.* $6.87 \approx 6.9$

Rule II : If the digit to be rounded off is less then 5, then the preceding digit is unaffected and is left unchanged *e.g.* $3.94 \approx 3.9$

RuleIII : If the digit to be rounded off is 5, then the preceding digit is increased by one if it is odd and is left unchanged if it is even *e.g.* $14.35 \approx 14.4$ and $14.45 \approx 14.4$



During the subtraction of quantities of nearly equal magnitudes, accuracy is almost destroyed, e.g., 3.28–3.23 = 0.05. Result 0.05 has only one significant figure whereas orignal measurements have three significant figures each.

ILLUSTRATION : 4

Round off the following numbers :

(a) 36.879 (b) 1.0084 (c) 11.115 (d) 11.1250

SOLUTION :

(a) $36.879 \approx 36.88$ [$\because 9 > 5 \ \therefore$ 7 is increased by one, *i.e.* Rule I)

(b) $1.0084 \approx 1.008$ [$\because 4 < 5 \ \therefore$ 8 left unchanged *i.e.* Rule II)

(c) $11.115 \approx 11.12$ [$\because$ last 1 is odd it is increased by one *i.e.* Rule III]

(d) $11.1250 \approx 11.12$ [$\because$ 2 is even it is left unchanged *i.e.* Rule III)

Rules for Arithmetical Operations With Significant Figures

Rule I : In addition or subtraction the number of decimal places in the result should be equal to the number of decimal places of that term in the operation which contain lesser number of decimal places.

e.g. $12.587 - 12.5 = 0.087 = 0.1$ ($\because$ second term contain lesser *i.e.* one decimal place)

Rule II : In multiplication or division, the number of significant figures in the product or quotient is same as the smallest number of SF in any of the factors,

e.g. $5.0 \times 0.125 = 0.625 = 0.62$

Note: First carry out actual addition or subtraction then round off.

Physics Point

INTRODUCTION TO DIMENSIONS

To express a derived physical quantity in terms of fundamental physical quantities, the letters are raised by some powers. These powers are termed as dimensions of the given physical quantity. For example, to express velocity in terms of fundamental quantities, length and time are raised by powers 1 and –1 respectively as

$$\text{velocity} = \frac{\text{displacement (length)}}{\text{time}} = (\text{length})^1 \cdot (\text{time})^{-1}$$

or $$v = [M^0LT^{-1}]$$

Therefore, dimensions of velocity are 1 in length and –1 in time.

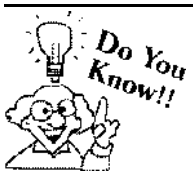
i.e., the dimensions of a physical quantity are the powers to which the fundamental quantities mass (M), length (L) and time (T) must be raised to represent it.

To write dimensions of a physical quantity, following symbols for the fundamental quantities are used.

Quantity	Symbol	Quantity	Symbol
Length	L	Temperature	K or θ
Mass	M	Electric current	A or I
Time	T	Luminous Intensity	Cd
Amount of substance	mol		

Think it Over

A quantity can have unit without dimensions but a quantity cannot have dimensions without units. Enlist some physical quantities which have units but no dimensions.



Dimensional analysis is used to check the correctness of a physical relationship, to convert the unit of a quantity fr®om one system to another and to derive a physical relationship..

ILLUSTRATION : 5

Write the dimensions of force.

SOLUTION :

To write dimensions of force, it is expressed in terms of fundamental quantities as follows :

$$\text{Force} = \text{mass} \times \text{acceleration} = \text{mass} \times \frac{\text{velocity}}{\text{time}} = \text{mass} \times \frac{\text{displacement (length)}}{(\text{time})^2}$$

$$\therefore \quad \text{Dimensions of force, } F = \frac{ML}{T^2} = [MLT^{-2}]$$

CHECK Point

A constant which is defined as the product of energy and time-period is known as Planck's constant (h). Write the dimensions of h.

SOLUTION

The unit of planck's constant is joule second

$h = ET$

$\therefore \quad [h] = [E]\,[T]$

$= ML^2T^{-2} \cdot T = [ML^2T^{-1}]$

Physics Point

SUMMARY

- **Physical quantity:** A quantity which can be measured is called a physical quantity.
- **Fundamental and derived quantities:** Independent quantities are called fundamental quantities and the quantities which depend on fundamental quantities are called derived quantities.
- **Unit of a physical quantity :** The standard used to measure a physical quantity is called its unit.
- **Fundamental and derived units** Units of fundamental quantities are called fundamental units and the units which are obtained by fundamental units are called derived units.
- **S.I. system of units:** It consists of seven fundamental units kilogram, metre, seocnd, ampere, kelvin, candela and mol and two supplementary units are radian and steradian.
- **Least count :** The least count of an instrument is defined as the minimum measurement that can be taken by it accurately.
- **Significant figures :** In a measurement, the reliable digits and the first unreliable digit are known as significant figures.
- **Rounding off :** When we do the calculations using measured values, the result may contain more than one uncertain digits which should be rounded off.
- **Dimensions of a physical quantity:** The powers by which fundamental quantities are raised to express a quantity are called the dimensions of that physical quantity.

ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

Single Option Correct :

DIRECTIONS(Qs. 1- 18) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct. Choose the correct option.*

1. Which of the follwoing is a derived unit?
(a) unit of mass (b) unit of length
(c) unit of time (d) unit of volume

2. One nanometer is equal to
(a) 10^9 mm (b) 10^{-6} cm
(c) 10^{-7} cm (d) 10^{-9} cm

3. Which of the following systems of units is not based on units of mass, length and time alone?
(a) SI (b) MKS
(c) CGS (d) FPS

4. Which of the following is not a unit of time?
(a) Solar year (b) Tropical year
(c) Leap year (d) Light year

5. Dyne-sec is the unit of
(a) Momentum (b) Force
(c) Work (d) Angular momentum

6. The ampere-second is a unit of
(a) Current (b) Charge
(c) Energy (d) Power

7. Light year is
(a) light emitted by the sun in one year
(b) time taken by light to travel from sun to earth
(c) the distance travelled by light in free space in one year
(d) time taken by earth to go once around the sun

8. The S.I. unit of pressure is
(a) Atmosphere (b) Bar
(c) Pascal (d) mm of Hg

9. Electron volt is a unit of
(a) Potential difference (b) Charge
(c) Energy (d) Capacity

10. Unit of power is
(a) Kilowatt hour (b) Kilowatt per hour
(c) Kilowatt (d) Erg

11. One second is defined to be equal to
(a) 1650763.73 periods of the Krypton clock
(b) 652189.63 periods of the Krypton clock
(c) 1650763.73 periods of the Cesium clock
(d) 9192631770 periods of the Cesium clock

12. The unit of current in S.I. system is
(a) ampere (b) kelvin
(c) mol (d) candela

13. Subtract 0.2 J from 7.26 J and express the result with correct number of significant figures
(a) 7.1 J (b) 7.06 J
(c) 7.0 J (d) 7 J

14. Multiply 107.88 by 0.610 and express the result with correct number of significant figures
(a) 65.8068 (b) 65.807
(c) 65.81 (d) 65.8

15. When 97.52 is divided by 2.54, the correct result is
(a) 38.3937 (b) 38.394
(c) 38.39 (d) 38.4

16. The dimensional formula for angular momentum is
(a) $[M^0L^2T^{-2}]$ (b) $[ML^2T^{-1}]$
(c) $[MLT^{-1}]$ (d) $[ML^2T^{-2}]$

17. The dimensional formula of torque is
(a) $[ML^2T^{-2}]$ (b) $[MLT^{-2}]$
(c) $[ML^{-1}T^{-2}]$ (d) $[ML^{-2}T^{-2}]$

18. The dimensional formula of pressure is
(a) $[MLT^{-2}]$ (b) $[ML^{-1}T^2]$
(c) $[ML^{-1}T^{-2}]$ (d) $[MLT^2]$

More than One Option Correct :

DIRECTIONS (Qs. 19- 22) : *This section contains Multiple Choice Questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE options may be correct.*

19. Regarding dimension, which of the folloing statements are correct?
(a) The pure number are dimensionless
(b) A physical quantity that does not have any unit must be dimensionless
(c) The dimensional formula of force is $[MLT^{-2}]$
(d) Strain is a dimensionless physical quantity

20. Pressure is defined as:
(a) momentum per unit area
(b) momentum per unit area per unit time
(c) momentum per unit volume
(d) energy per unit volume

21. Which of the following are not a unit of time
(a) parsec (b) light year
(c) micron (d) second

22. Newton-second is a unit of
(a) force (b) impulse
(c) momentum (d) energy

PhysicsPoint

Multiple Matching Questions :

DIRECTIONS (Qs. 23- 25) : *Match the entries given in column I with one or more entries given in column II.*

23. Column I consists of four physical quantities and column II consists of four dimensional formulae. Match entries in column I with entries in column II.

Column I	Column II
A. Velocity	(p) LT^{-2}
B. Acceleration due to gravity	(q) $ML^2 T^{-2}$
C. Heat energy	(r) LT^{-1}
D. Electric charge	(s) AT

24.

Column I (Physical quantities)	Column II (Units)
A. Length	(p) shake
B. Volume	(q) hour
C. Time	(r) kilometre
	(s) cubic metre
	(t) light year

25.

Column I	Column II
A. Practical unit	(p) radian
B. Base unit	(q) light year
C. Derived unit	(r) $kg\text{-}ms^{-1}$
D. Complementary unit	(s) second

Passage Based Questions :

DIRECTIONS (Qs. 26- 27) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Derived physical quantities are those which depend upon fundamental physical quantities. Their units are thus, obtained by expressing them in terms of fundamental units. Gravitational constant (G) depends upon the fundamental quantities mass (m) and length (d) as given below :

$$F = \frac{Gm^2}{d^2}$$, where F is the force.

26. The unit of G is
(a) Newton-metre/kilogram^2
(b) Newton-metre^2/kilogram^2
(c) Newton-metre/kilogram
(d) Newton^2-metre/kilogram

27. Dimensions of G are
(a) ML^3T^{-2} (b) $M^2L^3T^{-1}$
(c) $M^{-1}L^3T^{-2}$ (d) $M^{-1}L^{-3}T^2$

Assertion & Reason :

DIRECTIONS (Qs. 28- 31) : *Each of these questions contains an Assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

28. **Assertion :** Light year and year, both measure time.
Reason : Light year is the distance which light covers in one year.

29. **Assertion :** Planck's constant is dimensional constant.
Reason : Dimensional constants are those physical quantities which posses dimensions and have a fixed value.

30. **Assertion :** Energy cannot be divided by volume.
Reason : Dimensions for energy and volume are different.

31. **Assertion :** The dimensional formula for relative velocity is same as that of the change in velocity.
Reason : Relative velocity of P w.r.t. Q is the ratio of velocity of P and that of Q.

Integer/ Numeric Questions :

DIRECTIONS (Qs. 32- 35) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

32. A Vernier calliper has 20 divisions on the Vernier scale, which coincide with 19 on the main scale. The least count of the instrument is 0.1 mm. What is the value of 1 main scale division?

33. The pitch of the screw gauge is 0.5 mm. Its circular scale contains 50 divisions. The least count of the screw gauge is 1×10^{-x} mm. Find the value of x.

34. Each side of a cube is measured to be 7.203 m. What is the total surface area of the cube to appropriate significant figures?

35. Two full turns of the circular scale of a screw gauge cover a distance of 1 mm on its main scale. The total number of divisions on the circular scale is 50. Further, it is found that the screw gauge has a zero error of – 0.03 mm. While measuring the diameter of a thin wire, a student notes the main scale reading of 3 mm and the number of circular scale divisions in line with the main scale as 35. The diameter of the wire is 1.1x. Find the value of x.

Physics Point

SOLUTIONS

Brief Explanations of Selected Questions

ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

Single Option Correct :

1. (d) Unit of volume is m^3 depends on fundamental unit length.

2. (c) $1\ nm = 10^{-9}\ m = 10^{-7}\ cm$

3. (a) SI is based on seven fundamental units.

4. (d) Tropical year is the year in which there is total solar eclipse. Light year represents distance.

5. (a) As force = change in momentum/time.
$\therefore$ force × time = change in momentum

6. (b) Charge = current × time.

7. (c) 1 light year = speed of light in vacuum × no. of seconds in one year = $(3 \times 10^8) \times (365 \times 24 \times 60 \times 60)$
$= 9.467 \times 10^{15}$ m.

8. (c) 1 Pascal = 1 N/m^2.

9. (c) Electron volt is a unit of energy &
1 eV = 1.6×10^{-19} Joule

10. (c) S.I. unit of power = watt
$\therefore$ Kilowatt is also unit of power.

11. (d)

12. (a)

13. (a) Subtraction is correct upto one place of decimal, corresponding to the least number of decimal places.
$7.26 - 0.2 = 7.06 = 7.1$ J

14. (d) Number of significant figures in multiplication is three, corresponding to the minimum number.
$107.88 \times 0.610 = 65.8068 = 65.8$

15. (d) $\frac{97.52}{2.54} = 38.393 = 38.4$ (with least number of significant figures, 3).

16. (b) Angular momentum is given by
$L = mvr$
$\therefore [L] = M.LT^{-1}.L$
$= ML^2T^{-1}$

17. (a)

18. (c) $\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{MLT^{-2}}{L^2} = [ML^{-1}T^{-2}]$

More Than One Option Correct :

19. (a, b, c, d) $\text{Strain} = \frac{\Delta \ell}{\ell_0}$

20. (b, d)

21. (a, b, c)

22. (b, c)

Multiple Matching Questions :

23. A – (r), B – (p), C – (q), D – (s)

24. A – (r, t); B – (s); C – (p, q)

25. A – (q), B – (s), C – (r), D – (p)

Passage Based Questions :

26. (b) $\because F = \frac{Gm^2}{d}$ $\therefore G = \frac{Fd}{m^2}$

27. (c)

Assertion & Reason :

28. (d) Light year measures distance.

29. (a)

30. (d)

31. (c) Relative velocity is not the ratio of velocity of two bodies.

Integer/Numeric Questions :

32. **2** $\text{L.C} = \frac{0.1}{10} = \left(1 - \frac{19}{20}\right)\text{MSD} \Rightarrow \frac{1}{100} = \frac{1}{20} \times 1\ \text{MSD}$

$\Rightarrow 1\ \text{MSD} = \frac{1}{5} \times 10 = 2$

33. **2** $\text{Least count} = \frac{0.5}{50} = 0.01\ \text{mm}$ $\therefore$ x = 2

34. **311.3** The number of significant figures in the measured length is 4. The calculated area and the volume should, therefore, be rounded off to 4 significant figures.
Surface area of the cube = $6(7.203)^2\ m^2$
$= 311.299254\ m^2 = 311.3\ m^2$

35. **3** $\text{Least count of screw gauge} = \frac{0.5}{50}\ \text{mm} = 0.01\ \text{mm}$

$\therefore$ Reading = [Main scale reading + circular scale reading × L.C] – (zero error)
$= [3 + 35 \times 0.01] - (-0.03) = 3.3\ \text{mm}$

$\therefore$ x = 3

Physics Point

Chapter

9

MOTION

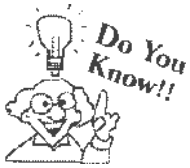
INTRODUCTION

Motion is an important part of our life. We can't perform our day-to-day activities without motion. We can't go to school without moving from our homes to our schools. We can't even take foods without moving our hands and mouths. We ride a bicycle or a car, we walk and run. Even when we are sleeping, we breathe and air moves into and out of our lungs and blood flows in arteries and veins. Trains and aeroplanes carry people from one place to the other. We observe water flowing down a dam and leaves falling from trees. The earth on which all lives exist is in motion. The sun itself is not at rest but moves in the Milky Way.

When position of an object changes we say that the object is in motion. This chapter attempts to describe motion and its different aspects. For this we develop the concepts of velocity and acceleration. To describe the motion on a straight line, called rectilinear motion, with uniform acceleration, a set of simple equations can be obtained. The chapter will also enable us the proper use of these Kinematic equations of uniformly accelerated motion.

REST AND MOTION

Rest : An object is said to be at rest if it does not change its position with respect to its surroundings with the passage of time.
Motion : A body is said to be in motion if its position changes continuously with respect to the surroundings (or with respect to an observer) with the passage of time.
We know that earth is rotating about its axis and revolving around the sun. The stationary objects like your class-room, a tree and the lamp posts etc. do not change their position with respect to each other i.e., they are at rest. Although earth is in motion, to an observer situated outside the earth say in a spaceship, your classroom, trees etc. would appear to be in motion. Therefore, all motions are relative. There is nothing like absolute motion. If you move with book in your hand, book is not moving with respect to you.
Rest and motion are relative terms.



Mechanics is the branch of physics which deals with the effect of forces on objects.
Kinematics : *It deals with the motion of objects without bothering about the cause of motion.*
Kinetics : *It deals with the motion of objects considering the cause of their motion.*

Observe like a science student : To the passengers in a moving bus or train, trees, buildings and people on the roadsides observe that the bus or the train and its passengers are moving in the forward direction. At the same time, each passenger in a moving bus or train finds that fellow passengers are not moving, as the distance between them is not changing. These observations tell us that the motion is relative. If you will observe the man moving on moving flat car from ground your observation will be different from what a man himself will observe.

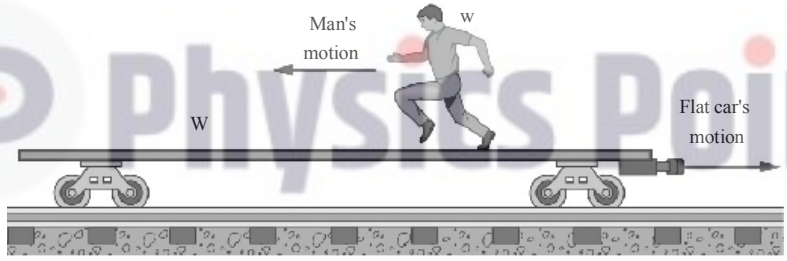


Fig. 9.1 : Man and flat car in relative motion with respect to an observer on the road.

Similarly, if you will observe pendulum in moving car from ground your observation will be different from what person inside car will observe.

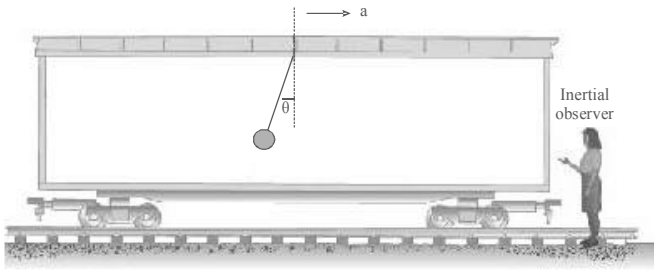


Fig. 9.2 : (a) An observer outside the car observing the motion of a pendulum.

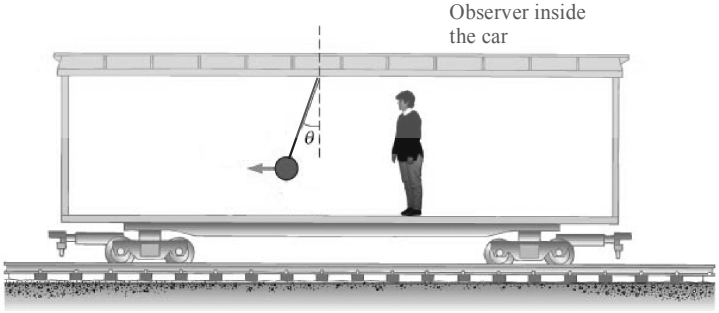
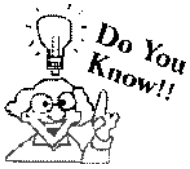


Fig. 9.2 : (b) An observer inside the car observing the motion of a pendulum.



