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Learning Objectives

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At the end of this lesson students will be able to:

- Understand the concepts of force and motion.
- Explain inertia and its types.
- State the three laws of Newton.
- Apply Newtonian concept of force and motion.
- Define force, momentum and impulse.
- Distinguish between mass and weight
- Analyze weightlessness and the principle of conservation of momentum.
- Explain the law of gravitation and its applications.
- Understand the variations in 'g' due to height and depth.
- Solve numerical problems related to force and motion

INTRODUCTION

Human beings are so curious about things around them. Things around us are related to one another. Some bodies are at rest and some are in motion. Rest and motion are interrelated terms.

In the previous classes you have learnt about various types of motion such as linear motion, circular motion, oscillatory motion, and so on. So far, you have discussed the motion of bodies in terms of their displacement, velocity, and acceleration. In this unit, let us investigate the cause of motion.

When a body is at rest, starts moving, a question that arises in our mind is 'what causes the body to move?' Similarly, when a moving object comes to rest, you would like to know what brings it to rest? If a moving object speeds up or slows down or changes its direction. what speeds up or slows down the body? What changes the direction of motion?

One answer for all the above questions is 'Force'. In a common man's understanding of motion, a body needs a 'push' or 'pull' to move, or bring to rest or change its velocity. Hence, this 'push' or 'pull' is called as 'force'.

Let us define force in a more scientific manner using the three laws proposed by Sir Isaac Newton. These laws help you to understand the motion of a body and also to predict the future course of its motion, if you know the forces acting on it. Before Newton formulated his three laws of motion, a different perception about the force and motion of bodies prevailed. Let us first look at these ideas and then eventually learn about Newton's laws in this unit.

Mechanics is the branch of physics that deals with the effect of force on bodies. It is divided into two branches, namely, statics and dynamics.

Statics: It deals with the bodies, which are at rest under the action of forces.

Dynamics: It is the study of moving bodies under the action of forces. Dynamics is further divided as follows.

Kinematics: It deals with the motion of bodies without considering the cause of motion.

Kinetics: It deals with the motion of bodies considering the cause of motion.

1.1 FORCE AND MOTION

According to *Aristotle* a Greek Philosopher and Scientist, the natural state of earthly bodies is 'rest'. He stated that a moving body naturally comes to rest without any external influence of the force. Such motions are termed as **'natural motion' (Force independent).** He also proposed that a force (a push or a pull) is needed to make the bodies to move from their natural state (rest) and behave contrary to their own natural state called as **'violent motion' (Force dependent)**. Further, he said, when two differnt mass bodies are dropped from a height, the heavier body falls faster than the lighter one.

Galileo proposed the following concepts about force, motion and inertia of bodies:

(i) The natural state of all earthly bodies is either the state of rest or the state of uniform motion.

(ii) A body in motion will continue to be in the same state of motion as long as no external force is applied.

(iii) When a force is applied on bodies, they resist any change in their state. This property of bodies is called 'inertia'.

(iv) When dropped from a height in vacuum, bodies of different size, shape and mass fall at the same rate and reach the ground at the same time.

1.2 INERTIA

While you are travelling in a bus or in a car, when a sudden brake is applied, the upper part of your body leans in the forward direction. Similarly, when the vehicle suddenly is move forward from rest, you lean backward. This is due to, any body would like to continue to be in its state of rest or the state of motion. This is known as 'inertia'.

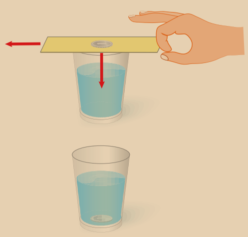
The inherent property of a body to resist any change in its state of rest or the state of uniform motion, unless it is influenced upon by an external unbalanced force, is known as **'inertia'.**

Activity 1

Take a glass tumbler and place a small cardboard on it as shown in the figure. Now, keep a coin at the centre of the cardboard. Then, flick the cardboard quickly. What do you observe?

The cardboard falls off the ground and the coin falls into the glass tumbler.

Inertia of rest



In activity described above, the inertia of the coin keeps it in the state of rest when the cardboard moves. Then, when the cardboard has moved, the coin falls into the tumbler due to gravity. This happen due to 'inertia of rest'.

1.2.1 Types of Inertia

a) **Inertia of rest:** The resistance of a body to change its state of rest is called inertia of rest.

b) **Inertia of motion**: The resistance of a body to

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change its state of motion is called inertia of motion.

c) **Inertia of direction:** The resistance of a body to change its direction of motion is called inertia of direction.

1.2.2 Examples of Inertia

- An athlete runs some distance before jumping. Because, this will help him jump longer and higher. (Inertia of motion)
- When you make a sharp turn while driving a car, you tend to lean sideways, (Inertia of direction).
- When you vigorously shake the branches of a tree, some of the leaves and fruits are detached and they fall down, (Inertia of rest).

Figure 1.1 Inertia of motion

1.3 LINEAR MOMENTUM

The impact of a force is more if the velocity and the mass of the body is more. To quantify the impact of a force exactly, a new physical quantity known as linear momentum is defined. The linear momentum measures the impact of a force on a body.

The product of mass and velocity of a moving body gives the magnitude of linear momentum. It acts in the direction of the velocity of the object. Linear momentum is a vector quantity.

Linear Momentum = mass × velocity

$$p = mv \quad \ldots\ldots\ldots\ldots (1.1)$$

It helps to measure the magnitude of a force. Unit of momentum in SI system is kg m s^{-1} and in C.G.S system its unit is g cm s^{-1}.

1.4 NEWTON'S LAWS OF MOTION

1.4.1 Newton's First Law

This law states that **every body continues to be in its state of rest or the state of uniform motion along a straight line unless it is acted upon by some external force.** It gives the definition of force as well as inertia.

1.4.2 Force

Force is an external effort in the form of push or pull, which:

1. produces or tries to produce the motion of a static body.
2. stops or tries to stop a moving body.
3. changes or tries to change the direction of motion of a moving body.

Force has both magnitude and direction. So, it is a vector quantity.

1.4.3 Types of forces

Based on the direction in which the forces act, they can be classified into two types as: (a) Like parallel forces and (b) Unlike parallel forces.

(a) **Like parallel forces:** Two or more forces of equal or unequal magnitude acting along the same direction, parallel to each other are called like parallel forces.

(b) **Unlike parallel forces:** If two or more equal forces or unequal forces act along opposite directions parallel to each other, then they are called unlike parallel forces. Action of forces are given in Table 1.1.

1.4.4 Resultant Force

When several forces act simultaneously on the same body, then the combined effect of the multiple forces can be represented by a single force, which is termed as '*resultant force*'. It is equal to the vector sum (adding the magnitude of the forces with their direction) of all the forces.

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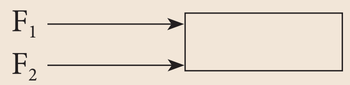
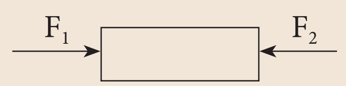
Table 1.1 Action of forces

Action of forces	Diagram	Resultant force (F_{net})
Parallel forces are acting in the same direction		$F_{net} = F_1 + F_2$
Parallel unequal forces are acting in opposite directions		$F_{net} = F_1 - F_2$ (if $F_1 > F_2$) $F_{net} = F_2 - F_1$ (if $F_2 > F_1$) F_{net} is directed along the greater force.
Parallel equal forces are acting in opposite directions in the same line of action ($F_1 = F_2$)		$F_{net} = F_1 - F_2$ $F_{net} = 0$ since ($F_1 = F_2$)

(a) Unlike parallel forces – Tug of war

(b) Unbalanced forces - Action of a lever

(c) Like parallel forces

Figure 1.2 Combined effect of forces

If the resultant force of all the forces acting on a body is equal to zero, then the body will be in equilibrium. Such forces are called **balanced forces**. If the resultant force is not equal to zero, then it causes the motion of the body due to **unbalanced forces**

Examples: Drawing water from a well, force applied with a crow bar, forces on a weight balance, etc.

A system can be brought to equilibrium by applying another force, which is equal to the resultant force in magnitude, but opposite in direction. Such force is called as '**Equilibrant**'.

1.4.5 Rotating Effect of Force

Have you observed the position of the handle in a door? It is always placed at the edge of door and not at some other place. Why? Have you tried to push a door by placing your hand closer to the hinges or the fixed edge? What do you observe?

The door can be easily opened or closed when you apply the force at a point far away from the fixed edge. In this case, the effect of the force you apply is to turn the door about the fixed edge. This turning effect of the applied force is more when the distance between the fixed edge and the point of application of force is more.

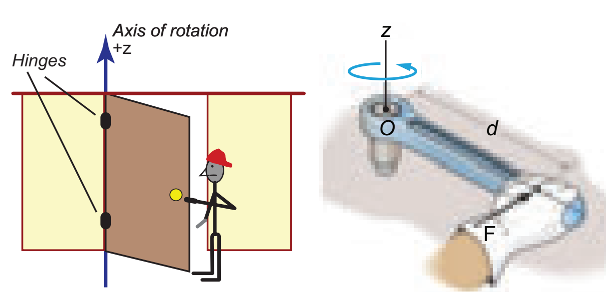


Figure 1.3 Rotating effect of a force

The axis of the fixed edge about which the door is rotated is called as the '*axis of rotation*'. Fix one end of a rod to the floor/wall, and apply a force at the other end tangentially.

The rod will be turned about the fixed point is called as '*point of rotation*'.

1.4.6 Moment of the Force

The rotating or turning effect of a force about a fixed point or fixed axis is called **moment of the force** about that point or **torque (τ)**. It is measured by the product of the force (F) and the perpendicular distance (d) between the fixed point or the fixed axis and the line of action of the force.

$$\tau = F \times d \quad \text{.......... (1.2)}$$

Torque is a vector quantity. It is acting along the direction, perpendicular to the plane containing the line of action of force and the distance. Its SI unit is Nm.

Couple: Two equal and unlike parallel forces applied simultaneously at two distinct points constitute a couple. The line of action of the two forces does not coincide. It does not produce any translatory motion since the resultant is zero. But, a couple results in causes the rotation of the body. Rotating effect of a couple is known as **moment of a couple**.

Examples: Turning a tap, winding or unwinding a screw, spinning of a top, etc.

Moment of a couple is measured by the product of any one of the forces and the perpendicular distance between the line of action of two forces. The turning effect of a couple is measured by the magnitude of its moment.

Moment of a couple = Force × perpendicular distance between the line of action of forces

$$M = F \times S \quad \text{............ (1.3)}$$

The unit of moment of a couple is newton metre (N m) in SI system and dyne cm in CGS system.

By convention, the direction of moment of a force or couple is taken as positive if the body is rotated in the anti-clockwise direction and negative if it is rotate in the clockwise direction. They are shown in Figures 1.4 (a and b)

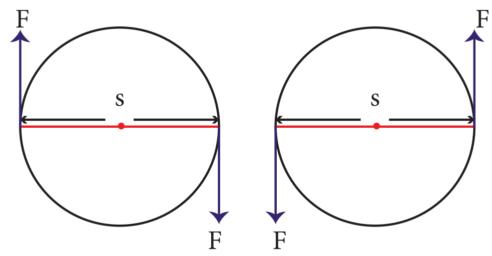


Figure 1.4 (a) Clockwise moment

Figure 1.4 (b) Anticlockwise moment

1.4.7 Application of Torque

1. Gears:

A gear is a circular wheel with teeth around its rim. It helps to change the speed of rotation of a wheel by changing the torque and helps to transmit power.

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2. Seasaw

Most of you have played on the seasaw. Since there is a difference in the weight of the persons sitting on it, the heavier person lifts the lighter person. When the heavier person comes closer to the pivot point (fulcrum) the distance of the line of action of the force decreases. It causes less amount of torque to act on it. This enables the lighter person to lift the heavier person.

3. Steering Wheel

A small steering wheel enables you to manoeuore a car easily by transferring a torque to the wheels with less effort.

1.4.8 Principle of Moments

When a number of like or unlike parallel forces act on a rigid body and the body is in equilibrium, then the algebraic sum of the moments in the clockwise direction is equal to the algebraic sum of the moments in the anticlockwise direction. In other words, at equilibrium, the algebraic sum of the moments of all the individual forces about any point is equal to zero.

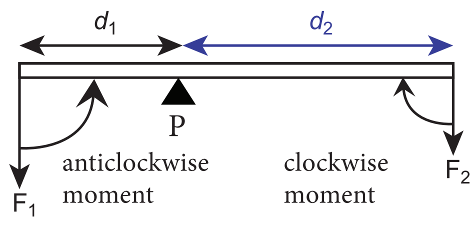

Figure 1.5 Principle of moments

In the illustration given in figure 1.5, the force F_1 produces an anticlockwise rotation at a distance d_1 from the point of pivot P (called fulcrum) and the force F_2 produces a clockwise rotation at a distance d_2 from the point of pivot P. The principle of moments can be written as follows:

Moment in clockwise direction = Moment in anticlockwise direction

$$F_1 \times d_1 = F_2 \times d_2 \quad \ldots\ldots\ldots (1.4)$$

1.5 NEWTON'S SECOND LAW OF MOTION

According to this law, "**the force acting on a body is directly proportional to the rate of change of linear momentum of the body and the change in momentum takes place in the direction of the force**".

This law helps us to measure the amount of force. So, it is also called as '*law of force*'. Let, 'm' be the mass of a moving body, moving along a straight line with an initial speed 'u' After a time interval of 't', the velocity of the body changes to 'v' due to the impact of an unbalanced external force F.

Initial momentum of the body $P_i = mu$

Final momentum of the body $P_f = mv$

Change in momentum $\Delta p = P_f - P_i$

$= mv - mu$

By Newton's second law of motion,

Force, F $\propto$ rate of change of momentum

F $\propto$ change in momentum / time

$$F \propto \frac{mv - mu}{t}$$

$$F = \frac{km(v - u)}{t}$$

Here, k is the proportionality constant. k = 1 in all systems of units. Hence,

$$\mathbf{F = \frac{m(v - u)}{t}} \quad (1.5)$$

Since, acceleration = change in velocity/ time, a=(v-u)/t. Hence, we have

$$\mathbf{F = m \times a} \quad (1.6)$$

Force = mass × acceleration

No external force is required to maintain the motion of a body moving with uniform velocity. When the net force acting on a body is not equal to zero, then definitely the velocity of the body will change. Thus, change in momentum takes place in the direction of the force. The change may take place either in magnitude or in direction or in both.

Force is required to produce the acceleration of a body. In a uniform circular motion, even though the speed (magnitude of velocity) remains constant, the direction of the velocity changes at every point on the circular path. So, the acceleration is produced along the radius called as *centripetal acceleration*. The force, which produces this acceleration is called as centripetal force, about which you have learnt in class IX.

Units of force: SI unit of force is newton (N) and in C.G.S system its unit is dyne.

Definition of 1 newton (N): The amount of force required for a body of mass 1 kg produces an acceleration of 1 m s^{-2}, $\mathbf{1\ N = 1\ kgms^{-2}}$

Definition of 1 dyne: The amount of force required for a body of mass 1 gram produces an acceleration of 1 cm s^{-2}, $\mathbf{1\ dyne = 1\ gcms^{-2}}$; also $\mathbf{1\ N = 10^5\ dyne}$.

Unit force:

The amount of force required to produce an acceleration of 1 ms^{-2} in a body of mass 1 kg is called '*unit force*'.

Gravitational unit of force:

In the SI system of units, gravitational unit of force is kilogram force, represented by kg f. In the CGS system its unit is gram force, represented by g f.

1 kgf = 1 kg × 9.8 ms^{-2} = 9.8 N;

1 gf = 1 g × 980 cms^{-2} = 980 dyne

1.6 Impulse

A large force acting for a very short interval of time is called as '**Impulsive force**'. When a force F acts on a body for a period of time t, then the product of force and time is known as '**impulse**' represented by 'J'

Impulse, $J = F \times t$ (1.7)

By Newton's second law

$F = \Delta p / t$ (Δ refers to change)

$\Delta p = F \times t$ (1.8)

From 1.7 and 1.8

$$\mathbf{J = \Delta p}$$

Impulse is also equal to the magnitude of change in momentum. Its unit is $kgms^{-1}$ or Ns.

Change in momentum can be achieved in two ways. They are:

i. a large force acting for a short period of time and

ii. a smaller force acting for a longer period of time.

Examples:

- Automobiles are fitted with springs and shock absorbers to reduce jerks while moving on uneven roads.
- In cricket, a fielder pulls back his hands while catching the ball. He experiences a smaller force for a longer interval of time to catch the ball, resulting in a lesser impulse on his hands.

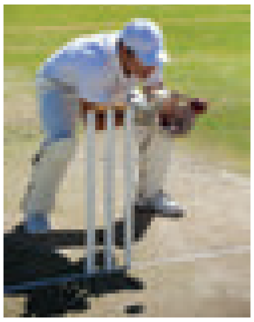

Figure 1.6 Example of impulsive force

1.7 NEWTON'S THIRD LAW OF MOTION

Newton's third law states that **'for every action, there is an equal and opposite reaction. They always act on two different bodies'.**

If a body A applies a force F_A on a body B, then the body B reacts with force F_B on the body A, which is equal to F_A in magnitude, but opposite in direction. $F_B = -F_A$

Examples:

- When birds fly they push the air downwards with their wings (Action) and the air pushes the bird upwards (Reaction).
- When a person swims he pushes the water using the hands backwards (Action), and the water pushes the swimmer in the forward direction (Reaction).
- When you fire a bullet, the gun recoils backward and the bullet is moving forward (Action) and the gun equalises this forward action by moving backward (Reaction).

1.8 PRINCIPLE OF CONSERVATION OF LINEAR MOMENTUM

There is no change in the linear momentum of a system of bodies as long as no net external force acts on them.

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Let us prove the law of conservation of linear momentum with the following illustration:

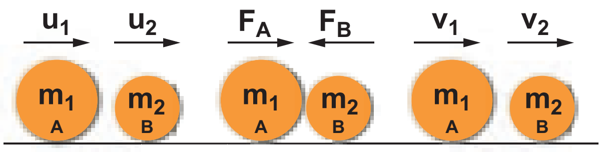

Figure 1.7 Conservation of linear momentum

Proof:

Let two bodies A and B having masses m_1 and m_2 move with initial velocity u_1 and u_2 in a straight line. Let the velocity of the first body be higher than that of the second body. i.e., $u_1 > u_2$. During an interval of time t second, they tend to have a collision. After the impact, both of them move along the same straight line with a velocity v_1 and v_2 respectively.

Force on body B due to A,

$$F_A = m_2 (v_2 - u_2)/t$$

Force on body A due to B,

$$F_B = m_1 (v_1 - u_1)/t$$

By Newton's III law of motion,

Action force = Reaction force

$$F_B = -F_A$$

$$m_1 (v_1 - u_1)/t = -m_2 (v_2 - u_2)/t$$

$$\mathbf{m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2 \text{ ------ } (1.9)}$$

The above equation confirms **in the absence of an external force, the algebraic sum of the momentum after collision is numerically equal to sum of the momentum before collision.**

Hence the law of conservation linear momentum is proved.

1.9 ROCKET PROPULSION

Propulsion of rockets is based on the law of conservation of linear momentum as well as Newton's III law of motion. Rockets are filled with a fuel (either liquid or solid) in the propellant tank. When the rocket is fired, this fuel is burnt and a hot gas is ejected with a high speed from the nozzle of the rocket, producing a huge momentum. To balance this momentum, an equal and opposite reaction force is produced in the combustion chamber, which makes the rocket project forward.

While in motion, the mass of the rocket gradually decreases, until the fuel is completely burnt out. Since, there is no net external force acting on it, the linear momentum of the system is conserved. The mass of the rocket decreases with altitude, which results in the gradual increase in velocity of the rocket. At one stage, it reaches a velocity, which is sufficient to just escape from the gravitational pull of the Earth. This velocity is called *escape velocity*. (This topic will be discussed in detail in higher classes).

1.10 GRAVITATION

1.10.1 Newton's universal law of gravitation

This law states that **every particle of matter in this universe attracts every other particle with a force. This force is directly proportional to the product of their masses and inversely proportional to the square of the distance between the centers of these masses. The direction of the force acts along the line joining the masses**.

Force between the masses is always attractive and it does not depend on the medium where they are placed.

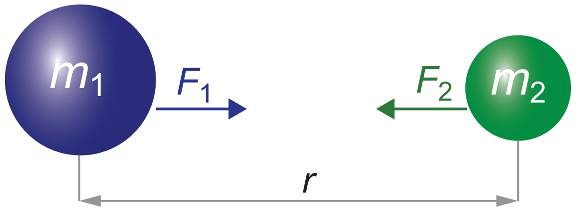

Figure 1.8 Gravitational force between two masses

Let, m_1 and m_2 be the masses of two bodies A and B placed *r* metre apart in space

Force $F \propto m_1 \times m_2$

$F \propto 1/r^2$

On combining the above two expressions

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

$$\mathbf{F} = \frac{\mathbf{G\,m_1\,m_2}}{\mathbf{r^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1.10)$$

Where G is the universal gravitational constant. Its value in SI unit is $6.674 \times 10^{-11}\ Nm^2 kg^{-2}$.

1.10.2 Acceleration due to gravity (g)

When you throw any object upwards, its velocity ceases at a particular height and then it falls down due to the gravitational force of the Earth.

The velocity of the object keeps changing as it falls down. This change in velocity must be due to the force acting on the object. The acceleration of the body is due to the Earth's gravitational force. So, it is called as 'acceleration due to the gravitational force of the Earth' or **'acceleration due to gravity of the Earth'**. It is represented as 'g'. Its unit is ms^{-2}

Mean value of the acceleration due to gravity is taken as 9.8 m s^{-2} on the surface of the Earth. This means that the velocity of a body during the downward free fall motion varies by 9.8 ms^{-1} for every 1 second. However, the value of 'g' is not the same at all points on the surface of the earth.

1.10.3 Relation between g and G

When a body is at rests on the surface of the Earth, it is acted upon by the gravitational force of the Earth. Let us compute the magnitude of this force in two ways. Let, M be the mass of the Earth and m be the mass of the body. The entire mass of the Earth is assumed to be concentrated at its centre. The radius of the Earth is R = 6378 km (= 6400 km approximately). By Newton's law of gravitation, the force acting on the body is given by

$$F = \frac{G\,M\,m}{R^2} \qquad (1.11)$$

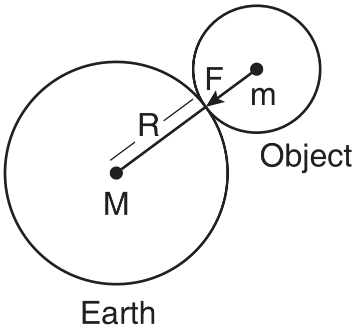

Figure 1.9 Relation between g and G

Here, the radius of the body considered is negligible when compared with the Earth's radius. Now, the same force can be obtained from Newton's second law of motion. According to this law, the force acting on the body is given by the product of its mass and acceleration (called as weight). Here, acceleration of the body is under the action of gravity hence a = g

$F = ma = mg$

$F = \text{weight} = mg$ ------------------ (1.12)

Comparing equations (1.7) and (1.8), we get

$$\mathbf{mg} = \frac{\mathbf{GMm}}{\mathbf{R^2}} \quad \text{-----------------------} \quad (1.13)$$

Acceleration due to gravity

$$\mathbf{g} = \frac{\mathbf{GM}}{\mathbf{R^2}} \quad \text{-----------------------------} \quad (1.14)$$

1.10.4 Mass of the Earth (M)

Rearranging the equation (1.14), the mass of the Earth is obtained as follows:

Mass of the Earth $M = g\,R^2/G$

Substituting the known values of g, R and G, you can calculate the mass of the Earth as

$\mathbf{M = 5.972 \times 10^{24}\ kg}$

1.10.5 Variation of acceleration due to gravity (g):

Since, g depends on the geometric radius of the Earth, ($g \propto 1/R^2$), its value changes from one place to another on the surface of the Earth. Since, the geometric radius of the Earth is maximum in the equatorial region and minimum in the polar region, the value of g is maximum in the polar region and minimum at the equatorial region.

When you move to a higher altitude from the surface of the Earth, the value of g reduces. In the same way, when you move deep below the surface of the Earth, the value of g reduces. (This topic will be discussed in detail in the higher classes). Value of g is zero at the centre of the Earth.

1.11 MASS AND WEIGHT

Mass: Mass is the basic property of a body. Mass of a body is defined as the quantity of matter contained in the body. Its SI unit is kilogram (kg).

Weight: Weight of a body is defined as the gravitational force exerted on a body due to the gravity.

Weight = Gravitational Force

= mass (m)× acceleration due to gravity(g).

g = acceleration due to gravity for Earth (at sea level) = 9.8 ms^{-2}.

Weight is a vector quantity. Direction of weight is always towards the centre of the Earth. SI unit of weight is newton (N). Weight of a body varies from one place to another place on the Earth since it depends on the acceleration due to gravity of the Earth (g) weight of a body is more at the poles than at the equatorial region.

The value of acceleration due to gravity on the surface of the moon is 1.625 ms^{-2}. This is about 0.1654 times the acceleration due to gravity of the Earth. If a person whose mass is 60 kg stands on the surface of Earth, his weight would be 588 N ($W = mg = 60 \times 9.8$). If the same person goes to the surface of the Moon, he would weigh only 97.5 N ($W = 60 \times 1.625$). But, his mass remains the same (60 kg) on both the Earth and the Moon.

1.12 APPARENT WEIGHT

The weight that you feel to possess during up and down motion, is not same as your actual weight. Apparent weight is the weight of the body acquired due to the action of gravity and other external forces acting on the body.

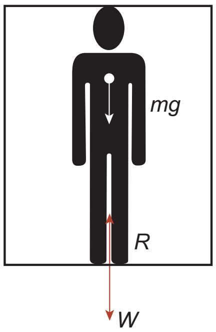

Figure 1.10
A person in a moving lift

Let us see this from the following illustration:

Let us consider a person of mass m, who is travelling in lift. The actual weight of the person is W = mg, which is acting vertically downwards. **The reaction force exerted by the lift's surface 'R', taken as apparent weight** is acting vertically upwards.

Let us see different possibilities of the apparent weight 'R' of the person that arise, depending on the motion of the lift; upwards or downwards which are given in Table 1.2

1.12.1 Weightlessness

Have you gone to an amusement park and taken a ride in a roller coaster? or in a giant wheel? During the fast downward and upward movement, how did you feel?

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Table 1.2 Apparent weight of a person in a moving lift

Case 1: Lift is moving **upward** with an acceleration 'a'	Case 2: Lift is moving **downward** with an acceleration 'a'	Case 3: Lift is at **rest**.	Case 4: Lift is **falling down freely**
$R - W = F_{net} = ma$ $R = W + ma$ $R = mg + ma$ $\mathbf{R = m(g+a)}$	$W - R = F_{net} = ma$ $R = W - ma$ $R = mg - ma$ $\mathbf{R = m(g-a)}$	Here, the acceleration is zero $a = 0$ $R = W$ $\mathbf{R = mg}$	Here, the acceleration is equal to g $a = g$ $\mathbf{R = m(g-g)}$
$R > W$	$R < W$	$R = W$	$R = 0$
Apparent weight is **greater** than the actual weight.	Apparent weight is **lesser** than the actual weight.	Apparent weight is **equal** to the actual weight.	Apparent weight is equal to **zero**.

Figure 1.11 Weightlessness in a roller coaster

Its amazing!!. You actually feel as if you are falling freely without having any weight. This is due to the phenomenon of 'weightlessness'. You seem to have lost your weight when you move down with a certain acceleration. Sometimes, you experience the same feeling while travelling in a lift.

When the person in a lift moves down with an acceleration (a) equal to the acceleration due to gravity (g), i.e., when $a = g$, this motion is called as '*free fall*'. Here, the apparent weight ($R = m(g-g) = 0$) of the person is zero. This condition or state refers to the state of weightlessness. (Refer case 4 from Table 1.2).

The same effect takes place while falling freely in a roller coaster or on a swing or in a vertical giant wheel. You feel an apparent weight loss and weight gain when you are moving up and down in such rides.

1.12.2 Weightlessness of the astronauts

Some of us believe that the astronauts in the orbiting spacestation do not experience any gravitational force of the Earth. So they float. But this is absolutely wrong.

Astronauts are not floating but falling freely around the earth due to their huge oribital velocity. Since spacestation and astronauts have equal acceleration, they are under free fall condition. ($R = 0$ refer case 4 in Table 1.2). Hence, both the astronauts and the spacestation are in the state of weightlessness.

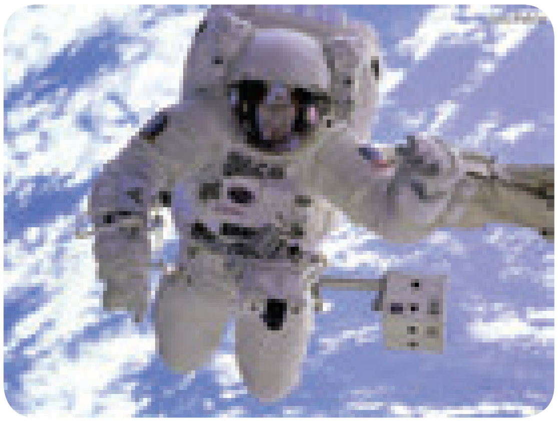


Figure 1.12 Weightlessness of astronauts

1.12.3 Application of Newton's law of gravitation

1) Dimensions of the heavenly bodies can be measured using the gravitation law. Mass of the Earth, radius of the Earth, acceleration due to gravity, etc. can be calculated with a higher accuracy.
2) Helps in discovering new stars and planets.
3) One of the irregularities in the motion of stars is called 'Wobble' lead to the disturbance in the motion of a planet nearby. In this condition the mass of the star can be calculated using the law of gravitation.
4) Helps to explain germination of roots is due to the property of geotropism which is the property of a root responding to the gravity.
5) Helps to predict the path of the astronomical bodies.

Points to Remember

- Mechanics is divided into statics and dynamics.
- Ability of a body to maintain its state of rest or motion is called Inertia.
- Moment of the couple is measured by the product of any one of the forces and the perpendicular distance between two forces.
- SI unit of force is newton (N). C.G.S unit is dyne.
- When a force F acts on a body for a period of time t, then the product of force and time is known as 'impulse'.
- The unit of weight is newton or kg f
- The weight of a body is more at the poles than at the equatorial region.
- Mass of a body is defined as the quantity of matter contained in the object. Its SI unit is kilogram (kg).
- Apparent weight is the weight of the body acquired due to the action of gravity and other external forces on the body.
- Whenever a body or a person falls freely under the action of Earth's gravitational force alone, it appears to have zero weight. This state is referred to as 'weightlessness'.