Although you may be at rest relative to the earth's surface, you're moving about 100,000 km/h relative to the sun.

Think it Over

Two trains A and B are moving on two parallel tracks with same velocity. Are the passengers in train A moving with respect to the passengers in train B?

SCALARS AND VECTORS

Physical quantities are of two kinds. They are scalars and vectors.

Scalars : Those physical quantities which have only magnitude and no direction are called scalars. Speed, area, volume, distance etc. are some examples of scalars.

Vectors : Those physical quantities which have both magnitude and direction and follow the law of vector addition are called vectors. Velocity, acceleration, electric field intensity, force, magnetic field intensity etc. are some examples of vectors.

A physical quantity which is neither a vector nor a scalar is called a tensor e.g., moment of inertia

Physics Point

Representation of a vector : A vector is represented by a directed arrow $(\rightarrow)$ such that the length of the arrow represents the magnitude and the direction of arrow head represents the direction of the vector.

Types of vectors

(i) Negative of a vector : The negative of given vector is a vector which has direction just opposite to given vector and have same magnitude.

(ii) Zero vector or null vector : A vector with zero magnitude having no specific direction is called a zero vector .

Methods of finding a zero vector

(a) By multiplying a vector by zero we get a zero vector, i.e. $0\ (\vec{A}) = \vec{0}$

(b) By adding a negative vector to the given vector, we get a zero vector.

$$\vec{A} + (-\vec{A}) = \vec{0}$$

(iii) Equal vectors : Two or more vectors are called equal vectors if they have equal magnitude, and same direction.

$$\vec{A} = \vec{B} = \vec{C}$$

(iv) Collinear vectors : Two vectors acting along same straight line or along parallel straight lines in same direction or in opposite direction are called collinear vectors.

(v) Coplanar vectors : Three (or more) vectors are called coplanar vectors if they lie in the same plane. Two (free) vectors are always coplanar.

(vi) Unit vector

A vector having unit magnitude is called a unit vector. It is used to denote the direction of a given vector.

$\vec{A} = \hat{a} \cdot A$ $\hat{a}$ is unit vector along the direction of $\vec{A}$.

Orthogonal unit vectors : The unit vectors along the X-axis, Y-axis and Z-axis of the right-handed Cartesian coordinate system are written as $\hat{i}$, $\hat{j}$ and $\hat{k}$ respectively. These are called orthogonal unit vectors.

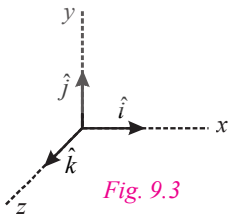


Fig. 9.3

ADDITION OF VECTORS

Vectors cannot be added according to simple rules of algebra but they are added by certain special rules known as laws of vector addition. The most important law is the parallelogram law which has been stated below.

Parallelogram Law of Vector Addition

This law is used to determine magnitude and direction of resultant vector, when two vectors act at an angle θ.

According to this law, *if two vectors* $\vec{P}$ *and* $\vec{Q}$ *are represented by two adjacent sides of a parallelogram both pointing outwards, the diagonal drawn through the intersection of the two vectors represents the resultant* $\vec{R}$.

$$\vec{R} = \vec{P} + \vec{Q}$$

The magnitude of vector $\vec{R}$ is given by

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

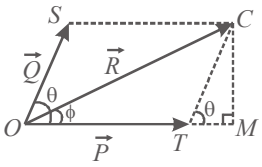


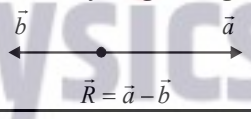
Fig. 9.4

The direction of resultant vector $\vec{R}$ is given by

$$\tan\phi = \frac{CM}{OM} = \frac{Q\sin\theta}{P + Q\cos\theta} \quad \text{or} \quad \phi = \tan^{-1}\left[\frac{Q\sin\theta}{P + Q\cos\theta}\right]$$

where ϕ is the angle made by $\vec{R}$ with $\vec{P}$.

- *Scalars ared simply numbers and hence added by ordinary laws of algebra.*
- *The sum of two vectors is always a vector.*
- *Two vectors acting along a straight line and pointing opposite to each other has a resultant in the direction of the vector of larger magnitude.*



Think it Over

Think of a physical quantity which is the product of two vectors but is a scalar.

DISTANCE AND DISPLACEMENT

Distance or Path Length

Distance is the actual length of the path. It is the characteristic property of any path i.e. path is always associated when we consider distance between two positions.

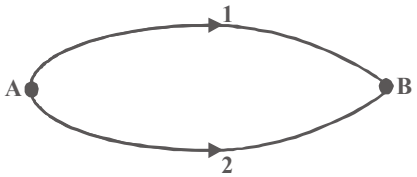


Fig. 9.5

Distance between A and B while moving through path (1) may or may not be equal to the distance between A and B while moving through path (2).

(i) It is a scalar quantity

(ii) Its dimension is $[M^0L^1T^0]$

(iii) Its unit : in C.G.S. is centimetre (cm), and in S.I. metre (m)

Displacement

It is *the shortest distance between the initial and the final positions of an object*. Its direction is taken from the initial position towards the final position.

(i) It is a vector quantity.

(ii) Its S.I. unit is metre (m) and C.G.S. unit is centimetre (cm).

Let an object starts moving from the point A and stops at C through the path ABC as shown in the figure.

Displacement of object = $\overrightarrow{AC}$

But distance covered

$= AB + BC$

$= 4\text{m} + 3\text{m} = 7\text{m}$

Magnitude of displacement

$= |\overrightarrow{AC}|$

$= \sqrt{AB^2 + BC^2}$

$= \sqrt{4^2 + 3^2} = \sqrt{25} = 5\text{m}$

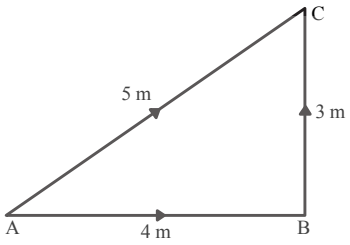


Fig. 9.6

Comparative Study of Distance and Displacement :

(i) Distance is scalar, while displacement is vector, both have same dimensions [L] and SI unit metre.

(ii) The magnitude of displacement is equal to minimum possible distance so,

Distance ≥ | Displacement |

(iii) For motion between two points displacement is single valued while distance depends on actual path and so can have many values.

(iv) For a moving particle distance can never decrease with time while displacement can. Decrease in displacement means body is moving towards the initial position.

(v) For moving particle distance can never be negative or zero, while displacement can be (zero displacement means that body after motion has come back to initial position.)

Distance > 0 but | Displacement | > = or < 0

(vi) In general, magnitude of displacement is not equal to distance. However it can be so if the motion is along a straight line without change in direction.

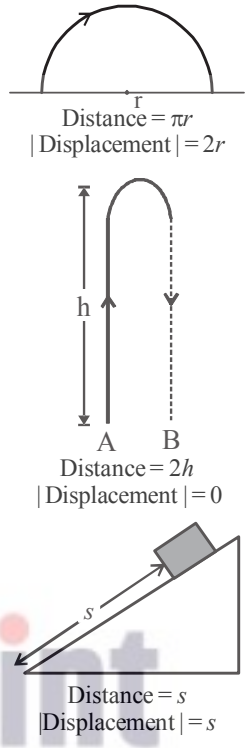


Fig. 9.7 : Different cases of distance and displacement.

Physics Point

Think it Over

- *A boy starts moving from a point in the north. After moving 5m, he turns right and travels 2m straight, after which he again turns right. Finally, he stops after travelling 5m. What is the path length, he travels? Also, find his displacement.*
- *Distance is often equal to or greater than displacement. Think an example in which both distance and displacement have equal magnitude.*

CHECK Point

A person moves from point A to point B and then from point B to point A on a circle of radius R as shown. Do the magnitudes of distance and displacement remains same or different during half cycle and full cycle? Write these magnitudes.

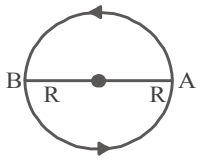


Fig.: 9.8

SOLUTION

During half cycle, distance = πR, displacement = $2R$

During full cycle, distance = $2\pi R$, displacement = 0

SPEED

Speed of an object is defined as the distance travelled in unit time.

Mathematically, $\text{Speed} = \dfrac{\text{distance travelled}}{\text{time taken}}$

It is a scalar quantity.

The **S.I. unit** of speed is metre per second (m/s or ms^{-1}) and the C.G.S. unit is centimetre per second (cm/s or cms^{-1}).

Other units : kmh^{-1} $\left(= \dfrac{5}{18} ms^{-1}\right)$; miles h^{-1} etc.

Instantaneous Speed

The speed of a particle at a particular instant of time is called its instantaneous speed.

A cheetah can maintain a very high speed but only for a short time.

CHECK Point

"Priya moves at a constant speed in a constant direction." Say the same sentence in fewer words.

SOLUTION

"Priya moves at constant velocity".

Note : A cheetah can maintain a very high speed but only for a short time.

Average Speed

The average speed of an object is defined as the total distance covered to the total time taken to cover that distance.

Mathematically, Average speed $= \dfrac{\text{total distance}}{\text{total time}}$ or $\bar{v} = \dfrac{s}{t}$

Note : If any car covers distances $x_1, x_2, \ldots\ldots x_n$ in the time intervals $t_1, t_2, \ldots\ldots t_n$ then $\bar{v} = \dfrac{x_1 + x_2 + x_3 + \ldots\ldots + x_n}{t_1 + t_2 + \ldots\ldots + t_n}$

Some important cases related to average speed :

Case : 1

If a car covers distances x_1, x_2, and x_3 with speeds v_1, v_2, and v_3 respectively in same direction then average speed of cars

$$\bar{v} = \frac{x_1 + x_2 + x_3}{t_1 + t_2 + t_3} \; ;$$

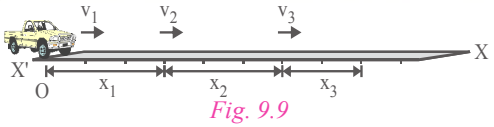


Fig. 9.9

Here, $t_1 = \dfrac{x_1}{v_1}$, $t_2 = \dfrac{x_2}{v_2}$, $t_3 = \dfrac{x_3}{v_3}$; $\bar{v} = \dfrac{x_1 + x_2 + x_3}{\frac{x_1}{v_1} + \frac{x_2}{v_2} + \frac{x_3}{v_3}}$

If car covers equal distances with different speeds then, $x_1 = x_2 = x_3 = x$

$$\bar{v} = \frac{3x}{\frac{x}{v_1} + \frac{x}{v_2} + \frac{x}{v_3}} = \frac{3}{\frac{1}{v_1} + \frac{1}{v_2} + \frac{1}{v_3}} = \frac{3v_1v_2v_3}{v_1v_2 + v_2v_3 + v_3v_1}$$

Case : 2

If any body travels with speeds v_1, v_2, v_3 during time intervals t_1, t_2, t_3 respectively then the average speed of the body will be

$$\bar{v} = \frac{x_1 + x_2 + x_3}{t_1 + t_2 + t_3} = \frac{v_1t_1 + v_2t_2 + v_3t_3}{t_1 + t_2 + t_3}$$

If $t_1 = t_2 = t_3 = t = \dfrac{(v_1 + v_2 + v_3) \times t}{3 \times t} = \dfrac{(v_1 + v_2 + v_3)}{3}$

Average speed is also measured in the same unit as that of instantaneous speed.

Think it Over

If you get a traffic ticket for speeding, is it because of your instantaneous speed or your average speed?

Uniform Speed

An object is said to be moving with a uniform speed if it covers equal distances in equal intervals of time, how so ever small these intervals may be. The uniform speed is shown by straight line in distance-time graph.
Let us consider a car which covers 5m in first second of its motion. In next second, it covers again 5m and so in further seconds. So, in every interval of time, it covers equal distance. Hence, its speed is uniform.

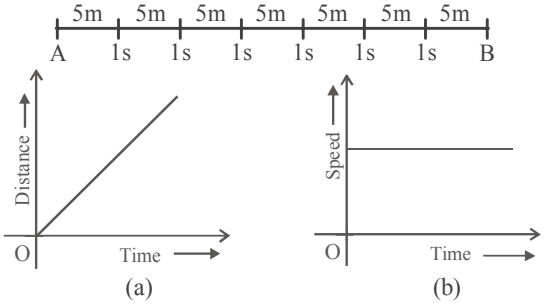


Fig. 9.10

Note : Uniform speed indicates that the instantaneous speed of particle remains the same throughout the motion.

Non-Uniform (or variable) Speed

An object is said to be moving with a non-uniform speed if it covers equal distances in unequal intervals of time or unequal distances in equal intervals of time, howsoever small these intervals may be.

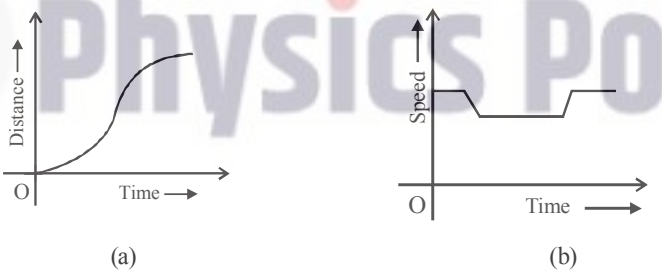


Fig. 9.11

When a particle moves from time t_1 to t_2 with uniform speed v as shown in the graph; the distance covered,

$$s = v(t_2 - t_1)$$

$$= AB \times AD$$

= Area of rectangle $ABCD$

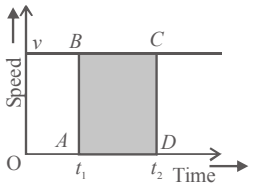
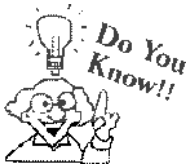


Fig. 9.12

$\therefore$ Total distance travelled by particle = area of speed-time graph.



- *In uniform motion on a straight line distance and displacement are equal.*
- *No net force is required for an object to be in uniform motion.*

Think it Over

A particle moving on a circular track of radius 7m takes 11 second to make one trip. What is the average speed of the particle?

ILLUSTRATION : 1

Find the distance travelled by the particle during the time $t = 0$ to $t = 3$ sec. from the figure.

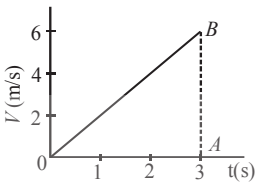


Fig. 9.13

SOLUTION :

$$\text{Distances} = \text{area of } \Delta OAB = \frac{1}{2} \times OA \times BA = \frac{1}{2} \times 3 \times 6 = 9 \text{ metre}$$

ILLUSTRATION : 2

What is the average speed of a cheetah that sprints 100 m in 4 seconds? How about if it sprints 50 m in 2 s?

SOLUTION :

In both cases, the answer is 25 m/s

$$\text{Average speed} = \frac{\text{total distance covered}}{\text{travelled time}} = \frac{100 \text{ metres}}{4 \text{ seconds}} = \frac{50 \text{ metres}}{2 \text{ seconds}} = 25 \text{ m/s}$$

ILLUSTRATION : 3

If a car travels at an average speed of 60 km/h for an hour, it will cover a distance of 60 km. (a) How far would it travel if it moved at this rate for 4 h? (b) For 10 h?

SOLUTION :

The distance travelled is the average speed × time of travel, so

(a) Distance = 60 km/h × 4h = 240 km

(b) Distance = 60 km/h × 10h = 600 km

Physics Point

CHECK Point

1. **In addition to the speedometer on the dashboard of every car, there is an odometer, which records the distance travelled. If the initial reading is set at zero at the beginning of a trip and the reading is 40 km one-half hour later, what was the average speed?**
2. **Would it be possible to attain this average speed and never go faster than 80 km/h?**

SOLUTION

1. $$\text{Average speed} = \frac{\text{total distance covered}}{\text{travelled time}} = \frac{40 \text{ km}}{0.5 \text{ h}} = 80 \text{ km/h}$$

2. No, not if the trip starts from rest and ends at rest. During the trip, there are times when the instantaneous speeds are less than 80 km/h, so the driver must at some time drive faster than 80 km/h in order to average 80 km/h. In practice, average speeds are usually much less than high instantaneous speeds.

VELOCITY

The rate of change of displacement of a particle with time is called the velocity of the particle.

i.e. $\text{Velocity} = \frac{\text{displacement}}{\text{time interval}}$

It is a vector quantity.

Its **S.I.** unit is meter per second (m/s or ms^{-1}).

Instantaneous Velocity

The velocity of the object at a given instant of time or at a given position during motion is called instantaneous velocity.

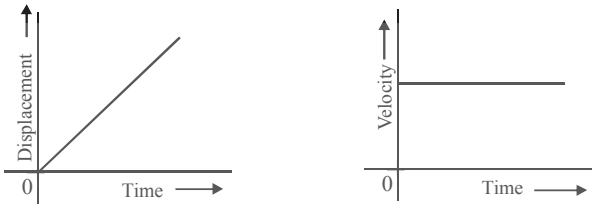
Average Velocity

The average velocity of an object is equal to the ratio of the displacement, to the time interval for which the motion takes place *i.e.*,

$$\text{average velocity} = \frac{\text{displacement}}{\text{time taken}}$$

Uniform Velocity

A body is said to move with uniform velocity, if it covers equal displacements in equal intervals of time, howsoever, small these intervals may be.

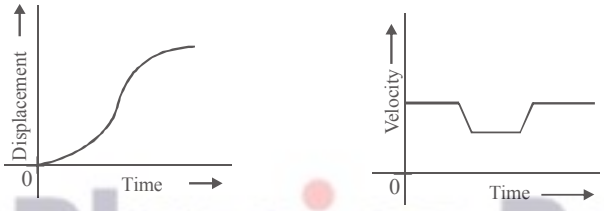


(a) (b)

Fig. 9.14 : Uniform velocity

Non-uniform Velocity

The particle is said to have non-uniform velocity if it covers unequal displacements in equal intervals of time, howsoever, small these time intervals may be. In this type of motion, velocity does not remain constant.



(a) (b)

Fig. 9.15 : Non-uniform velocity

Physics Point

The slope of displacement-time graph gives the instantaneous velocity.

Think it Over

Fig. 9.16

Although the car can maintain a constant speed along the circular track, it cannot maintain a constant velocity. Why?

ILLUSTRATION : 4

A car travels a distance A to B at a speed of 40 km/h and returns to A at a speed of 30 km/h.

(i) What is the average speed for the whole journey?

(ii) What is the average velocity?

SOLUTION :

(i) Let $AB = s$, time taken to go from A to B, $t_1 = \frac{s}{40}$ h and time taken to go from B to A, $t_2 = \frac{s}{30}$ h

$\therefore$ Total time taken $= t_1 + t_2 = \frac{s}{40} + \frac{s}{30} = \frac{(3+4)s}{120} = \frac{7s}{120}$ h

Total distance travelled $= s + s = 2s$

$\therefore$ Average speed $= \frac{\text{total distance travelled}}{\text{total time taken}} = \frac{2s}{\frac{7s}{120}} = \frac{120 \times 2}{7} = 34.3$ km/h.

(ii) Total displacement = zero, since the car returns to the original position.

Therefore, average velocity $= \frac{\text{total displacement}}{\text{time taken}} = \frac{0}{2t} = 0$

ACCELERATION

Most moving things usually experience variations in their motion. We say they undergo acceleration. It is defined as the rate of change of velocity with time.

Mathematically, Acceleration $= \frac{\text{change in velocity}}{\text{time interval}}$

Fig. 9.17 : Increasing speed (Acceleration)

The Greek letter Δ (delta) is often used for "change in" or "difference in". In this notation

Acceleration, $a = \frac{\Delta v}{\Delta t}$

Where, Δv = change in velocity and Δt = change in time

When a car makes a turn, even if its speed does not change, it is accelerating. Can you say why? Acceleration occurs because the car's direction is changing. Acceleration refers to a change in velocity. So acceleration involves a change in speed, a change in direction, or a change in both speed and direction.

(i) It is a vector quantity.
(ii) It is positive if the velocity is increasing and is negative if the velocity is decreasing.
(iii) The negative acceleration is also called retardation or deceleration.
(iv) Its unit in **S.I. system** m/s^2; In C.G.S. system cm/s^2
(v) Dimensions : $[M^0LT^{-2}]$

Fig. 9.18 : Decreasing speed (Deceleration)\

Change in direction

Fig. 9.19 : A body undergoes acceleration when there is a change in its state of motion

CHECK Point

At a given instant of time, a car and a truck are travelling side by side in adjacent lanes of a highway. The car has a greater velocity than the truck. Does the car necessarily have a greater acceleration? Explain.

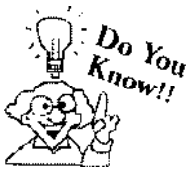
SOLUTION

The acceleration of an object is the rate at which its velocity is changing. No information can be gained concerning the acceleration of an object if all that is known is the velocity of the object at a single instant. No conclusion can be reached concerning the accelerations of the two vehicles, so the car does not necessarily have a greater acceleration.

Average Acceleration

When an object is moving with a variable acceleration, then the average acceleration of the object for the given motion is defined as the ratio of the total change in velocity of the object during motion to the total time taken

i.e., Average acceleration $= \frac{\text{total change in velocity}}{\text{total time taken}}$



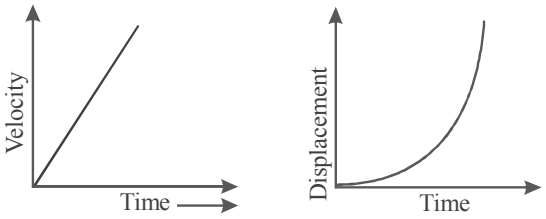
- *An object moving towards south can have acceleration towards north.*
- *If a body travels with a uniform acceleration a_1 for time t_1 and with uniform acceleration a_2 for time t_2, then average acceleration is given by* $a = \frac{a_1t_1 + a_2t_2}{t_1 + t_2}$

Instantaneous Acceleration

The acceleration of the object at a given instant of time or at a given point of motion, is called its instantaneous acceleration.

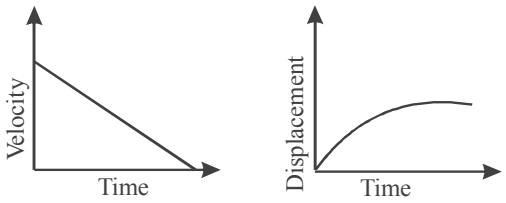
Uniform Acceleration

An object is said to be moving with a uniform acceleration if its velocity changes by equal amount in equal intervals of time.



(a) (b)

Fig. 9.20 : Uniformly accelerated motion



(a) (b)

Fig. 9.21 : Uniformly retarded motion

Note : (i) Slope of *v-t* graph gives the acceleration.

(ii) Area under the *v-t* graph gives the displacement of the body.

Non-uniform or Variable Acceleration

An object is said to be moving with a variable acceleration if its velocity changes by unequal amount in equal intervals of time.

A car has three controls that change velocity - the gas pedal (accelerator), the brakes and the steering wheel?

Physics Point

Think it Over

- *An apple falling down from its tree is acted upon by an acceleration produced by gravity. Whether this acceleration is uniform or variable?*
- *The velocity of a body is zero, does it mean that acceleration is always zero?*
  The acceleration of a body is zero, does it mean that velocity is also zero?

CHECK Point

An object moving with a constant acceleration can certainly slow down. But can an object ever come to a permanent halt if its acceleration truly remains constant? Explain.

SOLUTION

An object moving with a constant acceleration will slow down if the acceleration vector points in the opposite direction to the velocity vector; however, if the acceleration remains constant, the object will never come to a permanent halt. As time increases, the magnitude of the velocity will get smaller and smaller. At some time, the velocity will be instantaneously zero. If the acceleration is constant, however, the velocity vector will continue to change at the same rate. An instant after the velocity is zero, the magnitude of the velocity will begin increasing in the same direction as the acceleration. As time increases, the velocity of the object will then increase in the same direction as the acceleration. In other words, if the acceleration truly remains constant, the object will slow down, stop for an instant, reverse direction and then speed up.

ILLUSTRATION : 5

In 2.0 seconds, a car increases its speed from 60 km/h to 65 km/h while a bicycle goes from rest to 5 km/h. Which has the greater acceleration?

SOLUTION :

Both have the same acceleration, since both gain the same amount of speed in the same time. Both accelerate at 2.5 km/h.

ILLUSTRATION : 6

A cheetah can accelerate from 0 to 96 km/h in 2 sec., where as a cat requires 6 sec. Compute the average acceleration for the cheetah and cat.

SOLUTION :

For cheetah $|\vec{a}_{av}| = \frac{|\vec{v}_f - \vec{v}_i|}{\Delta t} = \frac{96\text{km/h} - 0}{2\,\text{sec}} = \frac{96 \times \frac{1000m}{3600\,\text{sec}}}{2\,\text{sec}} = 15\text{m/s}^2$

For cat $|\vec{a}_{av}| = \frac{96 \times \frac{10}{36}}{6} = 5\text{m/s}^2$

ILLUSTRATION : 7

The speed of a car as a function of time as shown in fig. Find the acceleration and distance travelled by the car in 8 seconds.

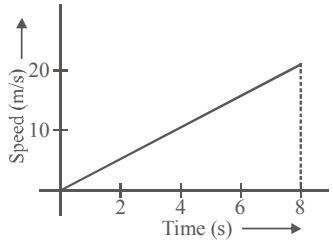


Fig. 9.22

SOLUTION :

Distance travelled = area under speed - time graph

$= \frac{1}{2} \times 20 \times 8 = 80\text{ m}$

Acceleration, $a = \frac{\Delta v}{\Delta t} = \frac{20}{8} = \frac{5}{2} = 2.5\text{ m/s}^2$

Physics Point

EQUATIONS OF MOTION

If a body moves with uniform (or constant) acceleration, the following equations describe the motion.

(1) **Velocity-time relation**

$v = u + at$

(2) **Position-time relation**

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

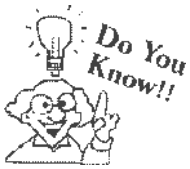
(3) **Velocity-position relation**

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

(4) **Distance travelled in nth second of uniformly accelerated motion**

$s_n^{th} = u + \frac{a}{2}(2n - 1)$

Where, u = initial velocity v = final velocity s = distance covered
n = time taken a = constant acceleration



Equations of motion are used only for constant acceleration.

ILLUSTRATION : 8

A body with an initial velocity of 18 km/h accelerates uniformly at the rate of 9 cm s^{-2} over a distance of 200m. Calculate :

(a) the acceleration in ms^{-2}. (b) its final velocity in ms^{-1}

SOLUTION :

(a) Acceleration = 9 cm $s^{-2} = \frac{9}{100}\text{ms}^{-2} = 0.09\text{ ms}^{-2}$

(b) Initial velocity $u = 18 \text{ km } h^{-1} = \dfrac{18000\text{m}}{60 \times 60\text{s}} = 5 \text{ ms}^{-1}$

Acceleration, $a = 0.09 \text{ ms}^{-2}$ and distance $s = 200\text{m}$

From equation of motion $v^2 = u^2 + 2as$

$v^2 = (5)^2 + 2 \times 0.09 \times 200$

or $v^2 = 25 + 36 = 61 \quad \therefore \; v = \sqrt{61} = 7.81 \text{ ms}^{-1}$.

Thus, final velocity $= 7.81 \text{ ms}^{-1}$.

ILLUSTRATION : 9

A body covers a distance of 20m in the 7th second and 24m in the 9th second. How much distance shall it cover in 15th sec.

SOLUTION :

As we know, distance twravelled in nth second, $S_{nth} = u + \dfrac{a}{2}(2n-1)$

$s_7th = u + \dfrac{a}{2}(2 \times 7 - 1)$ but $s_7th = 20\text{m}$

$\therefore \quad 20 = u + \dfrac{a}{2} \times 13 \Rightarrow 20 = u + \dfrac{13a}{2}$ ...(1)

Also $s_9th = 24\text{m}$ $\therefore \; 24 = u + \dfrac{17a}{2}$ ...(2)

From equation(1), $u = 20 - \dfrac{13a}{2}$ ...(3)

Substitute this value in eq. (2)

$24 = 20 - \dfrac{13a}{2} + \dfrac{17a}{2}$

$\Rightarrow \quad 24 - 20 = \dfrac{17a}{2} - \dfrac{13a}{2}$

$4 = \dfrac{4a}{2} \quad \Rightarrow \quad 4 = 2a \; \Rightarrow \; a = \dfrac{4}{2} = 2 \text{ m/s}^2$

Use this value in eq. (3) $u = 20 - \dfrac{13a}{2}$

$\therefore \quad u = 20 - \dfrac{13 \times 2}{2} \Rightarrow u = 20 - 13 = 7 \text{ m/s}$

Now, $s_{15}\text{th} = u + \dfrac{a}{2}(2 \times 15 - 1) = 7 + \dfrac{2}{2}(29) = 7 + 29 = 36 \text{ m}$

Physics Point

MOTION UNDER GRAVITY

When a body moves under the action of gravity only, its motion is said to be motion under gravity. The body can either move upward or downward. During the motion under gravity, a constant acceleration, known as acceleration due to gravity acts on the body in vertically downward direction. Its value is taken to be 9.8 m/s^2 and is represented by g.

Vertically downward motion

For vertically downward motion, g is taken to be positive. Therefore, equations of motion reduce to

(i) $v = u + gt$ (ii) $h = ut + \dfrac{1}{2} g t^2$

(iii) $v^2 = u^2 + 2gh$ (iv) $h_n th = u + \dfrac{g}{2}(2n-1)$

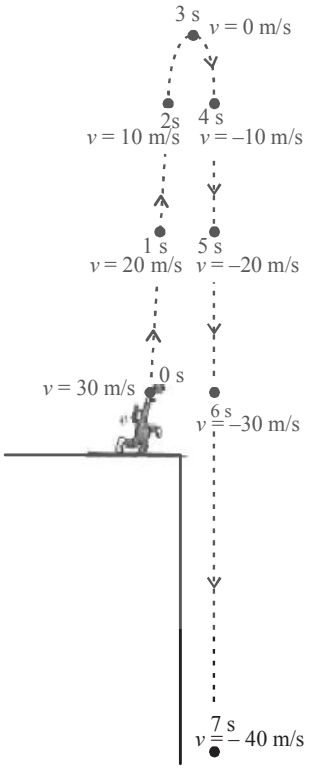


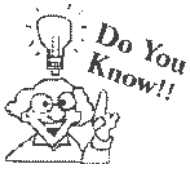
Fig. 9.23 : The rate at which velocity changes each second is the same.

Vertically upward motion

For vertically upward motion, g is taken to be negative. Therefore, equations of motion reduce to

(i) $v = u - gt$ (ii) $h = ut - \frac{1}{2} g t^2$ (iii) $v^2 = u^2 - 2gh$ (iv) $h_n{}^{th} = u - \frac{g}{2}(2n-1)$

Remember : The rate at which the velocity changes each second during upward motion is equal but opposite to the rate during downward motion.



- *A body dropped from a height H reaches the ground after time T given by* $T = \sqrt{\frac{2H}{g}}$
- *A body dropped from a height H reaches the ground with a velocity* $v = \sqrt{2gh}$

CHECK Point

A ball is thrown straight up with enough speed so

that it is in the air for several seconds. What is

(a) the velocity of the ball when it reaches its highest point?

(b) its velocity 1 s before it reaches its highest point?

(c) the change in its velocity during this 1s interval?

(d) its velocity 1 s after it reaches its highest point?

(e) the change in velocity during this 1s interval?

(f) the change in velocity during the 2s interval from 1st before the highest point to 1s after the highest point? (Caution : we are asking for velocity, not speed.)

(g) the acceleration of the ball during any of these time intervals and at the moment the ball has zero velocity?

Physics Point

SOLUTION

(a) Since the ball is moving upwards against the acceleration due to gravity (which acts downwards) so its velocity gradually decreases. Finally at its highest point the velocity of the ball becomes zero, acting downwards.

(b) The speed of an object moving vertically upwards decreases by an amount of 10 m/s each second. Also, at the highest point, the speed is zero. Therefore, the velocity of the ball, 1s before it reaches the highest point, will be 10 m/s.

(c) Change in velocity in 1s interval

= Final velocity – initial velocity

= 0 – 10 = – 10 m/s

The negative sign indicates velocity is decreasing.

(d) After the ball reaches to its highest point, it will come downwards due to gravitational force. Its speed increases by an equal amount of 10 m/s each second. Hence, the velocity of the ball 1s after it reaches its highest point is 10 m/s, acting vertically downward.

(e) Change in velocity in the 1s interval = final velocity – initial velocity

= 10 – 0 = 10 m/s.

(f) The ball will be at the same point before and after 1s the highest point with velocity of 10 m/s acting vertically upward and downward respectively. Therefore, change in velocity

= 10–(–10) (m/s) = 20 m/s.

(g) Acceleration of the ball is always equal to acceleration due to gravity that is acting downwards.

ILLUSTRATION : 10

A stone is dropped from a tower such that it strikes the ground after 4 seconds. Find the height of the tower.

SOLUTION :

Here, $u = 0$; $g = 9.8\ ms^{-2}$

$t = 4s$; $h = ?$

We have, $h = ut + \frac{1}{2} g t^2$

$= (0 \times 4) + \frac{1}{2} \times 9.8 \times (4)^2$

$= 78.4\ m$

$\therefore$ Height of the tower is 78.4 m

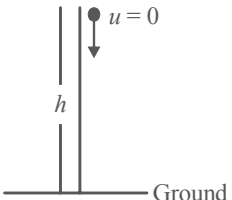


Fig. 9.24

ILLUSTRATION : 11

A ball is dropped from a building of height 50m. Find the time taken to fall through this height.

SOLUTION :

Here, $u = 0$; $h = 50\ m$

$g = 9.8\ ms^{-2}$; $t = ?$

We have, $h = ut + \frac{1}{2} g t^2$

$= \frac{1}{2} g t^2 \quad (\because u = 0)$

$\therefore \quad t = \sqrt{\frac{2h}{g}}$

$= \sqrt{\frac{2 \times 50}{9.8}} = 3.1$ sec.

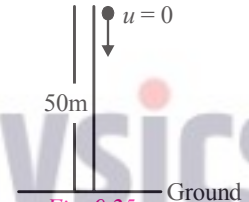


Fig. 9.25

Hence, time taken to fall through the height is 3.1 sec.

Physics Point

SUMMARY

- **Rest and motion :** If position of an object does not change with time then the object is said to be at rest. But if the position of an object changes with time then it is said to be in motion. Rest and motion are relative term.
- **Distance and displacement :** The total length of the path followed by an object to travel from one point to another is called the **distance travelled** by the object. It is a scalar. The distance travelled by an object in a particular direction is called the **displacement** of object. The SI unit of both distance and displacement is metre (m).
- **Scalars and vectors :** Quantities having only magnitudes are called **scalars**, e.g. area, speed, volume, density etc. Quantities having both magnitudes and directions are called vectors, e.g. velocity, acceleration, force etc.
- **Speed and velocity :** The rate of change of position with respect to time is called speed. It is a scalar.

  The rate of change of position with respect to time in a particular direction is called velocity. It is a vector.

  Both speed and velocity have S.I. units metre per second (ms^{-1}).
- **Acceleration and retardation :** The rate of change of velocity with respect to time is called **acceleration**. It is a vector. Its unit is metre per second square (m/s^2 or ms^{-2}). Negative acceleration is called **retardation**.
- **The slope of position-time graph** gives the average velocity.
- **The slope of velocity-time graph** gives the average acceleration. For uniform motion, acceleration is zero and the *x-t* graph is a straight line inclined to the time axis and the *v-t* graph is a straight line parallel to the time axis.
- **The area under velocity-time graph** gives the displacement of the object.
- **Kinematic equations of motion :** For objects in uniformly accelerated rectilinear motion, the five quantities, displacement s, time taken t, initial velocity u, final velocity v, and acceleration a are related by a set of equations called **kinematic equations of motion**. These are

  (i) $v = u + at$ (ii) $s = ut + \frac{1}{2}at^2$ (iii) $v^2 = u^2 + 2as$

- **Distance travelled in nth second :** $S_{nth} = u + \frac{a}{2}(2n - 1)$
- **Motion under gravity :** The motion of an object acted upon by gravity is called **motion under gravity**.

  The equations of motion in this case are

  (i) $v = u + gt$ (ii) $h = ut + \frac{1}{2}gt^2$ (iii) $v^2 = u^2 + 2gh$

  where, g is acceleration due to gravity and h is the height attained by the object.

  If object is falling vertically downward then g is taken as positive, whereas for objects moving vertically upward, g is taken as negative.

Physics Point

ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

Single Option Correct :

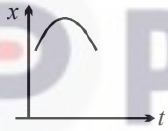
DIRECTIONS (Qs. 1–22) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. A person travels along a straight road for half the distance with velocity v_1 and the remaining half distance with velocity v_2 . The average velocity is given by

(a) $v_1 v_2$ (b) $\frac{v_2^2}{v_1^2}$

(c) $\frac{v_1 + v_2}{2}$ (d) $\frac{2v_1 v_2}{v_1 + v_2}$

2. Displacement-time curve for a particle moving a straight line is shown.



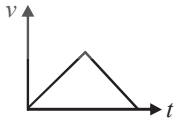
(a) particle has positive acceleration in initial and negative acceleration in later part of motion
(b) particle has negative acceleration in initial and positive acceleration in later part of motion
(c) particle has negative acceleration during whole course of motion
(d) particle has positive acceleration during whole course of motion

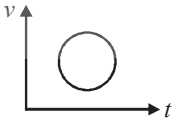
3. The numerical ratio of displacement to distance for a moving object is
(a) always less than 1 (b) always equal to 1
(c) always more than 1 (d) equal to less than 1

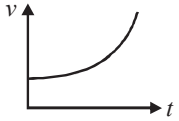
4. The numerical ratio of average velocity to average speed is
(a) always less than one (b) always equal to one
(c) always more than one (d) equal to or less than one

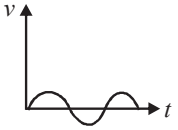
5. The distance travelled by a body is directly proportional to the time taken. Its speed
(a) increases (b) decreases
(c) becomes zero (d) remains constant

6. Which of the following curves do not represent motion of a body

(a) 

(b) 

(c) 

(d) 

7. Choose the correct statements from the following
(a) The magnitude of instantaneous velocity of a particle is equal to its instantaneous speed
(b) The magnitude of the average velocity in an interval is equal to its average speed in that interval.
(c) It is possible to have a situation in which the speed of the particle is never zero but the average speed in an interval is zero.
(d) It is possible to have a situation in which the speed of particle is zero but the average speed is not zero.