SOLVED PROBLEMS

Problem-1: Calculate the velocity of a moving body of mass 5 kg whose linear momentum is 2.5 $kg\,m\,s^{-1}$.

Solution: Linear momentum = mass × velocity

Velocity = linear momentum / mass.
V = 2.5 / 5 = 0.5 ms^{-1}

Problem 2: A door is pushed, at a point whose distance from the hinges is 90 cm, with a force of 40 N. Calculate the moment of the force about the hinges.

Solution:

Formula: The moment of a force M = F × d

Given: F = 40 N and d = 90 cm = 0.9 m.

Hence, moment of the force = 40 × 0.9 = 36 N m.

Problem 3 : At what height from the centre of the Earth the acceleration due to gravity will be ¼th of its value as at the Earth.

Solution:
Data: Height from the centre of the Earth, $R' = R + h$
The acceleration due to gravity at that height, $g' = g/4$

Formula: $g = GM/R^2$, $g' = GM/R'^2$

$$\frac{g}{g'} = \left(\frac{R'}{R}\right)^2 = \left(\frac{R+h}{R}\right)^2 = \left(1+\frac{h}{R}\right)^2$$

$$4 = \left(1+\frac{h}{R}\right)^2,$$

$$2 = 1+\frac{h}{R} \qquad \text{or } h = R. \qquad R' = 2R$$

From the centre of the Earth, the object is placed at twice the radius of the earth.

5J3MGE

TEXTBOOK EVALUATION

I. Choose the correct answer

1) Inertia of a body depends on
   a) weight of the object
   b) acceleration due to gravity of the planet
   c) mass of the object
   d) Both a & b

2) Impulse is equals to
   a) rate of change of momentum
   b) rate of force and time
   c) change of momentum
   d) rate of change of mass

3) Newton's III law is applicable
   a) for a body is at rest
   b) for a body in motion
   c) both a & b
   d) only for bodies with equal masses

4) Plotting a graph for momentum on the Y-axis and time on X-axis. slope of momentum-time graph gives
   a) Impulsive force b) Acceleration
   c) Force d) Rate of force

5) In which of the following sport the turning of effect of force used
   a) swimming b) tennis
   c) cycling d) hockey

6) The unit of 'g' is $m\,s^{-2}$. It can be also expressed as
   a) cms^{-1} b) Nkg^{-1}
   c) Nm^2kg^{-1} d) cm^2s^{-2}

7) One kilogram force equals to
   a) 9.8 dyne b) 9.8×10^4 N
   c) 98×10^4 dyne d) 980 dyne

8) The mass of a body is measured on planet Earth as M kg. When it is taken to a planet of radius half that of the Earth then its value will be____kg
   a) 4 M b) 2M c) M/4 d) M

9) If the Earth shrinks to 50% of its real radius its mass remaining the same, the weight of a body on the Earth will
   a) decrease by 50% b) increase by 50%
   c) decrease by 25% d) increase by 300%

10) To project the rockets which of the following principle(s) is /(are) required?
   a) Newton's third law of motion
   b) Newton's law of gravitation
   c) law of conservation of linear momentum
   d) both a and c

II. Fill in the blanks

1. To produce a displacement ____________ is required
2. Passengers lean forward when sudden brake is applied in a moving vehicle. This can be explained by ____________
3. By convention, the clockwise moments are taken as ____________ and the anticlockwise moments are taken as____________
4. ____________ is used to change the speed of car.
5. A man of mass 100 kg has a weight of ____________ at the surface of the Earth

III. State whether the following statements are true or false. Correct the statement if it is false

1. The linear momentum of a system of particles is always conserved.
2. Apparent weight of a person is always equal to his actual weight
3. Weight of a body is greater at the equator and less at the polar region.
4. Turning a nut with a spanner having a short handle is so easy than one with a long handle.
5. There is no gravity in the orbiting space station around the Earth. So the astronauts feel weightlessness.

IV. Match the following

Column I		Column II
a. Newton's I law	-	propulsion of a rocket
b. Newton's II law	-	Stable equilibrium of a body
c. Newton's III law	-	Law of force
d. Law of conservation of Linear momentum	-	Flying nature of bird

V. Assertion & Reasoning

Mark the correct choice as

(a) If both the assertion and the reason are true and the reason is the correct explanation of assertion.

(b) If both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.

(c) Assertion is true, but the reason is false.

(d) Assertion is false, but the reason is true.

1. **Assertion:** The sum of the clockwise moments is equal to the sum of the anticlockwise moments.

   Reason: The principle of conservation of momentum is valid if the external force on the system is zero.

2. **Assertion:** The value of 'g' decreases as height and depth increases from the surface of the Earth.

   Reason: 'g' depends on the mass of the object and the Earth.

VI. Answer briefly.

1. Define inertia. Give its classification.
2. Classify the types of force based on their application.
3. If a 5 N and a 15 N forces are acting opposite to one another. Find the resultant force and the direction of action of the resultant force
4. Differentiate mass and weight.
5. Define moment of a couple.
6. State the principle of moments.
7. State Newton's second law.
8. Why a spanner with a long handle is preferred to tighten screws in heavy vehicles?
9. While catching a cricket ball the fielder lowers his hands backwards. Why?
10. How does an astronaut float in a space shuttle?

VII. Solve the given problems

1. Two bodies have a mass ratio of 3:4 The force applied on the bigger mass produces an acceleration of 12 ms^{-2}.What could be the acceleration of the other body, if the same force acts on it.
2. A ball of mass 1 kg moving with a speed of 10 ms^{-1} rebounds after a perfect elastic collision with the floor. Calculate the change in linear momentum of the ball.
3. A mechanic unscrew a nut by applying a force of 140 N with a spanner of length 40 cm. What should be the length of the spanner if a force of 40 N is applied to unscrew the same nut?
4. The ratio of masses of two planets is 2:3 and the ratio of their radii is 4:7 Find the ratio of their accelerations due to gravity.

VIII. Answer in detail.

1. What are the types of inertia? Give an example for each type.
2. State Newton's laws of motion?
3. Deduce the equation of a force using Newton's second law of motion.
4. State and prove the law of conservation of linear momentum.
5. Describe rocket propulsion.
6. State the universal law of gravitation and derive its mathematical expression
7. Give the applications of universal law gravitation.

IX. HOT Questions

1. Two blocks of masses 8 kg and 2 kg respectively lie on a smooth horizontal surface in contact with one other. They are pushed by a horizontally applied force of 15 N. Calculate the force exerted on the 2 kg mass.
2. A heavy truck and bike are moving with the same kinetic energy. If the mass of the truck is four times that of the bike, then calculate the ratio of their momenta. (Ratio of momenta = 2:1
3. "Wearing helmet and fastening the seat belt is highly recommended for safe journey" Justify your answer using Newton's laws of motion.

REFERENCE BOOKS

- Concept of physics-HC verma
- Interactive physics(Newton's law)MTG learning.

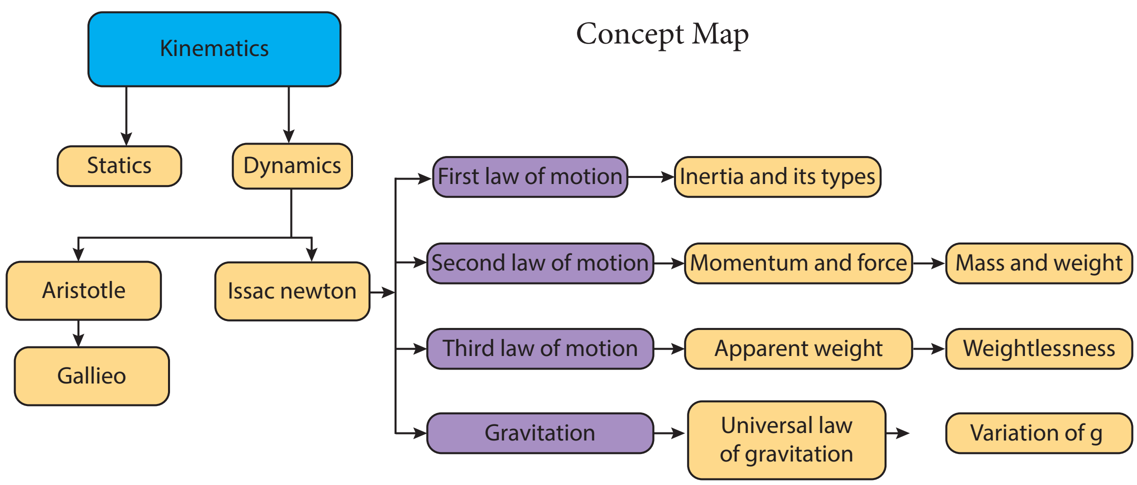
INTERNET RESOURCES

https://www.grc.nasa.gov

https://www.physicsclassroom.com

https://www.britannica.com/science/Newtons-law-of-gravitation

Concept Map



ICT CORNER

Newton's second law

Steps

- Open the browser and type "olabs.edu.in" in the address bar. Click physics tab and then click "Newton's second " under class 9 section. Go to "simulator" tab to do the experiment.
- Select the desired Cart mass (M_1) and vertical mass (M_2) using respective slider. Also select the desired distance (s) by moving the slider. Click on the "Start" button to start the experiment.
- Observe the time and note it down. Calculate acceleration (a) of the cart using the formula $a = 2s/t^2$. Find the fore due to rate of change of momentum using (M_1+M_2) a.
- Calculate force $F = M_2$ g.
- You will observe $(M_1+M_2)a = M_2 g$. Hence Newton's Second Law is verified. Repeat the experiment with different masses. Also do this in different environment like Earth, Moon, Uranus and Jupiter. Click reset to restart the experiment.

Link: http://amrita.olabs.edu.in/?sub=1&brch=1&sim=44&cnt=4

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Learning Objectives

At the end of this lesson, students will be able to:

- state the laws of refraction.
- list the properties of light.
- explain the scattering of light and its various kinds.
- understand the images formed by concave and convex lens.
- analyze the ray diagram of concave and convex lens.
- understand the working of human eye and optical instruments
- solve numerical problems

INTRODUCTION

Light is a form of energy which travels in the form of waves. The path of light is called ray of light and group of these rays are called as beam of light. Any object which gives out light are termed as source of light. Some of the sources emit their own light and they are called as luminous objects. All the stars, including the Sun, are examples for luminous objects. We all know that we are able to see objects with the help of our eyes. But, we cannot see any object in a dark room. Can you explain why? If your answer is 'we need light to see objects', the next question is 'if you make the light from a torch to fall on your eyes, will you be able to see the objects?' Definitely, 'NO'. We can see the objects only when the light is made to fall on the objects and the light reflected from the objects is viewed by our eyes. You would have studied about the reflection and refraction of light elaborately in your previous classes. In this chapter, we shall discuss about the scattering of light, images formed by convex and concave lenses, human eye and optical instruments such as telescopes and microscopes.

2.1 PROPERTIES OF LIGHT

Let us recall the properties of light and the important aspects on refraction of light.

1. Light is a form of energy.
2. Light always travels along a straight line.
3. Light does not need any medium for its propagation. It can even travel through vacuum.
4. The speed of light in vacuum or air is, $c = 3 \times 10^8\ ms^{-1}$.
5. Since, light is in the form of waves, it is characterized by a wavelength (λ) and a frequency (ν), which are related by the following equation: $c = \nu\lambda$ (c - velocity of light).

6. Different coloured light has different wavelength and frequency.
7. Among the visible light, violet light has the lowest wavelength and red light has the highest wavelength.
8. When light is incident on the interface between two media, it is partly reflected and partly refracted.

2.2 REFRACTION OF LIGHT

When a ray of light travels from one transparent medium into another obliquely, the path of the light undergoes deviation. This deviation of ray of light is called refraction. Refraction takes place due to the difference in the velocity of light in different media. The velocity of light is more in a rarer medium and less in a denser medium. Refraction of light obeys two laws of refraction.

2.2.1 First law of refraction:

The incident ray, the refracted ray of light and the normal to the refracting surface all lie in the same plane.

2.2.2 Second law of refraction:

The ratio of the sine of the angle of incidence and sine of the angle of refraction is equal to the ratio of refractive indices of the two media. This law is also known as Snell's law.

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \quad \cdots\cdots\cdots\cdots \quad (2.1)$$

- Refractive index gives us an idea of how fast or how slow light travels in a medium. The ratio of speed of light in vacuum (c) to the speed of light in a medium (v) is defined as refractive index 'μ' of that medium.

$$\mu = \frac{c}{v}$$

- The speed of light in a medium is low if the refractive index of the medium is high and vice versa.
- When light travels from a denser medium into a rarer medium, the refracted ray is bent away from the normal drawn to the interface.
- When light travels from a rarer medium into a denser medium, the refracted ray is bent towards the normal drawn to the interface.

2.3 REFRACTION OF A COMPOSITE LIGHT-DISPERSION OF LIGHT

We know that Sun is the fundamental and natural source of light. If a source of light produces a light of single colour, it is known as a monochromatic source. On the other hand, a composite source of light produces a white light which contains light of different colours. Sun light is a composite light which consists of light of various colours or wavelengths. Another example for a composite source is a mercury vapour lamp. What do you observe when a white light is refracted through a glass prism?

When a beam of white light or composite light is refracted through any transparent media such as glass or water, it is split into its component colours. This phenomenon is called as 'dispersion of light'.

The band of colours is termed as spectrum. This spectrum consists of following colours: Violet, Indigo, Blue, Green, Yellow, Orange, and Red. These colours are represented by the acronym "VIBGYOR". Why do we get the spectrum when white light is refracted by a transparent medium? This is because, different coloured lights are bent through different angles. That is the angle of refraction is different for different colours.

Angle of refraction is the smallest for red and the highest for violet. From Snell's law, we know that the angle of refraction is determined in terms of the refractive index of the medium. Hence, the refractive index of the medium is different for different coloured lights. This indicates that the refractive index of a medium is dependent on the wavelength of the light.

2.4 SCATTERING OF LIGHT

When sunlight enters the Earth's atmosphere, the atoms and molecules of different gases present in the atmosphere refract the light in all possible directions. This is called as 'Scattering of light'. In this phenomenon, the beam of light is redirected in all directions when it interacts with a particle of medium. The interacting particle of the medium is called as 'scatterer'.

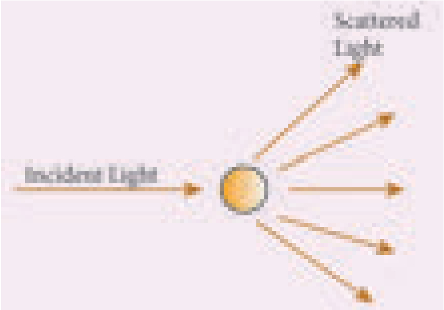

Figure 2.1 Scattering of light

2.4.1 Types of scattering

When a beam of light, interacts with a constituent particle of the medium, it undergoes many kinds of scattering. Based on initial and final energy of the light beam, scattering can be classified as,

1) Elastic scattering 2) Inelastic scattering

1) Elastic scattering

If the energy of the incident beam of light and the scattered beam of light are same, then it is called as 'elastic scattering'.

2) Inelastic scattering

If the energy of the incident beam of light and the scattered beam of light are not same, then it is called as 'inelastic scattering'. The nature and size of the scatterer results in different types of scattering. They are

- Rayleigh scattering
- Mie scattering
- Tyndall scattering
- Raman scattering

Rayleigh scattering

The scattering of sunlight by the atoms or molecules of the gases in the earth's atmosphere is known as Rayleigh scattering.

Rayleigh's scattering law

Rayleigh's scattering law states that, "The amount of scattering of light is inversely proportional to the fourth power of its wavelength".

Amount of scattering 'S' $\propto \frac{1}{\lambda^4}$

According to this law, the shorter wavelength colours are scattered much more than the longer wavelength colours.

When sunlight passes through the atmosphere, the blue colour (shorter wavelength) is scattered to a greater extent than the red colour (longer wavelength). This scattering causes the sky to appear in blue colour.

At sunrise and sunset, the light rays from the Sun have to travel a larger distance in the atmosphere than at noon. Hence, most of the blue lights are scattered away and only the red light which gets least scattered reaches us. Therefore, the colour of the Sun is red at sunrise and sunset.

Mie scattering

Mie scattering takes place when the diameter of the scatterer is similar to or larger than the wavelength of the incident light. It is also an elastic scattering. The amount of scattering is independent of wave length.

Mie scattering is caused by pollen, dust, smoke, water droplets, and other particles in the lower portion of the atmosphere.

Mie scattering is responsible for the white appearance of the clouds. When white light falls on the water drop, all the colours are equally scattered which together form the white light.

Tyndall Scattering

When a beam of sunlight, enters into a dusty room through a window, then its path becomes visible to us. This is because, the tiny dust particles present in the air of the room scatter the beam of light. This is an example of Tyndall Scattering

The scattering of light rays by the colloidal particles in the colloidal solution is called Tyndall Scattering or Tyndall Effect.

> **Do you Know**
>
> **Colloid** is a microscopically small substance that is equally dispersed throughout another material. Example: Milk, Ice cream, muddy water, smoke

Raman scattering

When a parallel beam of monochromatic (single coloured) light passes through a gas or liquid or transparent solid, a part of light rays are scattered.

The scattered light contains some additional frequencies (or wavelengths) other than that of incident frequency (or wavelength). This is known as Raman scattering or Raman Effect.

Raman Scattering is defined as *"The interaction of light ray with the particles of pure liquids or transparent solids, which leads to a change in wavelength or frequency."*

The spectral lines having frequency equal to the incident ray frequency is called 'Rayleigh line' and the spectral lines which are having frequencies other than the incident ray frequency are called 'Raman lines'. The lines having frequencies lower than the incident frequency is called stokes lines and the lines having frequencies higher than the incident frequency are called Antistokes lines.

You will study more about Raman Effect in higher classes.

2.5 LENSES

A lens is an optically transparent medium bounded by two spherical refracting surfaces or one plane and one spherical surface.

Lens is basically classified into two types. They are: (i) Convex Lens (ii) Concave Lens

(i) **Convex or bi-convex lens:** It is a lens bounded by two spherical surfaces such that it is thicker at the centre than at the edges. A beam of light passing through it, is converged to a point. So, a convex lens is also called as converging lens.

(ii) **Concave or bi-concave Lens:** It is a lens bounded by two spherical surfaces such that it is thinner at the centre than at the edges. A parallel beam of light passing through it, is diverged or spread out. So, a concave lens is also called as diverging lens.

2.5.1 Other types of Lenses

Plano-convex lens: If one of the faces of a bi-convex lens is plane, it is known as a plano-convex lens.

Plano-concave lens: If one of the faces of a bi-concave lens is plane, it is known as a plano-concave lens.

All these lenses are shown in Figure 2.2 given below:

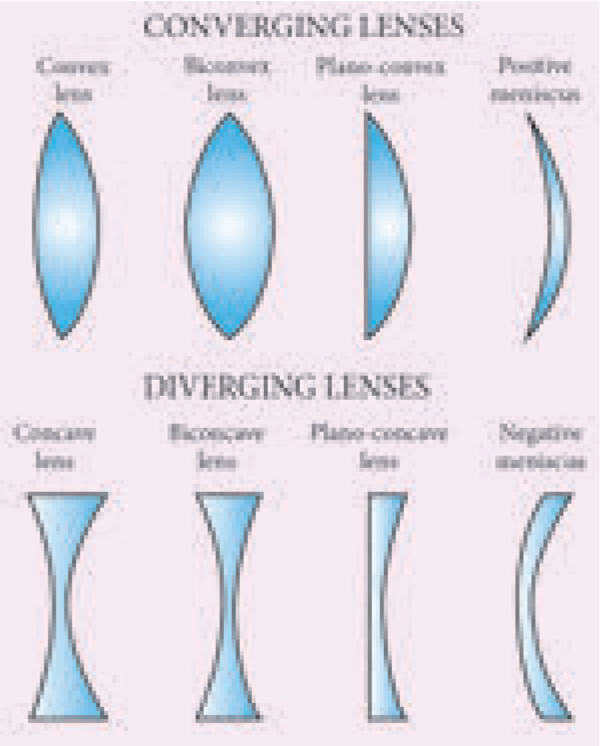

Figure 2.2 Types of lenses

2.6 IMAGES FORMED DUE TO REFRACTION THROUGH A CONVEX AND CONCAVE LENS

When an object is placed in front of a lens, the light rays from the object fall on the lens. The position, size and nature of the image formed can be understood only if we know certain basic rules.

Rule-1: When a ray of light strikes the convex or concave lens obliquely at its optical centre, it continues to follow its path without any deviation (Figure 2.3).

Figure 2.3 Rays passing through the optical centre

Rule-2: When rays parallel to the principal axis strikes a convex or concave lens, the refracted rays are converged to (convex lens) or appear to diverge from (concave lens) the principal focus (Figure 2.4).

Figure 2.4 Rays passing parallel to the optic axis

Rule-3: When a ray passing through (convex lens) or directed towards (concave lens) the principal focus strikes a convex or concave lens, the refracted ray will be parallel to the principal axis (Figure 2.5).

Figure 2.5 Rays passing through or directed towards the principal focus

2.7 REFRACTION THROUGH A CONVEX LENS

Let us discuss the formation of images by a convex lens when the object is placed at various positions.

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Object at infinity

When an object is placed at infinity, a real image is formed at the principal focus. The size of the image is much smaller than that of the object (Figure 2.6).

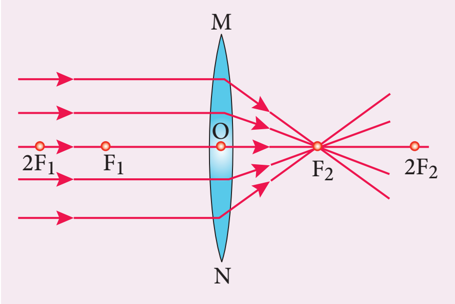

Figure 2.6 Object at infinity

Object placed beyond C (>2F)

When an object is placed behind the center of curvature(beyond C), a real and inverted image is formed between the center of curvature and the principal focus. The size of the image is the smaller than that of the object (Figure 2.7).

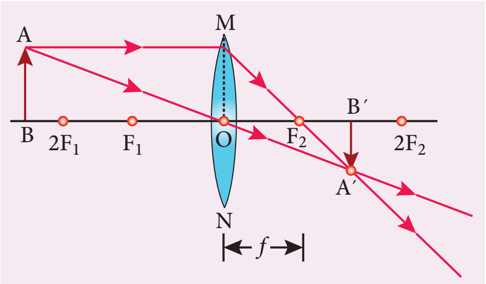

Figure 2.7 Object placed beyond C (>2F)

Object placed at C

When an object is placed at the center of curvature, a real and inverted image is formed at the other center of curvature. The size of the image is the same as that of the object (Figure 2.8).

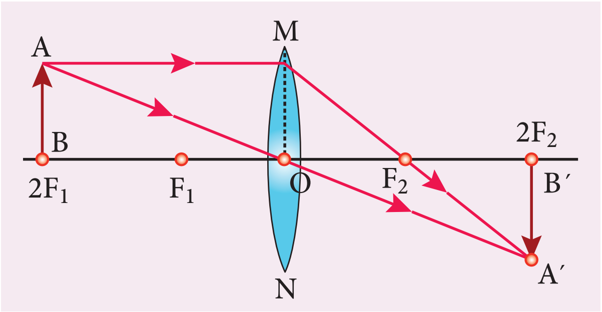

Figure.2.8 Object placed at C

Object placed between F and C

When an object is placed in between the center of curvature and principal focus, a real and inverted image is formed behind the center of curvature. The size of the image is bigger than that of the object (Figure 2.9).

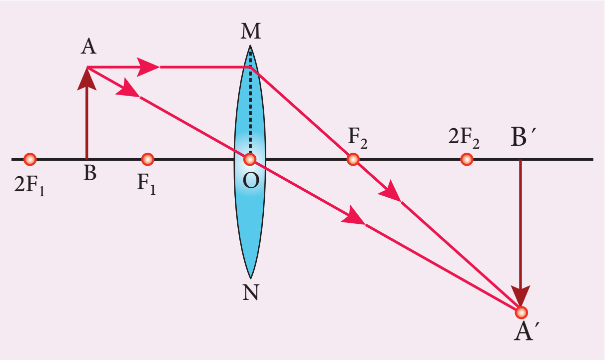

Figure 2.9 Object placed between F and C

Object placed at the principal focus F

When an object is placed at the focus, a real image is formed at infinity. The size of the image is much larger than that of the object (Figure 2.10).

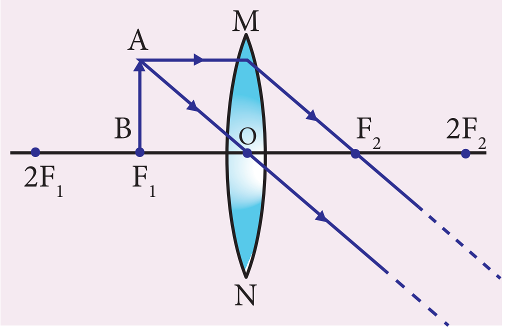

Figure 2.10 Object placed at the principal focus F

Object placed between the principal focus F and optical centre O

When an object is placed in between principal focus and optical centre, a virtual image is formed. The size of the image is larger than that of the object (Figure 2.11).

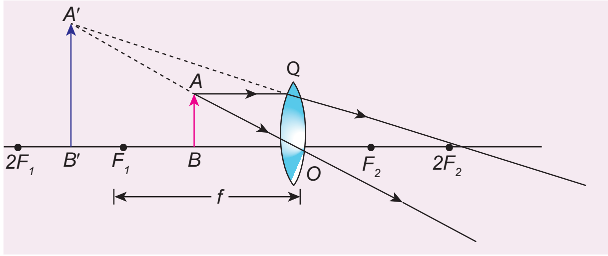

Figure 2.11 Object placed between the principal focus F and optical centre O

2.8 APPLICATIONS OF CONVEX LENSES

1. Convex lenses are used as camera lenses
2. They are used as magnifying lenses
3. They are used in making microscope, telescope and slide projectors
4. They are used to correct the defect of vision called hypermetropia

2.9 REFRACTION THROUGH A CONCAVE LENS

Let us discuss the formation of images by a concave lens when the object is placed at two possible positions.

Object at Infinity

When an object is placed at infinity, a virtual image is formed at the focus. The size of the image is much smaller than that of the object (Figure 2.12).

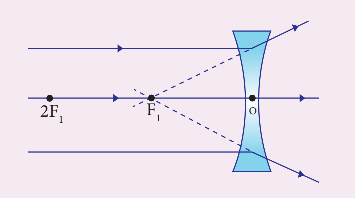

Figure 2.12 Concave lens-Object at infinity

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Object anywhere on the principal axis at a finite distance

When an object is placed at a finite distance from the lens, a virtual image is formed between optical center and focus of the concave lens. The size of the image is smaller than that of the object (Figure 2.13).

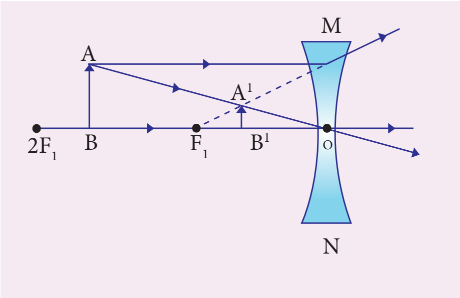

Figure 2.13 Concave lens-Object at a finite distance

But, as the distance between the object and the lens is decreased, the distance between the image and the lens also keeps decreasing. Further, the size of the image formed increases as the distance between the object and the lens is decreased. This is shown in (figure 2.14).

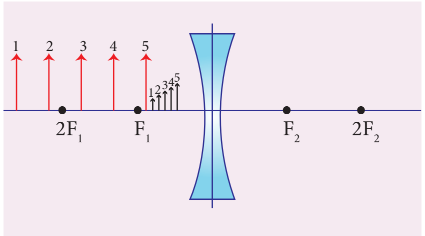

Figure 2.14 Concave lens-Variation in position and size of image with object distance

2.10 APPLICATIONS OF CONCAVE LENSES

1. Concave lenses are used as eye lens of 'Galilean Telescope'
2. They are used in wide angle spy hole in doors.
3. They are used to correct the defect of vision called 'myopia'

2.11 LENS FORMULA

Like spherical mirrors, we have lens formula for spherical lenses. The lens formula gives the relationship among distance of the object (u), distance of the image (v) and the focal length (f) of the lens. It is expressed as

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \text{.............} \quad 2.2$$

It is applicable to both convex and concave lenses. We need to give an at most care while solving numerical problems related to lenses in taking proper signs of different quantities.

2.12 SIGN CONVENTION

Cartesian sign conventions are used for measuring the various distances in the ray diagrams of spherical lenses. According to cartesian sign convention,

1. The object is always placed on the left side of the lens.
2. All the distances are measured from the optical centre of the lens.
3. The distances measured in the same direction as that of incident light are taken as positive.
4. The distances measured against the direction of incident light are taken as negative.
5. The distances measured upward and perpendicular to the principal axis is taken as positive.
6. The distances measured downward and perpendicular to the principal axis is taken as negative.

2.13 MAGNIFICATION OF A LENS

Like spherical mirrors, we have magnification for spherical lenses. Spherical lenses produce magnification and it is defined as the ratio of the height of the image to the

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height of an object. Magnification is denoted by the letter 'm'. If height of the object is *h* and height of the image is *h'* , the magnification produced by lens is,

$$m = \frac{height\ of\ the\ image}{height\ of\ the\ object} = \frac{h'}{h} \quad \ldots\ldots (2.3)$$

Also it is related to the distance of the object (u) and the distance of the image (v) as follows:

$$m = \frac{Distance\ of\ the\ image}{Distance\ of\ the\ object} = \frac{v}{u} \quad \ldots\ldots (2.4)$$

If the magnification is greater than 1, then we get an enlarged image. On the other hand, if the magnification is less than 1, then we get a diminished image.

2.14 LENS MAKER'S FORMULA

All lenses are made up of transparent materials. Any optically transparent material will have a refractive index. The lens formula relates the focal length of a lens with the distance of object and image. For a maker of any lens, knowledge of radii of curvature of the lens is required. This clearly indicates the need for an equation relating the radii of curvature of the lens, the refractive index of the given material of the lens and the required focal length of the lens. The lens maker's formula is one such equation. It is given as

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \cdots\cdots\cdots (2.5)$$

where μ is the refractive index of the material of the lens; R_1 and R_2 are the radii of curvature of the two faces of the lens; f is the focal length of the lens.

2.15 POWER OF A LENS

When a ray of light falls on a lens, the ability to converge or diverge these light rays depends on the focal length of the lens. This ability of a lens to converge (convex lens) or diverge (concave lens) is called as its power. Hence, the power of a lens can be defined as the degree of convergence or divergence of light rays. Power of a lens is numerically defined as the reciprocal of its focal length.

$$P = \frac{1}{f} \cdots\cdots\cdots\cdots\cdots (2.6)$$

The SI unit of power of a lens is dioptre. It is represented by the symbol D. If focal length is expressed in 'm', then the power of lens is expressed in 'D'. Thus 1D is the power of a lens, whose focal length is 1metre. $1D = 1m^{-1}$.

By convention, the power of a convex lens is taken as positive whereas the power of a concave lens is taken, as negative.

More to Know

The lens formula and lens maker's formula are applicable to only thin lenses. In the case of thick lenses, these formulae with little modifications are used.

Table 2.1 Differences between a Convex Lens and a Concave Lens

S. No	Convex Lens	Concave Lens
1	A convex lens is thicker in the middle than at edges.	A concave lens is thinner in the middle than at edges.
2	It is a converging lens.	It is a diverging lens.
3	It produces mostly real images.	It produces virtual images.
4	It is used to treat hypermeteropia.	It is used to treat myopia.

2.16 HUMAN EYE

The human eyes are most valuable and sensitive organs responsible for vision. They are the gateway to the wonderful world.

Structure of the eye

The eye ball is approximately spherical in shape with a diameter of about 2.3 cm. It consists of a tough membrane called sclera, which protects the internal parts of the eye.

Important parts of human eye are

Cornea: This is the thin and transparent layer on the front surface of the eyeball as shown in figure 2.15. It is the main refracting surface. When light enters through the cornea, it refracts or bends the light on to the lens.

Iris: It is the coloured part of the eye. It may be blue, brown or green in colour. Every person has a unique colour, pattern and texture. Iris controls amount of light entering into the pupil like camera aperture.

Pupil: It is the centre part of the Iris. It is the pathway for the light to retina.

Retina: This is the back surface of the eye. It is the most sensitive part of human eye, on which real and inverted image of objects is formed.

Eye Lens – It is the important part of human eye. It is convex in nature.

Ciliary muscles – Eye lens is fixed between the ciliary muscles. It helps to change the focal length of the eye lens according to the position of the object.

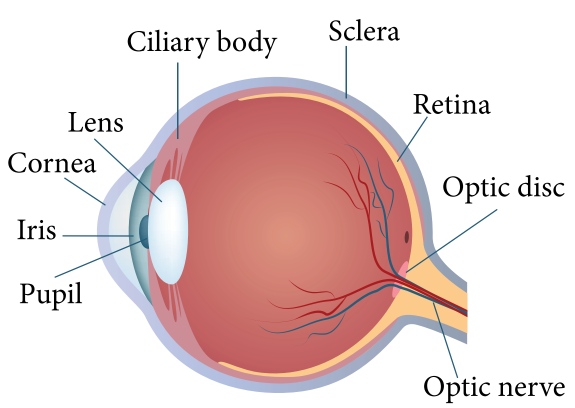

Figure 2.15 Human eye

Working of the eye

The transparent layer cornea bends the light rays through pupil located at the centre part of the Iris. The adjusted light passes through the eye lens. Eye lens is convex in nature. So, the light rays from the objects are converged and a real and inverted image is formed on retina. Then, retina passes the received real and inverted image to the brain through optical nerves. Finally, the brain senses it as erect image.

Power of Accommodation

The ability of the eye lens to focus nearby as well as the distant objects is called power of accommodation of the eye. This is achieved by changing the focal length of the eye lens with the help of ciliary muscles.

Eye lens is made of a flexible, jelly-like material. By relaxing and contracting the ciliary muscle, the curvature and hence the focal length of the eye lens can be altered. When we see distant objects, the ciliary muscle relaxes and makes the eye lens thinner. This increases the focal length of the eye lens. Hence, the distant object can be clearly seen. On the other hand, when we look at a closer object, the focal length of the eye lens is decreased by the contraction of ciliary muscle. Thus, the image of the closer object is clearly formed on the retina.

Persistence of vision

If the time interval between two consecutive light pulses is less than $\frac{1}{16}$ second, human eye cannot distinguish them separately. It is called persistence of vision.

The far point and near point of the human eye

The minimum distance required to see the objects distinctly without strain is called least distance of distinct vision. It is called as near point of eye. It is 25 cm for normal human eye.

The maximum distance up to which the eye can see objects clearly is called as far point of the eye. It is infinity for normal eye.

2.17 DEFECTS IN EYE

A normal human eye can clearly see all the objects placed between 25cm and infinity. But, for some people, the eye loses its power of accommodation. This could happen due to many reasons including ageing. Hence, their vision becomes defective. Let us discuss some of the common defects of human eye.

Myopia

Myopia, also known as short sightedness, occurs due to the lengthening of eye ball. With this defect, nearby objects can be seen clearly but distant objects cannot be seen clearly. The focal length of eye lens is reduced or the distance between eye lens and retina increases. Hence, the far point will not be infinity for such eyes and the far point has come closer. Due to this, the image of distant objects are formed before the retina (Figure 2.16-a). This defect can be corrected using a concave lens (Figure 2.16-b). The focal length of the concave lens to be used is computed as follows:

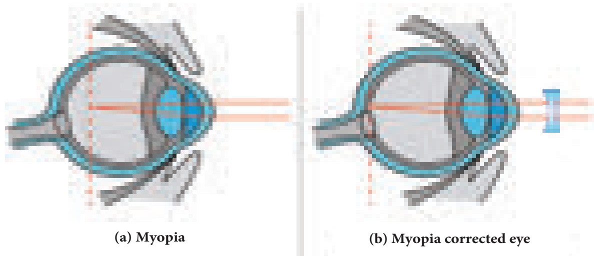

Figure 2.16 (a) Vision with myopia b) Corrected vision using a concave lens

Let a person with myopia eye can see up to a distance x. Suppose that he wants to see all objects farther than this distance, i.e., up to infinity. Then the focal length of the required concave lens is f = –x. If the person can see up to a distance x and if he wishes to see up to a distance y, then, the focal length of the required concave lens is,

$$f = \frac{xy}{x-y} \quad \text{..............(2.7)}$$

Hypermeteropia

Hypermeteropia, also known as long sightedness, occurs due to the shortening of eye ball. With this defect, distant objects can be seen clearly but nearby objects cannot be seen clearly. The focal length of eye lens is increased or the distance between eye lens and retina decreases. Hence, the near point will not be at 25cm for such eyes and the near point has moved farther. Due to this, the image of nearby objects are formed behind the retina (Figure 2.17-a). This defect can be corrected using a convex lens (Figure 2.17-b). The focal length of the convex lens to be used is computed as follows:

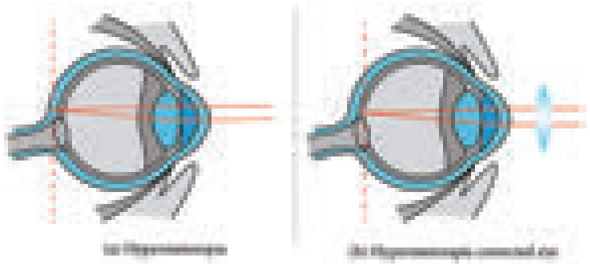

Figure 2.17 (a) Vision with hypermeteropia (b) Corrected vision using a convex lens

Let a person with hypermeteropia eye can see object beyond a distance d. Suppose that he wants to see all objects closer than this distance up to a distance D. Then, the focal length of the required convex lens is

$$f = \frac{dD}{d-D} \quad \text{..............(2.8)}$$

Presbyopia

Due to ageing, ciliary muscles become weak and the eye-lens become rigid (inflexible) andso the eye loses its power of accommodation.

Because of this, an aged person cannot see the nearby objects clearly. So, it is also called as 'old age hypermetropia'.

Some persons may have both the defects of vision - myopia as well as hypermetropia. This can be corrected by 'bifocal lenses'. In which, upper part consists of concave lens (to correct myopia) used for distant vision and the lower part consists of convex lens (to correct hypermetropia) used for reading purposes.

Astigmatism

In this defect, eye cannot see parallel and horizontal lines clearly. It may be inherited or acquired. It is due to the imperfect structure of eye lens because of the development of cataract on the lens, ulceration of cornea, injury to the refracting surfaces, etc. Astigmatism can be corrected by using cylindrical lenses.

2.18 MICROSCOPE

This is an optical instrument, which helps us to see tiny (very small) objects. It is classified as

1. Simple microscope
2. Compound microscope

Simple Microscope

Simple microscope has a convex lens of short focal length. It is held near the eye to get enlarged image of small objects.

Let an object (AB) is placed at a point within the principal focus ($u < f$) of the convex lens and the observer's eye is placed just behind

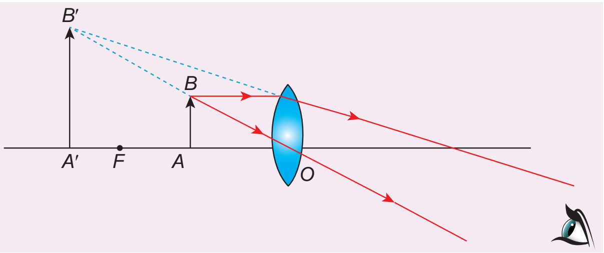

Figure 2.18 Image formation in simple microscope

the lens. As per this position the convex lens produces an erect, virtual and enlarged image (A'B'). The image formed is in the same side of the object and the distance equal to the least distance of distinct vision (D) (For normal human eye D = 25 cm).

Uses of Simple microscope

Simple microscopes are used

a) by watch repairers and jewellers.
b) to read small letters clearly.
c) to observe parts of flower, insects etc.
d) to observe finger prints in the field of forensic science.

Compound microscope

Compound microscope is also used to see the tiny objects. It has better magnification power than simple microscope.

Magnification power of microscopes can be increased by decreasing the focal length of the lens used. Due to constructional limitations, the focal length of the lens cannot be decreased beyond certain limit. This problem can be solved by using two separate biconvex lenses.

Construction

A compound microscope consists of two convex lenses. The lens with the shorter focal length is placed near the object, and is called as 'objective lens' or 'objective piece'. The lens with larger focal length and larger aperture placed near the observer's eye is called as 'eye lens' or 'eye piece'. Both the lenses are fixed in a narrow tube with adjustable provision.

Working

The object (AB) is placed at a distance slightly greater than the focal length of objective lens ($u > f_o$). A real, inverted and magnified image (A'B') is formed at the other

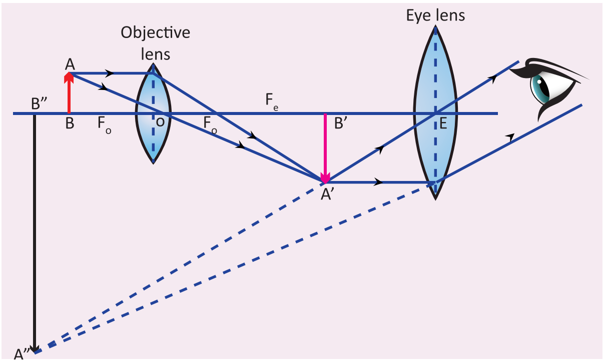

Figure 2.19 Image formation in compound microscope

side of the objective lens. This image behaves as the object for the eye lens. The position of the eye lens is adjusted in such a way, that the image (A'B') falls within the principal focus of the eye piece. This eye piece forms a virtual, enlarged and erect image (A″B″) on the same side of the object

Compound microscope has 50 to 200 times more magnification power than simple microscope

Travelling Microscope

A **travelling microscope** is one of the best instrument for measuring very small length with high degree of accuracy at the order of 0.01mm. It works based on the principle of vernier. Its least count is 0.01 mm.

2.19 TELESCOPE

Have you seen the recent lunar eclipse? With our naked eye we can't visualize the phenomena distinctly. Then, how can we see the distant object in clearer manner? It is possible with telescope.

Telescope is an optical instrument to see the distant objects. The first telescope was invented by Johann Lippershey in 1608. Galileo made a telescope to observe distant stars. He got the idea, from a spectacle maker who one day observed that the distant weather cock appeared magnified through his lens system fitted in his shop. Galileo observed the satellites of Jupiter and the rings of Saturn through his telescope. Kepler invented Telescope in 1611 which was fundamentally similar to the astronomical telescope.

Types of Telescope

According to optical property, it is classified into two groups:

i) refracting telescope ii) reflecting telescope

In **refracting telescope** lenses are used. Galilean telescope, Keplerian telescope, Achromatic refractors, are some refracting telescopes.

In **reflecting telescope** parabolic mirrors are used Gregorian, Newtonian, Cassegrain telescope are some **Reflecting telescopes**

According to the things which are observed, **Astronomical Telescope** and **Terrestrial Telescopes** are the two major types of telescope.

Astronomical Telescope

An astronomical telescope is used to view heavenly bodies like stars, planets galaxies and satellites.

Terrestrial Telescopes

The image in an astronomical telescope is inverted. So, it is not suitable for viewing objects on the surface of the Earth. Therefore, a terrestrial telescope is used. It provides an erect image. The major difference between astronomical and terrestrial telescope is erecting the final image with respect to the object.

Advantages of Telescopes

- Elaborate view of the Galaxies, Planets, stars and other heavenly bodies is possible.
- Camera can be attached for taking photograph for the celestial objects.
- Telescope can be viewed even with the low intensity of light.

Disadvantages

- Frequent maintenances needed.
- It is not easily portable one.

Points to Remember

- Light is a form of energy which travels along a straight line
- The deviation in the path of light ray is called refraction.
- The ratio of speed of light in vacuum to the speed of light in a medium is defined as refractive index 'μ' of that medium.
- Lens formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

- Magnification (m) $= \frac{h'}{h} = \frac{v}{u}$
- Power of lens. $P = \frac{1}{f}$
- The ability of the eye lens to focus nearby as well as the distant objects is called power of accommodation of the eye.
- A microscope is an optical instrument which helps us to see the objects which are very small in dimension.
- Telescope is an optical instrument used to see the distant objects clearly.

SOLVED PROBLEMS

Problem 1

Light rays travel from vacuum into a glass whose refractive index is 1.5. If the angle of incidence is 30°, calculate the angle of refraction inside the glass.

Solution:

accorting to Snell's law,

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

$$\mu_1 \sin i = \mu_2 \sin r$$

Here $\mu_1 = 1.0$, $\mu_2 = 1.5$, $i = 30°$

$$(1.0) \sin 30° = 1.5 \sin r$$

$$1 \times \frac{1}{2} = 1.5 \sin r$$

$$\sin r = \frac{1}{2 \times 1.5} = \frac{1}{3} = (0.333)$$

$$r = \sin^{-1}(0.333)$$

$$r = 19.45°$$

Problem-2

A beam of light passing through a diverging lens of focal length 0.3m appear to be focused at a distance 0.2m behind the lens. Find the position of the object.

Solution:

$f = -0.3$ m, $v = -0.2$ m

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$$

$$\frac{1}{u} = \frac{1}{-0.2} - \frac{1}{-0.3} = \frac{-10}{6}$$

$$u = \frac{-6}{10} = -0.6 \text{ m}$$

Problem-3

A person with myopia can see objects placed at a distance of 4m. If he wants to see objects at a distance of 20m, what should be the focal length and power of the concave lens he must wear?

Solution:

Given that x = 4m and y = 20m.

Focal length of the correction lens is

$$f = \frac{xy}{x-y} \quad \text{(Refer eqn.2.7)}$$

$$f = \frac{4 \times 20}{4 - 20} = \frac{80}{-16} = -5 \text{ m}$$

Power of the correction lens

$$= \frac{1}{f} = -\frac{1}{5} = -0.2 \text{ D}$$

Problem-4

For a person with hypermeteropia, the near point has moved to 1.5m. Calculate the focal length of the correction lens in order to make his eyes normal.

Solution:

Given that, d = 1.5m; D = 25cm = 0.25m (For a normal eye).

From equation (2.8), the focal length of the correction lens is

$$f = \frac{d \times D}{d - D} = \frac{1.5 \times 0.25}{1.5 - 0.25} = \frac{0.375}{1.25} = 0.3 \text{ m}$$

6E5CJ2

TEXTBOOK EVALUATION

I. Choose the correct answer

1. The refractive index of four substances A, B, C and D are 1.31, 1.43, 1.33, 2.4 respectively. The speed of light is maximum in

   a) A b) B c) C d) D

2. Where should an object be placed so that a real and inverted image of same size is obtained by a convex lens

   a) f b) 2f
   c) infinity d) between f and 2f

3. A small bulb is placed at the principal focus of a convex lens. When the bulb is switched on, the lens will produce

   a) a convergent beam of light
   b) a divergent beam of light
   c) a parallel beam of light
   d) a coloured beam of light

4. Magnification of a convex lens is

   a) Positive b) negative
   c) either positive or negative d) zero

5. A convex lens forms a real, diminished point sized image at focus. Then the position of the object is at

   a) focus b) infinity
   c) at 2f d) between f and 2f

6. Power of a lens is –4D, then its focal length is

   a) 4m b) –40m
   c) –0.25 m d) –2.5 m

7. In a myopic eye, the image of the object is formed

   a) behind the retina b) on the retina
   c) in front of the retina d) on the blind spot

8. The eye defect 'presbyopia' can be corrected by

   a) convex lens b) concave lens
   c) convex mirror d) Bi focal lenses

9. Which of the following lens would you prefer to use while reading small letters found in a dictionary?

   a) A convex lens of focal length 5 cm
   b) A concave lens of focal length 5 cm
   c) A convex lens of focal length 10 cm
   d) A concave lens of focal length 10 cm

10. If V_B, V_G, V_R be the velocity of blue, green and red light respectively in a glass prism, then which of the following statement gives the correct relation?

    a) $V_B = V_G = V_R$ b) $V_B > V_G > V_R$
    c) $V_B < V_G < V_R$ d) $V_B < V_G > V_R$

II. Fill in the blanks:

1. The path of the light is called as ________
2. The refractive index of a transparent medium is always greater than ________
3. If the energy of incident beam and the scattered beam are same, then the scattering of light is called as ________ scattering.
4. According to Rayleigh's scattering law, the amount of scattering of light is inversely proportional to the fourth power of its ________
5. Amount of light entering into the eye is controlled by ________

III. True or False. If false correct it.

1. Velocity of light is greater in denser medium than in rarer medium
2. The power of lens depends on the focal length of the lens
3. Increase in the converging power of eye lens cause 'hypermetropia'
4. The convex lens always gives small virtual image.

IV. Match the following:

	Column - I		Column - II
1	Retina	a	Path way of light
2	Pupil	b	Far point comes closer
3	Ciliary muscles	c	near point moves away
4	Myopia	d	Screen of the eye
5	Hypermetropia	f	Power of accommodation

V. Assertion and reasoning type

Mark the correct choice as

a) If both assertion and reason are true and reason is the correct explanation of assertion.
b) If both assertion and reason are true but reason is not the correct explanation of assertion.
c) Assertion is true but reason is false.
d) Assertion is false but reason is true.

1. **Assertion:** If the refractive index of the medium is high (denser medium) the velocity of the light in that medium will be small

   Reason: Refractive index of the medium is inversely proportional to the velocity of the light

2. **Assertion:** Myopia is due to the increase in the converging power of eye lens.

   Reason: Myopia can be corrected with the help of concave lens.

VI. Answer Briefly

1. What is refractive index?
2. State Snell's law.
3. Draw a ray diagram to show the image formed by a convex lens when the object is placed between F and 2F.
4. Define dispersion of light
5. State Rayleigh's law of scattering
6. Differentiate convex lens and concave lens.
7. What is power of accommodation of eye?
8. What are the causes of 'Myopia'?
9. Why does the sky appear in blue colour?
10. Why are traffic signals red in colour?

VII. Give the answer in detail

1. List any five properties of light
2. Explain the rules for obtaining images formed by a convex lens with the help of ray diagram.
3. Differentiate the eye defects: Myopia and Hypermetropia
4. Explain the construction and working of a 'Compound Microscope'.

VIII. Numerical Problems:

1. An object is placed at a distance 20cm from a convex lens of focal length 10cm. Find the image distance and nature of the image.
2. An object of height 3cm is placed at 10cm from a concave lens of focal length 15cm. Find the size of the image.

IX. Higher order thinking (HOT) questions:

1. While doing an experiment for the determination of focal length of a convex lens, Raja Suddenly dropped the lens. It got broken into two halves along the axis. If he continues his experiment with the same lens, (a) can he get the image? (b) Is there any change in the focal length?
2. The eyes of the nocturnal birds like owl are having a large cornea and a large pupil. How does it help them?

REFERENCE BOOKS

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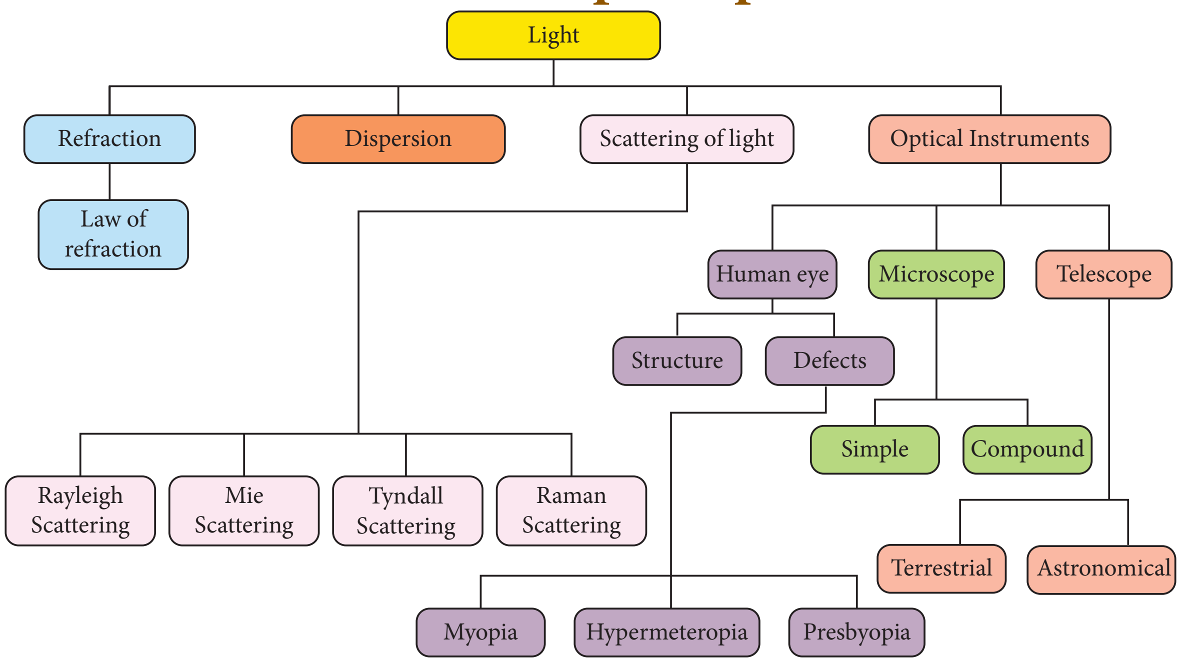
2. Principles of Physics – Halliday, Resnick & Walker, Wiley Publications, New Delhi.

INTERNET RESOURCES

1. www.physicsabout.com
2. www.khanacademy.org

Concept Map



ICT CORNER

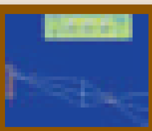
Formation of different types of images by a convex lens

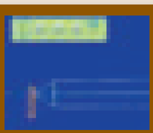
In this activity you will be able to understand the images formed by convex lenses.

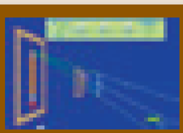
Steps

- Open the browser and type 'phet.colorado.edu/en/simulation/legacy/geometric-optics' in the address bar.
- Take the pencil and raise it so that the eraser is sitting on the principal axis. Click on the "principal rays" button.
- Place the object at different positions (infinity, beyond 2F, at 2F, between F and 2F, at F, between F and optic centre) from a convex lens and observe different types of images. Explain the result.
- Will the rays ever form an image? Click on "virtual image" to check your answer.


Step1


Step2


Step3


Step4

Cells alive

URL: https://phet.colorado.edu/en/simulation/legacy/geometric-optics

*Pictures are indicative only

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6TEBIQ

Learning Objectives

At the end of this lesson, students will be able to

- Understand the concept of heat and temperature
- Know the absolute scale of temperature
- Understand the thermal energy and the thermal equilibrium
- Classification of expansion of substances
- Know the fundamental laws of gases
- Distinguish between real gas and ideal gas
- Derive the ideal gas equation
- Solve the numerical problems

INTRODUCTION

Sun is the primary source of thermal energy for all living organisms. Thermal energy is the cause and temperature is the effect. All living organisms need a particular temperature for their survival. In the kitchen, a container with a steel bottom is placed on the induction stove. Do you know why? All of us have a common man's understanding of thermal energy and temperature. But, in this chapter, you shall learn about thermal energy and temperature in a scientific manner. We shall also discuss about how thermal energy is transferred and the effects of thermal energy.

3.1 TEMPERATURE

Temperature is defined as the degree of hotness of a body. The temperature is higher for a hotter body than for a colder body. It is also be defined as the property which determines whether a body is in equilibrium or not with the surroundings. (or average kinetic enegy of the molecules). Further, temperature is the property, which determines the direction of flow of heat. It is a scalar quantity. The SI unit of temperature is kelvin (K). There are other commonly used units of temperature such as degree celsius (°C) and degree fahrenheit (°F).

3.1.1 Absolute scale (kelvin scale) of temperature

The temperature measured in relation to absolute zero using the kelvin scale is known as absolute scale temperature. It is also known as the **thermodynamic temperature.** Each unit of the thermodynamic scale of temperature is defined as the fraction of 1/273.16th part of the thermodynamic temperature of the triple point of water. A temperature difference of 1°C is equal to that of 1K. Zero Kelvin is the absolute scale of temperature of the body.

The relation between the different types of scale of temperature:

Celsius and Kelvin: $K = C + 273$,

Fahrenheit and Kelvin: $[K] = (F + 460) \times \frac{5}{9}$

$$0\,K = -273°C.$$

3.1.2 Thermal equilibrium

Two or more physical systems or bodies are said to be in thermal equilibrium if there is no net flow of thermal energy between the systems. Heat energy always flows from one body to the other due to a temperature difference between them. Thus, you can define thermal equilibrium in another way. If two bodies are said to be in thermal equilibrium, then, they will be at the same temperature. What will happen if two bodies at different temperatures are brought in contact with one other? There will be a transfer of heat energy from the hot body to the cold body until a thermal equilibrium is established between them. This is depicted in Figure 3.1.

Figure 3.1 Establishing thermal equilibrium

When a cold body is placed in contact with a hot body, some thermal energy is transferred from the hot body to the cold body. As a result, there is some rise in the temperature of the cold body and decrease in the temperature of the hot body. This process will continue until these two bodies attain the same temperature.

3.2 THERMAL ENERGY

If you leave a cup of hot milk on a table for some time, what happens? The hotness of the milk decreases after some time. Similarly, if you keep a bottle of cold water on a table, the water becomes warmer after some time. What do you infer from these observations? In the case of hot milk, there is a flow of energy from the cup of milk to the environment. In the second case, the energy is transferred from the environment to the water bottle. This energy is termed as "thermal energy".

When a hot object is in contact with another cold object, a form of energy flows from the hot object to the cold object, which is known as **thermal energy**. Thus, thermal energy is a form of energy which is transferred between any two bodies due to the difference in their temperatures. Thermal energy is also known as 'heat energy' or simply 'heat'.

Heat energy is the agent, which produces the sensation of warmth and makes bodies hot. The process in which heat energy flows from a body at a higher temperature to another object at lower temperature is known as **heating**. This process of transmission of heat may be done in any of the ways like conduction, convection or radiation. Heat is a scalar quantity. The SI unit of heat energy absorbed or evolved is joule (J) .

During the process of transferring heat energy, the body at lower temperature is heated while the body at higher temperature is cooled. Thus, sometimes, this process of transfer of heat energy is termed as 'cooling'. But, in most of the cases the term 'heating' is used instead of 'cooling'. When the thermal energy is transferred from one body to another, this results in the rise or lowering of the temperature of either of the bodies.

3.2.1 Characteristic features of heat energy transfer

1. Heat always flows from a system at higher temperature to a system at lower temperature.
2. The mass of a system is not altered when it is heated or cooled.
3. For any exchange of heat, the heat gained by the cold system is equal to heat lost by the hot system.

Heat gained = Heat lost

3.2.2 Other units of Heat energy

Though the SI unit of heat energy is joule, there are some other commonly used units.

Calorie: *One calorie is defined as the amount of heat energy required to rise the temperature of 1 gram of water through 1°C.*

Kilocalorie: *One kilocalorie is defined as the amount of heat energy required to rise the temperature of 1 kilogram of water through 1°C.*

3.3 EFFECT OF HEAT ENERGY

When a certain amount of heat energy is given to a substance, it will undergo one or more of the following changes:

- Temperature of the substance rises.
- The substance may change its state from solid to liquid or from liquid to gas.
- The substance will expand when heated.

The rise in temperature is in proportion to the amount of heat energy supplied. It also depends on the nature and mass of the substance. About the rise in temperature and the change of state, you have studied in previous classes. In the following section, we shall discuss about the expansion of substances due to heat.

3.3.1 Expansion of Substances

When heat energy is supplied to a body, there can be an increase in the dimension of the object. This change in the dimension due to rise in temperature is called thermal expansion of the object. The expansion of liquids (e.g. mercury) can be seen when a thermometer is placed in warm water. All forms of matter (solid, liquid and gas) undergo expansion on heating.

6TN7KD

a) Expansion in solids

When a solid is heated, the atoms gain energy and vibrate more vigorously. This results in the expansion of the solid. For a given change in temperature, the extent of expansion is smaller in solids than in liquids and gases. This is due to the rigid nature of solids.

The different types of expansion of solid are listed and explained below:

1. Linear expansion
2. Superficial expansion
3. Cubical expansion

1. Linear expansion:

When a body is heated or cooled, the length of the body changes due to change in its temperature. Then the expansion is said to be **linear or longitudinal expansion**.

The ratio of increase in length of the body per degree rise in temperature to its unit length is called as the **coefficient of linear expansion**. The SI unit of Coefficient of Linear expansion is K^{-1}. The value of coefficient of linear expansion is different for different materials.