8. Which of the following can be zero, when a particle is in motion for some time?
(a) distance (b) displacement
(c) speed (d) none of them

9. Which of the following is not an example of linear motion?
(a) an aeroplane moving on a straight track with increasing speed
(b) a body in uniform circular motion
(c) wheel rotating at uniform speed on road
(d) a body rolling down an inclined plane

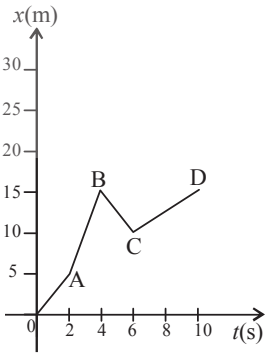
10. The slope of velocity-time graph for motion with uniform velocity is equal to
(a) final velocity (b) initial velocity
(c) zero (d) none of the above

11. If a ball is thrown vertically upwards with a velocity of 40 m/s, then velocity of the ball after two seconds is : ($g = 10\ m/sec^2$)
(a) 15 m/s (b) 20 m/s
(c) 25 m/s (d) 28 m/s

12. The acceleration of a moving body can be found from
(a) area under velocity - time graph
(b) area under distance -time graph
(c) slope of the velocity- time graph
(d) slope of distance-time graph

13. From the *x-t* graph, one can draw the following conclusions

A : $v_{OA} < v_{AB}$
B : v_{BC} is negative
C : v_{CD} is the least by magnitude
D : acceleration is uniform
(a) Only A is correct
(b) Only B and C are correct
(c) Only A , B and C are correct
(d) Only D is correct



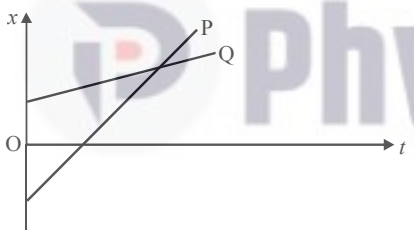
Physics Point

14. Two bodies of different masses say 1 kg and 5kg are dropped simultaneously from a tower. They will reach the ground
(a) simultaneously
(b) the heavier one arriving earlier
(c) the lighter one arriving earlier
(d) cannot say, the information is insufficient.

15. The initial velocity of the particle is 10 m/sec and its retardation is 2m/sec^2. The distance moved by the particle in 5th second of its motion is
(a) 1m (b) 19m
(c) 50m (d) 75m

16. For a body moving in a straight line, there can be situations with
A : $v = 0,\ a \neq 0$
B : $a = 0,\ v \neq 0$
(a) Only A is correct
(b) Only B is correct
(c) Both A and B are correct
(d) Both are incorrect.

17. Fig shows the time-displacement curve of the particles P and Q. Which of the following statement is correct?



(a) Both P and Q move with uniform equal speed
(b) P is accelerated Q is retarded
(c) Both P and Q move with uniform speeds but the speed of P is more than the speed of Q
(d) Both P and Q move with uniform speeds but the speed of Q is more than the speed of P.

18. The acceleration of a body found from the v-t graph which is parallel to the time axis is
(a) >0 (b) <0
(c) $=0$ (d) cannot be found

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

20. For a body which has turned by 300° in a circle of radius r,
(a) distance travelled is $\frac{5}{3}\pi r$
(b) acceleration is constant
(c) both (a) and (b)
(d) only (a)

21. A passenger in a moving train tosses a coin. If the coin falls behind him, the train must be moving with
(a) an acceleration (b) a deceleration
(c) a uniform speed (d) any of the above

22. A ball thrown vertically upward returns to its starting point in 4s. Its initial speed is
(a) 23.6 m/s (b) 6 m/s
(c) 19.6 m/s (d) zero

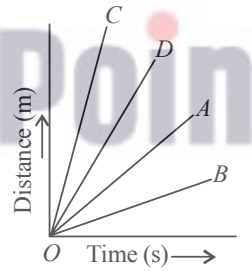
More than One Option Correct :

DIRECTIONS (Qs. 23–29): *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

23. If the velocity of a body is reducing, it is said to have
(a) negative acceleration (b) retardation
(c) positive acceleration (d) zero acceleration

24. The direction of motion of a body is decided by _____ of the body
(a) velocity (b) acceleration
(c) displacement (d) speed

25. Four cars *A*, *B*, *C* and *D* are moving on a levelled road. Their distance versus time graphs are shown in figure. Choose the correct statement



(a) Car *A* is faster than car *D*
(b) Car *B* is the slowest.
(c) Car *C* is faster than car *D*.
(d) Car *C* is the lowest.

26. A train covers equal displacements in equal intervals of time then it moves with
(a) uniform acceleration (b) uniform motion
(c) uniform speed (d) uniform velocity

27. A body having zero speed
(a) is always under rest
(b) has zero acceleration
(c) has uniform acceleration
(d) always under motion

28. A velocity-time graph gives
(a) the distance (b) the displacement
(c) the acceleration (d) the speed

29. A person seated in a train under motion, is at rest with reference to
(a) the train
(b) a person watching him from the front seat
(c) a car moving in the opposite to the train
(d) trees on the ground

Physics Point

Multiple Matching Questions :

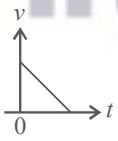
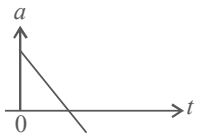
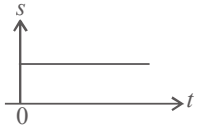
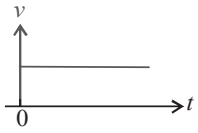
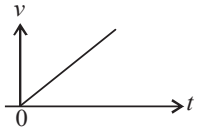
DIRECTIONS (Qs. 30-35) : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r and s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

Match the Column I and II.

30.

Column I	Column II
(A) Distance travelled by a body	(p) zero acceleration
(B) Uniform velocity	(q) scalar
(C) Speedometer	(r) instantaneous speed
(D) Height of a vertically thrown body	(s) $\frac{u^2}{2g}$
	(t) $ut + \frac{1}{2}at^2$

31.

Column I	Column II
(A) Decreasing acceleration at steady rate	(p) 
(B) A body at rest	(q) 
(C) Uniform velocity	(r) 
(D) Constant motion	(s) 
	(t) 

32.

Column I	Column II
(A) Physical quantity whose unit is cm s^{-2} in CGS system	(p) Linear motion
(B) Negative acceleration	(q) Zero
(C) Motion exhibited by body moving in a straight line	(r) Distance
(D) Area under a speed time graph	(s) Acceleration
(E) Velocity of an upward throwing body at the pick point	(t) Retardation

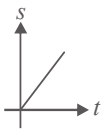
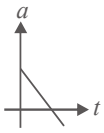
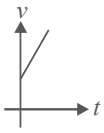
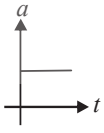
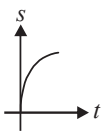
33.

Column I	Column II
(A) s_n	(p) m/s^2
(B) $v^2 - u^2$	(q) $\frac{u+v}{t}$
(C) Average speed	(r) $2gh$
(D) Acceleration	(s) $u+\frac{a}{2}(2n-1)$

34.

Column I	Column II
(A) Zero acceleration	(p) Retardation
(B) Velocity time graph	(q) Speed
(C) Speed in a direction	(r) Constant motion
(D) Acts in opposite direction of motion	(s) Acceleration
(E) Slope of a distance time graph	(t) Velocity

35.

Column I	Column II
(A) Uniform retardation	(p) 
(B) Uniform velocity	(q) 
(C) Uniform acceleration with initial velocity	(r) 
(D) Uniform acceleration	(s) 
(E) Decreasing acceleration at steady rate.	(t) 

Physics Point

Passage Based Questions :

DIRECTIONS (Qs. 36–46) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH-I

A subway train starting from rest along a straight track has a uniform acceleration of 1.8 m/s^2 for the first 20m it travels.

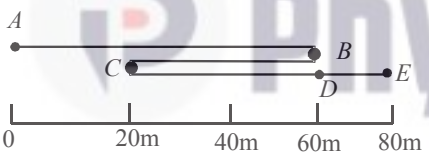
36. Calculate its speed when it has travelled 10m.
(a) 6.0 m/s (b) 8.5 m/s
(c) 3.0 m/s (d) 5.0 m/s

37. When it has travelled 20m, will its speed be less than double, double, or more than double its speed at 10m ?
(a) less than double (b) double
(c) more than double (d) None of these

38. Calculate its speed when it has travelled 20m
(a) 6.0 m/s (b) 8.5 m/s
(c) 3.0 m/s (d) 5.0 m/s

PARAGRAPH-II

A walker follows the path from A to E (figure) over an 80s time interval. Now answer the following questions –



39. What total distance does the walker cover between A and E?
(a) 160m (b) 80m
(c) 20m (d) 40m

40. What is the walker's total displacement between A and E ?
(a) 160m (b) 80m
(c) 20m (d) 40m

41. What is the walker's average velocity between A and E ?
(a) 16 m/s (b) 8 m/s
(c) 2 m/s (d) 1 m/s

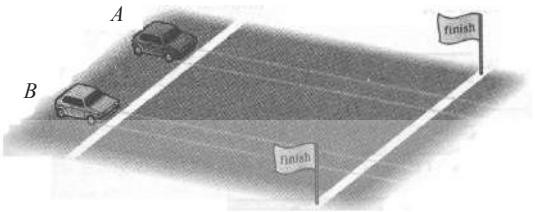
42. What is the walker's average speed between A and E ?
(a) 16 m/s (b) 8 m/s
(c) 2 m/s (d) 1 m/s

43. What is the walker's average velocity between points B and D ?
(a) 16 m/s (b) 8 m/s
(c) 0 m/s (d) 1 m/s

44. What is the walker's average speed between B and D ?
(a) 16 m/s (b) 8 m/s
(c) 2 m/s (d) 1 m/s

PARAGRAPH-III

The two cars in figure start from rest at $t = 0$ and each accelerates at a constant rate until it crosses the finish line. If car A takes 20% longer than car B to cross the finish line,



45. How do the speeds at which the two cars cross the finish line compare ? v_A = ... v_B. (Write the correct numerical multiplier in the blank).
(a) 0.83 (b) 0.69
(c) 0.31 (d 0.20

46. How to the acceleration of the two cars compare ? a_A = ... a_B. (Write the correct numerical mulitplier in the blank).
(a) 0.83 (b) 0.20
(c) 0.11 (d) 0.69

Assertion & Reason :

DIRECTIONS (Qs. 47–52) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

47. **Assertion :** A particle starting from rest and moving with uniform acceleration travels' a length of x and 3x in first two and next two-seconds.
Reason : Displacement is directly proportional to velocity.

48. **Assertion :** A body is momentarily at rest when it reverses the direction.
Reason : A body cannot have acceleration if its velocity is zero at a given instant of time.

49. **Assertion :** Two balls of different masses are thrown vertically upward with same speed. They will pass through their point of projection in the downward direction with the same speed.
Reason : The maximum height and downward velocity attained at the point of projection are independent of the mass of the ball.

50. **Assertion :** Snow flakes and raindrops fall to earth with a uniform velocity.
Reason : All freely falling objects have zero weight.

51. **Assertion :** Velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to the time axis.
Reason : In uniform motion of an object velocity increases as the square of time elapsed.

52. **Assertion :** A positive acceleration can be associated with a 'slowing down' of the body.
Reason : The origin and the positive direction of an axis are a matter of choice.

Integer/ Numerical Questions :

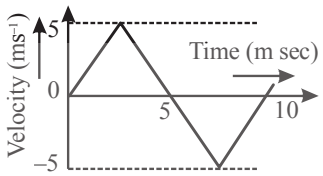
DIRECTIONS (Qs. 53 - 58) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

53. A particle moves for 20 seconds with velocity 3 m/s and then with velocity 4 m/s for another 20 seconds and finally moves with velocity 5 m/s for next 20 seconds. Find the average velocity of the particle.

54. A car moves for half of its time at 80 km/h and for rest half of time at 40 km/h. Total distance covered is 60 km. What is the average speed of the car is 12x km. Find the value of x.

55. A car travels half the distance with constant velocity of 40 kmph and the remaining half with a constant velocity of 60 kmph. The average velocity of the car in kmph is 16x. Find the value of x.

56. The v – t plot of a moving object is shown in the figure. Find the average velocity of the object during the first 10 seconds.



57. A particle moves along a straight line OX. At a time t (in second) the distance x (in metre) of the particle from O is given by $x = 40 + 12t - t^3$. If the particle travel 7x m before coming to rest, then find the value of x.

58. The average speed of a body moving with uniform acceleration travelling a distance of 3.06 m is 0.34 ms^{-1}. If the change in velocity of the body is 0.18 ms^{-1} during this time, then its uniform acceleration is $x \times 10^{-2}$ m/s^2. Find the value of x.

SOLUTIONS

Brief Explanations of Selected Questions

Physics Point

ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

Single Option Correct :

1. (d) $v_{av} = \frac{s}{t_1 + t_2} = \frac{s}{\frac{s}{2v_1} + \frac{s}{2v_2}} = \frac{2v_1v_2}{v_1 + v_2}$

2. (c) Particle has negative acceleration during whole course of motion.

3. (d)

4. (d) It is equal to or less than one.

5. (d) When $s \propto t$, so $\frac{s}{t} = \text{constant}$.

6. (b) **7.** (a) **8.** (b) **9.** (b) **10.** (c)

11. (b) From first equation of motion $v = u + at$
here $u = 40, a = g = -10, t = 2$
so $v = 40 - 10 \times 2 = 20$ m/sec

12. (c) Slope of velocity-time graph shows acceleration.

13. (c)

14. (a) Acceleration due to gravity independent of mass

$h = \frac{1}{2}gt^2$ both will reach simultaneously.

15. (a) $S_{5^{th}} = 10 - \frac{2}{2}(2 \times 5 - 1) = 10 - 9 = 1\text{m}$

16. (b) **17.** (c) **18.** (c) **19.** (c) **20.** (d)

21. (a)

22. (c) $4 = \frac{2u}{g} \Rightarrow u = 2g = 19.6$ m/s

More Than One Option Correct :

23. (a, b) **24.** (a, b) **25.** (b, c) **26.** (b, c, d)
27. (a, b) **28.** (a, c) **29.** (a, c)

Multiple Matching Questions :

30. A – (q, t); B – (p); C – (r); D – (s, t)
31. A – (p, q); B – (r); C – (t); D – (s)
32. A – (s), B – (t), C – (p), D – (r), E – (q)
33. A – (s), B – (r), C – (q), D – (p)
34. A – (r), B – (s), C – (t), D – (p), E – (q)
35. A – (t), B – (p), C – (r), D – (s), E – (q)

Passage Based Questions :

36. (a), **37.** (a), **38.** (b).

(i) With $v_0 = 0$, we have $v^2 = 2a(x - x_0)$.
The speed of the train after travelling for 10 m is

$v = \sqrt{2a(x - x_0)} = \sqrt{2(1.8\text{ m/s}^2)(10\text{m})} = \sqrt{36\text{m}^2/\text{s}^2}$
$= 6.0$ m/s

(ii) The speed of the train after travelling for 20 m will be less than doubled its speed at 10 m because the v is proportional to $\sqrt{|x - x_0|}$.

(iii) At $|x - x_0| = 20$ m, the speed is

$$v = \sqrt{2a(x - x_0)} = \sqrt{2(1.8\ m/s^2)(20m)} = \sqrt{72 m^2/s^2}$$

$$= 6.0\sqrt{2}\ m/s = 8.5\ m/s$$

The speed is $\sqrt{2} = 1.41$ times faster, as expected from (ii).

39. (a), **40.** (b), **41.** (d), **42.** (c), **43.** (c), **44.** (c).

(i) Total distance = 60 + 40 + 60 = 160m

(ii) Total displacement between A and E = 80m

(iii) Average velocity between A and E = 80/80 = 1m/s

(iv) Average speed between A and E = 160/80 = 2m/s

(v) Average velocity between points B and D = 0

(vi) Average speed between B and D = (40 + 40)/40 = 2 m/s

45. (a), **46.** (d)

$$S = \frac{1}{2}a_A\left(t_B + \frac{20}{100}t_B\right)^2 = \frac{1}{2}a_B t_B^2 \ ; 1.44a_A = a_B \ ;$$

$a_A = 0.69\, a_B$.

$$v_A = a_A\left(t_B + \frac{20}{100}t_B\right)$$

$v_B = a_B t_B$

$$\frac{v_A}{v_B} = \frac{1.2\, a_A}{a_B} = 1.2\,(0.69)$$

$v_A = 0.83\, v_B$

Assertion & Reason :

47. (c) **48.** (c)

49. (a) $h = ut - \frac{1}{2}gt^2$ and $v^2 = u^2 - 2gh$. ;
These equations are independent of mass.

50. (b)

51. (c) In uniform motion the object moves with uniform velocity, the magnitude of its velocity at different instant i.e., at $t = 0$, $t = 1$sec, t = 2sec ..... will always be constant. Thus velocity-time graph for an object in uniform motion along a straight path is a straight line parallel to time axis.

52. (a)

Integer/Numeric Questions :

53. **4** Average velocity

$$= \frac{v_1 + v_2 + v_3}{3} = \frac{3 + 4 + 5}{3} = 4\ m/s$$

54. **5** Average speed $= \frac{v_1 + v_2}{2} = \frac{80 + 40}{2} = 60\,km/h$

$\therefore \quad x = 5$

55. **3** $v_{av} = \frac{2v_1v_2}{v_1 + v_2} = \frac{2 \times 40 \times 60}{100} = 48\,kmph.$

$\therefore \quad x = 3$

56. **0** Since total displacement is zero, hence average velocity is also zero.

57. **8** $x = 40 + 12t - t^3 \quad V = \frac{dx}{dt} = 12 - 3t^2$

For V = 0; $t = \sqrt{\frac{12}{3}} = 2$ sec

So, after 2 seconds velocity becomes zero.
Value of x in 2 secs = $40 + 12.2 - 2^3 = 40 + 24 - 8 = 56$ m

$\therefore \quad x = 8$

58. **2** $\text{Time} = \frac{\text{Distance}}{\text{Average velocity}} = \frac{3.06}{0.34} = 9\,sec$

$\therefore$ Uniform accelocation, $a = \frac{\text{Change in velocity}}{\text{Time interval}}$

$$= \frac{0.18\ ms^{-1}}{9\ sec} = 0.02\ ms^{-2} = 2 \times 10^{-2}\ ms^{-2}$$

Physics Point

Chapter

10

HEAT

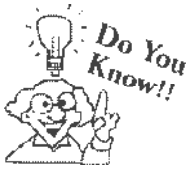
INTRODUCTION

When we touch a hot electric iron, something transfers from the iron to our hands due to which we feel the sensation of hotness. Similarly, when we touch a piece of ice, something transfers from our hands to the ice. This something is actually a kind of energy which transfers from a hot body to a cold body and is known as heat. The degree of hotness or coldness is termed as temperature. When heat is added to a substance its temperature increases and when heat is taken out from a substance its temperature decreases. So, heat is the cause and temperature is its effect. This chapter is an attempt to elaborate different aspects of heat and temperature, their measurement, their effects and some laws to govern the branch of physics dealing with heat and temperature.

Physics Point

THERMAL OR HEAT ENERGY

Matter is made up of atoms or molecules which are in constant motion. When the motion is slow the particles form solids. When the motion is faster, they slide over one another and we have a liquid. When atoms and molecules moves so fast that they disconnect and fly loose, we have a gas. Due to the movement of atoms or molecules matter possess some kinetic energy. If the molecules are made, somehow, to move faster, such as if a coin is hammered its atoms move faster, then the kinetic energy of atoms or molecules increases. Also, due to the configuration of the atoms or molecules, matter has some potential energy as well. The total energy (kinetic + potential) of all of its atoms and molecules of a matter is called its *thermal energy* or *internal energy*. A hot matter has more thermal energy as their atoms and molecules move faster. Similarly, a cold matter has less thermal energy as their atoms and molecules move slower.



- *Heat energy possessed by a body is due to the kinetic energy of the molecules constituting the body.*
- *Heat flows from a body at higher temperature to a body at lower temperature in the same way as water flows from a higher level to a lower level.*

TEMPERATURE

The quantity that indicates how hot or cold an object is with respect to some standard is called temperature. Temperature of an object is measured by an instrument which is known as **thermometer**.

Think it Over

Can we trust our sense hot and cold? Will both fingers feel the same temperature when they are put in the warm water?