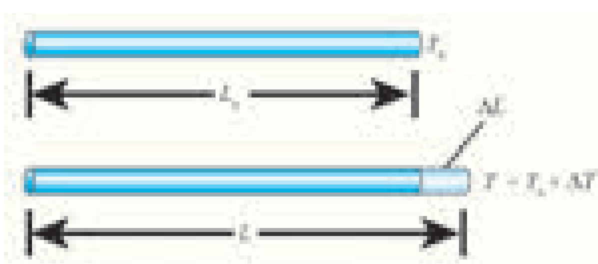

Figure 3.2 Linear expansion

The equation relating the change in length and the change in temperature of a body is given below:

$$\frac{\Delta L}{L_o} = \alpha_L \Delta T$$

ΔL - Change in length (Final length-Original length)

L_o - Original length

ΔT - Change in temperature (Final temperature - Initial temperature)

α_L - Coefficient of linear expansion.

2. Superficial expansion:

If there is an increase in the area of a solid object due to heating, then the expansion is called **superficial or areal expansion.**

Superficial expansion is determined in terms of coefficient of superficial expansion. The ratio of increase in area of the body per degree rise in temperature to its unit area is called as **coefficient of superficial expansion**. Coefficient of superficial expansion is different for different materials. The SI unit of Coefficient of superficial expansion is K^{-1}

The equation relating to the changein area and the change in temperature is given below:

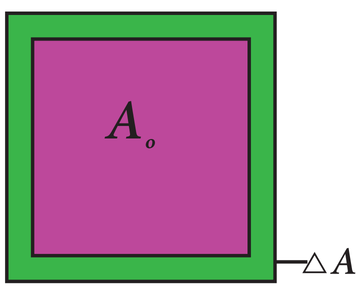

Figure 3.3 Superficial expansion

$$\frac{\Delta A}{A_o} = \alpha_A \Delta T$$

ΔA - Change in area (Final area - Initial area)

A_o - Original area

ΔT - Change in temperature (Final temperature - Initial temperature)

α_A - Coefficient of superficial expansion.

3. Cubical expansion:

If there is an increase in the volume of a solid body due to heating, then the expansion is called **cubical or volumetric expansion.**

As in the cases of linear and areal expansion, cubical expansion is also expressed in terms of coefficient of cubical expansion. The ratio of increase in volume of the body per degree rise in temperature to its unit volume is called as **coefficient of cubical expansion**. This is also measured in K^{-1}.

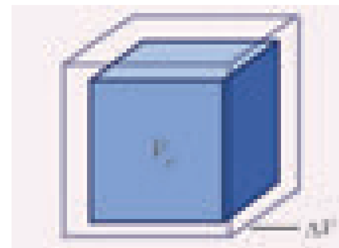

Figure 3.4 Cubical expansion

The equation relating to the change in volume and the change in temperature is given below:

$$\frac{\Delta V}{V_o} = \alpha_V \Delta T$$

ΔV - Change in volume(Final volume - Intial volume)

V_o - Original volume

ΔT - Change in temperature (Final temperature - Initial temperature)

α_V - Coefficient of cubical expansion.

Different materials possess different coefficient of cubical expansion. Table 3.1 gives the coefficient of cubical expansion for some common materials.

Table 3.1 Coefficient of cubical expansion of some materials

S.No.	Name of the material	Coefficient of cubic expansion (K^{-1})
1	Aluminium	7×10^{-5}
2	Brass	6×10^{-5}
3	Glass	2.5×10^{-5}
4	Water	20.7×10^{-5}
5	Mercury	18.2×10^{-5}

b) Expansion in liquids and gases

When heated, the atoms in a liquid or gas gain energy and are forced further apart. The extent of expansion varies from substance to substance. For a given rise in temperature, a liquid will have more expansion than a solid and a gaseous substance has the highest expansion when compared with the other two. The coefficient of cubical expansion of liquid is independent of temperature whereas its value for gases depends on the temperature of gases.

When a liquid is heated, it is done by keeping the liquid in some container and supplying heat energy to the liquid through the container. The thermal energy supplied will be partly used in expanding the container and partly used in expanding the liquid. Thus, what we observe may not be the actual or real expansion of the liquid. Hence, for liquids, we can define real expansion and apparent expansion.

1) Real expansion

If a liquid is heated directly without using any container, then the expansion that you observe is termed as **real expansion** of the liquid.

Coefficient of real expansion is defined as the ratio of the true rise in the volume of the liquid per degree rise in temperature to its unit volume. The SI unit of coefficient of real expansion is K^{-1}.

2) Apparent expansion

Heating a liquid without using a container is not possible. Thus, in practice, you can heat any liquid by pouring it in a container. A part of thermal energy is used in expanding the container and a part is used in expanding the liquid. Thus, what you observe is not the actual or real expansion of the liquid. The expansion of a liquid apparently observed without considering the expansion of the container is called the **apparent expansion** of the liquid.

Coefficient of apparent expansion is defined as the ratio of the apparent rise in the volume of the liquid per degree rise in temperature to its unit volume. The SI unit of coefficient of apparent expansion is K^{-1}.

3.3.2 Experiment to measure real and apparent expansion of liquid

To start with, the liquid whose real and apparent expansion is to be determined is poured in a container up to a level. Mark this level as L_1. Now, heat the container and the liquid using a burner as shown in the Figure 3.5. Initially, the container receives the thermal energy and it expands. As a result, the volume of the liquid appears to have reduced. Mark this reduced level of liquid as L_2.

On further heating, the thermal energy supplied to the liquid through the container results in the expansion of the liquid. Hence, the level of liquid rises to L_3. Now, the difference between the levels L_1 and L_3 is called as **apparent expansion,** and the difference between the levels L_2 and L_3 is called **real expansion**. The real expansion is always more than that of apparent expansion.

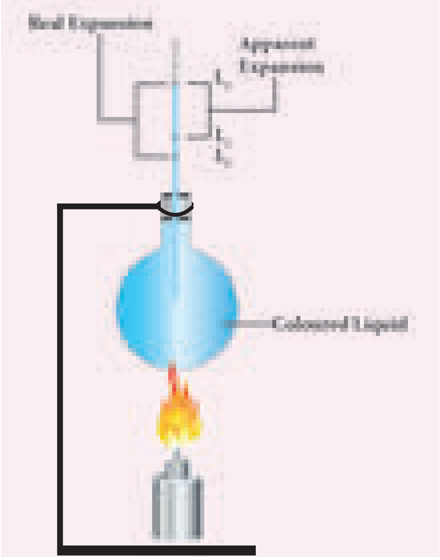

Figure 3.5 Real and apparent expansion of liquid

Real expansion = $L_3 - L_2$

Apparent expansion = $L_3 - L_1$

3.4 FUNDAMENTAL LAWS OF GASES

The three fundamental laws which connect the relation between pressure, volume and temperature are as follows:

1) Boyle's Law
2) Charles's law
3) Avogadro's law

7NG1LD

3.4.1 Boyle's law:

When the temperature of a gas is kept constant, the volume of a fixed mass of gas is inversely proportional to its pressure. This is shown in Figure 3.6.

$$P \propto 1/V$$

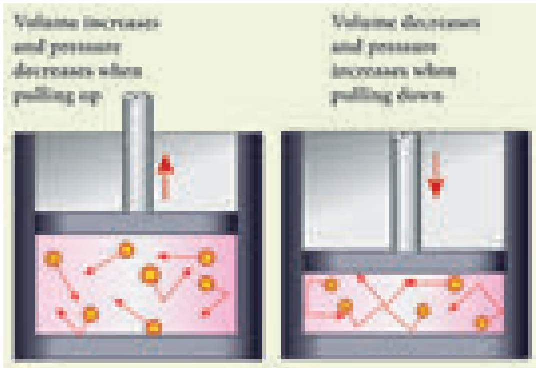

Figure 3.6 Variation of volume with pressure

In other words, for an invariable mass of a perfect gas, at constant temperature, the product of its pressure and volume is a constant.

(i.e) $PV = \text{constant}$

3.4.2 Charles's law (The law of volume)

Charles's law was formulated by a French scientist Jacques Charles. According to this law, *When the pressure of gas is kept constant, the volume of a gas is directly proportional to the temperature of the gas.*

$$V \propto T$$

$$\text{or } \frac{V}{T} = \text{constant}$$

3.4.3 Avogadro's law

Avogadro's law states that at constant pressure and temperature, the volume of a gas is directly proportional to number of atoms or molecules present in it.

8I8UMD

i.e. $V \propto n$

(or) $\frac{V}{n} = \text{constant}$

Avogadro's number (N_A) is the total number of atoms per mole of the substance. It is equal to 6.023×10^{23} /mol.

3.5 GASES

Gases are classified as real gases and ideal gases.

3.5.1 Real Gases

If the molecules or atoms of a gases interact with each other with a definite amount of intermolecular or inter atomic force of attraction, then the gases are said to be **real gases.** At very high temperature or low pressure, a real gases behaves as an ideal gases because in this condition there is no interatomic or intermolecular force of attraction.

3.5.2 Ideal Gases

If the atoms or molecules of a gas do not interact with each other, then the gas is said to be an **ideal gas** or a **perfect gas.**

Actually, in practice, no gas is ideal. The molecules of any gas will have a certain amount of interaction among them. But, these interactions are weaker when the pressure is low or the temperature is high because the interatomic or intermolecular forces of attraction are weak in ideal gas. Hence, a real gas at low pressure or high temperature can be termed as a perfect gas.

Ideal gases obey Boyle's law, Charles's law and Avogadro's law. All these laws state the relationship between various properties of a gas such as pressure (P), volume (V), temperature (T) and number of atoms (n). In a given state of the gas, all these parameters will have a definite set of values. When there is a change in the state of the gas, any one or more of these parameters change its value. The above said laws relate these changes.

3.5.3 Ideal Gas Equation

The ideal gas equation is an equation, which relates all the properties of an ideal gas. An ideal gas obeys Boyle's law and Charles' law and Avogadro's law. According to Boyle's law,

$$PV = \text{constant} \qquad (3.1)$$

According to Charles's law,

$$V/T = constant \quad (3.2)$$

According to Avogadro's law,

$$V/n = constant \quad (3.3)$$

After combining equations (3.1), (3.2) and (3.3), you can get the following equation.

$$PV/nT = constant \quad (3.4)$$

The above relation is called the combined law of gases. If you consider a gas, which contains μ moles of the gas, the number of atoms contained will be equal to μ times the Avogadro number, N_A.

$$i.e. \quad n = \mu N_A. \quad (3.5)$$

Using equation (3.5), equation (3.4) can be written as

$$PV/ \mu N_A T = constant$$

The value of the constant in the above equation is taken to be k_B, which is called as **Boltzmann constant (1.38×10^{-23} JK^{-1}).** Hence, we have the following equation:

$$PV/ \mu N_A T = k_B$$

$$PV = \mu N_A\, k_B\, T$$

Here, $\mu N_A k_B = R$, which is termed as universal gas constant whose value is

$8.31\ J\ mol^{-1} K^{-1}$.

$$PV = RT \quad (3.6)$$

Ideal gas equation is also called as *equation of state* because it gives the relation between the state variables and it is used to describe the state of any gas.

Points to Remember

- The SI unit of heat energy absorbed or evolved is joule (J)
- Heat always flows from a system at higher temperature to a system at lower temperature.
- **Temperature** is defined as the degree of hotness of a body. The SI unit of temperature is kelvin (K).
- All the substances will undergo one or more of the following changes when heated:
  - i) Temperature of the substance rises.
  - ii) The substance may change state from solid to liquid or gas.
  - iii) The substance will expand when heated.
- All forms of matter (solid, liquid and gas) undergo expansion on heating.
- For a given rise in temperature, a liquid will have more expansion than a solid and a gaseous substance has the highest expansion than the other two.
- If a liquid is heated directly without using any container, then the expansion that you observe is termed as **real expansion** of the liquid.
- The expansion of a liquid apparently observed without considering the expansion of the container is called the **apparent expansion** of liquid.
- For a given heat energy, the real expansion is always more than that of apparent expansion.
- If the atoms or molecules of a gas do not interact with each other, then the gas is said to be an **ideal gas** or a **perfect gas**.
- Ideal gas equation, also called as equation of state is PV = RT. Here, R is known as universal gas constant whose value is $8.31\ J\ mol^{-1} K^{-1}$

Solved Problems

Example 1

A container whose capacity is 70 ml is filled with a liquid up to 50 ml. Then, the liquid in the container is heated. Initially, the level of the liquid falls from 50 ml to 48.5 ml. Then we heat more, the level of the liquid rises to 51.2 ml. Find the apparent and real expansion.

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Data:

Level of the liquid L_1 = 50 ml

Level of the liquid L_2 = 48.5 ml

Level of the liquid L_3 = 51.2 ml

$$\text{Apparent expansion} = L_3 - L_1$$
$$= 51.2\,\text{ml} - 50\,\text{ml} \quad = 1.2\,\text{ml}$$
$$\text{Real expansion} = L_3 - L_2$$
$$= 51.2\,\text{ml} - 48.5\,\text{ml} \quad = 2.7\,\text{ml}$$

So, Real expansion > apparent expansion

Example 2

Keeping the temperature as constant, a gas is compressed four times of its initial pressure. The volume of gas in the container changing from 20cc (V_1 cc) to V_2 cc. Find the final volume V_2.

Data:

Initial pressure (P_1)= P

Final Pressure (P_2) = 4P

Initial volume (V_1) = 20cc = 20cm³

Final volume (V_2) = ?

Using Boyle's Law, PV = constant

$$P_1V_1 = P_2V_2$$
$$V_2 = \frac{P_1}{P_2} \times V_1$$
$$= \frac{P}{4P} \times 20\text{cm}^3$$
$$V_2 = 5\ \text{cm}^3$$

8XRPNP

TEXTBOOK EVALUATION

I. Choose the correct answer

1. The value of universal gas constant

   a) 3.81 $\text{Jmol}^{-1}\ \text{K}^{-1}$ b) 8.03 $\text{Jmol}^{-1}\ \text{K}^{-1}$

   c) 1.38 $\text{Jmol}^{-1}\ \text{K}^{-1}$ d) 8.31 $\text{Jmol}^{-1}\ \text{K}^{-1}$

2. If a substance is heated or cooled, the change in mass of that substance is

   a) positive b) negative

   c) zero d) none of the above

3. If a substance is heated or cooled, the linear expansion occurs along the axis of

   a) X or −X b) Y or −Y

   c) both (a) and (b) d) (a) or (b)

4. Temperature is the average ___________ of the molecules of a substance

   a) difference in K.E and P.E

   b) sum of P.E and K.E

   c) difference in T.E and P.E

   d) difference in K.E and T.E

5. In the Given diagram, the possible direction of heat energy transformation is

II. Fill in the blanks:

1. The value of Avogadro number _________
2. The temperature and heat are __________ quantities
3. One calorie is the amount of heat energy required to raise the temperature of ________ of water through_______.
4. According to Boyle's law, the shape of the graph between pressure and reciprocal of volume is _________________

III. State whether the following statements are true or false, if false explain why?

1. For a given heat in liquid, the apparent expansion is more than that of real expansion.

2. Thermal energy always flows from a system at higher temperature to a system at lower temperature.
3. According to Charles's law, at constant pressure, the temperature is inversely proportional to volume.

IV. Match the items in column-I to the items in column-II

Column-I	Column-II
1. Linear expansion	- (a) change in volume
2. Superficial expansion	- (b) hot body to cold body
3. Cubical expansion	- (c) 1.381×10^{-23} JK^{-1}
4. Heat transformation	- (d) change in length
5. Boltzmann constant	- (e) change in area

V. Assertion and reason type questions

a. Both the assertion and the reason are true and the reason is the correct explanation of the assertion.

b. Both the assertion and the reason are true but the reason is not the correct explanation of the assertion.

c. Assertion is true but the reason is false.

d. Assertion is false but the reason is true.

1. **Assertion:** There is no effects on other end when one end of the rod is only heated.

   Reason: Heat always flows from a region of lower temperature to higher temperature of the rod.

2. **Assertion:** Gas is highly compressible than solid and liquid

   Reason: Interatomic or intermolecular distance in the gas is comparably high.

VI. Answer in briefly

1. Define one calorie.
2. Distinguish between linear, arial and superficial expansion.
3. What is co-efficient of cubical expansion?
4. State Boyle's law
5. State-the law of volume
6. Distinguish between ideal gas and real gas.
7. What is co-efficient of real expansion?
8. What is co-efficient of apparent expansion?

VII. Numerical problems

1. Find the final temperature of a copper rod. Whose area of cross section changes from $10\,m^2$ to $11\,m^2$ due to heating. The copper rod is initially kept at 90 K. (Coefficient of superficial expansion is 0.0021 /K)
2. Calculate the coefficient of cubical expansion of a zinc bar. Whose volume is increased $0.25\,m^3$ from $0.3\,m^3$ due to the change in its temperature of 50 K.

VIII. Answer in detail

1. Derive the ideal gas equation.
2. Explain the experiment of measuring the real and apparent expansion of a liquid with a neat diagram.

IX. HOT question

If you keep ice at 0° C and water at 0° C in either of your hands, in which hand you will feel more chillness? Why?

REFERENCE BOOKS

- Thermodynamics and an introduction to thermo statistics by Herbert Hallen
- Fundamentals of Engineering Thermodynamics by Michael Moran.

INTERNET RESOURCE

http://aplusphysics.com/courses/honors/thermo/thermal_physics.html

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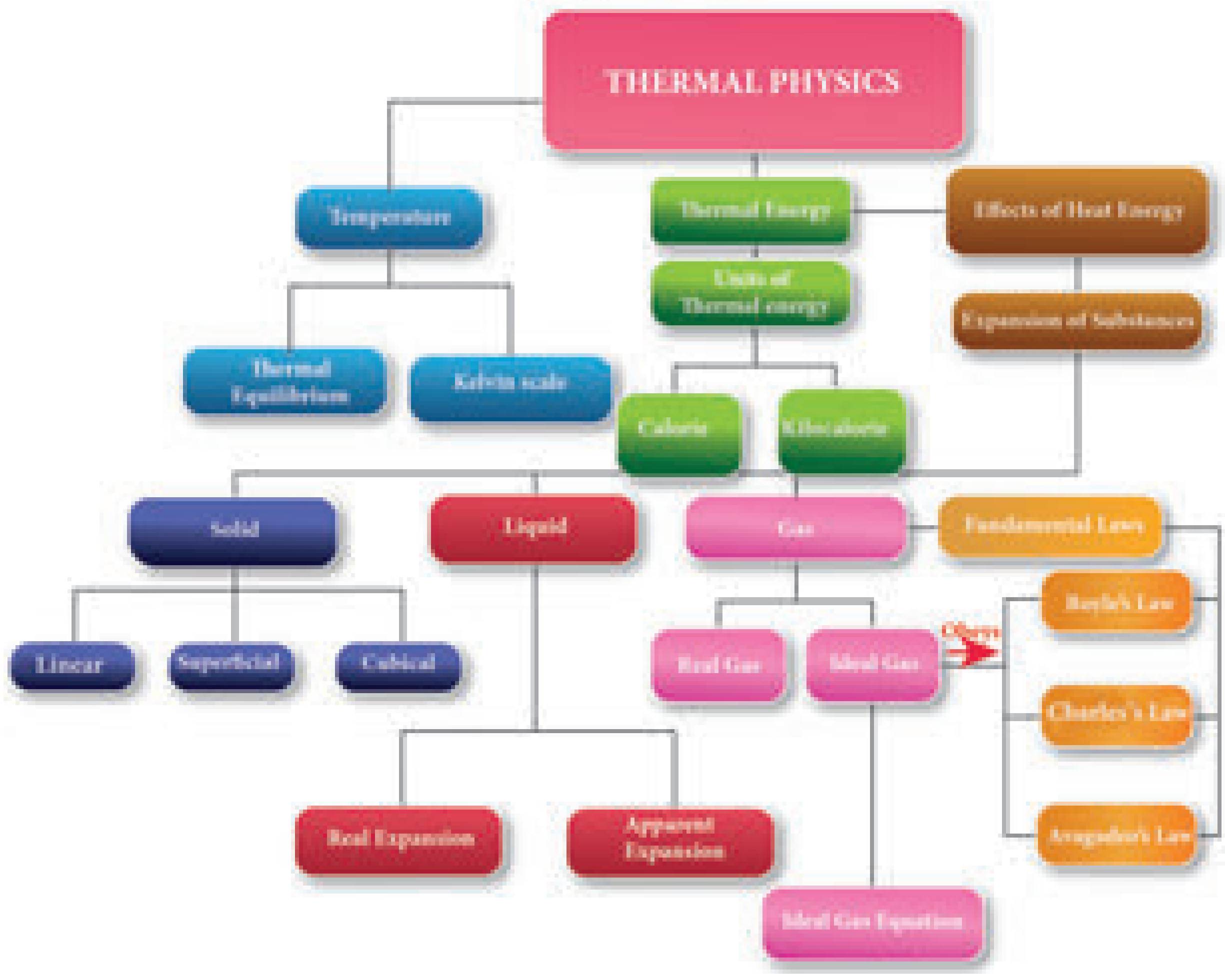
CONCEPT MAP



ICT CORNER

Boyle's law

In this activity you will be able to verify pressure is proportional to reciprocal of volume (Boyle's law).

Steps

- Open the browser and type "physics-chemistry-interactive-flash-animation.com/matter_change_state_measurement_mass_volume/pressure_volume_boyle_mariotte_law_ideal_gas_closed_system_MCQ.htm" in the address bar. Click enter to start the experiment.
- Change the volume by adjusting the piston of the syringe (between 20 ml to 80 ml) and observe how the pressure changes.
- Tabulate observed values. You will observe when volume decreases pressure inside the syringe gets increased and vice versa. Thus boyle's law (PV = constant) verified.

Cells alive

URL: http://www.physics-chemistry-interactive-flash-animation.com/matter_change_state_measurement_mass_volume/pressure_volume_boyle_mariotte_law_ideal_gas_closed_system_MCQ.htm

B375_10_SCIENCE_EM

ELECTRICITY

Learning Objectives

9DAJQ1

At the end of this lesson, students will be able to:

- Make an electric circuit.
- Differentiate between electric potential and potential difference.
- Infer what electrical resistivity and conductivity mean.
- Know the effective resistance of a system of resistors connected in series and parallel.
- Understand the heating effect of the electric current.
- Define electric power and electric energy and explain domestic electric circuits.
- Know the modern appliances such as LED bulb and LED television.

INTRODUCTION

You have already learnt about electricity in your lower classes, haven't you? Well, electricity deals with the flow of electric charges through a conductor. As a common term it refers to a form of energy. The usage of electric current in our day to day life is very important and indispensable. You are already aware of the fact that it is used in houses, educational institutions, hospitals, industries, etc. Therefore, its generation and transmission becomes a very crucial aspect of our life. In this lesson you will learn various terms used in understanding the concept of electricity. Eventually, you will realise the importance of the applications of electricity in day to day situations.

4.1 ELECTRIC CURRENT

The motion of electric charges (electrons) through a conductor (e.g., copper wire) will constitute an electric current. This is similar to the flow of water through a channel or flow of air from a region of high pressure to a region of low pressure.

In a similar manner, the electric current passes from the positive terminal (higher electric potential) of a battery to the negative terminal (lower electric potential) through a wire as shown in the Figure 4.1.

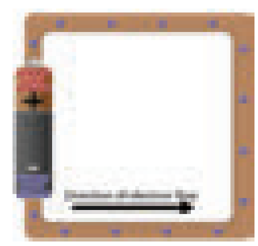


Figure 4.1
Electron flow

4.1.1 Definition of electric current

Electric current is often termed as 'current' and it is represented by the symbol 'I'. It is defined **as the rate of flow of charges in a conductor**. This means that the electric current represents the amount of charges flowing in any cross section of a conductor (say a metal wire) in unit time. If a net charge 'Q' passes through any cross section of a conductor in time 't', then the current flowing through the conductor is

$$I = \frac{Q}{t} \qquad (4.1)$$

4.1.2 SI unit of electric current

The SI unit of electric current is ampere (A). The current flowing through a conductor is said to be one ampere, when a charge of one coulomb flows across any cross-section of a conductor, in one second. Hence,

$$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}.$$

Solved Problem-1

A charge of 12 coulomb flows through a bulb in 5 second. What is the current through the bulb?

Solution:

Charge Q = 12 C, Time t = 5 s. Therefore,

current $I = \frac{Q}{t} = \frac{12}{5} = 2.4$ A

4.2 ELECTRIC CIRCUIT

An electric circuit is a closed conducting loop (or) path, which has a network of electrical components through which electrons are able to flow. This path is made using electrical wires so as to connect an electric appliance to a source of electric charges (battery). A schematic diagram of an electric circuit comprising of a battery, an electric bulb, and a switch is given in Figure 4.2.

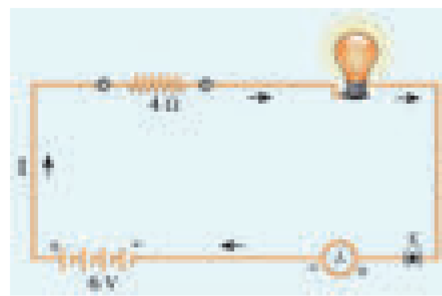
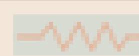
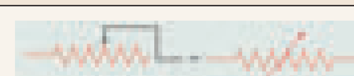
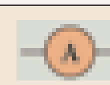
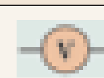
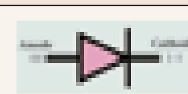
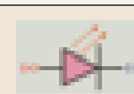
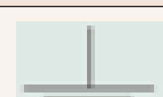


Figure 4.2 A simple electric circuit

Table 4.1 Symbols of some components of a circuit

COMPONENT	USE OF THE COMPONENT	SYMBOL USED
Resistor	Used to fix the magnitude of the current through a circuit	
Variable resistor or Rheostat	Used to select the magnitude of the current through a circuit.	
Ammeter	Used to measure the current.	
Voltmeter	Used to measure the potential difference.	
Galvanometer	Used to detect the current and its direction.	
A diode	It is used in electronic devices.	
Light Emitting Diode (LED)	It is used in seven segment display.	
Ground connection	Used to provide protection to the electrical components. It also serves as a reference point to measure the electric potential.	

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In this circuit, if the switch is 'on', the bulb glows. If it is switched off, the bulb does not glow. Therefore, the circuit must be closed in order that the current passes through it. The potential difference required for the flow of charges is provided by the battery. The electrons flow from the negative terminal to the positive terminal of the battery.

By convention, the direction of current is taken as the direction of flow of positive charge (or) opposite to the direction of flow of electrons. Thus, electric current passes in the circuit from the positive terminal to the negative terminal.

4.2.1 Electrical components

The electric circuit given in Figure 4.2 consists of different components, such as a battery, a switch and a bulb. All these components can be represented by using certain symbols. It is easier to represent the components of a circuit using their respective symbols.

The symbols that are used to represent some commonly used components are given in Table 4.1. The uses of these components are also summarized in the table.

4.3 ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

You are now familiar with the water current and air current. You also know that there must be a difference in temperature between two points in a solid for the heat to flow in it. Similarly, a difference in electric potential is needed for the flow of electric charges in a conductor. In the conductor, the charges will flow from a point in it, which is at a higher electric potential to a point, which is at a lower electric potential.

4.3.1 Electric Potential

The electric potential at a point is defined as the amount of work done in moving a unit positive charge from infinity to that point against the electric force.

4.3.2 Electric Potential Difference

The electric potential difference between two points is defined as the amount of work done in moving a unit positive charge from one point to another point against the electric force.

Figure 4.3 Electric potential

Suppose, you have moved a charge Q from a point A to another point B. Let 'W' be the work done to move the charge from A to B. Then, the potential difference between the points A and B is given by the following expression:

$$\text{Potential Difference (V)} = \frac{\text{Work Done (W)}}{\text{Charge (Q)}} \quad (4.2)$$

Potential difference is also equal to the difference in the electric potential of these two points. If V_A and V_B represent the electric potential at the points A and B respectively, then, the potential difference between the points A and B is given by:

$V = V_A - V_B$ (if V_A is more than V_B)

$V = V_B - V_A$ (if V_B is more than V_A)

4.3.3 Volt

The SI unit of electric potential or potential difference is volt (V).

The potential difference between two points is one volt, if one joule of work is done in moving one coulomb of charge from one point to another against the electric force.

$$1\text{volt} = \frac{1\text{ joule}}{1\text{ coulomb}}$$

Solved Problem-2

The work done in moving a charge of 10 C across two points in a circuit is 100 J. What is the potential difference between the points?

Solution:

Charge, Q = 10 C Work Done, W = 100 J

Potential Difference V = $\frac{W}{Q} = \frac{100}{10}$.

Therefore, V = 10 volt

4.4 OHM'S LAW

A German physicist, Georg Simon Ohm established the relation between the potential difference and current, which is known as Ohm's Law. This relationship can be understood from the following activity.

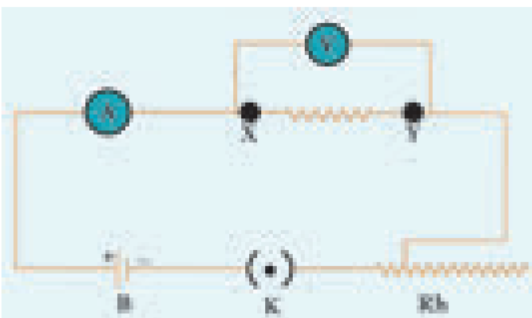

Figure 4.4 Electric circuit to understand Ohm's law

According to Ohm's law, at a constant temperature, the steady current 'I' flowing through a conductor is directly proportional to the potential difference 'V' between the two ends of the conductor.

$I \propto V$. Hence, $\frac{I}{V}$ = constant.

The value of this proportionality constant is found to be $\frac{1}{R}$

Therefore, $I = \left(\frac{1}{R}\right) V$

$$V = I\,R \qquad (4.3)$$

Here, R is a constant for a given material (say Nichrome) at a given temperature and is known as the **resistance** of the material. Since, the potential difference V is proportional to the current I, the graph between V and I is a straight line for a conductor, as shown in the Figure 4.5.

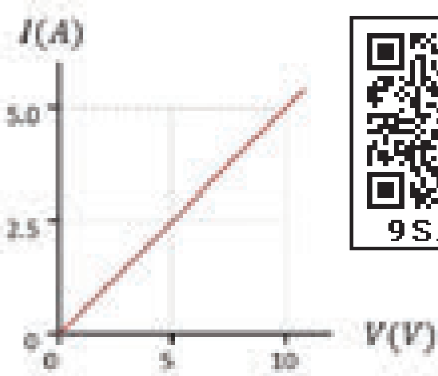

Figure 4.5 Relation between potential difference and current

4.5 RESISTANCE OF A MATERIAL

In Figure 4.4, a Nichrome wire was connected between X and Y. If you replace the Nichrome wire with a copper wire and conduct the same experiment, you will notice a different current for the same value of the potential difference across the wire. If you again replace the copper wire with an aluminium wire, you will get another value for the current passing through it. From equation (4.3), you have learnt that V/I must be equal to the resistance of the conductor used. The variations in the current for the same values of potential difference indicate that the resistance of different materials is different. Now, the primary question is, "what is resistance?"

Resistance of a material is its property to oppose the flow of charges and hence the passage of current through it. ***It is different for different materials***.

From Ohm's Law, $\frac{V}{I}$ = R.

The resistance of a conductor can be defined as the ratio between the potential difference across the ends of the conductor and the current flowing through it.

4.5.1 Unit of Resistance

The SI unit of resistance is ohm and it is represented by the symbol Ω.

Resistance of a conductor is said to be one ohm if a current of one ampere flows through it when a potential difference of one volt is maintained across its ends.

$$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

Solved Problem-3

Calculate the resistance of a conductor through which a current of 2 A passes, when the potential difference between its ends is 30 V.

Solution:

Current through the conductor I = 2 A, Potential Difference V = 30 V

From Ohm's Law: $R = \frac{V}{I}$.

Therefore, $R = \frac{30}{2} = 15\ \Omega$

4.6 ELECTRICAL RESISTIVITY & ELECTRICAL CONDUCTIVITY

4.6.1 Electrical Resistivity

You can verify by doing an experiment that the resistance of any conductor 'R' is directly proportional to the length of the conductor 'L' and is inversely proportional to its area of cross section 'A'.

$$R \propto L, \; R \propto \frac{1}{A},$$

$$\text{Hence }, R \propto \frac{L}{A}$$

$$\text{Therefore, } R = \rho \frac{L}{A} \qquad (4.4)$$

Where, ρ (rho) is a constant, called as electrical resistivity or specific resistance of the material of the conductor.

From equation (4.4), $\rho = \frac{RA}{L}$

If L = 1 m, A = 1 m^2 then, from the above equation $\rho = R$

Hence, the electrical resistivity of a material is ***defined as the resistance of a conductor of unit length and unit area of cross section***. Its unit is **ohm metre**.

Electrical resistivity of a conductor is a measure of the resisting power of a specified material to the passage of an electric current. It is a constant for a given material.

> **DO YOU KNOW?**
> Nichrome is a conductor with highest resistivity equal to $1.5 \times 10^{-6}\ \Omega$ m. Hence, it is used in making heating elements.

4.6.2 Conductance and Conductivity

Conductance of a material is the property of a material to aid the flow of charges and hence, the passage of current in it. The conductance of a material is mathematically ***defined as the reciprocal of its resistance*** (R). Hence, the conductance '**G**' of a conductor is given by

$$G = \frac{1}{R} \qquad (4.5)$$

Its unit is ohm^{-1}. It is also represented as 'mho'.

The reciprocal of electrical resistivity of a material is called its electrical conductivity.

$$\sigma = \frac{1}{\rho} \qquad (4.6)$$

Its unit is $\text{ohm}^{-1}\ \text{metre}^{-1}$. It is also represented as mho metre^{-1}. The conductivity is a constant for a given material. Electrical conductivity of a conductor is a measure of its ability to pass the current through it. Some materials are good conductors of electric current. Example: copper, aluminium, etc. While some other materials are non-conductors of electric current (insulators). Example: glass, wood, rubber, etc.

Conductivity is more for conductors than for insulators. But, the resistivity is less for conductors than for insulators. The resistivity of some commonly used materials is given in Table 4.2.

Table 4.2 Resistivity of some materials

NATURE OF THE MATERIAL	MATERIAL	RESISTIVITY (Ω m)
Conductor	Copper	1.62×10^{-8}
	Nickel	6.84×10^{-8}
	Chromium	12.9×10^{-8}
Insulator	Glass	10^{10} to 10^{14}
	Rubber	10^{13} to 10^{16}

Solved Problem-4

The resistance of a wire of length 10 m is 2 ohm. If the area of cross section of the wire is 2×10^{-7} m^2, determine its (i) resistivity (ii) conductance and (iii) conductivity

Solution:

Given: Length, L = 10 m, Resistance, R = 2 ohm and Area, A = 2×10^{-7} m^2

$$\text{Resistivity, } \rho = \frac{RA}{L} = \frac{2 \times 2 \times 10^{-7}}{10}$$

$$= 4 \times 10^{-8}\ \Omega\ \text{m}$$

$$\text{Conductance, } \mathbf{G} = \frac{1}{R} = \frac{1}{2} = 0.5 \text{ mho}$$

$$\text{Conductivity, } \sigma = \frac{1}{\rho} = \frac{1}{4 \times 10^{-8}}$$

$$= 0.25 \times 10^{8} \text{ mho m}^{-1}$$

4.7 SYSTEM OF RESISTORS

So far, you have learnt how the resistance of a conductor affects the current through a circuit. You have also studied the case of the simple electric circuit containing a single resistor. Now in practice, you may encounter a complicated circuit, which uses a combination of many resistors. This combination of resistors is known as 'system of resistors' or 'grouping of resistors'. Resistors can be connected in various combinations. The two basic methods of joining resistors together are:

a) Resistors connected in series, and b) Resistors connected in parallel.

In the following sections, you shall compute the effective resistance when many resistors having different resistance values are connected in series and in parallel.

4.7.1 Resistors in series

A series circuit connects the components one after the other to form a 'single loop'. A series circuit has only one loop through which current can pass. If the circuit is interrupted at any point in the loop, no current can pass through the circuit and hence no electric appliances connected in the circuit will work. Series circuits are commonly used in devices such as flashlights. ***Thus, if resistors are connected end to end, so that the same current passes through each of them, then they are said to be connected in series.***

Figure 4.6 Series connection of resistors

Let, three resistances R_1, R_2 and R_3 be connected in series (Figure 4.6). Let the current flowing through them be I. According to Ohm's Law, the potential differences V_1, V_2 and V_3 across R_1, R_2 and R_3 respectively, are given by:

$$V_1 = I R_1 \qquad (4.7)$$

$$V_2 = I R_2 \qquad (4.8)$$

$$V_3 = I R_3 \qquad (4.9)$$

The sum of the potential differences across the ends of each resistor is given by:

$$V = V_1 + V_2 + V_3$$

Using equations (4.7), (4.8) and (4.9), we get

$$V = I R_1 + I R_2 + I R_3 \quad (4.10)$$

The effective resistor is a single resistor, which can replace the resistors effectively, so as to allow the same current through the electric circuit. Let, the effective resistance of the series-combination of the resistors, be R_S. Then,

$$V = I R_S \quad (4.11)$$

Combining equations (4.10) and (4.11), you get,

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

$$R_S = R_1 + R_2 + R_3 \quad (4.12)$$

Thus, you can understand that when a number of resistors are connected in series, their equivalent resistance or effective resistance is equal to the sum of the individual resistances. When 'n' resistors of equal resistance R are connected in series, the equivalent resistance is 'n R'.

i.e., $R_S = n R$

The equivalent resistance in a series combination is greater than the highest of the individual resistances.

Solved Problem-5

Three resistors of resistances 5 ohm, 3 ohm and 2 ohm are connected in series with 10 V battery. Calculate their effective resistance and the current flowing through the circuit.

Solution:

$R_1 = 5\ \Omega$, $R_2 = 3\ \Omega$, $R_3 = 2\ \Omega$, $V = 10$ V

$R_s = R_1 + R_2 + R_3$, $R_s = 5 + 3 + 2 = 10$, hence $R_s = 10\ \Omega$

The current, $I = \frac{V}{R_S} = \frac{10}{10} = 1$ A

4.7.2 Resistances in Parallel

A parallel circuit has two or more loops through which current can pass. If the circuit is disconnected in one of the loops, the current can still pass through the other loop(s). The wiring in a house consists of parallel circuits.

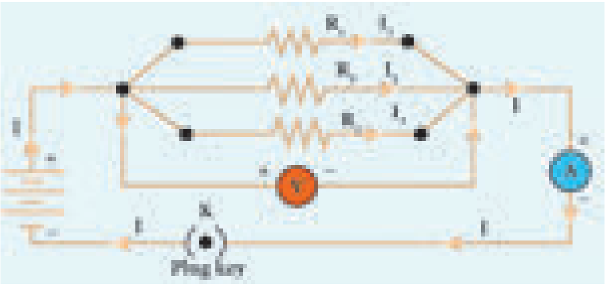

Figure 4.7 Parallel connections of resistors

Consider that three resistors R_1, R_2 and R_3 are connected across two common points A and B. The potential difference across each resistance is the same and equal to the potential difference between A and B. This is measured using the voltmeter. The current I arriving at A divides into three branches I_1, I_2 and I_3 passing through R_1, R_2 and R_3 respectively.

According to the Ohm's law, you have,

$$I_1 = \frac{V}{R_1} \quad (4.13)$$

$$I_2 = \frac{V}{R_2} \quad (4.14)$$

$$I_3 = \frac{V}{R_3} \quad (4.15)$$

The total current through the circuit is given by

$$I = I_1 + I_2 + I_3$$

Using equations (4.13), (4.14) and (4.15), you get

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \quad (4.16)$$

Let the effective resistance of the parallel combination of resistors be R_P. Then,

$$I = \frac{V}{R_P} \quad (4.17)$$

Combining equations (4.16) and (4.17), you have

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

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad (4.18)$$

Thus, when a number of resistors are connected in parallel, the sum of the reciprocals of the individual resistances is equal to the reciprocal of the effective or equivalent resistance. When 'n' resistors of equal resistances R are connected in parallel, the equivalent resistance is $\frac{R}{n}$.

i.e., $\frac{1}{R_P} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} \cdots + \frac{1}{R} = \frac{n}{R}$.

Hence, $R_p = \frac{R}{n}$

The equivalent resistance in a parallel combination is less than the lowest of the individual resistances.

4.7.3 Series Connection of Parallel Resistors

If you consider the connection of a set of parallel resistors that are connected in series, you get a series – parallel circuit. Let R_1 and R_2 be connected in parallel to give an effective resistance of R_{P1}. Similarly, let R_3 and R_4 be connected in parallel to give an effective resistance of R_{P2}. Then, both of these parallel segments are connected in series (Figure 4.8).

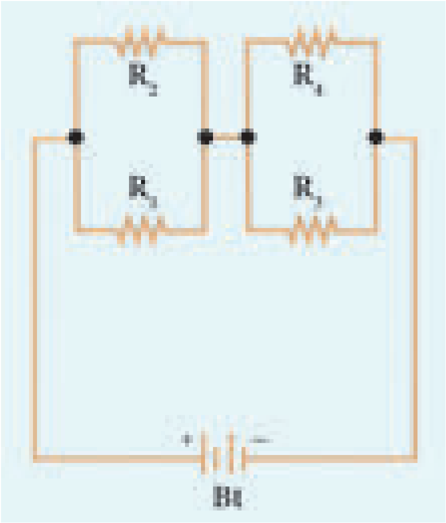

Figure 4.8 Series-parallel combination of resistors

Using equation (4.18), you get

$$\frac{1}{R_{P1}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_{P2}} = \frac{1}{R_3} + \frac{1}{R_4}$$

Finally, using equation (4.12), the net effective resistance is given by $R_{total} = R_{P1} + R_{P2}$

4.7.4 Parallel Connection of Series Resistors

If you consider a connection of a set of series resistors connected in a parallel circuit, you get a parallel-series circuit. Let R_1 and R_2 be connected in series to give an effective resistance of R_{S1}. Similarly, let R_3 and R_4 be connected in series to give an effective resistance of R_{S2}. Then, both of these serial segments are connected in parallel (Figure 4.9).

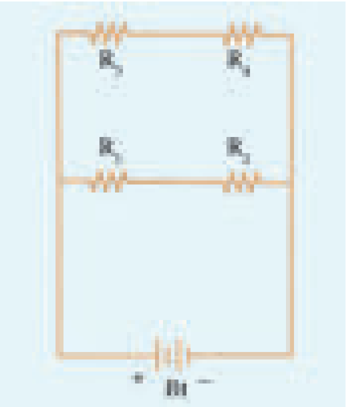

Figure 4.9 Parallel-series combination of resistors

Using equation (4.12), you get

$R_{S1} = R_1 + R_2$, $R_{S2} = R_3 + R_4$

Finally, using equation (4.18), the net effective resistance is given by

$$\frac{1}{R_{total}} = \frac{1}{R_{S1}} + \frac{1}{R_{S2}}$$

4.7.5 Difference between series and parallel connections

The difference between series and parallel circuits may be summed as follows in Table 4.3

Table 4.3 Difference between series and parallel circuit

S. No.	CRITERIA	SERIES	PARALLEL
1	Equivalent resistance	More than the highest resistance.	Less than the lowest resistance.
2	Amount of current	Current is less as effective resistance is more.	Current is more as effective resistance is less.
3	Switching ON/OFF	If one appliance is disconnected, others also do not work.	If one appliance is disconnected, others will work independently.

4.8 HEATING EFFECT OF CURRENT

Have you ever touched the motor casing of a fan, which has been used for a few hours continuously? What do you observe? The motor casing is warm. This is due to the heating effect of current. The same can be observed by touching a bulb, which was used for a long duration. Generally, a source of electrical energy can develop a potential difference across a resistor, which is connected to that source. This potential difference constitutes a current through the resistor. For continuous drawing of current, the source has to continuously spend its energy. A part of the energy from the source can be converted into useful work and the rest will be converted into heat energy. Thus, the passage of electric current through a wire, results in the production of heat. This phenomenon is called heating effect of current. This heating effect of current is used in devices like electric heater, electric iron, etc.

4.8.1 Joule's Law of Heating

Let 'I' be the current flowing through a resistor of resistance 'R', and 'V' be the potential difference across the resistor. The charge flowing through the circuit for a time interval 't' is 'Q'.

The work done in moving the charge Q across the ends of the resistor with a potential difference of V is VQ. This energy spent by the source gets dissipated in the resistor as heat. Thus, the heat produced in the resistor is:

$$H = W = VQ$$

You know that the relation between the charge and current is Q = I t. Using this, you get

$$H = V I t \qquad (4.19)$$

From Ohm's Law, V = I R. Hence, you have

$$\mathbf{H = I^2 R t} \qquad (4.20)$$

This is known as Joule's law of heating.

Joule's law of heating states that the heat produced in any resistor is:

- directly proportional to the square of the current passing through the resistor.
- directly proportional to the resistance of the resistor.
- directly proportional to the time for which the current is passing through the resistor.

4.8.2 Applications of Heating Effect

1. Electric Heating Device:

The heating effect of electric current is used in many home appliances such as electric iron, electric toaster, electric oven, electric heater, geyser, etc. In these appliances Nichrome, which is an alloy of Nickel and Chromium is used as the heating element. Why? Because:

(i) it has high resistivity, (ii) it has a high melting point, (iii) it is not easily oxidized.

2. Fuse Wire:

The fuse wire is connected in series, in an electric circuit. When a large current passes through the circuit, the fuse wire melts due to Joule's heating effect and hence the circuit gets disconnected. Therefore, the circuit and the electric appliances are saved from any damage. The fuse wire is made up of a material whose melting point is relatively low.

3. Filament in bulbs:

In electric bulbs, a small wire is used, known as filament. The filament is made up of a material whose melting point is very high. When current passes through this wire, heat is produced in the filament. When the filament is heated, it glows and gives out light. Tungsten is the commonly used material to make the filament in bulbs.

Solved Problem-6

An electric heater of resistance 5 Ω is connected to an electric source. If a current of 6 A flows through the heater, then find the amount of heat produced in 5 minutes.

Solution:

Given resistance R = 5 Ω, Current I = 6 A, Time t = 5 minutes = 5 × 60 s = 300 s

Amount of heat produced, $H = I^2Rt$, $H = 6^2 \times 5 \times 300$. Hence, H = 54000 J

4.9 ELECTRIC POWER

In general, power is defined as the rate of doing work or rate of spending energy. Similarly, the electric power is defined as the rate of consumption of electrical energy. It represents the rate at which the electrical energy is converted into some other form of energy.

Suppose a current 'I' flows through a conductor of resistance 'R' for a time 't', then the potential difference across the two ends of the conductor is 'V'. The work done 'W' to move the charge across the ends of the conductor is given by the equation (4.19) as follows:

$$W = V I t, \text{ Power } P = \frac{\text{Work}}{\text{Time}} = \frac{VIt}{t}$$

$$\mathbf{P = V I} \qquad (4.21)$$

Thus, the electric power is the product of the electric current and the potential difference due to which the current passes in a circuit.

4.9.1 Unit of Electric Power

The SI unit of electric power is watt. When a current of 1 ampere passes across the ends of a conductor, which is at a potential difference of 1 volt, then the electric power is

$$P = 1 \text{ volt} \times 1 \text{ ampere} = 1 \text{ watt}$$

Thus, one watt is the power consumed when an electric device is operated at a potential difference of one volt and it carries a current of one ampere. A larger unit of power, which is more commonly used is kilowatt.

DO YOU KNOW?

HORSE POWER:

The horse power (hp) is a unit in the foot-pound-second (fps) or English system, sometimes used to express the electric power. It is equal to 746 watt.

4.9.2 Consumption of electrical energy

Electricity is consumed both in houses and industries. Consumption of electricity is based on two factors: (i) Amount of electric power and (ii) Duration of usage. Electrical energy consumed is taken as the product of electric power and time of usage. For example, if 100 watt of electric power is consumed for two hours, then the power consumed is 100 × 2 = 200 watt hour. Consumption of electrical energy is measured and expressed in watt hour, though its SI unit is watt second. In practice, a larger unit of electrical energy is needed. This larger unit is kilowatt hour (kWh). One kilowatt hour is otherwise known as one unit of electrical energy. One kilowatt hour means that an electric power of 1000 watt has been utilized for an hour. Hence,

1 kWh = 1000 watt hour = 1000 × (60 × 60) watt second = 3.6×10^6 J

4.10 DOMESTIC ELECTRIC CIRCUITS

The electricity produced in power stations is distributed to all the domestic and industrial consumers through overhead and underground

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cables. The diagram, which shows the general scheme of a domestic electric circuit, is given in Figure 4.10.

In our homes, electricity is distributed through the domestic electric circuits wired by the electricians. The first stage of the domestic circuit is to bring the power supply to the main-box from a distribution panel, such as a transformer. The important components of the main-box are: (i) a fuse box and (ii) a meter. The meter is used to record the consumption of electrical energy. The fuse box contains either a fuse wire or a miniature circuit breaker (MCB). The function of the fuse wire or a MCB is to protect the house hold electrical appliances from overloading due to excess current.

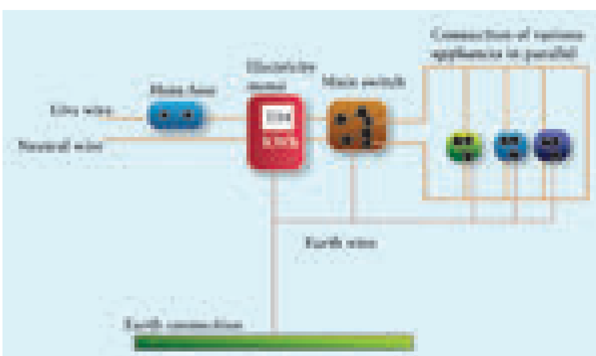


Figure 4.10 Domestic electric circuit

You have learnt about a fuse wire in section 4.8.2. An MCB is a switching device, which can be activated automatically as well as manually. It has a spring attached to the switch, which is attracted by an electromagnet when an excess current passes through the circuit. Hence, the circuit is broken and the protection of the appliance is ensured. Figure 4.11 represents a fuse and an MCB.

Figure 4.11 A fuse and an MCB

The electricity is brought to houses by two insulated wires. Out of these two wires, one wire has a red insulation and is called the 'live wire'. The other wire has a black insulation and is called the 'neutral wire'. The electricity supplied to your house is actually an alternating current having an electric potential of 220 V. Both, the live wire and the neutral wire enter into a box where the main fuse is connected with the live wire. After the electricity meter, these wires enter into the main switch, which is used to discontinue the electricity supply whenever required. After the main switch, these wires are connected to live wires of two separate circuits. Out of these two circuits, one circuit is of a 5 A rating, which is used to run the electric appliances with a lower power rating, such as tube lights, bulbs and fans. The other circuit is of a 15 A rating, which is used to run electric appliances with a high power rating, such as air-conditioners, refrigerators, electric iron and heaters. It should be noted that all the circuits in a house are connected in parallel, so that the disconnection of one circuit does not affect the other circuit. One more advantage of the parallel connection of circuits is that each electric appliance gets an equal voltage.

DO YOU KNOW? In India, domestic circuits are supplied with an alternating current of potential 220/230V and frequency 50 Hz. In countries like USA and UK, domestic circuits are supplied with an alternating current of potential 110/120 V and frequency 60 Hz.

4.10.1 Overloading and Short circuiting

The fuse wire or MCB will disconnect the circuit in the event of an overloading and short circuiting. Over loading happens when a large number of appliances are connected in series to the same source of electric power. This leads to a flow of excess current in the electric circuit. When the amount of current passing through a wire exceeds the maximum permissible limit, the wires get heated to such an extent that a fire may be caused. This is known as overloading. When a live wire comes in contact with a neutral wire, it causes a 'short circuit'. This happens when the insulation of the wires get damaged due to temperature changes or some external force. Due to a short circuit, the effective resistance in the circuit becomes very small, which leads to the flow of a large current through the wires. This results in heating of wires to such an extent that a fire may be caused in the building.

4.10.2 Earthing

In domestic circuits, a third wire called the earth wire having a green insulation is usually connected to the body of the metallic electric appliance. The other end of the earth wire is connected to a metal tube or a metal electrode, which is buried into the Earth. This wire provides a low resistance path to the electric current. The earth wire sends the current from the body of the appliance to the Earth, whenever a live wire accidentally touches the body of the metallic electric appliance. Thus, the earth wire serves as a protective conductor, which saves us from electric shocks.

4.11 LED BULB

An LED bulb is a semiconductor device that emits visible light when an electric current passes through it. The colour of the emitted light will depend on the type of materials used. With the help of the chemical compounds like Gallium Arsenide and Gallium Phosphide, the manufacturer can produce LED bulbs that radiates red, green, yellow and orange colours. Displays in digital watches and calculators, traffic signals, street lights, decorative lights, etc., are some examples for the use of LEDs.

4.11.1 Seven Segment Display

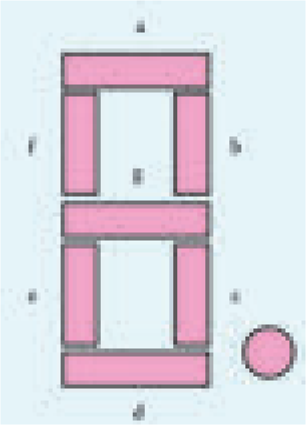


Figure 4.12 Seven segment display

A 'Seven Segment Display' is the display device used to give an output in the form of numbers or text. It is used in digital meters, digital clocks, micro wave ovens, etc. It consists of 7 segments of LEDs in the form of the digit 8. These seven LEDs are named as a, b, c, d, e, f and g (Figure 4.12). An extra 8^{th} LED is used to display a dot.

4.11.2 Merits of a LED bulb

1. As there is no filament, there is no loss of energy in the form of heat. It is cooler than the incandescent bulb.
2. In comparison with the fluorescent light, the LED bulbs have significantly low power requirement.
3. It is not harmful to the environment.
4. A wide range of colours is possible here.
5. It is cost-efficient and energy efficient.
6. Mercury and other toxic materials are not required.

One way of overcoming the energy crisis is to use more LED bulbs.

4.12 LED TELEVISION

LED Television is one of the most important applications of Light Emitting Diodes. An LED TV is actually an LCD TV (Liquid Crystal Display) with LED display.

An LED display uses LEDs for backlight and an array of LEDs act as pixels. LEDs emitting white light are used in monochrome (black and white) TV; Red, Green and Blue (RGB) LEDs are used in colour television. The first LED television screen was developed by James P. Mitchell in 1977. It was a monochromatic display. But, after about three decades, in 2009, SONY introduced the first commercial LED Television.

4.12.1 Advantages of LED television

- It has brighter picture quality.
- It is thinner in size.
- It uses less power and consumes very less energy.
- Its life span is more.
- It is more reliable.

Points to Remember

- ❖ The magnitude of current is defined as the rate of flow of charges in a conductor.
- ❖ The SI unit of electric current is ampere (A).
- ❖ The SI unit of electric potential and potential difference is volt (V).
- ❖ An electric circuit is a network of electrical components, which forms a continuous and closed path for an electric current to pass through it.
- ❖ The parameters of conductors like its length, area of cross-section and material, affect the resistance of the conductor.
- ❖ SI unit of electrical resistivity is ohm metre. The resistivity is a constant for a given material.
- ❖ The reciprocal of electrical resistivity of a material is called its electrical conductivity.

  $$\sigma = \frac{1}{\rho}$$
- ❖ The passage of electric current through a wire results in the production of heat. This phenomenon is called heating effect of current.
- ❖ One horse power is equal to 746 watts.
- ❖ The function of a fuse wire or a MCB is to protect the house hold electrical appliances from excess current due to overloading or a short circuit.

Solved Problems

1. Two bulbs are having the ratings as 60 W, 220 V and 40 W, 220 V respectively. Which one has a greater resistance?

Solution:

Electric power $P = \frac{V^2}{R}$

For the same value of V, R is inversely proportional to P.

Therefore, lesser the power, greater the resistance

Hence, the bulb with 40 W, 220 V rating has a greater resistance.

2. Calculate the current and the resistance of a 100 W, 200 V electric bulb in an electric circuit.

Solution:

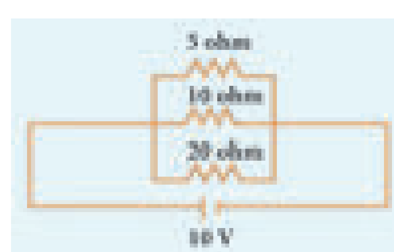
Power P = 100 W and Voltage V = 200 V

Power P = V I

So, Current, $I = \frac{P}{V} = \frac{100}{200} = 0.5$ A

Resistance, $R = \frac{V}{I} = \frac{200}{0.5} = 400\ \Omega$

3. In the circuit diagram given below, three resistors R_1, R_2 and R_3 of 5 Ω, 10 Ω and 20 Ω respectively are connected as shown. Calculate:



A) Current through each resistor
B) Total current in the circuit
C) Total resistance in the circuit

Solution:

A) Since the resistors are connected in parallel, the potential difference across each resistor is same (i.e. V=10V)

Therefore, the current through R_1 is,

$$I_1 = \frac{V}{R_1} = \frac{10}{5} = 2\ A$$

Current through $R_2 = I_2 = \frac{V}{R_2} = \frac{10}{10} = 1\ A$

Current through $R_3 = I_3 = \frac{V}{R_3} = \frac{10}{20} = 0.5\ A$

B) Total current in the circuit, $I = I_1 + I_2 + I_3$

$$= 2 + 1 + 0.5 = 3.5\ A$$

C) Total resistance in the circuit $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$$= \frac{1}{5} + \frac{1}{10} + \frac{1}{20}$$

$$= \frac{4+2+1}{20}$$

$$\frac{1}{R_P} = \frac{7}{20}$$

Hence, $R_P = \frac{20}{7} = 2.857\ \Omega$

4. Three resistors of 1 Ω, 2 Ω and 4 Ω are connected in parallel in a circuit. If a 1 Ω resistor draws a current of 1 A, find the current through the other two resistors.

Solution:

$R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$, $R_3 = 4\ \Omega$ Current $I_1 = 1\ A$

The potential difference across the 1 Ω resistor $= I_1 R_1 = 1 \times 1 = 1\ V$

Since, the resistors are connected in parallel in the circuit, the same potential difference will exist across the other resistors also.

So, the current in the 2 Ω resistor, $\frac{V}{R_2} = \frac{1}{2} = 0.5\ A$

Similarly, the current in the 4 Ω resistor,

$$\frac{V}{R_3} = \frac{1}{4} = 0.25\ A$$

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TEXTBOOK EVALUATION

I. Choose the best answer

1. Which of the following is correct?
   a) Rate of change of charge is electrical power.
   b) Rate of change of charge is current.
   c) Rate of change of energy is current.
   d) Rate of change of current is charge.

2. SI unit of resistance is
   a) mho b) joule
   c) ohm d) ohm meter

3. In a simple circuit, why does the bulb glow when you close the switch?
   a) The switch produces electricity.
   b) Closing the switch completes the circuit.
   c) Closing the switch breaks the circuit.
   d) The bulb is getting charged.

4. Kilowatt hour is the unit of
   a) resistivity b) conductivity
   c) electrical energy d) electrical power

II. Fill in the blanks

1. When a circuit is open, ____________ cannot pass through it.
2. The ratio of the potential difference to the current is known as ________.
3. The wiring in a house consists of _________ circuits.
4. The power of an electric device is a product of _________ and __________.
5. LED stands for ____________________.

III. State whether the following statements are true or false: If false correct the statement.

1. Ohm's law states the relationship between power and voltage.
2. MCB is used to protect house hold electrical appliances.
3. The SI unit for electric current is the coulomb.
4. One unit of electrical energy consumed is equal to 1000 kilowatt hour.
5. The effective resistance of three resistors connected in series is lesser than the lowest of the individual resistances.

IV. Match the items in column-I to the items in column-II:

Column - I	Column - II
(i) electric current	(a) volt
(ii) potential difference	(b) ohm meter
(iii) specific resistance	(c) watt
(iv) electrical power	(d) joule
(v) electrical energy	(e) ampere

V. Assertion and reason type questions:

Mark the correct choice as

a) if both the assertion and the reason are true and the reason is the correct explanation of the assertion.

b) if both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.

c) if the assertion is true, but the reason is false.

d) if the assertion is false, but the reason is true.

1. **Assertion:** Electric appliances with a metallic body have three wire connections.

   Reason: Three pin connections reduce heating of the connecting wires

2. **Assertion:** In a simple battery circuit the point of highest potential is the positive terminal of the battery.

   Reason: The current flows towards the point of the highest potential

3. **Assertion:** LED bulbs are far better than incandescent bulbs.

   Reason: LED bulbs consume less power than incandescent bulbs.

VI. Very short answer questions.

1. Define the unit of current.
2. What happens to the resistance, as the conductor is made thicker?
3. Why is tungsten metal used in bulbs, but not in fuse wires?
4. Name any two devices, which are working on the heating effect of the electric current.

VII. Short answer questions

1. Define electric potential and potential difference.
2. What is the role of the earth wire in domestic circuits?
3. State Ohm's law.
4. Distinguish between the resistivity and conductivity of a conductor.