Physics Point

Different Thermometric Scales

Celsius Scale : The most common thermometer in the world is the **Celsius thermometer**, named in honour of the Swedish astronomer Anders Celsius (1701–1744), who first suggested the scale of 100 degrees between the freezing point and boiling point of water. The number 0 is assigned to the temperature at which water freezes, and the number 100 to the temperature at which water boils (at standard atmospheric pressure). In between are 100 equal parts called degrees.

Fahrenheit Scale : In the United States, the number 32 is assigned to the temperature at which water freezes, and the Fahrenheit thermometer number 212 is assigned to the temperature at which water boils. In between are 180 equal parts called degrees. Such a scale makes up a named after its originator, the German physicist G.D. Fahrenheit (1686–1736).

In the Fig. 10.2, Celsius and Fahrenheit temperatures has been closely approximated.

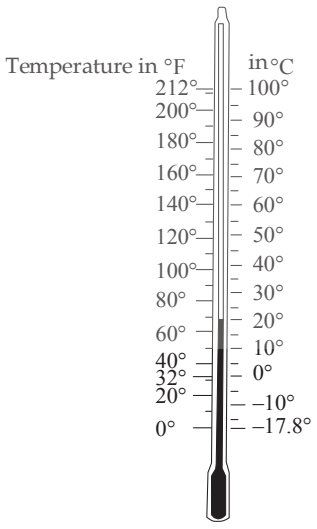
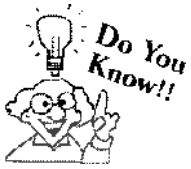


Fig.10.2 : *Fahrenheit and Celsius scales on a thermometer.*



- *At –40°C, the reading on Celsius and Fahrenheit scales are same. That is –40°C and – 40°F represent the same temperature.*
- *Normal human temperature is 37°C = 98.6°F*

A thermometer is made by taking the lower fixed point at which water freezes and the upper fixed point where water boils. The region between the two points is equally divided into a number of parts. For example, in Celsius thermometer, the region is divided into 100 equal divisions, each division being called as degree. Let us construct a thermometer which has θ and θ_0 as the upper fixed point and lower fixed point respectively. Divide the region between them into n equal divisions. Relate this scale with Celsius scale.

Relation between Celsius and Fahrenheit scales : Celsius and Fahrenheit scales are related as follows:

$$\frac{C-0}{100-0}=\frac{F-32}{212-32}$$

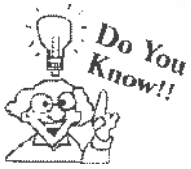
$$\Rightarrow \frac{C}{100}=\frac{F-32}{180} \Rightarrow F=\frac{9}{5}C+32$$

Here, C and F denote the readings an Celsius and Fahrenheit scales respectively.

Kelvin scale

In this scale, the number 273 is assigned to the temperature at which water freezes, and the number 373 is assigned to the temperature at which water boils. In between are 100 equal parts.

Relation between Celsius and Kelvin scale : If K and C be the readings on Kelvin and Celsius scales respectively, then $K = 273 + C$



The temperature of the sparks is very high, about 2000°C. That's a lot of thermal energy per molecule of spark. Because there are only a few molecules per spark, however, the total amount of thermal energy in the spakrs is safely small. Temperature is one thing; transfer of thermal energy is another.

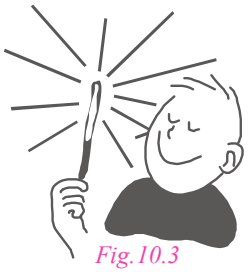


Fig. 10.3

CHECK Point

1. **Which is larger, a degree celsius or a kelvin?**
2. **A sample of hydrogen gas has a temperature of 0°C. If it is heated until it has twice the thermal energy, what is its temperature?**

SOLUTION

1. Neither. They are equal.
2. The 0°C gas has an absolute temperature of 273 K. Twice the thermal energy means that it has twice the absolute temperature or two times 273 K. This would be 546 K, or 273°C.

ILLUSTRATION : 1

The temperature of an iron block is 140°F. What is its temperature on the Celsius scale ?

SOLUTION :

The relation between Celsius and Fahrenheit scales

$$\frac{F-32}{9}=\frac{C}{5}$$

$$\Rightarrow \quad \frac{140-32}{9}=\frac{C}{5} \text{ or } \frac{700-160}{9}=C \text{ or } C=60^{\circ}C$$

ILLUSTRATION : 2

A mountain climber finds that water boils at 80°C. What is the temperature of this boiling water on Fahrenheit scale ?

SOLUTION :

As we know, $\frac{F-32}{9}=\frac{C}{5} \Rightarrow \frac{F-32}{9}=\frac{80}{5}$

$\Rightarrow \quad F-32=144$ or $F=176^{\circ}F$.

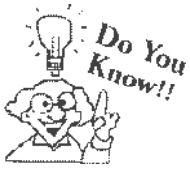
HEAT

Heat is defined as the thermal energy transferred from one thing to another due to a temperature difference. Heat is a form of energy which provides us the sensation of hotness or coldness.

If two substances are in contact, thermal energy transfers from substance at higher temperature to the substance at lower temperature until temperature of both substances becomes equal. This state of the substances in which the heat transfer from one substance to the other stops is known as **thermal equilibrium**.

This does not mean that thermal energy necessarily flows from a substance with more thermal energy into one with less thermal energy. For example, there is more thermal energy in a bowl of warm water than there is in a red-hot thumbtack. If the tack is placed into the water, thermal energy doesn't flow from the warm water to the tack. Instead, it flows from the hot tack to the cooler water. Thermal energy never flows unassisted from a low-temperature substance into a higher-temperature one.

A cold object is that which locks thermal energy. In a winter day we feel cold not because cold gets to us but because we lose heat. The purpose of our coat is to slow down the heat flow from our body.



- *The temperature, volume or pressure of a system may remain constant when it absorbs heat.*
- *The temperature of the system may increase when heat is supplied to it or work is done on the system.*

CHECK Point

1. **Suppose you apply a flame to 1 litre of water for a certain time and its temperature rises by 2°C. If you apply the same flame for the same time to 2 litres of water, by how much will its temperature rise?**
2. **If a fast marble hits a random scatter of slow marbles, does the fast marble usually speed up or slow down? Which lose(s) kinetic energy and which gain(s) kinetic energy, the initially fast-moving marble or the initially slow ones? How do these questions relate to the direction of heat flow?**

SOLUTION

1. Its temperature will rise by only 1°C, because there are twice as many molecules in 2 litres of water, and each molecule receives only half as much energy on the average. So the average kinetic energy, and thus, the temperature, increases by half as much.
2. A fast-moving marble slows when it hits slower-moving marbles. It gives up some of its kinetic energy to the slower ones. Likewise with heat. Molecules with more kinetic energy that make contact with molecules that has lower kinetic energy give up some of their excess kinetic energy to the slower ones. The direction of energy transfer is from hot to cold. For both the marbles and the molecules, however, the total energy before and after contact is the same.

Units of Heat

The **S.I. unit** of heat is joule and **C.G. S unit** calorie.

A calorie is defined as the amount of heat needed to change the temperature of 1 gram of water by 1 degree celsius (from 14.5 to 15.5°C)

1 calorie = 4.19 joule

To express bigger amount of heat, kilocalorie is used which is equal to 1000 calorie.

i.e., 1 kcal = 1000 cal.

CHECK Point

Which will raise the temperature of water more, adding 4.18 joules or 1 calorie?

SOLUTION

Both the same. This is like asking which is longer, a 1-mile long track or a 1.6-kilometer-long track. They are same in different unit.

CONDUCTORS AND INSULATORS OF HEAT

On the basis of the conduction of heat through the materials, they can be divided into two categaries – (i) good conductors and (ii) bad conductors or insulators. **Good conductors** of heat are those materials through which heat passes rapidly, e.g., all metals.

Bad conductors or Insulators are those through which heat conducts slowly or do not conduct at all, e.g., wood, cork, mica, papers etc.

THERMAL EXPANSION

When heat is added to a solid, a liquid or a gas, it expands. Similarly, when heat is subtracted from a substance, it contracts. This is called *thermal expansion*.

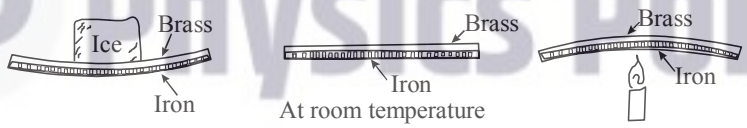
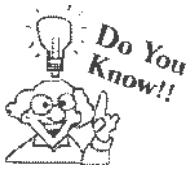


***Fig.10.4 :** A bimetallic strip. Brass expands more when heated than iron does. Because of this behavior, the strip bends as shown.*

Thermal expansion and contraction are sometimes advantageous and, at other times, disadvantageous. Due to thermal expansion, a railway track would bend, if no gaps are left between two successive rails. A pendulum clock loses or gains time due to thermal expansion or contraction of its length.



When a body is heated, it can expand in length, in area or in volume. Accordingly, the expansion is called linear expansion, superficial or area expansion or volume expansion.

Think it Over

This gap in the roadway of a bridge is called an expansion joint ; it allows the bridge to expand and contract. Was this photo taken on a warm or a cold day?

Fig. 10.5

CHECK Point

A Concorde supersonic airplane is 20 cm longer when in flight than it was before take off. Offer an explanation.

SOLUTION

At cruising speed (faster than the speed of sound), air friction against the concorde raises its temperature, resulting in this significant therma.

EXPANSION OF WATER

Water, like most other substances, expands when it is heated. But, it doesn't expand in the temperature range between 0°C and 4°C. Something quite fascinating happens in this range. Ice has a crystalline structure, with open structured crystals. Water molecules in this open structure occupy a greater volume than they do in the liquid phase (Figure 10.6). This means that ice is less dense than water. As the temperature of water at 0°C is increased, more of the remaining ice crystal collapse. This further decreases the volume of the water. This contracion continues only up to 4°C. That's because two things occur at the same time–contraction and expansion. Volume tends to decrease as ice crystals collapse, while volume tends to increase due to greater molecular motion. The collapsing effect dominates until the temperature reaches 4°C. After that, expansion overrides contraction because most of the ice crystals have melted. When ice water freezes to become solid ice, its volume increases tremendously–and its density is therefore, much lower. That's why ice floats on water. Like most other substances, solid ice contracts with further cooling. This behavior of water is very important in nature. If water was most dense at 0°C, it would settle to the bottom of a pond or lake. Because water at 0°C is less dense, it floats at the surface. That's why ice forms at the surface.

So, a pond freezes from the surface downward. In a cold winter, the ice will be thicker than in a milder winter. Water at the bottom of an ice-covered pond is 4°C, relatively warm for organisms that live there. Interestingly, very deep bodies of water are not ice-covered, even in the coldest of winters. This is because all of the water must be cooled to 4°C before lower temperature can be reached. For deep water, the winter is not long enough to reduce an entire pond to 4°C. Any 4°C water lies at the bottom. Because of water's high specific heat and poor ability to conduct heat, the bottom of deep bodies of water in cold regions remains at a constant 4°C year round. Fish should be glad that this is so.

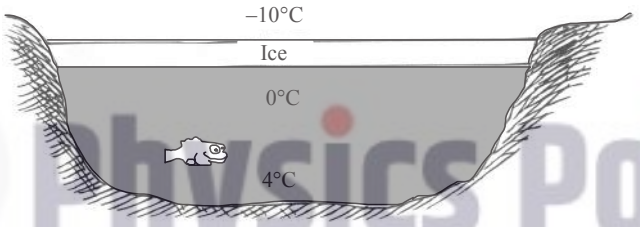


Fig.10.6 : As water cools, it sinks until the entire pond is at 4°C. Then, as water at the surface is cooled further, it floats on top and can freeze. Once ice is formed, temperatures lower than 4°C can extend down into the pond.

Water contracts on heating between 0°C to 4°C. maximum contraction at 4°C. This is called anomalous expansion of water. It has the minimum volume and hence the maximum density (1000 kg m^{-3}) at 4°C

SPECIFIC HEAT CAPACITY

You might have noticed that some hot food remain hotter much longer than others. A piece of toast may be comfortably eaten a few seconds after coming from the hot toaster, whereas we must wait several minutes before eating soup that initially has the same high temperature.

Different substances store different thermal energy. If we heat a piece of silver on a store, we might find that it requires 1 minute to raise it from room temperature to its boiling temperature. But if we add an equal mass of water on the same store we'd find it would rise through the same temperature range in about 15 minutes. For iron, the time would be about 2 minutes.

We find that different materials require different quantities of heat to raise the temperature of a given mass of the material by a specified number of degrees. This is because different materials absorb energy in different ways. The energy may increase the jiggling motion of molecules, which raises the temperature; or it may increase the amount of internal vibration or rotation within the molecules and go into potential energy, which does not raise the temperature. Generally, there is a combination of both.

Water absorbs more heat than iron for the same change in temperature. We say water has a higher *specific heat capacity* (sometimes simply called specific heat).

The ***specific heat capacity*** of any substance is defined as *the quantity of heat required to change the temperature of a unit mass of the substance by 1°C.*

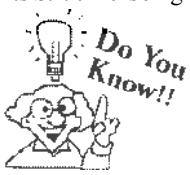
Water has much higher capacity for storing energy than most all other substances. A lot of heat energy is needed to change the temperature of water. This explains why water is very useful in the cooling systems of automobiles and other engines. It absorbs a great quantity of heat for small increase in temperature. Water also takes longer to cool.

If the specific heat capacity C is known, the formula for the quantity of heat Q involved when a mass m of a substance undergoes a change in temperature ΔT is

$Q = mc\,\Delta T$.

i.e., Heat transferred = specific heat capacity × mass × temperature change.

Its **S.I. unit** is J kg^{-1} K^{-1}



- *Because water has a high specific heat capacity and is transparent, it takes more energy to warm than land. Solar energy striking the land is concentrated at the surface, but that striking the water extends beneath the surface and so is "diluted."*

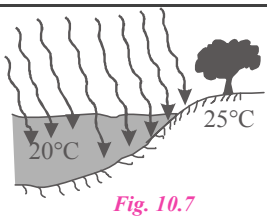


Fig. 10.7

- *Gases have two specific heats-specific heat at constant pressure C_p and specific heat at constant volume C_v.*

CHECK Point

Which has a higher specific heat capacity, water or sand? In other words, which takes longer to warm in sunlight (or longer to cool at night)?.

SOLUTION

Water has the higher specific heat capacity. In the same sunlight, the temperature of water increases more slowly than the temperature of sand. And water will cool more slowly at night. The low specific heat capacity of sand and soil, as evidenced by how quickly they warm in the morning sun and how quickly they cool at night, affects local climates..

Thermal Capacity

It is the amount of heat required to raise the temperature of substance through 1°C or 1K.

Thermal capacity = mass × specific heat.

[Its unit is cal/°C, kcal/°C, J/K.]

Water Equivalent

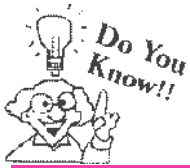
It is the mass of water in grams which would require the same amount of heat to raise its temperature through 1°C as the body when heated through the same temperature. It is measured in gram.

Hence *water equivalent of a body = mass of the body × specific heat*

PRINCIPLE OF CALORIMETRY OR LAW OF MIXTURE

When two bodies at different temperatures are placed in contact with each other then heat will flow from the body at higher temperature to the body at lower temperature until both reach a common temperature, i.e. *Heat lost by hot body = heat gained by cold body*.

It follows the law of conservation of energy.



Calorimetry is the branch of physics that deals with the measurement of heat.

LATENT HEAT (CHANGE OF STATE)

When heat is supplied to a substance, it raises the temperature of the substance. However, it is not always true. Sometimes, heat supplied to a substance brings about a change in the state of the substance instead of producing a rise in its temperature. It is found that the temperature of the substance does not change, as long as the change of state takes place. The heat supplied to the substance during the change of state is used up in increasing the intermolecular distance against the force of intermolecular attraction. The heat supplied to the substance to produce the change of state depends upon *its mass* and *the nature of the substance*. Thus, the heat required to change the state of a unit mass of the substance will depend only upon the nature of the substance and it is called ***latent heat*** of the substance.

The latent heat of a substance may be defined as the quantity of heat required to change the unit mass of the substance completely from its one state to another at constant temperature.

A substance changes from its solid to liquid state at its melting point and a substance changes from its liquid to vapour state at its boiling point.

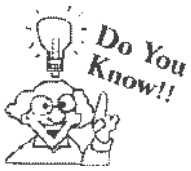
Latent Heat of Fusion

It is the quantity of heat required to change unit mass of the solid into liquid at its melting point, e.g. latent heat of fusion of ice is 80 cal/g.

Latent Heat of Vaporisation

It is the quantity of heat required to convert unit mass of liquid into vapour at its boiling point. Latent heat of vaporisation of water is 536 cal/g.

Latent heat increases the intermolecular potential energy of the molecules while kinetic energy remains constant.



- *When two substances are mixed together, the final temperature of the mixture can never be less than the temperature of the colder substance or more than the temperature of the hotter substance.*
- *According to principle of calorimetery, heat lost = heat gained. It does not necessitate that the fall in temperature of one substance should be equal to the rise of temperature of the other.*

CHANGE OF STATE

Any state of a substance (solid/ liquid/ gas) can be changed into another by heating or cooling. The transition of a substance from one state to another is called a change of state.

Some common changes of states :

(i) Melting : When heat is supplied, solid substance changes into liquid, this change of state of substance is called melting.

$$\text{Solid} \xrightarrow{\text{Heat}} \text{Liquid}$$

The temperature at which the solid and the liquid states of a substance coexist in thermal equilibrium with each other is called its **melting point**.

(ii) Freezing : When heat is released, liquid changes into solid, this change of state of substance is called freezing.

$$\text{Liquid} \xrightarrow{\text{Cool}} \text{Solid}$$

(iii) Condensation : When vapour is cooled, it changes into liquid, this change of state is called condensation

$$\text{Vapour} \xrightarrow{\text{Cool}} \text{liquid}$$

(iv) Evaporation : Conversion of liquid into gaseous state at all the temperatures is called evaporation or boiling.

$$\text{Liquid} \xrightarrow{\text{Heat}} \text{Vapour}$$

The temperature at which the liquid and vapour states of a substance coexsist in thermal equilibrium with each other is called its **boiling point**.

It is a phenomenon that occurs at the surface of liquids. The rate of evaporation increases with rise in temperature. Heat required to change unit mass of liquid into vapour at a given temperature is called heat of evaporation at that temperature.

(v) Sublimation : It is the conversion of a solid directly into vapours.

$$\text{Solid} \xrightarrow{\text{Heat}} \text{Vapour}$$

Sublimation takes place when boiling point is less than the melting point.

HEAT TRANSFER

Heat energy transfer from a body at higher temperature to a body at lower temperature by three different methods. They are conduction, convection and radiation.

Conduction

Conduction is that mode of transmission of heat in which heat is transferred from a region of higher temperature to a region of lower temperature by the aid of particles of the body without their actual migration. Conduction requires material medium.

Variable state and steady state :

When one end of a rod is heated, then initially the temperature of various points of the rod changes continuously and the rod is said to exist in a **variable state**. After some time, a state is reached, when the temperature of each cross-section becomes steady. This state is known as **steady state**.