5. What connection is used in domestic appliances and why?

VIII. Long answer questions.

1. With the help of a circuit diagram derive the formula for the resultant resistance of three resistances connected: a) in series and b) in parallel
2. a) What is meant by electric current?
   b) Name and define its unit.
   c) Which instrument is used to measure the electric current? How should it be connected in a circuit?
3. a) State Joule's law of heating.
   b) An alloy of nickel and chromium is used as the heating element. Why?
   c) How does a fuse wire protect electrical appliances?
4. Explain about domestic electric circuits. (circuit diagram not required)
5. a) What are the advantages of LED TV over the normal TV?
   b) List the merits of LED bulb.

IX. Numerical problems:

1. An electric iron consumes energy at the rate of 420 W when heating is at the maximum rate and 180 W when heating is at the minimum rate. The applied voltage is 220 V. What is the current in each case?
2. A 100 watt electric bulb is used for 5 hours daily and four 60 watt bulbs are used for 5 hours daily. Calculate the energy consumed (in kWh) in the month of January.
3. A torch bulb is rated at 3 V and 600 mA. Calculate it's
   a) power
   b) resistance
   c) energy consumed if it is used for 4 hour.
4. A piece of wire having a resistance R is cut into five equal parts.
   a) How will the resistance of each part of the wire change compared with the original resistance?
   b) If the five parts of the wire are placed in parallel, how will the resistance of the combination change?
   c) What will be ratio of the effective resistance in series connection to that of the parallel connection?

X. HOTS:

1. Two resistors when connected in parallel give the resultant resistance of 2 ohm; but when connected in series the effective resistance becomes 9 ohm. Calculate the value of each resistance.
2. How many electrons are passing per second in a circuit in which there is a current of 5 A?
3. A piece of wire of resistance 10 ohm is drawn out so that its length is increased to three times its original length. Calculate the new resistance.

REFERENCE BOOKS

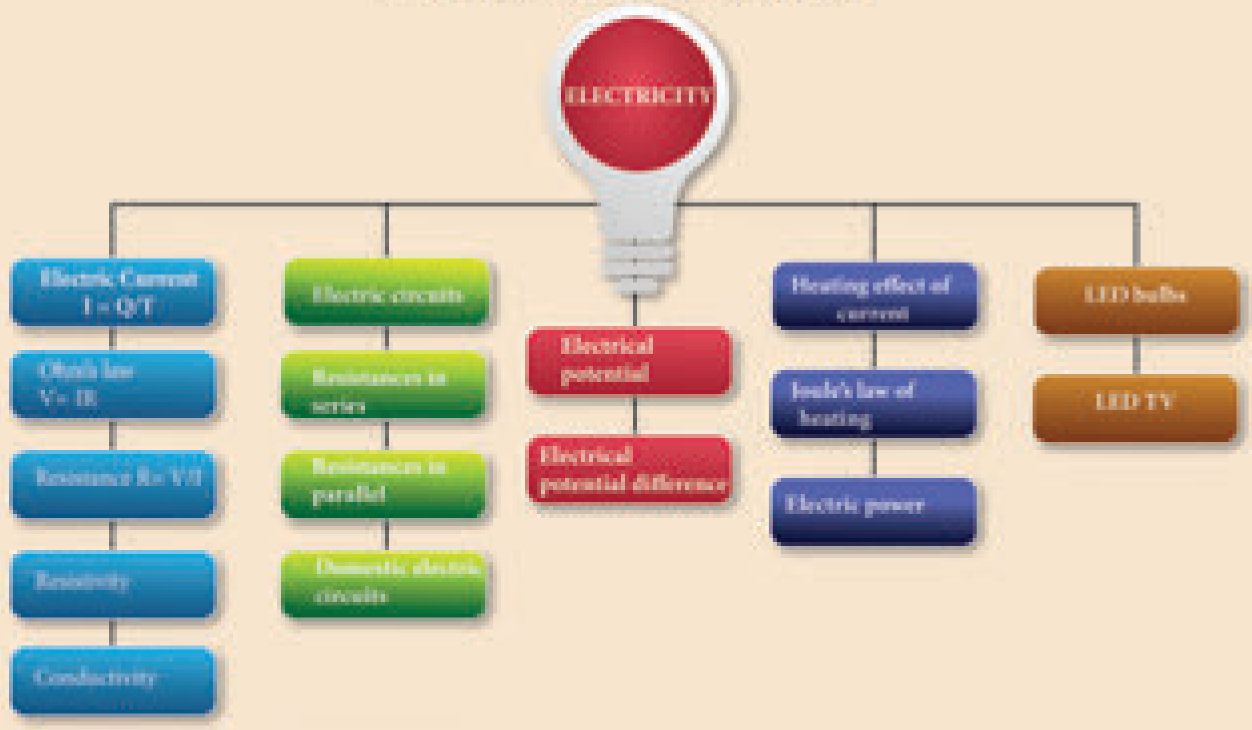
1. Electrodynamics by Griffiths
2. Fundamentals of Electric Circuits by Charles Alexander

INTERNET RESOURCES

https://www.elprocus.com/basic-electrical-circuits-and-their-working-for-electrical-engineers/

https://www.physicsclassroom.com/calcpad/circuits

CONCEPT MAP



ICT CORNER

Ohm's Law

In this activity you will be able to (i) verify Ohm's law (ii) understand the relation between current, voltage and resistance.

Steps

- Open the browser and type "olabs.edu.in" in the address bar. Click physics tab and then click "Ohm's law and resistance" under class 10 section. Go to "simulator" tab to do the experiment.
- Construct the electric circuit as per the connection diagram by clicking "show circuit diagram" tab. You can connect wires between electric component by dragging the mouse between the component.
- Switch on the key and note down the voltage (V) and curren (I). Find the value of resistance using the formula $R = \frac{V}{I}$. Repeat the experiment for different values of voltage and current. Check whether the resistance remains constant.
- Find the value of Resistance/(length (in Cm)). Enter the value of resistance and resistance per unit length in the result. Verify the answer.

Note:

1. One time sign up is needed to do simulation. Then login using that username and password.
2. Read theory, procedure and animation to get the theory by clicking the corresponding tab.

Link

URL:http://amrita.olabs.edu.in/?sub=1&brch=4&sim=99&cnt=4

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UNIT 5

ACOUSTICS

Learning Objectives

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By the end of this section, the students will be able to:

- Understand how sound is produced and transmitted.
- Relate the speed of sound, its frequency, and its wavelength.
- Know the speed of sound in various media.
- Explain the factors affecting the speed of sound in a gaseous medium.
- Demonstrate the phenomenon of reflection of sound.
- Determine the speed of sound using the method of echo.
- Understand Doppler Effect.
- Solve numerical problems related to the above topics.

INTRODUCTION

Sound plays a major role in our lives. We communicate with each other mainly through sound. In our daily life, we hear a variety of sounds produced by different sources like humans, animals, vehicle horns, etc. Hence, it becomes inevitable to understand how sound is produced, how it is propagated and how you hear the sound from various sources. It is sometimes misinterpreted that acoustics only deals with musical instruments and design of auditoria and concert halls. But, acoustics is a branch of physics that deals with production, transmission, reception, control, and effects of sound. You have studied about propagation and properties of sound waves in IX standard. In this lesson we will study about reflection of sound waves, Echo and Doppler effect.

5.1 SOUND WAVES

When you think about sound, the questions that arise in your minds are: How is sound produced? How does sound reach our ears from various sources? What is sound? Is it a force or energy? Let us answer all these questions.

By touching a ringing bell or a musical instrument while it is producing music, you can conclude that sound is produced by vibrations. The vibrating bodies produce energy in the form of waves, which are nothing but sound waves (Figure 5.1).

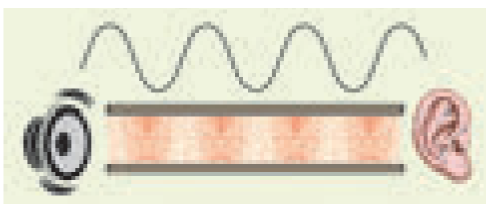

Figure 5.1 Production of sound waves

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Suppose you and your friend are on the Moon. Will you be able to hear any sound produced by your friend? As the Moon does not have air, you will not be able to hear any sound produced by your friend. Hence, you understand that the sound produced due to the vibration of different bodies needs a material medium like air, water, steel, etc, for its propagation. Hence, sound can propagate through a gaseous medium or a liquid medium or a solid medium.

ACTIVITY 1

Take a squeaky toy or old mobile phone and put it inside a plastic bag. Seal the bag with the help of a candle or with a thread. Fill a bucket with water and place the bag in the water bucket and squeeze the toy or ring the mobile. You will hear a low sound. Now place your ear against the side of the bucket and squeeze the toy or ring the mobile phone again. You will hear a louder sound.

5.1.1 Longitudinal Waves

Sound waves are longitudinal waves that can travel through any medium (solids, liquids, gases) with a speed that depends on the properties of the medium. As sound travels through a medium, the particles of the medium vibrate along the direction of propagation of the wave. This displacement involves the longitudinal displacements of the individual molecules from their mean positions. This results in a series of high and low pressure regions called compressions and rarefactions as shown in figure 5.2.

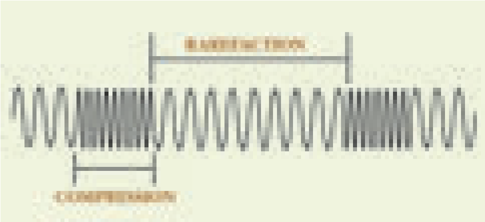

Figure 5.2 Sound propagates as longitudinal waves

5.1.2 Categories of sound waves based on their frequencies

(i) Audible waves – These are sound waves with a frequency ranging between 20 Hz and 20,000 Hz. These are generated by vibrating bodies such as vocal cords, stretched strings etc.

(ii) Infrasonic waves – These are sound waves with a frequency below 20 Hz that cannot be heard by the human ear. e.g., waves produced during earth quake, ocean waves, sound produced by whales, etc.

(iii) Ultrasonic waves – These are sound waves with a frequency greater than 20 kHz, Human ear cannot detect these waves, but certain creatures like mosquito, dogs, bats, dolphins can detect these waves. e.g., waves produced by bats.

5.1.3 Difference between the sound and light waves

S.No.	SOUND	LIGHT
1	Medium is required for the propagation.	Medium is not required for the propagation.
2	Sound waves are longitudinal.	Light waves are transverse.
3	Wavelength ranges from 1.65 cm to 1.65 m.	Wavelength ranges from 4×10^{-7} m to 7×10^{-7} m.
4	Sound waves travel in air with a speed of about 340 ms^{-1} at NTP.	Light waves travel in air with a speed of 3×10^{8} ms^{-1}.

5.1.4 Velocity of sound waves

When you talk about the velocity associated with any wave, there are two velocities, namely particle velocity and wave velocity. SI unit of velocity is ms^{-1}

Particle velocity:

The velocity with which the particles of the medium vibrate in order to transfer the energy in the form of a wave is called particle velocity.

Wave velocity:

The velocity with which the wave travels through the medium is called wave velocity. In other words, the distance travelled by a sound wave in unit time is called the velocity of a sound wave.

$$\therefore \text{ Velocity} = \frac{\text{Distance}}{\text{Time taken}}$$

If the distance travelled by one wave is taken as one wavelength (λ) and, the time taken for this propagation is one time period (T), then, the expression for velocity can be written as

$$\therefore V = \frac{\lambda}{T} \qquad (5.1)$$

Therefore, velocity can be defined as the distance travelled per second by a sound wave. Since, Frequency (n) =1/T, equation (5.1) can be written as

$$V = n\lambda \qquad (5.2)$$

Velocity of a sound wave is maximum in solids because they are more elastic in nature than liquids and gases. Since, gases are least elastic in nature, the velocity of sound is the least in a gaseous medium.

So, $v_S > v_L > v_G$

5.1.5 Factors affecting velocity of sound

In the case of solids, the elastic properties and the density of the solids affect the velocity of sound waves. Elastic property of solids is characterized by their elastic moduli. The speed of sound is directly proportional to the square root of the elastic modulus and inversely proportional to the square root of the density. Thus the velocity of sound in solids decreases as the density increases whereas the velocity of sound increases when the elasticity of the material increases. In the case of gases, the following factors affect the velocity of sound waves.

Effect of density: The velocity of sound in a gas is inversely proportional to the square root of the density of the gas. Hence, the velocity decreases as the density of the gas increases.

$$v \propto \sqrt{\frac{1}{d}}$$

Effect of temperature: The velocity of sound in a gas is directly proportional to the square root of its temperature. The velocity of sound in a gas increases with the increase in temperature. $v \propto \sqrt{T}$. Velocity at temperature T is given by the following equation:

$$v_T = (v_o + 0.61\,T)\ \text{ms}^{-1}$$

Here, v_o is the velocity of sound in the gas at 0° C. For air, v_o = 331 ms^{-1}. Hence, the velocity of sound changes by 0.61 ms^{-1} when the temperature changes by one degree celsius.

Effect of relative humidity: When humidity increases, the speed of sound increases. That is why you can hear sound from long distances clearly during rainy seasons.

Speed of sound waves in different media are given in table 5.1.

Table 5.1 Speed of sound in different media

S. No.	Nature of the medium	Name of the Medium	Speed of sound (in ms^{-1})
1	Solid	Copper	5010
2		Iron	5950
3		Aluminium	6420
4	Liquid	Kerosene	1324
5		Water	1493
6		Sea water	1533
7	Gas	Air (at 0° C)	331
8		Air (at 20° C)	343

Example Problem 5.1

1. At what temperature will the velocity of sound in air be double the velocity of sound in air at 0° C?

Solution:

Let T° C be the required temperature. Let v_1 and v_2 be the velocity of sound at temperatures T_1K and T_2K respectively. T_1 = 273K (0° C) and T_2 = (T° C + 273)K

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{273 + T}{273}} = 2$$

Here, it is given that, $v_2 / v_1 = 2$.

$$\text{So, } \frac{273 + T}{273} = 4$$

T = (273 × 4) – 273 = 819° C

5.2 REFLECTION OF SOUND

When you speak in an empty room, you hear a soft repetition of your voice. This is nothing but the reflection of the sound waves that you produce. Let us discuss about the reflection of sound in detail through the following activity.

When sound waves travel in a given medium and strike the surface of another medium, they can be bounced back into the first medium. This phenomenon is known as reflection. In simple the reflection and refraction of sound is actually similar to the reflection of light. Thus, the bouncing of sound waves from the interface between two media is termed as the reflection of sound. The waves that strike the interface are termed as the incident wave and the waves that bounce back are termed as the reflected waves, as shown in Figure 5.3

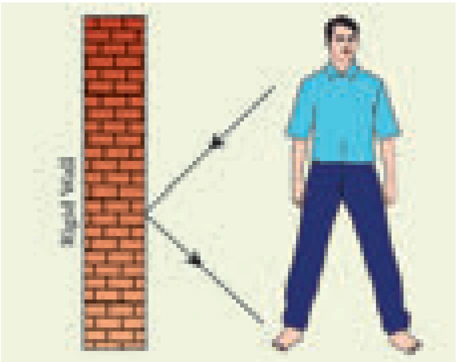

Figure 5.3 Reflection of sound

5.2.1 Laws of reflection

Like light waves, sound waves also obey some fundamental laws of reflection. The following two laws of reflection are applicable to sound waves as well.

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- The incident wave, the normal to the reflecting surface and the reflected wave at the point of incidence lie in the same plane.
- The angle of incidence ∠i is equal to the angle of reflection ∠r.

These laws can be observed from Figure 5.4.

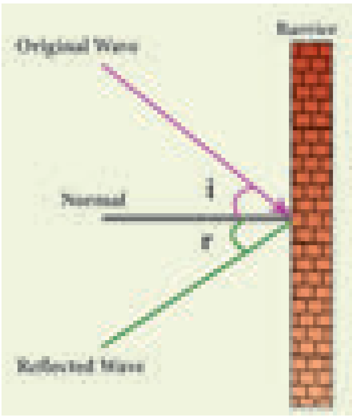

Figure 5.4 Laws of reflection

In the above Figure 5.4, the sound waves that travel towards the reflecting surface are called the incident waves. The sound waves bouncing back from the reflecting surface are called reflected waves. For all practical purposes, the point of incidence and the point of reflection is the same point on the reflecting surface.

A perpendicular line drawn at the point of incidence is called the normal. The angle which the incident sound wave makes with the normal is called the angle of incidence, 'i'. The angle which the reflected wave makes with the normal is called the angle of reflection, 'r'.

DO YOU KNOW?

Acoustical wonder of Golconda fort (Hyderabad, Telangana)

The Clapping portico in Golconda Fort is a series of arches on one side, each smaller than the preceding one. So, a sound wave generated under the dome would get compressed and then bounce back amplified sufficiently to reach a considerable distance.

5.2.2 Reflection at the boundary of a denser medium

54TNGQ

A longitudinal wave travels in a medium in the form of compressions and rarefactions. Suppose a compression travelling in air from left to right reaches a rigid wall. The compression exerts a force F on the rigid wall. In turn, the wall exerts an equal and opposite reaction R = – F on the air molecules. This results in a compression near the rigid wall. Thus, a compression travelling towards the rigid wall is reflected back as a compression. That is the direction of compression is reversed (Figure 5.5).

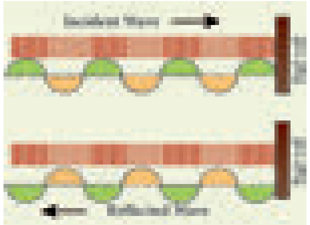

Figure 5.5 Reflection of sound at a denser medium

5.2.3 Reflection at the boundary of a rarer medium

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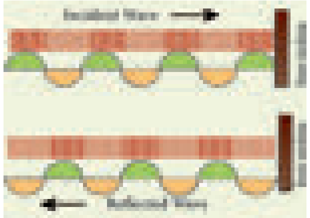
Consider a wave travelling in a solid medium striking on the interface between the solid and the air. The compression exerts a force F on the surface of the rarer medium. As a rarer medium has smaller resistance for any deformation, the surface of separation is pushed backwards (Figure 5.6). As the particles of the rarer medium are free to move, a rarefaction is produced at the interface. Thus, a compression is reflected as a rarefaction and a rarefaction travels from right to left.



5.6 Reflection of sound at a rarer medium

More to know:

What is meant by rarer and denser medium?
The medium in which the velocity of sound increases compared to other medium is called rarer medium. (Water is rarer compared to air for sound).
The medium in which the velocity of sound decreases compared to other medium is called denser medium. (Air is denser compared to water for sound)

5.2.4 Reflection of sound in plane and curved surfaces

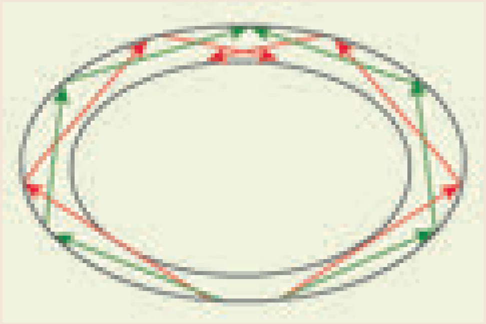
When sound waves are reflected from a plane surface, the reflected waves travel in a direction, according to the law of reflection. The intensity of the reflected wave is neither decreased nor increased. But, when the sound waves are reflected from the curved surfaces, the intensity of the reflected waves is changed. When reflected from a convex surface, the reflected waves are diverged out and the intensity is decreased. When sound is reflected from a concave surface, the reflected waves are converged and focused at a point. So the intensity of reflected waves is concentrated at a point. Parabolic surfaces are used when it is required to focus the sound at a particular point. Hence, many halls are designed with parabolic reflecting surfaces. In elliptical surfaces, sound from one focus will always be reflected to the other focus, no matter where it strikes the wall.

This principle is used in designing whispering halls. In a whispering hall, the speech of a person standing in one focus can be heard clearly by a listener standing at the other focus.

DO YOU KNOW?

Whispering Gallery

One of the famous whispering galleries is in St. Paul's cathedral church in London. It is built with elliptically shaped walls. When a person is talking at one focus, his voice can be heard distinctly at the other focus. It is due to the multiple reflections of sound waves from the curved walls.



5.3 ECHOES

An echo is the sound reproduced due to the reflection of the original sound from various rigid surfaces such as walls, ceilings, surfaces of mountains, etc.

If you shout or clap near a mountain or near a reflecting surface, like a building you can hear the same sound again. The sound, which you hear is called an echo. It is due to the reflection of sound. One does not experience any echo sound in a small room. This does not mean that sound is not reflected in a small room. This is because smaller rooms do not satisfy the basic conditions for hearing an echo.

5.3.1 Conditions necessary for hearing echo

1. The persistence of hearing for human ears is 0.1 second. This means that you can hear two sound waves clearly, if the time interval between the two sounds is at least 0.1 s. Thus, the minimum time gap between the original sound and an echo must be 0.1 s.

2. The above criterion can be satisfied only when the distance between the source of sound and the reflecting surface would satisfy the following equation:

$$\text{Velocity} = \frac{\text{distance travelled by sound}}{\text{time taken}}$$

$$v = \frac{2d}{t}$$

$$d = \frac{vt}{2}$$

Since, t = 0.1 second, then $d = \frac{v \times 0.1}{2} = \frac{v}{20}$

Thus the minimum distance required to hear an echo is 1/20th part of the magnitude of the velocity of sound in air. If you consider the velocity of sound as 344 ms^{-1}, the minimum distance required to hear an echo is 17.2 m.

5.3.2 Applications of echo

- Some animals communicate with each other over long distances and also locate objects by sending the sound signals and receiving the echo as reflected from the targets.
- The principle of echo is used in obstetric ultrasonography, which is used to create real-time visual images of the developing embryo or fetus in the mother's uterus. This is a safe testing tool, as it does not use any harmful radiations.
- Echo is used to determine the velocity of sound waves in any medium.

5.3.3 Measuring velocity of sound by echo method

Apparatus required:

A source of sound pulses, a measuring tape, a sound receiver, and a stop watch.

Procedure:

1. Measure the distance 'd' between the source of sound pulse and the reflecting surface using the measuring tape.

2. The receiver is also placed adjacent to the source. A sound pulse is emitted by the source.

3. The stopwatch is used to note the time interval between the instant at which the sound pulse is sent and the instant at which the echo is received by the receiver. Note the time interval as 't'.

4. Repeat the experiment for three or four times. The average time taken for the given number of pulses is calculated.

Calculation of speed of sound:

The sound pulse emitted by the source travels a total distance of 2d while travelling from the source to the wall and then back to the receiver. The time taken for this has been observed to be 't'. Hence, the speed of sound wave is given by:

$$\text{Speed of sound} = \frac{\text{distance travelled}}{\text{time taken}} = \frac{2d}{t}$$

5.4 APPLICATIONS REFLECTION OF SOUND

5.4.1 Sound board

These are basically curved surfaces (concave), which are used in auditoria and halls to improve the quality of sound. This board is placed such that the speaker is at the focus of the concave surface. The sound of the speaker is reflected towards the audience thus improving the quality of sound heard by the audience.

5.4.2 Ear trumpet

Ear trumpet is a hearing aid, which is useful by people who have difficulty in hearing. In this device, one end is wide and the other end is narrow. The sound from the sources fall into the wide end and are reflected by its walls into the narrow part of the device. This helps in concentrating the sound and the sound enters the ear drum with more intensity. This enables a person to hear the sound better.

5.4.3 Mega phone

A megaphone is a horn-shaped device used to address a small gathering of people. Its one end is wide and the other end is narrow. When a person speaks at the narrow end, the sound of his speech is concentrated by the multiple reflections from the walls of the tube. Thus, his voice can be heard loudly over a long distance.

5.5 DOPPLER EFFECT

The whistle of a fast moving train appears to increase in pitch as it approaches a stationary listener and it appears to decrease as the train moves away from the listener. This apparent change in frequency was first observed and explained by Christian Doppler (1803-1853), an Austrian Mathematician and Physicist. He observed that the frequency of the sound as received by a listener is different from the original frequency produced by the source whenever there is a relative motion between the source and the listener. This is known as Doppler effect This relative motion could be due to various possibilities as follows:

(i) The listener moves towards or away from a stationary source

(ii) The source moves towards or away from a stationary listener

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(iii) Both source and listener move towards or away from one other

(iv) The medium moves when both source and listener are at rest

DEFINITION

When ever there is a relative motion between a source and a listener, the frequency of the sound heard by the listener is different from the original frequency of sound emitted by the source. This is known as "Doppler effect".

For simplicity of calculation, it is assumed that the medium is at rest. That is the velocity of the medium is zero.

Let S and L be the source and the listener moving with velocities v_S and v_L respectively. Consider the case of source and listener moving towards each other (Figure 5.7). As the distance between them decreases, the apparent frequency will be more than the actual source frequency.

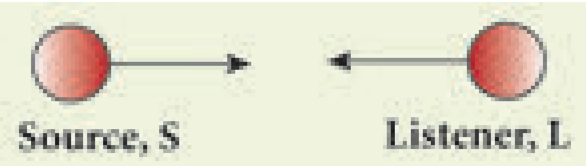

Figure 5.7 Source and listener moving towards each other

Let n and n' be the frequency of the sound produced by the source and the sound observed by the listener respectively. Then, the expression for the apparent frequency n' is

$$n' = \left(\frac{v + v_L}{v - v_s}\right)\mathbf{n}$$

Here, v is the velocity of sound waves in the given medium. Let us consider different possibilities of motions of the source and the listener. In all such cases, the expression for the apparent frequency is given in table 5.2.

Table 5.2 Expression for apparent frequency due to Doppler effect

Case No.	Position of source and listener	Note	Expression for apparent frequency
1	❖ Both source and listener move ❖ They move towards each other	a) Distance between source and listener decreases. b) Apparent frequency is more than actual frequency.	$n' = \left(\frac{v + v_L}{v - v_s}\right) n$
2	❖ Both source and listener move ❖ They move away from each other	a) Distance between source and listener increases. b) Apparent frequency is less than actual frequency. c) v_S and v_L become opposite to that in case-1.	$n' = \left(\frac{v - v_L}{v + v_s}\right) n$
3	❖ Both source and listener move ❖ They move one behind the other ❖ Source follows the listener	a) Apparent frequency depends on the velocities of the source and the listener. b) v_S becomes opposite to that in case-2.	$n' = \left(\frac{v - v_L}{v - v_s}\right) n$

4	❖ Both source and listener move ❖ They move one behind the other ❖ Listener follows the source	a) Apparent frequency depends on the velocities of the source and the listener. b) v_S and v_L become opposite to that in case-3.	$n' = \left(\frac{v + v_L}{v + v_s}\right) n$
5	❖ Source at rest ❖ Listener moves towards the source	a) Distance between source and listener decreases. b) Apparent frequency is more than actual frequency. c) $v_S = 0$ in case-1.	$n' = \left(\frac{v + v_L}{v}\right) n$
6	❖ Source at rest ❖ Listener moves away from the source	a) Distance between source and listener increases. b) Apparent frequency is less than actual frequency. c) $v_S = 0$ in case-2.	$n' = \left(\frac{v - v_L}{v}\right) n$
7	❖ Listener at rest ❖ Source moves towards the listener	a) Distance between source and listener decreases. b) Apparent frequency is more than actual frequency. c) $v_L = 0$ in case-1.	$n' = \left(\frac{v}{v - v_s}\right) n$
8	❖ Listener at rest ❖ Source moves away from the listener	a) Distance between source and listener increases. b) Apparent frequency is less than actual frequency. c) $v_L = 0$ in case-2.	$n' = \left(\frac{v}{v + v_s}\right) n$

Suppose the medium (say wind) is moving with a velocity W in the direction of the propagation of sound. For this case, the velocity of sound, 'v' should be replaced with (v + W). If the medium moves in a direction opposite to the propagation of sound, then 'v' should be replaced with (v – W).

Solved problems

1. A source producing a sound of frequency 90 Hz is approaching a stationary listener with a speed equal to (1/10) of the speed of sound. What will be the frequency heard by the listener?

Solution: When the source is moving towards the stationary listener, the expression for apparent frequency is

$$n' = \left(\frac{v}{v - v_s}\right) n$$

$$= \left(\frac{v}{v - \left(\frac{1}{10}\right) v}\right) n = \left(\frac{10}{9}\right) n$$

$$= \left(\frac{10}{9}\right) \times 90 = 100 \text{ Hz}$$

2. A source producing a sound of frequency 500 Hz is moving towards a listener with a velocity of 30 ms^{-1}. The speed of the sound is 330 ms^{-1}. What will be the frequency heard by listener?

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Solution: When the source is moving towards the stationary listener, the expression for apparent frequency is

$$n' = \left(\frac{v}{v - v_s}\right) n$$

$$n' = \left(\frac{330}{330 - 30}\right) \times 500$$

= 550 Hz

3. A source of sound is moving with a velocity of 50 ms^{-1} towards a stationary listener. The listener measures the frequency of the source as 1000 Hz. what will be the apparent frequency of the source when it is moving away from the listener after crossing him? (velocity of sound in the medium is 330 m s^{-1})

Solution: When the source is moving towards the stationary listener, the expression for apparent frequency is

$$n' = \left(\frac{v}{v - v_s}\right) n$$

$$1000 = \left(\frac{330}{330 - 50}\right) n$$

$$n = \left(\frac{1000 \times 280}{330}\right)$$

n = 848.48 Hz.

The actual frequency of the sound is 848.48 Hz. When the source is moving away from the stationary listener, the expression for apparent frequency is

$$n' = \left(\frac{v}{v + v_s}\right) n$$

$$= \left(\frac{330}{330 + 50}\right) \times 848.48$$

= 736.84 Hz

4. A source and listener are both moving towards each other with a speed v/10 where v is the speed of sound. If the frequency of the note emitted by the source is f, what will be the frequency heard by the listener?

Solution: When source and listener are both moving towards each other, the apparent frequency is

$$n' = \left(\frac{v + v_l}{v - v_s}\right) . n$$

$$n' = \left(\frac{v + \frac{v}{10}}{v - \frac{v}{10}}\right) . n$$

$$n' = \frac{11}{9} . f$$

= 1.22 f

5. At what speed should a source of sound move away from a stationary observer so that observer finds the apparent frequency equal to half of the original frequency?

Solution: When the source is moving away from the stationary listener, the expression for the apparent frequency is

$$n' = \left(\frac{v}{v + v_s}\right) . n$$

$$\frac{n}{2} = \left(\frac{v}{v + v_s}\right) . n$$

$$V_s = V$$

5.5.1 Conditions for no Doppler effect

Under the following circumstances, there will be no Doppler effect and the apparent frequency as heard by the listener will be the same as the source frequency.

(i) When source (S) and listener (L) both are at rest.

(ii) When S and L move in such a way that distance between them remains constant.

(iii) When source S and L are moving in mutually perpendicular directions.

(iv) If the source is situated at the center of the circle along which the listener is moving.

5.5.2 Applications of Doppler effect

(a) To measure the speed of an automobile

An electromagnetic wave is emitted by a source attached to a police car. The wave is reflected by a moving vehicle, which acts as a moving source. There is a shift in the frequency of the reflected wave. From the frequency shift, the speed of the car can be determined. This helps to track the over speeding vehicles.

(b) Tracking a satellite

The frequency of radio waves emitted by a satellite decreases as the satellite passes away from the Earth. By measuring the change in the frequency of the radio waves, the location of the satellites is studied.

(c) RADAR (RAdio Detection And Ranging)

In RADAR, radio waves are sent, and the reflected waves are detected by the receiver of the RADAR station. From the frequency change, the speed and location of the aeroplanes and aircrafts are tracked.

(d) SONAR

In SONAR, by measuring the change in the frequency between the sent signal and received signal, the speed of marine animals and submarines can be determined.

Points to Remember

- Wave velocity is the velocity with which the wave travels through the medium.
- Velocity of a sound wave is maximum in solids because they are more elastic in nature than liquids and gases. Since gases are least elastic in nature.
- Infrasonic waves are sound wave with a frequency below 20 Hz. A human ear cannot hear these waves.
- Ultrasonic waves are sound waves with frequency greater than 20 kHz, A human ear cannot detect these waves.
- Reflection of sound waves obey the laws of reflection.
- when a compression hits the boundary of a rarer medium, it is reflected as a rarefaction.
- An echo is the sound reproduced due to the reflection of the original sound wave.
- The minimum distance between the source and the reflecting surface should be 17.2 m to hear an echo clearly.
- "The apparent frequency" is the frequency of the sound as heard by the listener.

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TEXTBOOK EVALUATION

I. Choose the correct answer

1. When a sound wave travels through air, the air particles
   a) vibrate along the direction of the wave motion
   b) vibrate but not in any fixed direction
   c) vibrate perpendicular to the direction of the wave motion
   d) do not vibrate

2. Velocity of sound in a gaseous medium is 330 ms^{-1}. If the pressure is increased by 4 times without causing a change in the temperature, the velocity of sound in the gas is
   a) 330 ms^{-1} b) 660 ms^{1}
   c) 156 ms^{-1} d) 990 ms^{-1}

3. The frequency, which is audible to the human ear is
   a) 50 kHz b) 20 kHz
   c) 15000 kHz d) 10000 kHz

4. The velocity of sound in air at a particular temperature is 330 ms^{-1}. What will be its value when temperature is doubled and the pressure is halved?
   a) 330 ms^{-1} b) 165 ms^{-1}
   c) $330 \times \sqrt{2}$ ms^{-1} d) $320 / \sqrt{2}$ ms^{-1}

5. If a sound wave travels with a frequency of 1.25×10^4 Hz at 344 ms^{-1}, the wavelength will be
   a) 27.52 m b) 275.2 m
   c) 0.02752 m d) 2.752 m

6. The sound waves are reflected from an obstacle into the same medium from which they were incident. Which of the following changes?
   a) speed b) frequency
   c) wavelength d) none of these

7. Velocity of sound in the atmosphere of a planet is 500 ms^{-1}. The minimum distance between the sources of sound and the obstacle to hear the echo, should be
   a) 17 m b) 20 m c) 25 m d) 50 m

II. Fill up the blanks

1. Rapid back and forth motion of a particle about its mean position is called ______
2. If the energy in a longitudinal wave travels from south to north, the particles of the medium would be vibrating in ______
3. A whistle giving out a sound of frequency 450 Hz, approaches a stationary observer at a speed of 33 ms^{-1}. The frequency heard by the observer is (speed of sound = 330 ms^{-1}) ______.
4. A source of sound is travelling with a velocity 40 km/h towards an observer and emits a sound of frequency 2000 Hz. If the velocity of sound is 1220 km/h, then the apparent frequency heard by the observer is ____________.

III. True or false:- (If false give the reason)

1. Sound can travel through solids, gases, liquids and even vacuum.
2. Waves created by Earth Quake are Infrasonic.
3. The velocity of sound is independent of temperature.
4. The Velocity of sound is high in gases than liquids.

IV. Match the following

1. Infrasonic	-	(a) Compressions
2. Echo	-	(b) 22 kHz
3. Ultrasonic	-	(c) 10 Hz
4. High pressure region	-	(d) Ultrasonography

V. Assertion and Reason Questions

Mark the correct choice as

a. If both the assertion and the reason are true and the reason is the correct explanation of the assertion.

b. If both the assertion and the reason are true but the reason is not the correct explanation of the assertion.

c. Assertion is true, but the reason is false.

d. Assertion is false, but the reason is true.

1) Assertion: The change in air pressure affects the speed of sound.

   Reason: The speed of sound in a gas is proportional to the square of the pressure

2) Assertion: Sound travels faster in solids than in gases.

   Reason: Solid posses a greater density than that of gases.

VI. Answer very briefly

1. What is a longitudinal wave?
2. What is the audible range of frequency?
3. What is the minimum distance needed for an echo?
4. What will be the frequency sound having 0.20 m as its wavelength, when it travels with a speed of 331 ms^{-1}?
5. Name three animals, which can hear ultrasonic vibrations.

VII. Answer briefly

1. Why does sound travel faster on a rainy day than on a dry day?
2. Why does an empty vessel produce more sound than a filled one?
3. Air temperature in the Rajasthan desert can reach 46°C. What is the velocity of sound in air at that temperature? (V_0 = 331 ms^{-1})
4. Explain why, the ceilings of concert halls are curved.
5. Mention two cases in which there is no Doppler effect in sound?

VIII. Problem Corner

1. A sound wave has a frequency of 200 Hz and a speed of 400 ms^{-1} in a medium. Find the wavelength of the sound wave.
2. The thunder of cloud is heard 9.8 seconds later than the flash of lightning. If the speed of sound in air is 330 ms^{-1}, what will be the height of the cloud?
3. A person who is sitting at a distance of 400 m from a source of sound is listening to a sound of 600 Hz. Find the time period between successive compressions from the source?
4. An ultrasonic wave is sent from a ship towards the bottom of the sea. It is found that the time interval between the transmission and reception of the wave is 1.6 seconds. What is the depth of the sea, if the velocity of sound in the seawater is 1400 ms^{-1}?
5. A man is standing between two vertical walls 680 m apart. He claps his hands and hears two distinct echoes after 0.9 seconds and 1.1 second respectively. What is the speed of sound in the air?
6. Two observers are stationed in two boats 4.5 km apart. A sound signal sent by one, under water, reaches the other after 3 seconds. What is the speed of sound in the water?
7. A strong sound signal is sent from a ship towards the bottom of the sea. It is received back after 1s.What is the depth of sea given that the speed of sound in water 1450 ms^{-1}?

IX. Answer in Detail

1. What are the factors that affect the speed of sound in gases?

2. What is mean by reflection of sound? Explain:
   a) reflection at the boundary of a rarer medium
   b) reflection at the boundary of a denser medium
   c) Reflection at curved surfaces

3. a) What do you understand by the term 'ultrasonic vibration'?
   b) State three uses of ultrasonic vibrations.
   c) Name three animals which can hear ultrasonic vibrations.

4. What is an echo?
   a) State two conditions necessary for hearing an echo.
   b) What are the medical applications of echo?
   c) How can you calculate the speed of sound using echo?

X. HOT Questions

1. Suppose that a sound wave and a light wave have the same frequency, then which one has a longer wavelength?
   a) Sound b) Light
   c) both a and b d) data not sufficient

2. When sound is reflected from a distant object, an echo is produced. Let the distance between the reflecting surface and the source of sound remain the same. Do you hear an echo sound on a hotter day? Justify your answer.

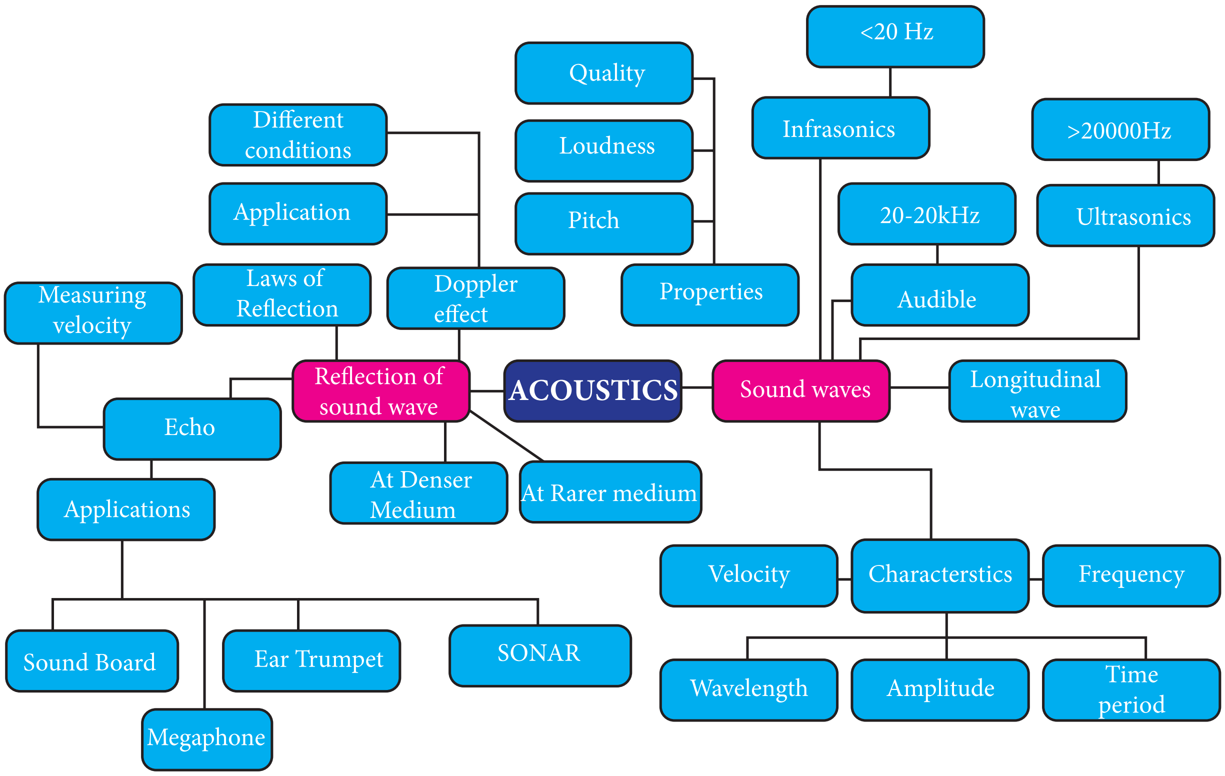
REFERENCE BOOKS

1. Fundamental Physics by K.L. Gomber and K.L. Gogia
2. Fundamentals of sound and vibration by Franky Fahy and David Thombson
3. The theory of sound by Rayleigh and John William Strutt

INTERNET RESOURCE

1. http://people.bath.ac.uk/ensmjc/Notes/acoustics.pdf

Concept Map



ICT CORNER

Doppler effect

In this activity you will be able to learn how the observed frequencies of a sound changes with the velocities of the source and the observer (Doppler effect).

Steps

- Open the browser and type "vlab.amrita.edu" in the address bar. Click 'Physical Sciences' and then click 'Harmonic Motion and Waves Virtual Lab'. Click 'Doppler Effect' and Go to "simulator" tab to do the experiment. sign up one time with your e-mail
- Select medium of travel, detector direction and source direction by clicking the drop down menu.
- Change relative motion between source and observer by adjusting the velocity of the source and observer using the slider.
- Discuss how apparent frequency is changes with respect to actual frequency by changing position of source and listener. Also try for different source frequencies.

Link

http://vlab.amrita.edu/?sub=1&brch=201&sim=368&cnt=4

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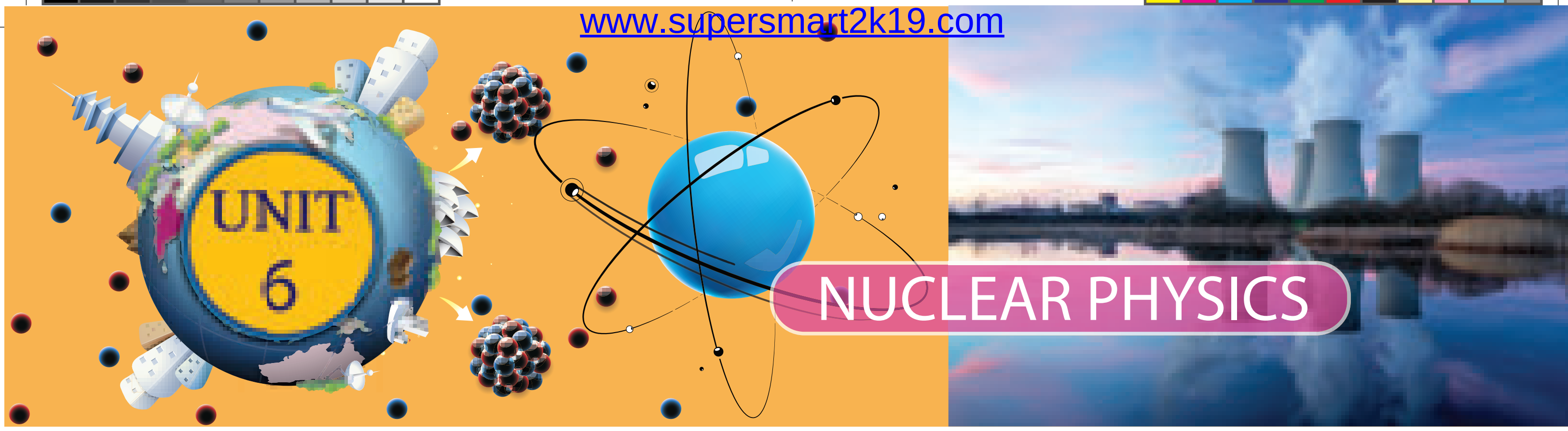

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Learning Objectives

After learning this unit, students will be able to

- Define radio activity.
- Distingush between natural and artificial radio activity.
- Relate the properties of alpha, beta and gamma rays.
- State Soddy and Fajan's displacement law of nuclear disintegration.
- Understand the concept of nuclear fission and nuclear fusion.
- Identify fissionable materials.
- Analyze controlled and uncontrolled chain reactions.
- Explain the principle of atom bomb and hydrogen bomb.
- List the uses of radio activity.
- Understand the components of a nuclear reactor.
- Identify the precautionary measures while handling a radioactive material.

INTRODUCTION

Humans are very much interested in knowing about atoms. Things around us are made up of atoms. A Greek Philosopher 'Democritus' in 400 BC(BCE) believed that matter is made up of tiny indestructible units called atoms. Later, in 1803, John Dalton considered that elements consist of atoms, which are identical in nature. J J Thomson discovered cathode rays, known as electrons, experimentally and Goldstein discovered positive rays, which were named as protons by Rutherford. In 1932, James Chadwick discovered the chargeless particles called neutrons. Presently, a large number of elementary particles like photon, meson, positron and nutrino have been discovered. In 1911, the British scientist, Ernest **Rutherford** explained that the mass of an atom is concentrated in its central part called **Nucleus**. You have already learnt about the atomic structure in the earlier classes.

6.1 RADIOACTIVITY

6.1.1 Discovery of radioactivity

In 1896, French physicist **Henri Becquerel** finished his research for the week and stored a certain amount of uranium compound away in a drawer for the week end. By chance, an unexposed photographic plate was also stored in the same drawer. After a week he returned and noticed that the film had been exposed to some radiation. He discovered that he could reproduce the effect whenever he placed uranium near a photographic film. Apparently, uranium radiated something that could affect a photographic plate. This phenomenon was called as **Radioactivity**. Uranium was identified to be a radioactive element.

Two years later, the Polish physicist **Marie Curie** and her husband **Pierre Curie** detected radioactivity in 'Pitchblende', a tiny black substance. They were not surprised at the radioactivity of pitchblende, which is known as an ore of uranium. Later, they discovered that the radiation was more intense from pure uranium. Also, it was found that the pitchblende had less concentration of uranium. They concluded that **some other substance** was present in pitchblende. After separating this new substance, they discovered that it had unknown chemical properties and it also emitted radiations spontaneously like uranium. They named this new substance as **'Radium'**.The radioactive elements emit harmful radioactive radiations like alpha rays or beta rays or gamma rays.

6.1.2 Definition of radioactivity

The nucleus of some elements is unstable. Such nuclei undergo nuclear decay and get converted into more stable nuclei. During this nuclear reaction, these nuclei emit certain harmful radiations and elementary particles. The phenomenon of nuclear decay of certain elements with the emission of radiations like alpha, beta, and gamma rays is called 'radioactivity' and the elements, which undergo this phenomenon are called 'radioactive elements'.

6.1.3 Natural Radioactivity

The elements such as uranium and radium undergo radioactivity and emit the radiations on their own without any human intervention. This phenomenon of spontaneous emission of radiation from certain elements on their own is called 'natural radioactivity'.

The elements whose atomic number is more than 82 undergo spontaneous radioactivity. Eg: uranium, radium, etc. There are only two elements, which have been identified as radioactive substances with atomic number less than 82. They are technetium (Tc) with atomic number 43 and promethium (Pm) with atomic number 61.

DO YOU KNOW? There have been 29 radioactive substances discovered so far. Most of them are rare earth metals and transition metals.

6.1.4 Artificial Radioactivity (or) Induced Radioactivity

The phenomenon by which even light elements are made radioactive, by artificial or induced methods, is called 'artificial radioactivity' or 'man-made radioactivity'.

This kind of radioactivity was discovered by Irene Curie and F.Joliot in 1934. Artificial radioactivity is induced in certain lighter elements like boron, aluminium etc., by bombarding them with radiations such as 'alpha particles' emitted during the natural radioactivity of uranium. This also results in the emission of invisible radiations and elementary particles. During such a disintegration, the nucleus which undergoes disintegration is called 'parent nucleus' and that which is produced after the disintegration is called a 'daughter nucleus'. The particle, which

Table 6.1 Comparison between Natural and Artificial Radioactivity

S.No.	Natural radioactivity	Artificial radioactivity
1	Emission of radiation due to self-disintegration of a nucleus.	Emission of radiation due to disintegration of a nucleus through induced process.
2	Alpha, beta and gamma radiations are emitted.	Mostly elementary particles such as neutron, positron, etc. are emitted.
3	It is a spontaneous process.	It is an induced process.
4	Exhibited by elements with atomic number more than 83.	Exhibited by elements with atomic number less than 83.
5	This cannot be controlled.	This can be controlled.

is used to induce the artificial disintegration is termed as projectile and the particle which is produced after the disintegration is termed as ejected particle. When the projectile hits the parent nucleus, it is converted into an unstable nucleus, which in turn decays spontaneously emitting the daughter nucleus along with an ejected particle.

Activity 6.1

Using the periodic table, list out the radioactive elements. Also identify the name of the groups in which they are present.

If you denote the parent and daughter nuclei as X and Y respectively, then the nuclear disintegration is represented as follows: X (P,E) Y. Here, P and E represent the projectile particle and ejected particle respectively.

Example:

$$_4Be^9 + {}_2He^4 \longrightarrow {}_6C^{13*}$$

$$_6C^{13*} \longrightarrow {}_6C^{12} + {}_0n^1$$

In the above nuclear reaction, $_6C^{13*}$ is unstable and is radioactive. This reaction can be represented as $_4Be^9$ (α, n) $_6C^{12}$

$$_4Be^9 + {}_2He^4 \longrightarrow {}_6C^{12} + {}_0n^1$$

6.1.5 Units of Radioactivity

Curie: It is the traditional unit of radioactivity. It is defined as the quantity of a radioactive substance which undergoes 3.7×10^{10} disintegrations in one second. This is actually close to the activity of 1 g of radium 226.

1 curie = 3.7×10^{10} disintegrations per second.

Rutherford (Rd): It is another unit of radioactivity. It is defined as the quantity of a radioactive substance, which produces 10^6 disintegrations in one second.

1 Rd = 10^6 disintegrations per second.

Becquerel (Bq) : It is The SI unit of radioactivity is becquerel. It is defined as the quantity of one disintegration per second.

Roentgen (R): It is The radiation exposure of γ and x-rays is measured by another unit called roentgen. One roentgen is defined as the quantity of radioactive substance which produces a charge of 2.58×10^{-4} coulomb in 1 kg of air under standard conditions of pressure, temperature and humidity.

6.2 ALPHA, BETA AND GAMMA RAYS

When a radioactive nucleus undergoes radioactivity, it emits harmful radiations. These radiations are usually comprised of any of the three types of particles. They are **alpha(α), beta (β) and gamma(γ)** rays.

DO YOU KNOW?

Uranium, named after the planet Uranus, was discovered by Martin Klaproth, a German chemist in a mineral called pitchblende.

6.2.1 Properties of Alpha, Beta and Gamma rays

These three particles possess certain similarities and dissimilarities in their properties as listed below in Table 6.2.

6.2.2 Radioactive displacement law

In 1913, Soddy and Fajan framed the displacement laws governing the daughter nucleus produced during an alpha and beta decay. They are stated below:

(i) When a radioactive element emits an alpha particle, a daughter nucleus is formed whose mass number is less by 4 units and the atomic number is less by 2 units, than the mass number and atomic number of the parent nucleus.

(ii) When a radioactive element emits a beta particle, a daughter nucleus is formed whose mass number is the same and the atomic number is more by 1 unit, than the atomic number of the parent nucleus.

Table 6.2 Properties of alpha, beta and gamma rays

Properties	α rays	β rays	γ rays
What are they?	Helium nucleus ($_2He^4$) consisting of two protons and two neutrons.	They are electrons ($_{-1}e^0$), basic elementary particle in all atoms.	They are electromagnetic waves consisting of photons.
Charge	Positively charged particles. Charge of each alpha particle = +2e	Negatively charged particles. Charge of each beta particle = –e	Neutral particles. Charge of each gamma particle = zero
Ionising power	100 time greater than β rays and 10,000 times greater than γ rays	Comparatively low	Very less ionization power
Penetrating power	Low penetrating power (even stopped by a thick paper)	Penetrating power is greater than that of α rays. They can penetrate through a thin metal foil.	They have a very high penetrating power greater than that of β rays. They can penetrate through thick metal blocks.
Effect of electric and magnetic field	Deflected by both the fields. (in accordance with Fleming's left hand rule)	Deflected by both the fields; but the direction of deflection is opposite to that for alpha rays. (in accordance with Fleming's left hand rule)	They are not deflected by both the fields.
Speed	Their speed ranges from 1/10 to 1/20 times the speed of light.	Their speed can go up to 9/10 times the speed of light.	They travel with the speed of light.

6.2.3 Alpha decay

A nuclear reaction in which an unstable parent nucleus emits an alpha particle and forms a stable daughter nucleus, is called 'alpha decay'.

E.g.: Decay of uranium (U^{238}) to thorium (Th^{234}) with the emission of an alpha particle.

$$_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_{2}He^{4} \quad (\alpha\text{ - decay})$$

In α - decay, the parent nucleus emits an α particle and so it is clear that for the daughter nucleus, the mass number decreases by four and the atomic number decreases by two as illustrated in Figure 6.1

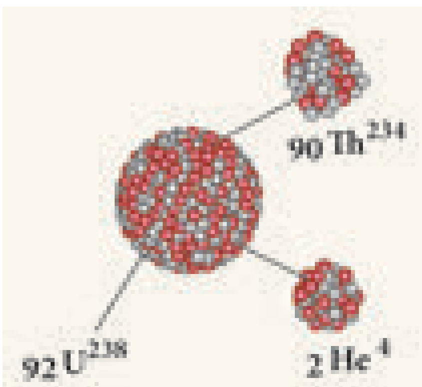

Figure 6.1 Alpha decay

6.2.4 Beta decay

A nuclear reaction, in which an unstable parent nucleus emits a beta particle and forms a stable daughter nucleus, is called 'beta decay'.

E.g.: Beta decay of phosphorous.

$$_{15}P^{32} \longrightarrow {}_{16}S^{32} + {}_{-1}e^{0} \quad (\beta\text{ - decay})$$

In β - decay there is no change in the mass number of the daughter nucleus but the atomic number increases by one.

Note: In a nuclear reaction, the element formed as the product nucleus is identified by the atomic number of the resulting nucleus and not by its mass number.

6.2.5 Gamma decay

In a γ - decay, only the energy level of the nucleus changes. The atomic number and mass number of the radioactive nucleus remain the same.

6.3 NUCLEAR FISSION

6.3.1 Definition

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In 1939, German Scientist Otto Hahn and F.Strassman discovered that when a uranium nucleus is bombarded with a neutron, it breaks up into two smaller nuclei of comparable mass along with the emission of a few neutrons and energy. This process of breaking (splitting) up of a heavier nucleus into two smaller nuclei with the release of a large amount of energy and a few neutrons is called 'nuclear fission'.

E.g.: Nuclear fission of a uranium nucleus (U^{235})

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_{0}n^{1} + Q \text{ (energy)}$$

The average energy released in each fission process is about 3.2×10^{-11} J. Nuclear fission is pictorially represented in Figure 6.2.

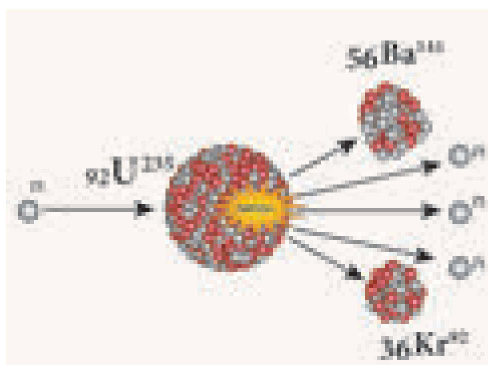

Figure 6.2 Nuclear fission

6.3.2 Fissionable materials

A fissionable material is a radioactive element, which undergoes fission in a sustained manner when it absorbs a neutron. It is also termed as 'fissile material'.

E.g.: U^{235}, plutonium (Pu^{239} and Pu^{241})

All isotopes of uranium do not undergo nuclear fission when they absorb a neutron. For example, natural uranium consists of 99.28 % of $_{92}U^{238}$ and 0.72 % of $_{92}U^{235}$. Of these two, U^{238} does not undergo fission whereas U^{235} undergoes fission. Hence, U^{235} is a fissionable material and U^{238} is non-fissionable.

There are some radioactive elements, which can be converted into fissionable material. They are called as **fertile materials**.

E.g.: Uranium-238, Thorium-232, Plutonium-240.

6.3.3 Chain Reaction

A uranium nucleus (U-235) when bombarded with a neutron undergoes fission producing three neutrons. These three neutrons in turn can cause fission in three other uranium nuclei present in the sample, thus producing nine neutrons. These nine neutrons in turn may produce twenty seven neutrons and so on. This is known as 'chain reaction'. A chain reaction is a self-propagating process in which the number of neutrons goes on multiplying rapidly almost in a geometrical progression.

Two kinds of chain reactions are possible. They are: (i) controlled chain reaction and (ii)uncontrolled chain reaction.

(a) Controlled chain reaction

In the controlled chain reaction the number of neutrons released is maintained to be one. This is achieved by absorbing the extra neutrons with a neutron absorber leaving only one neutron to produce further fission. Thus, the reaction is sustained in a controlled manner. The energy released due to a controlled chain reaction can be utilized for constructive purposes. Controlled chain reaction is used in a nuclear reactor to produce energy in a sustained and controlled manner.

(b) Uncontrolled chain reaction

In the uncontrolled chain reaction the number of neutrons multiplies indefinitely and causes fission in a large amount of the fissile material. This results in the release of a huge amount of energy within a fraction of a second. This kind of chain reaction is used in the atom bomb to produce an explosion. Figure 6.3 represents an uncontrolled chain reaction.

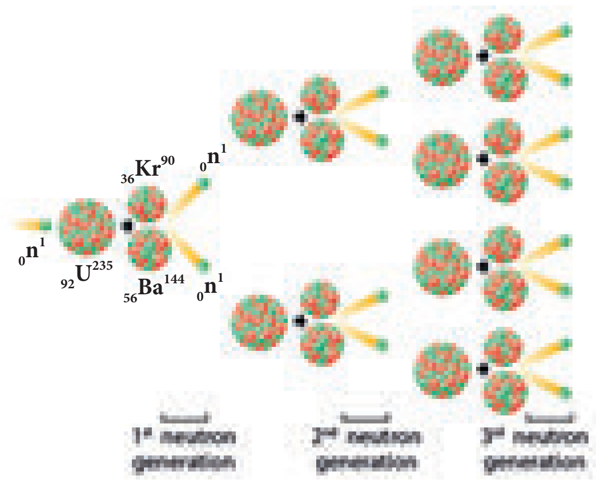

Figure 6.3 Uncontrolled chain reaction

6.3.4 Critical Mass

During a nuclear fission process, about 2 to 3 neutrons are released. But, all these neutrons may not be available to produce further fission. Some of them may escape from the system, which is termed as 'leakage of neutrons' and some may be absorbed by the non-fissionable materials present in the system. These two factors lead to the loss of neutrons. To sustain the chain reaction, the rate of production of neutrons due to nuclear fission must be more than the rate of its loss. This can be achieved only when the size (i.e., mass) of the fissionable material is equal to a certain optimum value. This is known as 'critical mass'.

The minimum mass of a fissile material necessary to sustain the chain reaction is called 'critical mass (m_c)'. It depends on the nature, density and the size of the fissile material.

If the mass of the fissile material is less than the critical mass, it is termed as 'subcritical'. If the mass of the fissile material is more than the critical mass, it is termed as 'supercritical'.

Activity 6.2

Using beads make a chain reaction model

6.3.5 Atom bomb

The atom bomb is based on the principle of uncontrolled chain reaction. In an uncontrolled chain reaction, the number of neutrons and the number of fission reactions multiply almost in a geometrical progression. This releases a huge amount of energy in a very small time interval and leads to an explosion.

Structure:

An atom bomb consists of a piece of fissile material whose mass is subcritical. This piece has a cylindrical void. It has a cylindrical fissile material which can fit into this void and its mass is also subcritical. When the bomb has to be exploded, this cylinder is injected into the void using a conventional explosive. Now, the two pieces of fissile material join to form the supercritical mass, which leads to an explosion. The structure of an atom bomb is shown in Figure 6.4

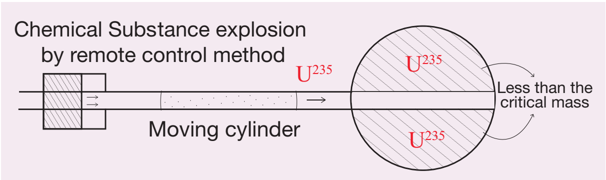

Figure 6.4 Atom bomb

During this explosion tremendous amount of energy in the form of heat, light and radiation is released. A region of very high temperature and pressure is formed in a fraction of a second along with the emission of hazardous radiation like γ rays, which adversely affect the living creatures. This type of atom bombs were exploded in 1945 at Hiroshima and Nagasaki in Japan during the World War II.