Convection

Convection like conduction requires a material medium. *It is the process in which heat is transferred from one place to other by actual movement of heated material particles.* It is possible only in fluids. The type of convection which results from difference in densities is called **natural convection.** For example, a fluid in a container heated through its bottom. However, if a heated fluid is forced to move by a blower, fan or pump, the process is called **forced convection**. The rate of heat convection from an object is proportional to the temperature difference ($\Delta\theta$) between the object and convective fluid and the area of contact A,

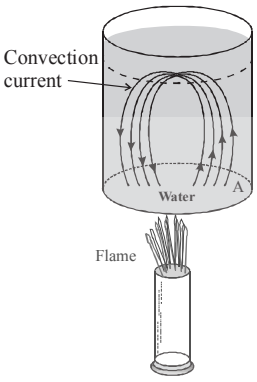


Fig 10.8

i.e., $$\left[\frac{dQ}{dt}\right]_{convection} = hA\,\Delta\theta$$

where, h represents a constant of proportionality called **convection coefficient** and depends on the properties of fluid such as density, viscosity, specific heat and thermal conductivity.

Radiation

When a body is heated and placed in vacuum, it loses heat even when there is no medium surrounding it. The heat cannot go out from the body by the process of conduction or convection since both of these process require the presence of a material medium between source and surrounding objects. The process by which heat is lost in this case is called radiation. This does not require the presence of any material medium. It is by radiation that the heat from the sun reaches the earth.

Radiation has the following properties :

(a) Radiant energy travels in straight line and when some object is placed in the path, it's shadow is formed at the detector.
(b) It is reflected and refracted or can be made to interfere. The reflection or refraction are exactly as in case of light.
(c) It can travel through vacuum.
(d) Intensity of radiation follows the law of inverse square.
(e) Thermal radiation can be polarised in the same way as light by transmission through a nicol prims.

Physics Point

THE FIRST LAW OF THERMODYNAMICS

When the conservation of energy is applied to thermal systems, we have a law known as the **first law of thermodynamics**. It is stated as below.

Whenever heat is added to or taken from a system, the gain or loss of thermal energy equals the amount of heat transferred.

In the above definition a *system* may be any substance, device or well-defined group of atoms or molecules. The system may be the air inside the room in which we live, the entire earth's atmosphere, or even the body of a living creature. When heat is supplied to a system, its hermal energy increases and the system does work.

If ΔQ be the amount of heat supplied, ΔW be the increase in the thermal energy (or internal energy) of the system then the first law provides that $\Delta Q = \Delta W + \Delta U$.

The firs law is nicely illustrated when you put an airtight can of air on a hot stove and warm it. The energy put in increases the thermal energy of the enclosed air, so its temperature rises. If the can is fitted with a movable piston, then the heated air can do *mechanical work* as it expands and pushes the piston outward. This ability to do mechanical work is energy that comes from the energy you put in to begin with the first law says you don't get energy from nothing.

Think it Over

When you push down on the piston, you do work on the air inside. What happens to its temperature?


Fig 10.9

THE SECOND LAW OF THERMODYNAMICS

The second law of thermodynamics provides the direction in which heat flow takes place. It states that

Heat never spontaneously flows from a cold substance to a hot substance.

Heat flow, without the help of an external work, always takes place from a hot body to a cold body. In summer, heat flows from the hot air outside into the interior of cold rooms. Opposite is the case in the winter. Heat can be made to flow from a colder object to a hotter one only by doing work on the system or by adding energy from another source. This occurs with heat pumps and airconditioners. In

these devices, thermal energy is pumped from a cooler to a warmer region. But without external effort heat can never flow from a cold substance to a hot substance.

KINETIC THEORY OF GASES

A gas is a collection of a large number of molecules, which are in continuous rapid motion. The gas molecules can be considered as to be moving freely with respect to each other. However, during motion, when they come close to each other, they suffer a change in their velocities due to the inter-molecular forces. Therefore, such changes in velocities of the molecules of a gas are due to molecular collisions.

A gas exerts pressure on the walls of the containing vessel due to continuous collisions of the molecules against the wall.

The kinetic theory of gases is based upon some assumptions which are summarised below :

(i) A gas consist of particles called molecules which move randomly in all directions.

(ii) All the molecules of a gas are identical. The molecules of different gases are different.

(iii) The volume of molecule is very small in comparison to the volume occupied by gas i.e., the size of molecule is infinitesimely small.

(iv) The collision between two molecules or between a molecule and wall are perfectely elastic and collision time is (duration of collision) very small.

(v) The molecules exert no force on each other or on the walls of containers except during collision.

(vi) The total number of molecules are large and they obey Newtonian Mechanics.

Internal energy of a perfect gas is totally due to the kinetic energies of the molecules constituting the gas.

Physics Point

SUMMARY

- **Thermal or heat energy :** The total energy (kinetic + potential) of all of its atoms and molecules of a matter is called its thermal energy or internal energy.
- **Temperature :** The quantity that indicates how hot or cold an object is with respect to some standard is called temperature.
- **Relation between Celsius and Kelvin scales :** $F = \frac{9}{5}C + 32$
- **Relation between Celsius and Kelvin scales :** $K = 273 + C$
- **Heat :** Heat is defined as the thermal energy transferred from one thing to another due to a temperature difference.
- **Conductors and insulators of heat :** Good conductors of heat are those materials through which heat passes rapidly, e.g. all metals. Insulators are those through which heat conducts slowly or do not conduct at all, e.g., wood, cork, mica, papers etc.
- **Thermal expansion :** When heat is added to a solid or a liquid or a gas, it expands. Similarly, when heat is subtracted from a substance, it contracts. This is called thermal expansion.
- **Expansion of water :** Water, like most other substances, expands when it is heated. But, it doesn't expand in the temperature range between 0°C and 4°C.
- **Specific heat capacity :** The specific heat capacity of any substance is defined as the quantity of heat required to change the temperature of a unit mass of the substance by 1 degree Celsius (from 14.5 to 15.5° C)
- **Thermal capacity :** It is the amount of heat required to raise the temperature of substance through 1ºC or 1K.
- **Water equivalent :** It is the mass of water in grams which would require the same amount of heat to raise its temperature through 1ºC as the body when heated through the same temperature.
- **Latent heat of fusion :** It is the quantity of heat required to change unit mass of the solid into liquid at its melting point. Latent heat of fusion of ice is 80 cal/g.
- **Latent heat of vaporisation :** It is the quantity of heat required to convert unit mass of liquid into vapour at its boiling point. Latent heat of vaporisation of water is 536 cal/g. Evaporation is a slow process occurring at all the temperature at the surface of liquid.
- **Evaporation :** Conversion of liquid into gaseous state at all temperatures is called evaporation.
- **Boiling :** Boiling is a fast process involving whole of the liquid heated to a particular temperature called boiling point of the liquid.
- **First law of thermodynamics :** Whenever heat is added to or taken from a system, the gain or loss of thermal energy equals the amount of heat transferred i.e., $\delta Q = \delta u + \delta w$
- **Second law of thermodynamics :** Heat never spontaneously flows from a cold substance to a hot substance.
- **Kinetic theory of gases :** A gas is a collection of a large number of molecules, which are in continuous rapid motion. The gas molecules can be considered as to be moving freely with respect to each other. However, during motion, when they come close to each other, they suffer a change in their velocities due to the inter-molecular forces.

ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

Single Option Correct :

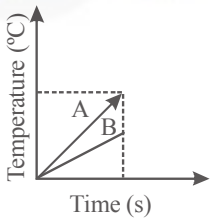
DIRECTIONS (Qs. 1-26) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct. Choose the correct option.*

1. If C, F and K are temperature on Celsius, Fahrenheit and Kelvin scales, ΔC, ΔF and ΔK are the change in temperature in Celsius, Fahrenheit and Kelvin scales respectively, the correct relation among the following is

(a) $\frac{C}{5}=\frac{F}{9}=\frac{K-273}{5}$ (b) $\frac{\Delta C}{5}=\frac{\Delta F}{9}=\frac{\Delta K}{5}$

(c) $\frac{\Delta C}{5}=\frac{\Delta F-32}{9}=\frac{\Delta K-273}{5}$ (d) $\frac{C}{5}=\frac{F}{9}=\frac{K}{5}$

2. When equal amount of heat is supplied to two different substances 'A' and 'B', the rise in temperature with time is graphically represented as follows.



(a) If masses of 'A' and 'B' are equal, specific heat of 'A' is equal to specific heat of 'B'.

(b) If mass of 'A' is greater than mass of 'B' the specific heat capacity of 'A' is greater than the specific heat capacity of 'B'.

(c) Heat capacity of A is less than heat capacity of B

(d) None of these

3. Food in the pressure cooker is cooked faster, as

(a) the boiling point increases due to an increase in pressure

(b) the boiling point decreases due to an increase in pressure

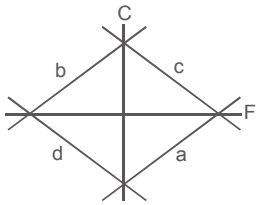
(c) more steam is available at 100°C

(d) more pressure is available at 100°C

4. The change in temperature of a body is 20°C, then the change in temperature on Kelvin scale is

(a) 293 K (b) 25 K (c) 20 K (d) 253 K

5. Which of the curves in figure represents the relation between Celsius and Fahrenheit temperatures?



(a) a (b) b

(c) c (d) d

6. Which of the following pairs may give equal numerical values of the temperature of a body?

(a) Fahrenheit and Celsius

(b) Celsius and Kelvin

(c) Kelvin and Platinum

(d) None of these

7. A metal sheet with a circular hole is heated. The hole

(a) gets larger

(b) gets smaller

(c) remains of the same size

(d) gets deformed

8. The temperature of water at the surface of a deep lake is 2°C. The temperature expected at the bottom is

(a) 0°C (b) 2°C

(c) 4°C (d) –6°C

9. When water is heated from 0°C to 10°C, its volume

(a) increases

(b) decreases

(c) does not change

(d) first decreases and then increases

10. Two spheres of same size are made of the same metal but one is hollow and the other is solid. They are heated to same temperature, then

(a) both spheres will expand equally

(b) hollow sphere will expand more than the solid one

(c) solid sphere will expand more than the hollow one

(d) none of the above

Physics Point

11. The pressure exerted on the walls of container by a gas is due to the fact that gas molecules are
(a) losing their kinetic energy
(b) sticking to the walls
(c) changing their momenta due to collision with the walls
(d) getting accelerated towards the wall

12. Heat is transmitted from higher to lower temperature through actual mass motion of the molecules in
(a) conduction (b) convection
(c) radiation (d) None of these

13. Good absorbers of heat are
(a) poor emitters (b) non-emitters
(c) good emitters (d) highly polished

14. When vapour condenses into liquid
(a) it absorbs heat
(b) it liberates heat
(c) its temperature rises
(d) its temperature decreases

15. The temperature of the sun is measured with
(a) Platinum thermometer
(b) Gas theromometer
(c) Pyrometer
(d) Vapour pressure thermometer

16. On which of the following scales of temperature, the temperature is never negative?
(a) Celsius (b) Fahrenheit
(c) Reumer (d) Kelvin

17. Temperature is a
(a) microscopic concept (b) macroscopic concept
(c) space-time concept (d) none of the above

18. According to kinetic theory of gases, at absolute zero of temperature
(a) water freezes
(b) liquid helium freezes
(c) molecular motion stops
(d) liquid hydrogen freezes

19. Of the following, the one which has the highest specific heat is
(a) Aluminium (b) Copper
(c) Water (d) Ice

20. When an impurity is added to a liquid, the boiling point of the liquid
(a) remains unchanged (b) rises
(c) falls (d) may rise or fall

21. The first law of thermodynamics expresses
(a) law of conservationof momentum
(b) law of conservation of energy
(c) law of conservation of mass
(d) all of these

22. The first law of thermodynamics is a special case of
(a) Newton's law
(b) The law of conservation of energy
(c) Charle's law
(d) The law of heat exchange

23. The second law of thermodynamics implies
(a) whole of the heat can be converted into mechanical energy
(b) no heat engine can be 100% efficient
(c) every heat engine has an efficiency of 100%
(d) a refrigerator can reduce the temperature to absolute zero

24. In first law of thermodynamics
(a) the internal energy of system changes
(b) the internal energy of system does not change
(c) the change in internal energy of the system does not depend on the path
(d) none of these

25. If a liquid is heated in space under no gravity, the transfer of heat will take place by process of
(a) conduction
(b) convection
(c) radiation
(d) can not be heated in the absence of gravity

26. 500 g of water at 100°C is mixed with 300 g at 30°C. Find the the temperature of the mixture. Specific heat of water = 4.2 J $g^{-1}°C^{-1}$.
(a) 73.8 °C (b) 53.8°C
(c) 40°C (d) 60°C

More than One Option Correct :

DIRECTIONS (Qs. 27-31) : *This section contains* **5** *multiple Choice Questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE options may be correct.*

27. Temperature of a body is a measure of
(a) sum of total kinetic and potential energy of the molecules of the given body

Physics Point

(b) amount of heat energy present inside the given body
(c) degree of hotness or coldness
(d) only average kinetic energy of the molecules present inside the body

28. When ice water is heated,
(a) its volume first decreases then increases
(b) its density decreases
(c) its density first increases, then decreases
(d) its density first decreases, then increases

29. Which of the following temperatures are equal
(a) $-40°C$ (b) $-40K$
(c) $-40°F$ (d) $233\,K$

30. The specific heat capacities of two bodies A and B is in the ratio 1:2 and masses in the ratio 3 : 4 respectively. The ratio of their heat capacities are
(a) 3 : 2 (b) 2 : 3
(c) 6 : 16 (d) 3 : 8

31. Choose the correct statements among the following ?
(a) Heat capacity is the product of mass and specific heat
(b) In SI system, thermal capacity and water equivalent are numerically equal
(c) Heat always flows from higher temperature body to lower temperature body
(d) At thermal equilibrium, rate of heat flow from hot body is equal to the rate of heat flow from cold body

Multiple Matching Questions :

DIRECTIONS (Qs. 32-34) : *Following question has statements (A, B, C and D) given in Column I and statements (p, q, r, s and t) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in column I with entries in column II.*

Match the Column I and II.

32.

Column I	Column II
(A) Heat	(p) Equal temperature
(B) Thermal equilibrium	(q) Surface area of liquid
(C) Temperature	(r) $mc\Delta\theta$
(D) Vaporisation depends	(s) Scalar
	(t) Temperature

33.

Column I	Column II
(A) Temperature	(p) $J\ kg^{-1}$
(B) Specific heat	(q) K
(C) Latent heat	(r) $J\ K^{-1}$
(D) Thermal capacity	(s) $J\ kg^{-1}\ K^{-1}$
	(t) °C

34.

Column I	Column II
(A) Melting	(p) Solid to gas
(B) Sublimation	(q) Solid to liquid
(C) Condensation	(r) Gas to liquid
(D) Vaporisation	(s) Liquid to gas
	(t) Heat is added

Passage Based Questions :

DIRECTIONS (Qs. 35-37) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

In a process 10 g of ice at –5°C is converted into the steam at 100°C.

35. If specific heat of ice is 0.5 cal $g^{-1}°C^{-1}$, then the amount of heat required to convert 10 g of ice from –5°C to 0°C is
(a) 15 cal (b) 25 cal
(c) 50 cal (d) 100 cal

36. If latent heat of fusion of ice is 80 cal g^{-1}, then the amount of heat required to convert 10 g of ice at 0°C into 10 g of water at same temperature is
(a) 400 cal (b) 800 cal
(c) 1200 cal (d) 1600 cal

37. If specific heat of water is 1 cal $g^{-1}\ °C^{-1}$, the heat required to raise the temperature of 10gwater from 0°C to 100°C
(a) 100 cal (b) 1000 cal
(c) 10^4 cal (d) 10^5 cal

Assertion & Reason :

DIRECTIONS (Qs. 38-41) : *Each of these questions contains an Assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

38. **Assertion :** Two thin blanket put together are warmer than a single blanket of double the thickness.
Reason : Thickness increases because of air layer enclosed between the two blankets.

39. **Assertion :** Water is used as a coolant in a vehicles.
Reason : Water has low specific heat capacity.

Physics Point

40. **Assertion :** The temperature of a body is 10°C. Its temperature in Fahrenheit scale is 50°F.

Reason : Celcius (C) and Fahrenheit (F) are related as

$$F = \frac{9}{5}C + 32$$

41. **Assertion :** When a body *A* at temperature 50°C is brought in contact with a body *B* at temperature 30°C, heat flows from the body *A* to the body *B*.

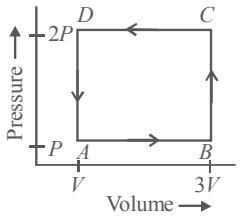
Reason : Heat always flows from a body at a low temperature to a body at a high temperature.

Integer/ Numeric Questions :

DIRECTIONS (Qs. 42-44) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

42. The internal energy change in a system that has absorbed 2 Kcal of heat and done 400 J of work is x kilo joule. Find the value of x.

43. A thermodynamic system is taken through the cycle *ABCD* as shown in figure. Heat rejected by the gas during the cycle is x PV. Find the value of x.



44. In an energy recycling process, x gm of steam at 100°C becomes water at 100°C which converts y gm of ice at 0°C into water at 100°C. The ratio x/y is $\frac{1}{z}$. Find the value of x.

SOLUTIONS

Brief Explanations of Selected Questions

ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

Single Option Correct :

1.	**(b)**	**2.**	**(b)**	**3.**	**(a)**	**4.**	**(c)**	**5.**	**(a)**
6.	**(a)**	**7.**	**(a)**	**8.**	**(c)**	**9.**	**(d)**	**10.**	**(a)**
11.	**(c)**	**12.**	**(b)**	**13.**	**(c)**	**14.**	**(b)**	**15.**	**(c)**
16.	**(d)**	**17.**	**(b)**	**18.**	**(c)**	**19.**	**(c)**	**20.**	**(d)**
21.	**(b)**	**22.**	**(b)**	**23.**	**(b)**	**24.**	**(c)**	**25.**	**(c)**
26.	**(a)**								

More Than One Option Correct :

27. **(a, c)** **28.** **(a, c)** **29.** **(a, c, d)**

30. **(c, d)** **31.** **(a, c, d)**

Multiple Matching Questions :

32. A – (r, s); B – (p); C – (s); D – (q, t)

33. A – (q, t); B – (s); C – (p); D – (r)

34. A – (q, t); B – (p, t); C – (r); D – (s, t)

Passage Based Questions :

35. **(b)** **36.** **(b)** **37.** **(b)**

Assertion & Reason :

38. **(c)** **39.** **(c)** **40.** **(a)** **41.** **(a)**

Integer/Numeric Questions :

42. **8** $\Delta Q = \Delta U + \Delta W \Rightarrow 2 \times 10^3 \times 4.2 = \Delta U + 400$

$\Rightarrow \Delta U = 8000J \quad \therefore x = 8$

43. **2** ∵ Internal energy is the state function.

∴ In cyclie process; $\Delta U = 0$

According to 1st law of thermodynamics

$\boxed{\Delta Q = \Delta U + W}$

So heat absorbed

$\Delta Q = W$ = Area under the curve

$= -(2V)(P) = -2PV$

So heat rejected = 2PV ∴ x = 2

44. **3** Specific heat of water = 4200 J/kg-K

Latent heat of fusion = 3.36×10^5 J/kg

Latent heat of vapourisation = 22.68×10^5 J/kg

$x \times 10^{-3} \times 22.68 \times 10^5 J = y \times 10^{-3} \times 3.36 \times 10^5 J + y \times 10^{-3} \times 4200 \times 100$

$\Rightarrow \frac{x}{y} = \frac{7.56}{22.68} = \frac{1}{3} \quad \therefore z = 3$

Chapter

11

MAGNETISM

INTRODUCTION

Now-a-days magnets are used in a number of devices such as telephones, radios, loudspeakers, television,maglev trains, etc. Magnets are solid substances which have the property of attracting certain substances like iron. This attracting property is either natural or artificial.

The term *magnetism* comes from Magnesia, the name of an ancient city in Asia Minor, where the Greeks found certain very unusual stones more than 2000 years ago. These stones, called *lodestones*, possess the unusual property of attracting pieces of iron. These stones were named as *magnets* which were first used to make compasses and for navigation by the Chinese in the twelfth century A.D.