> **DO YOU KNOW?**
>
> Electron Volt (eV) is the unit used in nuclear physics to measure the energy of small particles. It is nothing but the energy of one electron when it is accelerated using an electric potential of one volt.
>
> 1eV = 1.602×10^{-19} joule.
>
> 1 million electron volt = 1 MeV = 10^6 eV (mega electron volt)
>
> The energy released in a nuclear fission process is about 200 MeV.

6.4 NUCLEAR FUSION

You have learnt that energy can be produced when a heavy nucleus is split up into two smaller nuclei. Similarly, energy can be produced when two lighter nuclei combine to form a heavier nucleus. This phenomenon is known as nuclear fusion.

BHE2TC

6.4.1 Definition

The process in which two lighter nuclei combine to form a heavier nucleus is termed as 'nuclear fusion'.

E.g.: ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + Q$ (Energy)

Here, ${}_1H^2$ represents an isotope of hydrogen known as 'deuterium'. The average energy released in each fusion reaction is about 3.84×10^{-12} J. Figure 6.5 represents this.

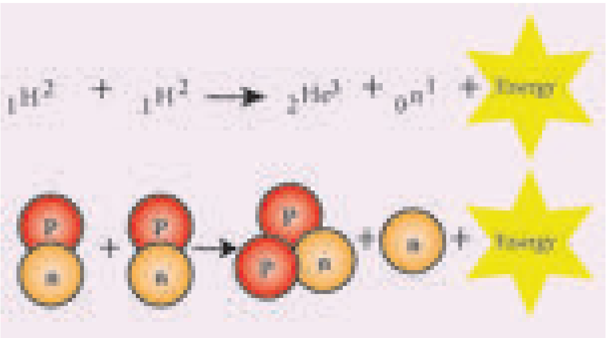

Figure 6.5 Nuclear fusion

The mass of the daughter nucleus formed during a nuclear reaction (fission and fusion) is lesser than the sum of the masses of the two parent nuclei. This difference in mass is called mass defect. This mass is converted into energy, according to the mass-energy equivalence. This concept of mass-energy equivalence was proposed by Einstein in 1905. It stated that mass can be converted into energy and vice versa. The relation between mass and energy proposed by Einstein is $\mathbf{E = mc^2}$ where c is the velocity of light in vacuum and is equal to 3×10^8 ms^{-1}.

DO YOU KNOW?

The nuclear bomb that was dropped in Hiroshima during World War II was called as 'Little boy'. It was a gun-type bomb which used a uranium core. The bomb, which was subsequently dropped over Nagasaki was called as 'Fat man'. It was an explosion type bomb, which used a plutonium core.

6.4.2 Conditions necessary for nuclear fusion

Earth's atmosphere contains a small trace of hydrogen. If nuclear fusion is a spontaneous process at normal temperature and pressure, then a number of fusion processes would happen in the atmosphere which may lead to explosions. But, we do not encounter any such explosions. Can you explain why?

The answer is that nuclear fusion can take place only under certain conditions.

Nuclear fusion is possible only at an extremly high temperature of the order of 10^7 to 10^9 K and a high pressure to push the hydrogen nuclei closer to fuse with each other. Hence, it is named as 'Thermonuclear reaction'.

DO YOU KNOW?

Nuclear fusion is the combination of two lighter nuclei. The charge of both nuclei is positive. According to electrostatic theory, when they come closer they tend to repel each other. This repulsive force will be overcome by the kinetic energy of the nuclei at higher temperature of the order of 10^7 to 10^9 K.

6.4.3 Stellar Energy

The stars like our Sun emit a large amount of energy in the form of light and heat. This energy is termed as the stellar energy. Where does this high energy come from? All stars contain a large amount of hydrogen. The surface temperature of the stars is very high which is sufficient to induce fusion of the hydrogen nuclei.

Fusion reaction that takes place in the cores of the Sun and other stars results in an enormous amount of energy, which is called as 'stellar energy. Thus, nuclear fusion or thermonuclear reaction is the source of light and heat energy in the Sun and other stars.

6.4.4 Hydrogen Bomb

Hydrogen bomb is based on the principle of nuclear fusion. A hydrogen bomb is always designed to have an inbuilt atom bomb which creates the high temperature and pressure required for fusion when it explodes. Then, fusion takes place in the hydrogen core and leads to the release of a very large amount of energy in an uncontrolled manner. The energy released in a hydrogen bomb (or fusion bomb) is much higher than that released in an atom bomb (or fission bomb).

Table 6.3 Features of Nuclear fission and nuclear fusion

S.No.	NUCLEAR FISSION	NUCLEAR FUSION
1	The process of breaking up (splitting) of a heavy nucleus into two smaller nuclei is called '**nuclear fission**'.	Nuclear fusion is the combination of two lighter nuclei to form a heavier nucleus.
2	Can be performed at room temperature.	Extremely high temperature and pressure is needed.
3	Alpha, beta and gamma radiations are emitted.	Alpha rays, positrons, and neutrinos are emitted.
4	Fission leads to emission of gamma radiation. This triggers the mutation in the human gene and causes genetic transform diseases.	Only light and heat energy is emitted.

DO YOU KNOW?

Sun fuses about 620 million metric tons of hydrogen each second and radiates about 3.8×10^{26} joule of energy per second. When this energy is radiated towards the Earth, it decreases in its intensity. When it reaches the Earth its value is about 1.4 kilo joule per unit area in unit time.

6.5 USES OF RADIOACTIVITY

Many radio isotopes can be obtained from radioactivity. These radio isotopes have found wide variety of applications in the fields of medicine, agriculture, industry and archeological research.

6.5.1 Agriculture

The radio isotope of phosphorous (P-32) helps to increase the productivity of crops. The radiations from the radio isotopes can be used to kill the insects and parasites and prevent the wastage of agricultural products. Certain perishable cereals exposed to radiations remain fresh beyond their normal life, enhancing the storage time. Very small doses of radiation prevent sprouting and spoilage of onions, potatoes and gram.

6.5.2 Medicine

Medical applications of radio isotopes can be divided into two parts:

i) Diagnosis ii) Therapy

Radio isotopes are used as tracers to diagnose the nature of circulatory disorders of blood, defects of bone metabolism, to locate tumors, etc. Some of the radio isotopes which are used as tracers are: hydrogen, carbon, nitrogen, sulphur, etc.

- Radio sodium (Na^{24}) is used for the effective functioning of heart.
- Radio – Iodine (I^{131}) is used to cure goiter.
- Radio-iron is (Fe^{59}) is used to diagnose anaemia and also to provide treatment for the same.
- Radio phosphorous (P^{32}) is used in the treatment of skin diseases.

- Radio cobalt (Co^{60}) and radio-gold (Au^{198}) are used in the treatment of skin cancer.
- Radiations are used to sterilize the surgical devices as they can kill the germs and microbes.

6.5.3 Industries

In industries, radioactive isotopes are used as tracers to detect any manufacturing defects such as cracks and leaks. Packaging faults can also be identified through radio activity. Gauges, which have radioactive sources are used in many industries to check the level of gases, liquids and solids.

- An isotope of californium (Cf^{252}) is used in the airlines to detect the explosives in the luggage.
- An isotope of Americium (Am^{241}) is used in many industries as a smoke detector.

6.5.4. Archeological research

Using the technique of radio carbon dating, the age of the Earth, fossils, old paintings and monuments can be determined. In radio carbon dating, the existing amount of radio carbon is determined and this gives an estimate about the age of these things.

6.6 SAFETY MEASURES

In day to day life, you do receive some natural radiation from the Sun. The radioactive elements present in the soil and rocks, the house hold appliances like television, microwave ovens, cell phones and the X-rays used in hospitals. These radiations do not produce any severe effects as they are very low in intensity.

The second source of radiation exposure is man-made. These are due to nuclear reactors and during the testing of the nuclear devices in the atmosphere or in the ground.

Improper and careless handling of radioactive materials release harmful radiations in our environment. These radiations are very harmful to the human body. A person who is exposed to radiations very closely or for a longer duration, is at a greater health risk and can be affected genetically.

DO YOU KNOW?

How old is our mother Earth? Any guess?? It is nearly 4.54×10^9 years (around 45 Crore 40 lakh years). Wow!!

6.6.1 Permitted range

The International Commission on Radiological Protection (ICRP) has recommended certain maximum permissible exposure limits to radiation that is believed to be safe without producing any appreciable injury to a person. Safe limit of overall exposure to radiation is given as 20 milli sievert per year. In terms of roentgen, the safe limit of receiving the radiation is about 100 mR per week. If the exposure is 100 R, it may cause fatal diseases like leukemia (death of red blood corpuscle in the blood) or cancer. When the body is exposed to about 600 R, it leads to death.

DO YOU KNOW?

*Dosimeter is a device used to detect the levels of exposure to an ionizing radiation. It is frequently used in the environments where exposure to radiation may occur such as nuclear power plants and medical imaging facilities. Pocket dosimeter is used to provide the wearer with an immediate reading of his/her exposure to X-rays and γ rays.

6.6.2 Preventive measures

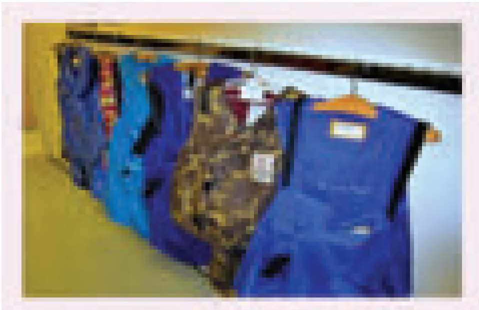

Figure. 6.6 Lead coated aprons model.

- Radioactive materials should be kept in a thick walled lead container.
- Lead coated aprons and lead gloves should be used while working with hazardous radioactive materials.
- You should avoid eating while handling radioactive materials.
- The radioactive materials should be handled only by tongs or by a remote control device.
- Dosimeters should be worn by the users to check the level of radiation.

6.7 NUCLEAR REACTOR

A Nuclear reactor is a device in which the nuclear fission reaction takes place in a self-sustained and controlled manner to produce electricity. The first nuclear reactor was built in 1942 at Chicago, USA.

6.7.1 Types of nuclear reactors

Breeder reactor, fast breeder reactor, pressurized water reactor, pressurized heavy water reactor, boiling water reactor, water-cooled reactor, gas-cooled reactor, fusion reactor and thermal reactor are some types of nuclear reactors, which are used in different places world-wide.

6.7.2 Components of a nuclear reactors

The essential components of a nuclear reactor are (i) fuel, (ii) moderator, (iii) control rod, (iv) coolant and (v) protection wall.

i. **Fuel:** A fissile material is used as the fuel. The commonly used fuel material is uranium.

ii. **Moderator:** A moderator is used to slow down the high energy neutrons to provide slow neutrons. Graphite and heavy water are the commonly used moderators.

iii. **Control rod:** Control rods are used to control the number of neutrons in order to have sustained chain reaction. Mostly boron or cadmium rods are used as control rods. They absorb the neutrons.

iv. **Coolant:** A coolant is used to remove the heat produced in the reactor core, to produce steam. This steam is used to run a turbine in order to produce electricity. Water, air and helium are some of the coolants.

v. **Protection wall:** A thick concrete lead wall is built around the nuclear reactor in order to prevent the harmful radiations from escaping into the environment.

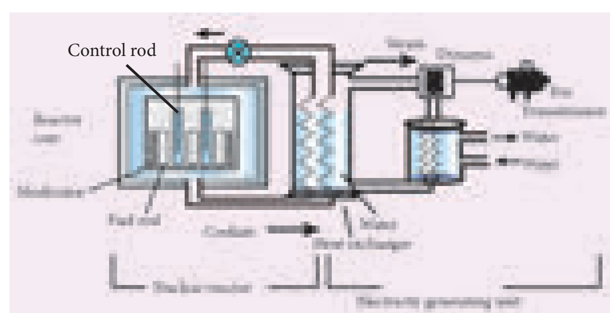

Figure 6.7 Schematic diagram of a nuclear reactor

6.7.3 Uses of a nuclear reactor

- Nuclear reactors are widely used in power generation.
- They are also used to produce radio isotopes, which are used in a variety of applications.
- Some reactors help us to do research in the field of nuclear physics.
- Breeder reactors are used to convert non-fissionable materials into fissionable materials.

6.7.4 Nuclear power plants in India

Indian Atomic Energy Commission (AEC) was established in August 1948 by the

Department of Indian Scientific Research committee at Bombay (now Mumbai) in Maharashtra. It is the nodal agency for all the research done in the field of atomic energy. Dr. Homi Jahangir Bhaba was the first chairman of Indian Atomic Energy Commission. Now, it is known as Bhaba Atomic Research Centre (BARC).

Nuclear power is the fifth largest source of power in India. Tarapur Atomic Power Station is India's first nuclear power station. Now, there are a total of seven power stations, one each in Maharashtra, Rajasthan, Gujarat, Uttar Pradesh and two in Tamilnadu. In Tamilnadu, we have nuclear power stations in Kalpakkam and Kudankulam. Apsara was the first nuclear reactor built in India and Asia. Now, there are 22 nuclear reactors which are operating in India. Some other operating reactors are

- Cirus
- Dhuruva
- Purnima

Solved problem 6.1

Identify A, B, C, and D from the following nuclear reactions.

(i) $_{13}Al^{27}$ + A --------> $_{15}P^{30}$ + B

(ii) $_{12}Mg^{24}$ + B --------> $_{11}Na^{24}$ + C

(iii) $_{92}U^{238}$ + B --------> $_{93}Np^{239}$ + D

Solution:

(i) $_{13}Al^{27}$ + $_{2}He^{4}$ --------> $_{15}P^{30}$ + $_{0}n^{1}$

(ii) $_{12}Mg^{24}$ + $_{0}n^{1}$ --------> $_{11}Na^{24}$ + $_{1}H^{1}$

(iii) $_{92}U^{238}$ + $_{0}n^{1}$ --------> $_{93}Np^{239}$ + $_{-1}e^{0}$

A is alpha particle, B is neutron, C is proton, and D is electron.

Solved problem 6.2

A radon specimen emits radiation of 3.7×10^{3} GBq per second. Convert this disintegration in terms of curie. (one curie = 3.7×10^{10} disintegration per second)

$$1 \text{ Bq} = \text{one disintegration per second}$$

$$\text{one curie} = 3.7 \times 10^{10} \text{ Bq}$$

$$1 \text{ Bq} = \frac{1}{3.7 \times 10^{10}} \text{ curie}$$

$$\therefore 3.7 \times 10^{3} \text{ G Bq} = 3.7 \times 10^{3} \times 10^{9} \times \frac{1}{3.7 \times 10^{10}}$$

$$= 100 \text{ curie}$$

Solved problem 6.3

$_{92}U^{235}$ experiences one **α** - decay and one **β** - decay. Find number of neutrons in the final daughter nucleus that is formed.

Solution:

Let X and Y be the resulting nucleus after the emission of the alpha and beta particles respectively.

$$_{92}U^{235} \xrightarrow{\alpha \text{ decay}} {}_{90}X^{231} + {}_{2}He^{4}$$

$$_{90}X^{231} \xrightarrow{\beta \text{ decay}} {}_{91}Y^{231} + {}_{-1}e^{0}$$

Number of neutrons = Mass number – Atomic number

= 231 – 91 = 140

Solved problem 6.4

Calculate the amount of energy released when a radioactive substance undergoes fusion and results in a mass defect of 2 kg.

Solution:

Mass defect in the reaction (m) = 2 kg

Velocity of light (c) = 3×10^{8} m s^{-1}

By Einstein's equation,

Energy released $E = mc^{2}$

So $E = 2 \times (3 \times 10^{8})^{2}$

$= 1.8 \times 10^{17}$ J

Points to Remember

- This phenomenon of spontaneous emission of radiation from certain elements on its own is called 'natural radioactivity'.
- **Curie** is defined as the quantity of a radioactive substance, which undergoes 3.7×10^{10} disintegrations in one second. This is actually close to the activity of 1 g of radium-226.

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- **Rutherford (Rd)** is defined as the quantity of a radioactive substance which produces 10^6 disintegrations in one second.
  1 Rd = 10^6 disintegrations per second.
- The SI unit of radioactivity is **becquerel.** It is defined as the quantity of one disintegration per second.

CCFRVZ

- Helium nucleus ($_2He^4$) consisting of two protons and two neutrons is known as alpha particle.
- Beta particles are electrons ($_{-1}e^0$), which are the basic elementary particles present in all atoms.
- Gamma rays are electromagnetic waves consisting of photons.
- A nuclear reaction in which an unstable parent nucleus emits an alpha particle and forms a stable daughter nucleus is called as 'alpha decay'.
- A nuclear reaction in which an unstable parent nucleus emits a beta particle and forms a stable daughter nucleus is called as 'beta decay'.
- The process of breaking (splitting) up of a heavier nucleus into two smaller nuclei with the release of a large amount of energy is called **'nuclear fission'.**
- The energy released in a nuclear fission process is about 200 MeV.
- There are some radioactive elements which can be converted into a fissionable material. They are called as '**fertile materials**'. e.g. Uranium-238, Thorium-232, Plutonium-240.
- Controlled chain reaction is used in a nuclear reactor to produce energy in a sustained and controlled manner.
- The process in which two lighter nuclei combine to form a heavier nucleus is termed as **'nuclear fusion'.**
- Nuclear fusion or thermonuclear reaction is the source of light and heat energy in the Sun and other stars.
- The safe limit of receiving the radiation is about 100 mR per week.

TEXTBOOK EVALUATION

CRPQVN

I. Choose the correct answer

1. Man-made radioactivity is also known as ____________

   a. Induced radioactivity

   b. Spontaneous radioactivity

   c. Artificial radioactivity

   d. a & c

2. Unit of radioactivity is ____________

   a. roentgen b. curie

   c. becquerel d. all the above

3. Artificial radioactivity was discovered by ____________

   a. Bequerel b. Irene Curie

   c. Roentgen d. Neils Bohr

4. In which of the following, no change in mass number of the daughter nuclei takes place

   i) α decay ii) β decay

   iii) γ decay iv) neutron decay

   a. (i) is correct

   b. (ii) and (iii) are correct

   c. (i) & (iv) are correct

   d. (ii) & (iv) are correct

5. ____________ isotope is used for the treatment of cancer.

a. Radio Iodine b. Radio Cobalt

c. Radio Carbon d. Radio Nickel

6. Gamma radiations are dangerous because

a. it affects eyes & bones

b. it affects tissues

c. it produces genetic disorder

d. it produces enormous amount of heat

7. ____________ aprons are used to protect us from gamma radiations

a. Lead oxide b. Iron

c. Lead d. Aluminium

8. Which of the following statements is/are correct?

i. α particles are photons

ii. Penetrating power of γ radiation is very low

iii. Ionization power is maximum for α rays

iv. Penetrating power of γ radiation is very high

a. (i) & (ii) are correct

b. (ii) & (iii) are correct

c. (iv) only correct

d. (iii) & (iv) are correct

9. Proton - Proton chain reaction is an example of

____

a. Nuclear fission b. α - decay

c. Nuclear fusion d. β - decay

10. In the nuclear reaction ${}_{6}X^{12} \xrightarrow{\alpha\ decay} {}_{Z}Y^{A}$, the value of A & Z.

a. 8, 6 b. 8, 4

c. 4, 8 d. cannot be determined with the given data

11. Kamini reactor is located at ________

a. Kalpakkam b. Koodankulam

c. Mumbai d. Rajasthan

12. Which of the following is/are correct?

i. Chain reaction takes place in a nuclear reactor and an atomic bomb.

ii. The chain reaction in a nuclear reactor is controlled

iii. The chain reaction in a nuclear reactor is not controlled

iv. No chain reaction takes place in an atom bomb

a. (i) only correct b. (i) & (ii) are correct

c. (iv) only correct d. (iii) & (iv) are correct

II. Fill in the blanks

1. One roentgen is equal to ____________ disintegrations per second

2. Positron is an____________.

3. Anemia can be cured by ____________ isotope

4. Abbreviation of ICRP______

5. _________is used to measure exposure rate of radiation in humans.

6. ________ has the greatest penetration power.

7. ${}_{Z}Y^{A} \rightarrow {}_{Z+1}Y^{A}$ + X ; Then, X is __________

8. ${}_{Z}X^{A} \rightarrow {}_{Z}Y^{A}$ This reaction is possible in ______________ decay.

9. The average energy released in each fusion reaction is about ________ J.

10. Nuclear fusion is possible only at an extremely high temperature of the order of ____ K.

11. The radio isotope of ________ helps to increase the productivity of crops.

12. If the radiation exposure is 100 R, it may cause ______________.

III State whether the following statements are true or false: If false, correct the statement

1. Plutonium -239 is a fissionable material.

2. Elements having atomic number greater than 83 can undergo nuclear fusion.

3. Nuclear fusion is more dangerous than nuclear fission.

4. Natural uranium U-238 is the core fuel used in a nuclear reactor.

5. If a moderator is not present, then a nuclear reactor will behave as an atom bomb.

6. During one nuclear fission on an average, 2 to 3 neutrons are produced.

7. Einstein's theory of mass energy equivalence is used in nuclear fission and fusion.

IV. Match the following

Match: I

a. BARC	Kalpakkam
b. India's first atomic power station	Apsara
c. IGCAR	Mumbai
d. First nuclear reactor in India	Tarapur

Match: II

a. Fuel	lead
b. Moderator	heavy water
c. Control rods	cadmium rods
d. Shield	uranium

Match: III

a. Soddy Fajan	Natural radioactivity
b. Irene Curie	Displacement law
c. Henry Bequerel	Mass energy equivalence
d. Albert Einstein	Artificial Radioactivity

Match: IV

a. Uncontrolled fission reaction	Hydrogen Bomb
b. Fertile material	Nuclear Reactor
c. Controlled fission reaction	Breeder reactor
d. Fusion reaction	Atom bomb

Match: V

a. Co - 60	Age of fossil
b. I - 131	Function of Heart
c. Na - 24	Leukemia
d. C - 14	Thyroid disease

V. Arrange the following in the correct sequence:

1. **Arrange in descending order, on the basis of their penetration power**

   Alpha rays, beta rays, gamma rays, cosmic rays

2. **Arrange the following in the chronological order of discovery**

   Nuclear reactor, radioactivity, artificial radioactivity, discovery of radium.

VI. Use the analogy to fill in the blank

1. Spontaneous process : Natural Radioactivity, Induced process : ________
2. Nuclear Fusion : Extreme temperature, Nuclear Fission : ____________
3. Increasing crops : Radio phosphorous, Effective functioning of heart : _____
4. Deflected by electric field : α ray, Null Deflection : ___________

VII. Numerical problems:

1. $_{88}\mathbf{Ra}^{226}$ experiences three **α** - decay. Find the number of neutrons in the daughter element.

2. A cobalt specimen emits induced radiation of 75.6 millicurie per second. Convert this disintegration in to becquerel (one curie = 3.7×10^{10} Bq)

VIII. Assertion and reason type questions:

Mark the correct choice as

(a) If both the assertion and the reason are true and the reason is the correct explanation of the assertion.

(b) If both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.

(c) Assertion is true, but the reason is false.

(d) Assertion is false, but the reason is true.

1. **Assertion:** A neutron impinging on U^{235}, splits it to produce Barium and Krypton.
   Reason: U - 235 is a fissile material.

2. **Assertion**: In a β - decay, the neutron number decreases by one.
   Reason: In β - decay atomic number increases by one.

3. **Assertion**: Extreme temperature is necessary to execute nuclear fusion.
   Reason: In a nuclear fusion, the nuclei of the reactants combine releasing high energy.

4. **Assertion**: Control rods are known as 'neutron seeking rods'
Reason: Control rods are used to perform sustained nuclear fission reaction

IX. Answer in one or two word (VSA)

1. Who discovered natural radioactivity?
2. Which radioactive material is present in the ore of pitchblende?
3. Write any two elements which are used for inducing radioactivity?
4. Write the name of the electromagnetic radiation which is emitted during a natural radioactivity.
5. If A is a radioactive element which emits an α - particle and produces $_{104}Rf^{259}$. Write the atomic number and mass number of the element A.
6. What is the average energy released from a single fission process?
7. Which hazardous radiation is the cause for the genetic disease?
8. What is the amount of radiation that may cause death of a person when exposed to it?
9. When and where was the first nuclear reactor built?
10. Give the SI unit of radioactivity.
11. Which material protects us from radiation?

X. Answer the following questions in few sentences.

1. Write any three features of natural and artificial radioactivity.
2. Define critical mass.
3. Define one roentgen.
4. State Soddy and Fajan's displacement law.
5. Give the function of control rods in a nuclear reactor.
6. In Japan, some of the new born children are having congenital diseases. Why?
7. Mr. Ramu is working as an X - ray technician in a hospital. But, he does not wear the lead aprons. What suggestion will you give to Mr. Ramu?
8. What is stellar energy?
9. Give any two uses of radio isotopes in the field of agriculture?

XI. Answer the following questions in detail.

1. Explain the process of controlled and uncontrolled chain reactions.
2. Compare the properties of alpha, beta and gamma radiations.
3. What is a nuclear reactor? Explain its essential parts with their functions.

XII. HOT Questions:

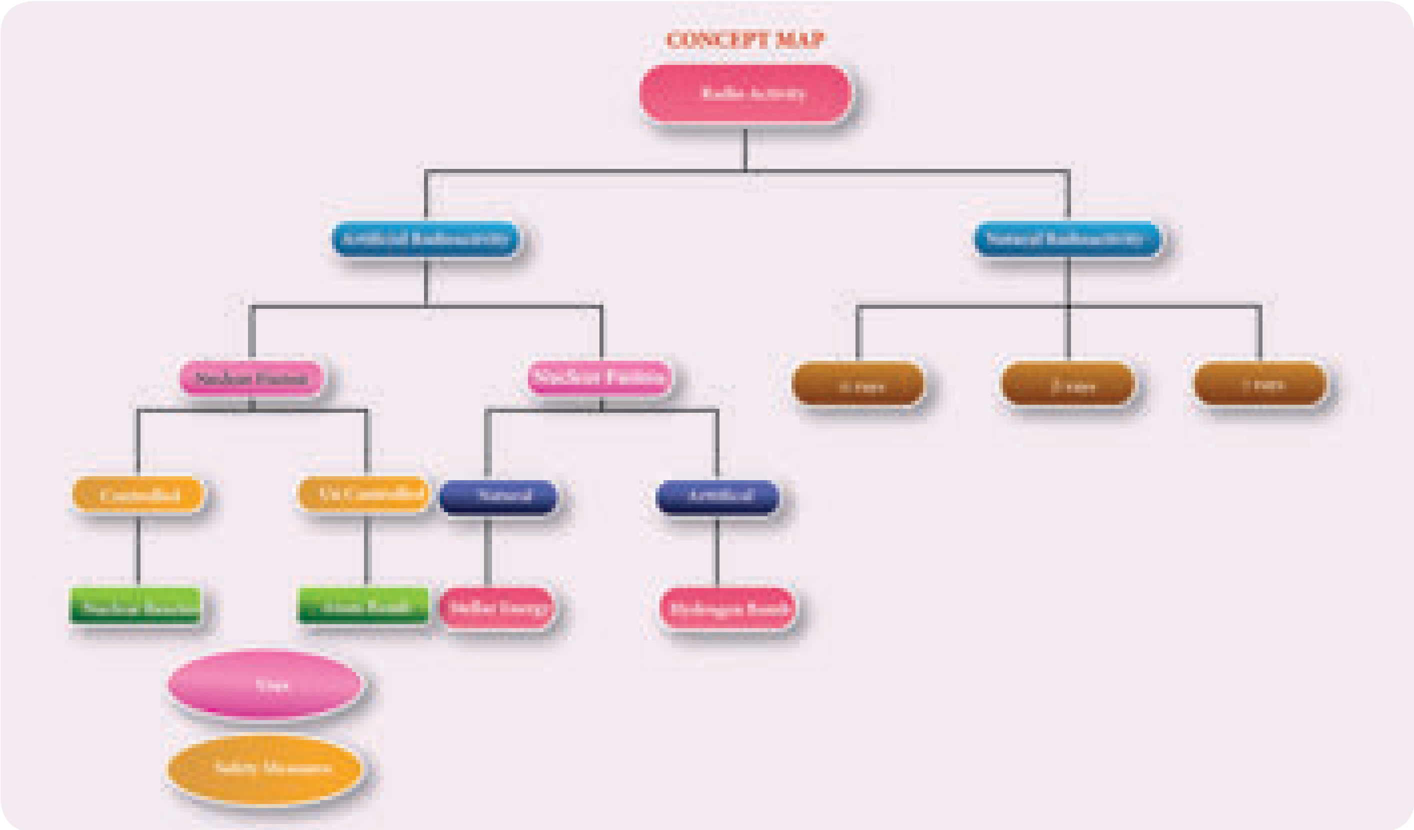
1. Mass number of a radioactive element is 232 and its atomic number is 90. When this element undergoes certain nuclear reactions, it transforms into an isotope of lead with a mass number 208 and an atomic number 82. Determine the number of alpha and beta decay that can occur.
2. 'X – rays should not be taken often'. Give the reason.
3. Cell phone towers should be placed far away from the residential area – why?

REFERENCE BOOKS

1. Physics concepts and connections – by Art Hobson Edition: Pearson education
2. Modern Physics – by Dr. R Murugesan & Er. Kiruthiga Sivaprasath – S. Chand publications

INTERNET RESOURCES

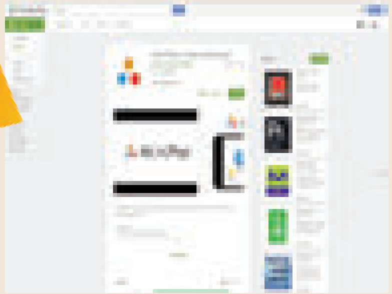
1. https://physics.columbia.edu/research/nuclear-physics
2. http://www.newworldencyclopedia.org/entry/Nuclear_physics



ICT CORNER

Modern Atomic Theory

To enable the students to build structure of different elements with electrons, protons and neutrons. They also know how new elements are formed as a result of Nuclear decays.



Steps

- Access and download the application 'atom.phys' in your mobile by using the provided URL or QR code.
- Click '**Modeling**' to build the structure of an element by making changes in electron, proton and neutron.
- Click '**Nuclear decays**' to know how new elements are formed because of the decay/ destruction of atoms.
- Finally click '**Tests**' to check your knowledge by answering the questions.

Cells alive

URL: https://play.google.com/store/apps/details?id=com.CowboyBebop.AtomPhys&hl=en or Scan the QR Code.

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