In the sixteenth century, William Gilbert, Queen Elizabeth's physician, made artificial magnets by rubbing pieces of iron against Iodestones. He suggested that a compass always points north and south because the earth itself has magnetic properties.

The property of a material due to which it attracts other materials (like iron, nickel, etc.) is known as *magnetism*.

The subjects of electricity and magnetism developed almost independently until 1820. In 1820, a Danish physicist named Hans Christian Oersted discovered that an electric current affects a magnetic compass. He saw that magnetism was related to electricity. Andre Marie Ampere, a French physicist, shortly after proposed that electric currents are the source of all magnetic phenomena.

MAGNETS AND MAGNETISM

The phenomenon of attracting magnetic substances like iron, cobalt, nickel etc is called magnetism and the mater that attracts magnetic materials are called magnet.

Types of Magnets

There are two types of magnets. (i) *natural magnets* and (ii) *artificial magnets*.

Natural magnets : The magnets found in nature are called natural magnets. The lodestone is a natural magnet. Natural magnets are of irregular shapes and their attractive property is weak.

Artificial magnets : The magnets which are made artificially by magnetic materials are called *artificial magnets*. These types of magnets are of fixed shapes, sizes and their attractive property is more than that of natural magnets.

Types of artificial magnets

(i) **Bar magnet :** A magnet in the shape of a bar is known as a bar magnet Fig. 11.1 (a). It can have either a rectangular or a circular cross-section.

(ii) **Horse-shoe magnet :** A U-shaped magnet is called a horseshoe magnet Fig. 11.1 (b)

(iii) **Magnetic needle :** A magnetic needle is a magnet in the form of a bar which is tapered from the centre towards the ends is pivoted at its centre on a stand fig. 11.1 (c).

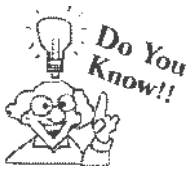
(iv) **Magnetic compass :** A magnetic compass consists of a small magnetic needle pivoted at the centre and encased in a small brass box with a glass top Fig. 11.1 (d). It can be used to find the direction of a magnetic field at a place and also to test the polarity of a magnet.

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

Fig. 11.1

Permanent and Temporary Magnets

Those magnets which retain their magnetic properties over a long time are known as *permanent magnets*. These are made of hard steel. The magnets which retain their magnetic properties only under certain external conditions like presence of an electric current in the vicinity or of a strong magnet are called *temporary magnets*. e.g., electromagnet.



- *Magnetite or lodestone was the world's first natural magnet found in Magnesia in Asia minor.*
- *Hard steel, alnico (an alloy of aluminium, nickel, cobalt and iron) and nipermag (an alloy of aluminium, iron and titanium) are used to make permanent magnets.*

Properties of Magnets

A magnet possesses the following properties.

1. **Attractive property** : A magnet attracts small pieces of objects made of metals like iron, nickel, steel, cobalt, etc. The attractive property of a magnet is strongest at the poles. Materials can be classified into two categories on the basis of this property. They are -
   (i) *magnetic materials* and (ii) *non-magnetic materials*. Magnetic materials are those which are easily attracted by a magnet, such as, iron, steel, cobalt and nickel.
   Non-magnetic materials are those which are not attracted by a magnet, such as, wood, paper, copper, brass, etc.
2. **Directive property :** When a bar magnet is suspended freely, it always stands in a direction pointing north and south. This property of a magnet is called directive property.

3. **Poles exist in pair :** The two poles of a magnet always exist in pair. If we break a magnet into pieces, each piece becomes a tiny magnet having both poles-south and north.

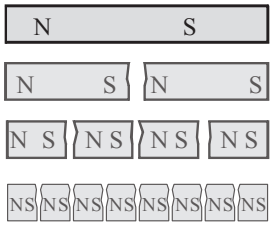
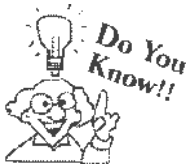


Fig. 11.2

4. **Unlike poles attract and like poles repel :** If two magnets are brought nearer such that two north poles face each other or two south poles face each other, they repel one another on the other hand a north and a south pole always attract one another. Repulsion and not attraction is the sure test for the polarity of a magnet.



The attractive property of magnet was discovered by the Greeks whereas the directive proparty was discovered by the chinese.

CHECK Point

Every magnet necessarily have a north and south pole?

SOLUTION

Yes, just as every coin has two sides, a head and a tail. Some "trick" magnets may have more than one pair of poles, but, nevertheless, the poles occur in pairs.

Physics Point

Terms used in the study of magnetism

(1) **Magnetic axis :** The straight line joining the two poles of a magnet is known as its magnetic axis.
(2) **Equatorial line :** The line passing through the centre of the magnet and perpendicular to its magnetic axis is called the equatorial line.
(3) **Magnetic length :** The distance between the poles of a magnet is called its magnetic length.
(4) **Magnetic meridian :** The imaginary vertical plane passing through the north-south direction of a magnet is called magnetic meridian.

MAGNETIC FIELD

The region around a magnet where magnetic forces act is called magnetic field.

The shape of the field is revealed by magnetic field lines that spread out from one pole and return to the other pole.

The direction of the field outside the magnet is from the north pole to the south pole. Where the lines are closer together, the field is stronger. We can see that the magnetic field strength is greater at the poles. If we place another magnet or a small compass anywhere in the field, its poles will tend to align with the magnetic field.

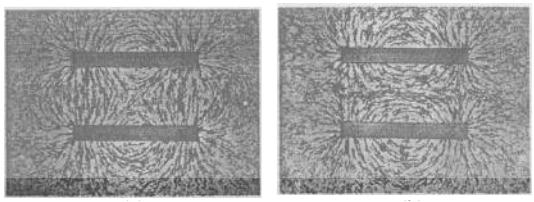
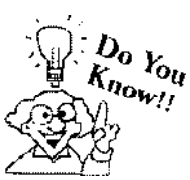


Fig. 11.3 : The magnetic field patterns for a pair of magnets.



Magnetic field is said to be uniform if its magnitude is equal and direction is same at every point in the space. Magnetic field is said to be non-uniform if its magnitude is not equal and direction is not same at every point in space.

MAGNETIC DOMAINS

We know that each atom of a magnetic material behaves like a tiny magnet. The magnetic field of an individual atom is so strong that interactions among adjacent atoms cause large clusters of them to line up with one another. These clusters of aligned atoms are called *magnetic domains*. Each domain is made up of billions of aligned atoms.

Fig. 11.4 : A microscopic view of magnetic domains in a crystal of iron.

Not every piece of iron is a magnet, because the domains in ordinary iron are not aligned. In a common iron nail, for example, the domains are randomly oriented. But when you bring a magnet nearby, they can be induced into alignment. The domains align themselves much as electrical charges in a piece of paper align themselves (become polarized) in the presence of a charged rod. When you remove the nail from the magnet, ordinary thermal motion causes most or all of the domains in the nail to return to a random arrangement.

Unmagnetized iron *Slightly magnetized iron* *Strongly magnetized iron*

Fig. 11.5 : Pieces of iron in successive stages of magnetism. The arrows represent domains; the head is a north pole and the tail is a south pole. Poles of neighboring domains neutralize each others effects except at the ends.

Permanent magnets can be made by placing a magnetic material like iron in a strong magnetic field. The magnetic field helps to align the domains of the material and hence, the material gets magnetised. Soft iron is easier to magnetise than steel. Another way to magnetise a material is to stroke the material with a magnet. The stroking motion aligns the domains. If a permanent magnet is dropped or heated outside of the strong magnetic field from which it was made, some of the domains are jostled out of alignment and the magnet becomes weaker. or demagnetise

When a magnet is broken into two pieces, each piece is an equally strong magnet.

Fig. 11.6

CHECK Point

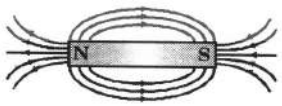
1. **Why will a magnet not pick up a penny or a piece of wood?**
2. **How can a magnet attract a piece of iron that is not magnetized?**

SOLUTION

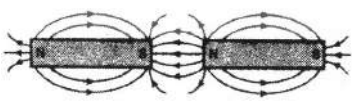
1. A penny and a piece of wood have no magnetic domains that can be induced into alignment.
2. Like the compass needle domains in the unmagnetized piece of iron are induced into alignment by the magnetic field of the magnet. One domain pole is attracted to the magnet and the other domain pole is repelled. Does this mean the net force is zero? No, because the force is slightly greater on the domain pole closest to the magnet than it is on the farther pole. that's why there is a net attraction. In this way, a magnet attracts unmagnetized pieces of iron .

MAGNETIC LINES OF FORCE

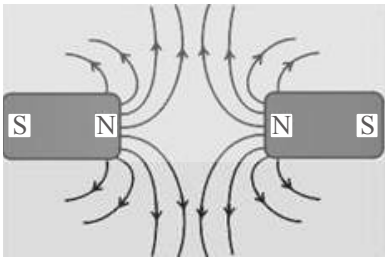
The path taken by a unit north pole if it is free to move is called the magnetic lines of force. The magnetic lines of force around a bar magnet are shown in figure below.



Lines of force due to a single bar magnet
(a)



Lines of force when unlike poles of two magnets face each other
(b

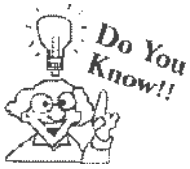


Lines of force when like poles of two magnets face each other
(c)

Fig. 11.7 : Magnetic lines of force

Properties of Magnetic Lines of Force

(i) They are closed, continuous curves.
(ii) Magnetic lines of force start at the north pole and end at the south pole outside the magnet. Inside the magnet, the lines of force move from the south pole to the north pole.
(iii) Two lines of force can never meet each other.
(iv) They are crowded near the poles.
(v) The strength of the field is more where the lines of forces are crowded.
(vi) The lines of force have longitudinal tension and lateral pressure.
(vii) Number of magnetic lines of force per unit area gives the intensity of the magnetic field at a point.



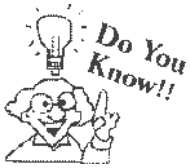
- *Magnetic field lines demostrate the magnetic field of a magnet pictorially.*
- *The tangent to the magnetic field line at a point gives the direction of the magnetic field at that point.*

Think it Over

Magnetic field lines never intersect. What happens if it happens so ?

THE EARTH AS A MAGNET

The interior of the earth contains a hot plasma which is in circulation. This circulation of plasma is just like flow of currents and due to this there is a magnetic field outside the earth. This is called terrestrial magnetism.
The earth behaves as a huge magnet. Its north pole is near the geographical south and the south pole is near the geographical North. The reason that a freely suspended bar magnet stands in a direction, point north-south is included in the magnetism of the earth.
The north pole of the suspended magnet is attracted by the south pole of the earth's magnet and the south pole of the suspended magnet is attracted by the north pole of the earth's magnet. Thus, the north pole of the magnet stands near geographical north and the south pole near geographical south. The magnetism of the earth is known as the terrestrial magnetism. Terrestrial magnetism is studied with its elements, viz., horizontal component of earth's magnetism, angle of dip and angle of declination.
The space where the effect of earth's magnetism is experienced is called earth's magnetic field.



In 1600, Dr. William Gilbert, an English physicist observed that the Earth behaves as a large permanent magnet.

The imaginary line joining the earth's geographic north pole to south pole is called ***geographic axis*** and the imaginary plane containing geographic north, south poles at a given place is called ***geographic meridian*** at that place.
The imaginary line joining the earth's magnetic north pole to the south pole is called ***magnetic axis.*** The earth's magnetic axis makes an angle of about 17° with its geographic axis. An imaginary vertical plane passing through a given place and containing the earth's magnetic poles is called the ***magnetic meridian***.

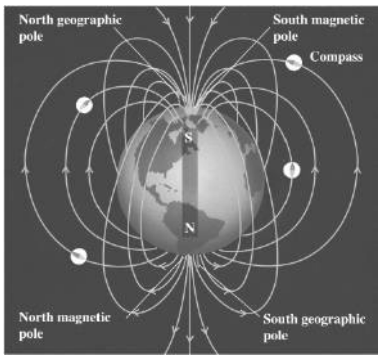


Fig. 11.8

Angle of Dip

The earth's magnetic field can be resolved into horizontal and vertical components. T*he angle between the earth's magnetic field and its horizontal component is called the angle of dip or angle of inclination.* It varies from place to place. Its value is zero at the magnetic equator and 90° at the earth's magnetic poles.
It is measured with the help of a device called dip circle.

Angle of Declination

The angle between the magnetic meridian and the geographic meridian at a given place is called the angle of declination. It varies from place to place on the earth.

It has an average value of 17.5°

ELECTROMAGNETISM

In early ages, it was understood that electricity and magnetism are separate branches of Physics. But Hans Christian Oersted, a Danish physicist, co-related electricity and magnetism. He showed that a magnetic compass got deflected when brought near a wire carrying electric current.

Thus, magnetism is an effect of electricity also. A charge moving with certain velocity produces a magnetic field apart from electric field. A charge at rest produces electric field only.

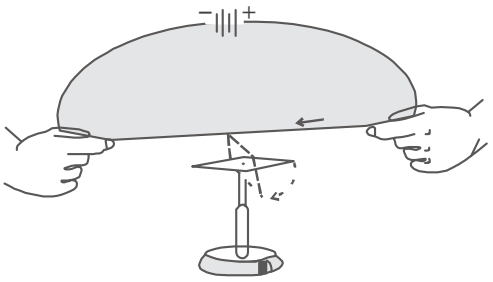


Fig. 11.9

Direction of Electromagnetic Field

The direction of electromagnetic field due to a current carrying conductor can be found using Maxwell's right hand grip rule.

Maxwell's right hand grip rule : Hold a linear object like a wire or a rod as a grip in your right hand. If the direction of pointing a thumb indicates the direction of current through the conductor, then, the direction of the other four fingers curled around the rod indicates the direction of the magnetic field produced by the current through the conductor.

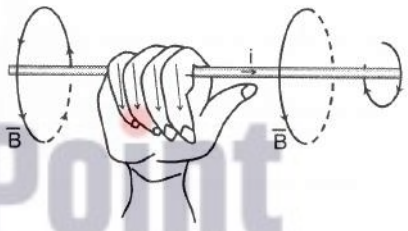
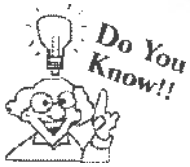


Fig. 11.10

Physics Point



- *The direction of deflection of the magnetic compass due to the electric current passing through the wire can be found by Ampere's swimming rule. It is also known as SNOW rule.*
- *In C.G.S. system, the unit of magnetic field strength is oersted named in the honour of Hans christian oersted.*

Magnetic Field due to Current in a Straight Conductor

The following experiment demonstrates the nature of magnetic field around a straight current carrying conductor. Take a plane cardboard 'ABCD' of square shape. Make a small hole at its centre so as to allow an insulated wire 'PQ' to pass through the hole; such that the length of the wire is perpendicular to the plane of the cardboard figure. Connect the wire to a less plug key and a cell as shown in figure

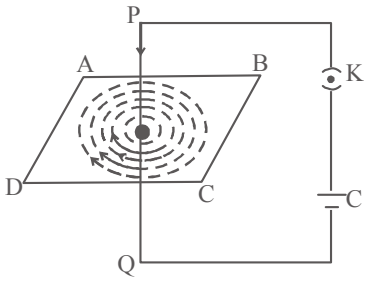
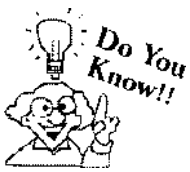


Fig. 11.11

Sprinkle some iron filings on the cardboard, and insert the plug in the key to give electric connection to the conductor PQ. We observe that the iron filings are arranged in concentric circles with the centre at the hole on the cardboard as shown in figure.

The concentric circles indicate the direction of magnetic field around the current carrying conductor.



- *A curent carying conductor placed perpendicular to the magnetic field experiences a maximum force.*
- *A current carrying conductor placed in the direction of the magnetic field (or parallel to the magnetic field) experiences no force.*

Magnetic Field Around a Circular Conductor

Consider a circular loop PQRS passing through two holes 1 and 2 on a rectangular cardboard ABCD. Some iron filings are sprinkled on the cardboard. When the circular loop is connected to a cell, via a plug key and the circuit is switched on, we observe that the iron filings are arranged like concentric circles around the two holes 1 and 2 as shown in figure. The concentric circles formed by the iron filings represent the directions of the magnetic field surrounding the circular loop, i.e., they represent the magnetic field lines due to the current carrying loop. The lines are straight at the centre of the loop. A small magnetic needle placed at the centre of the loop on the plane of the cardboard, points north towards edge AD of the cardboard. This implies that the circular loop acts like a magnet with its south pole towards the edge BC and north pole towards edge AD.

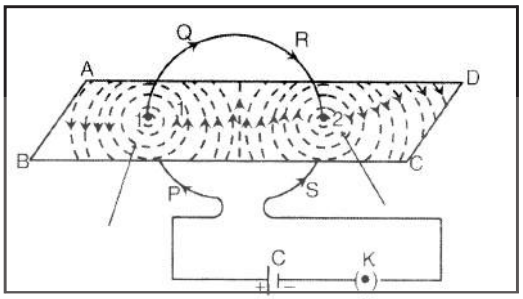


Fig. 11.12

The magnetic needle deflects due to the force which the magnetic field of the current exerts on it. The direction of this force is obtained by **Fleming's left hand rule** which states that *when we stretch out the fore-finger, middle finger and the thumb perpendicular to each other such that the fore-finger gives the direction of the magnetic field, the middle finger gives the direction of current then the thumb will give the direction of the force experienced by the current carrying conductor*.

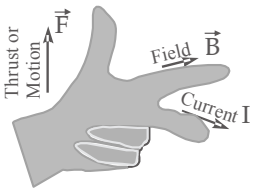


Fig. 11.13

A circular wire carrying current in anticlockwise direction is behaved as north-pole of a magnet while that carrying current in clockwise direction is behaved as south-pole of a magnet.

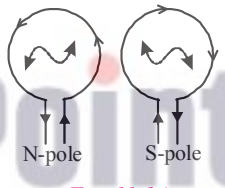


Fig. 11.14

Physics Point

Advantages of Electromagnet

(i) An electromagnet can produce a strong magnetic field and its strength can be controlled by changing the strength of the current or the number of turns in the coil.

(ii) The polarity of an electromagnet can be changed by reversing the direction of current that flows in the solenoid.

Uses of Electromagnets

Electromagnets are used in electric bells, telephone earpieces, electric motor, etc.

ELECTROMAGNETIC INDUCTION

In the early 1800s, the only current-producing devices were voltaic cells, which produced small currents by dissolving metals in acids. These were the forerunners of our present-day batteries. The question arose as to whether electricity could be produced from magnetism. The answer was provided in 1831 by two physicists, Michael Faraday in England and Joseph Henry in the United States each working without knowledge of the other. Their discovery changed the world by making electricity commonplace powering industries by day and lighting up cities at night.

Faraday and Henry both discovered that electric current could be produced in a wire simply by moving a magnet into or out of a coil of wire. No battery or other voltage source was needed only the motion of a magnet in a wire loop. They discovered that voltage is caused, or *induced,* by the relative motion between a wire and a magnetic field. Whether the magnetic field moves near a stationary conductor or vice-versa, voltage is induced either way.

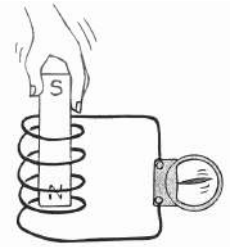


Fig. 11.15 : When the magnet is plunged into the coil, charges in the coil are set in motion, and voltage is induced in the coil.

Fig. 11.16: Voltage is induced in the wire loop whether the magnetic field moves past the wire or the wire moves through the magnetic field.

The greater the number of loops of wire moving in a magnetic field, the greater the induced voltage. Pushing a magnet into a coil with twice as many loops induces twice as much voltage; pushing into a coil with ten times as many loops induces ten times as much voltage; and so on.

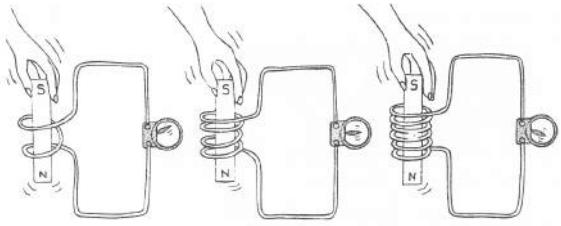


Fig. 11.17 : When a magnet is plunged into a coil with twice as many loops as another, twice as much voltage is induced. and so on.

We find that it is more difficult to push the magnet into a coil made up of more loops. This is because the induced voltage produces a current, which makes an electromagnet, which repels the magnet in our hand. So we must do more work against this "back force" to induce more voltage.

The amount of voltage induced depends on how fast the magnetic field lines are entering or leaving the coil. Very slow motion produces hardly any voltage at all. Rapid motion induces a greater voltage. *This phenomenon of inducing voltage by changing the magnetic field in a coil of wire is called* ***electromagnetic induction***.

Fig. 11.18 : It is more difficult to push the magnet into a coil with many loops.

Physics Point

CHECK Point

If you push a magnet into a coil, as shown in figure 11.19 you'll feel a resistance to your push. Why is this resistance greater in a coil with more loops?

SOLUTION

Simply put, more work is required to provide more energy. You can also look at it this way: When you push a magnet into a coil, you cause the coil to become an electromagnet. The more loops in the coil, the stronger the electromagnet that you produce and the stronger it pushes back against you. (if the electromagnetic coil attracted your magnet instead of repelling it, energy would have been created from nothing and the law of energy conservation would have been violated. So the coil must repel the magnet.)

APLICATIONS OF ELECTROMAGNETIC INDUCTION

A.C. Generator

When a magnet is repeatedly plunged into and back out of a coil of wire, the direction of the induced voltage alternates. As the magnetic field strength inside the coil is increased (as the magnet enters), the induced voltage in the coil is directed one way. When the magnetic field strength diminishes (as the magnet leaves), the voltage is induced in the opposite direction. The frequency of the alternating voltage that is induced is equal to the frequency of the changing magnetic field within the loop.

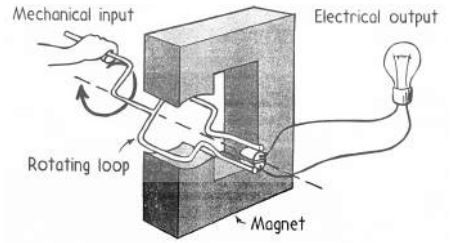


Fig. 11.19 : A simple generator. Voltage is induced in the loop when it is rotated in the magnetic field.

It is more practical to induce voltage by moving a coil rather than by moving a magnet. This can be done by rotating the coil in a stationary magnetic field. Such an arrangement is called a **generator**. A generator is a motor in reverse. The device is much the same, with the roles of input and output reversed. In a motor, electrical energy is the input and mechanical energy is the output. Both devices simply transform energy from one form to another.

The direction of induced current in a conductor is determined by Fleming's right hand rule .

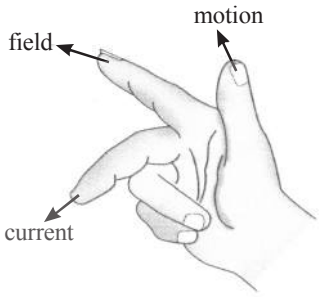


Fig. 11.20

Fleming's right hand rule is also known as Dynamo rule.

Electric Motor

An electric motor is a device that converts electrical energy into mechanical energy. (Kinetic energy)
When a current carrying conductor, capable of moving freely, is placed in a magnetic field, it experiences a force and begins to move in a direction given by Fleming's left hand rule.

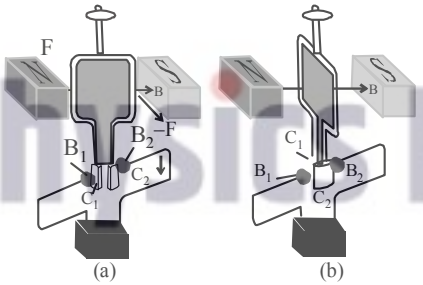


Fig. 11.21 Electric motor

Transformer

A transformer is a device which is used to change the alternating voltage (or current). It converts a low voltage at high current into a high voltage at low current, and vice-versa.

A transformer cannot change a d.c.

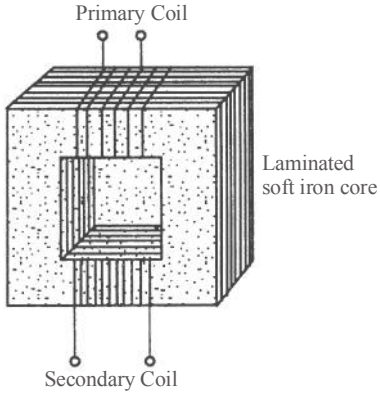


Fig. 11.22 : Transformer

It is of two types

(i) **Step-down transformer -** It converts a high voltage at low current ac into a low voltage at high current ac.
(ii) **Step-up transformer -** It converts a low voltage at high current ac into a high voltage at low current ac.

SUMMARY

Magnetism is the property of a material due to which it attracts magnetic materials like iron, cobalt, nickel, etc.

- **Magnetic poles :** It is responsible for magnetic force.
- **Natural magnets :** The magnets found in nature are called natural magnets.
- **Artificial magnets :** The magnets which are made artificially by magnetic materials are called *artificial magnets*.
- **Permanent and temporary magnets :** Those magnets which retain their magnetic properties over a long time are known as *permanent magnets*. The magnets which retain their magnetic properties only under certain external conditions like presence of an electric current in the vicinity or of a strong magnet are called *temporary magnets*.
- **Properties of magnets :** (1) Attractive property (2) Directive property
  (3) Poles exist in pair (4) Unlike poles attract and like poles repel
- **Magnetic field :** The region around a magnet where magnetic forces act is called magnetic field.
- **Magnetic domains :** The magnetic field of an individual atom is so strong that interactions among adjacent atoms cause large clusters of them to line up with one another. These clusters of aligned atoms are called *magnetic domains*.
- **Magnetic lines of force :** The path taken by a unit north pole if it is free to move is called the magnetic lines of force.
- **Earth's magnetism :** The interior of the earth contains a hot plasma which is in circulation. This circulation of plasma is just like flow of currents and due to this there is a magnetic field outside the earth. This is called earth's or terrestrial magnetism.
- **Angle of dip :** The angle made by the earth's magnetic field with its horizontal component is called the angle of dip or angle of inclination.
- **Angle of declination :** The angle between the earth's magnetic meridian and the geographic meridian at a given place is called the angle of declination.
- **Electromagnetism :** Magnetism produced by electricity is called electromagnetism. The electromagnet is a temporary magnet which can be magnetized or demagnetized in a very short time as per our requirements.
- **Magnetic field due to current in different conductors :** The magnetic field around a current carrying conductor or wire is represented by concentric circles centred at the wire. A circular wire carrying current in anticlockwise direction is behaved as north-pole of a magnet while that carrying current in clockwise direction is behaved as south-pole of a magnet.
- **Solenoid :** A solenoid is a cylindrical coil of many tightly wound turns of insulated wires with generally diameter of the coil smaller than its length.
- **Electric motor :** An electric motor is a device that converts electrical energy into mechanical energy (Kinetic energy).
- **Electromagnetic induction :** The phenomenon of inducing voltage by changing the magnetic field in a coil of wire is called electromagnetic induction.
- **Generator :** A generator is a device which converts mechanical energy into electrical energy.
- **Transformer :** A transformer is a device which is used to change the alternating voltage (or current). It converts a low voltage at high current into a high voltage at low current, and vice-versa.

Physics Point

ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

Single Option Correct :

DIRECTIONS (Qs. 1–16) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which only one is correct.*

1. What is the reason to pivot the compass needle on a sharp pin?
(a) To minimise the magnetic effect on the pin
(b) To maximize the magnetic effect on the pin
(c) To minimize the friction between the pin and the compass needle
(d) To ensure that the compass needle will not drop from the pivoted point

2. When an iron bar is moved over a bar magnet along its length the attractive force
(a) increases first and then decreases
(b) decreases first and then increases
(c) remains same
(d) increase

3. When the S–pole of a magnet is placed near an unknown pole of another magnet, the two magnets
(a) repel each other because the unknown pole is N–pole
(b) repel each other because the unknown pole is S–pole
(c) attract each other because the unknown pole is S–pole
(d) can either attract or repel

4. The magnet is strongest near the
(a) poles of the magnet
(b) ends of the magnet
(c) centre of magnet
(d) on equater point from the poles of the magnet

5. Which of the following is an artificial magnet?
(a) Bar magnet
(b) Horse-shoe magnet
(c) Magnetic needle
(d) all the above

6. The magnetic lines of force due to a bar magnet are
(a) curved lines (b) curved closed loops
(c) concentric circles (d) parallel and straight

7. A conducting wire can give magnetic poles when it
(a) bent into the form of a circular ring
(b) placed in an external magnetic field
(c) suspended freely in air
(d) all the above

8. The direction of magnetic field at any point inside the field is given by
(a) perpendicular to the lines of force
(b) tangent to the lines of force
(c) the lines of force itself
(d) none of the above

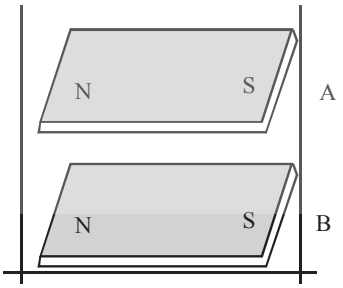
9. Whenever, current is changed in a coil, an induced e.m.f. is produced in the same coil. This property of the coil is due to
(a) mutual induction (b) self induction
(c) eddy currents (d) hysteresis

10. Two identical coaxial circular loops carry a current i each circulating in the same direction. If the loops approach each other, you will observe that
(a) the current in each increases,
(b) the current in each decreases,
(c) the current in each remains the same,
(d) the current in one increases whereas that in the other decreases

11. An induced e.m.f. is produced when a magnet is plunged into a coil. The strength of the induced e.m.f. is independent of
(a) the strength of the magnet
(b) number of turns of coil
(c) the resistivity of the wire of the coil
(d) speed with which the magnet is moved

12. Earth's magnetic field always has a horizontal component except at
(a) magnetic equator
(b) magnetic pole
(c) geographical north pole
(d) at an altitude of 45°

13. Two magnets A and B are placed with like poles having one above another. What will happen?



(a) A will stuck to B
(b) A will remain as shown in the figure
(c) A will move side ways
(d) Can't say

Physics Point

14. The laws of electromagnetic induction have been used in the construction of a
(a) galvanometer (b) voltmeter
(c) electric motor (d) generator

15. In which of the following devices temporary magnets are used?
(a) Dynamo (b) Electric motors
(c) Generators (d) Electric cranes

16. A magnet is moved towards a coil (i) quickly (ii) slowly, then the induced e.m.f. is
(a) larger in case (i)
(b) smaller in case (i)
(c) equal to both the cases
(d) larger or smaller depending upon the radius of the coil

More than One Option Correct :

DIRECTIONS (Qs. 17–22): *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which one or more may be correct.*

17. The magnetic field due to a bar magnet .....
(a) has the same direction at any point
(b) is uniform
(c) is non-uniform
(d) has different directions at different point

18. Which of the following is a property shown by a magnet?
(a) Attractive (b) Directive
(c) Induction (d) Repulsive

19. The strength of a magnetic field increases as .....
(a) the number of magnetic lines of force passing through a given area increases
(b) strength of the magnetic poles increases
(c) distance between the magnetic poles increase
(d) strength of the magnetic poles decreases

20. Magnetic lines of force:
(a) never intersect
(b) are closed curves
(c) tend to crowd near the poles of a magnet
(d) do not pass through vacuum.

21. Choose the correct statement(s) from the following ?
(a) Magnetic lines of force appear to converge or diverge at poles
(b) Magnetic lines of force never intersect each other.
(c) On passing AC through a wire wounded around a magnet its strengh of magnetism enhances
(d) A magnet attracts certain other substances through the phenomenon of magnetic induction

22. Choose the correct statements(s) from the following ?
(a) At a neutral point, there cannot be any lines of force.
(b) Magnetic lines of force exist inside every magnetised material
(c) Soft iron pieces are used as magnetic keepers
(d) The magnetic moment of a magnet decreases on bending it into a semi-circle.

Multiple Matching Questions :

DIRECTIONS (Qs. 23-26) : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r, s ....) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

Match the Column I and II.

23.

Column I	Column II
(A) Magnet with single pole	(p) resultant field is zero
(B) Null points	(q) earth's magnetic fields
(C) Terrestrial magnetism	(r) does not exist
(D) Artificial magnet	(s) horse shoe magnet

24.

Column I	Column II
(A) Orsted's experiment	(p) Magnetic meridian
(B) Steel	(q) Permanent magnet
(C) Sure test of magnet	(r) Magnetic effects of current
(D) Vertical plane passing through magnetic axis	(s) Repulsion

25.

Column I	Column II
(A) Magnetic lines	(p) Earth's magnet
(B) Magnetic field	(q) Lodestone
(C) Terrestrial magnet	(r) Emerge into south pole
(D) Natural magnet	(s) Right hand grip rule
	(t) Originate from north pole

26.

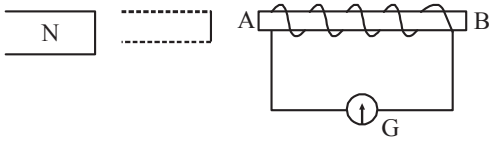
Column I	Column II
(A) Magnetic axis	(p) Distance between the poles
(B) Equatorial line	(q) Imaginary vertical plane
(C) Magnetic length	(r) Nature of magnetic substance
(D) Magnetic meridian	(s) Line joining the poles
(E) Magnetic induction depends on	(t) Line perpendicular to the magnet
	(u) Distance between magnetic substance and magnet

Passage Based Questions :

DIRECTIONS (Qs. 27–29) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

The diagram shows a coil connected to a galvanometer G (note that a galvanometer reads current). The galvanometer shows a deflection to the right when the north pole of a powerful magnet is moved to the right as shown.



Physics Point

27. What is the direction of current in the coil when viewed from end A ?

(a) clock-wise (b) anti-clockwise

(c) downward (d) upward

28. When the coil is moved away from N, then

(a) the galvanometer now deflects towards left

(b) the galvanometer now deflects towards right

(c) the galvanometer doesn't deflect

(d) none of these

29. When both coil and the magnet, are moved to the right at the same speed, then

(a) the galvanometer deflects towards left

(b) the galvanometer deflects towards right

(c) the galvanometer doesn't deflect

(d) none of these

Assertion & Reason :

DIRECTIONS (Qs. 30–37) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.

(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.

(c) If **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

30. **Assertion:** Free electrons always keep on moving in a conductor even then, no magnetic force act on them in magnetic field unless a current is passed through it.

Reason: The average velocity of a free electron is zero.

31. **Assertion:** Basic difference between an electric lines of force and magnetic lines of force is that former is discontinuous and the latter is continuous or endless.

Reason: No electric lines of force exist inside a charged body but magnetic lines do exist inside a magnet.

32. **Assertion:** At neutral point, a compass needle point out any arbitrary direction.

Reason: Magnetic field of earth is balanced by field due to magnets at the neutral point.

33. **Assertion:** Poles of a magnet can never be separated.

Reason: Since, each atom of a magnetic material is itself a magnet.

34. **Assertion:** Magnetic lines of force never intersect

Reason: The direction of magnetic lines of force in a magnetic field is from north to south.

35. **Assertion :** An unmagnetised piece of iron is attracted to a bar magnet.

Reason: An atom is equivalent to current loop.

36. **Assertion:** A compass needle when placed on the magnetic north pole of the earth rotates in vertical direction.

Reason: The earth has both horizontal and vertical components of its magnetic field at the north pole.

37. **Assertion:** The earth magnetic field is due to iron present in its core.

Reason: At a high temperature magnet loses its magnetic property or magnetism.

Integer/ Numerical Questions :

DIRECTIONS (Qs. 38-40) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

38. The horizontal component of the earth's magnetic field is 3.6×10^{-5} tesla where the dip angle is 60°. The magnitude of the earth's magnetic field is $(1.2)x \times 10^{-5}$ tesla. Find the value of x.

39. A short bar magnet of magnetic moment 0.4J T^{-1} is placed in a uniform magnetic field of 0.16 T. The magnet is in stable equilibrium when the potential energy is $8\ x \times 10^{-3}$ joule. Find the value of x.

40. The true value of angle of dip at a place is 60°, the apparent dip in a plane inclined at an angle of 30° with magnetic meridian is $\tan^{-1}\frac{1}{x}$. Find the value of x.

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SOLUTIONS

Brief Explanations of Selected Questions

ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

Single Option Correct :

1. (c) Sharp pin to minimize the area so friction force.

2. (b) **3.** (b) **4.** (b) **5.** (d)

6. (c) **7.** (a) **8.** (b) **9.** (b) **10.** (b)

11. (c) **12.** (b)

13. (b) Unlike poles repel. The repulsive magnetic force will not allow the like poles to get stuck.

14. (d) **15.** (d)

16. (a) Induced emf increases when a magnet moves towards a coil quickly.

More Than One Option Correct :

17. (a, c) **18.** (a, b, c) **19.** (a, b) **20.** (a, b, c)

21. (a, b, d) **22.** (a, b, c, d)

Multiple Matching Questions :

23. A – (r); B – (p); C – (q); D – (s)

24. A – (r); B – (q); C – (s); D – (p)

25. A – (r, t); B – (s); C – (p); D – (p, q)

26. A – (s); B – (t); C – (p); D – (q); E – (r, u)

Passage Based Questions :

27. (b) The current appears anti-clockwise when viewed from end A. (because end A will form a north pole).

28. (a) The galvanometer now deflects towards left.

29. (c) No deflection is observed as there is no relative motion between the magnet and

Assertion & Reason :

30. (a) In the absence of the electric current, the free electrons in a conductor are in a state of random motion, like molecule in a gas. Their average velocity is zero. i.e. they do not have any net velocity in a direction. As a result, there is no net magnetic force on the free electrons in the magnetic field. On passing the current, the free electrons acquire drift velocity in a definite direction, hence magnetic force acts on them, unless the field has no perpendicular component.

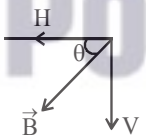
31. (a) **32.** (a) **33.** (a) **34.** (c) **35.** (b)

36. (d)

37. (d) Due to circulation of hot plasma in the interior of the earth.

Integer/Numeric Questions :

38. 6



Horizontal component of earth's field, $H = B\cos\theta$, since, $\theta = 60°$

$3.6\times10^{-5} = B\times\frac{1}{2} \Rightarrow B = 7.2\times10^{-5}$ tesla

$\therefore \quad x = 6$

39. 8 For stable equilibrium

$U = -MB = -(0.4)(0.16) = -0.064$ J $\quad \therefore \quad x = 8$

40. 2 $\tan\phi' = \frac{\tan\phi}{\cos\beta}$; where ϕ' = Apparent angle of dip,

ϕ = True angle of dip, β = Angle made by vertical plane with magnetic meridian.

$\Rightarrow \tan\phi' = \frac{\tan 60°}{\cos 30°} = 2 \Rightarrow \phi' = \tan^{-1}(2)$

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