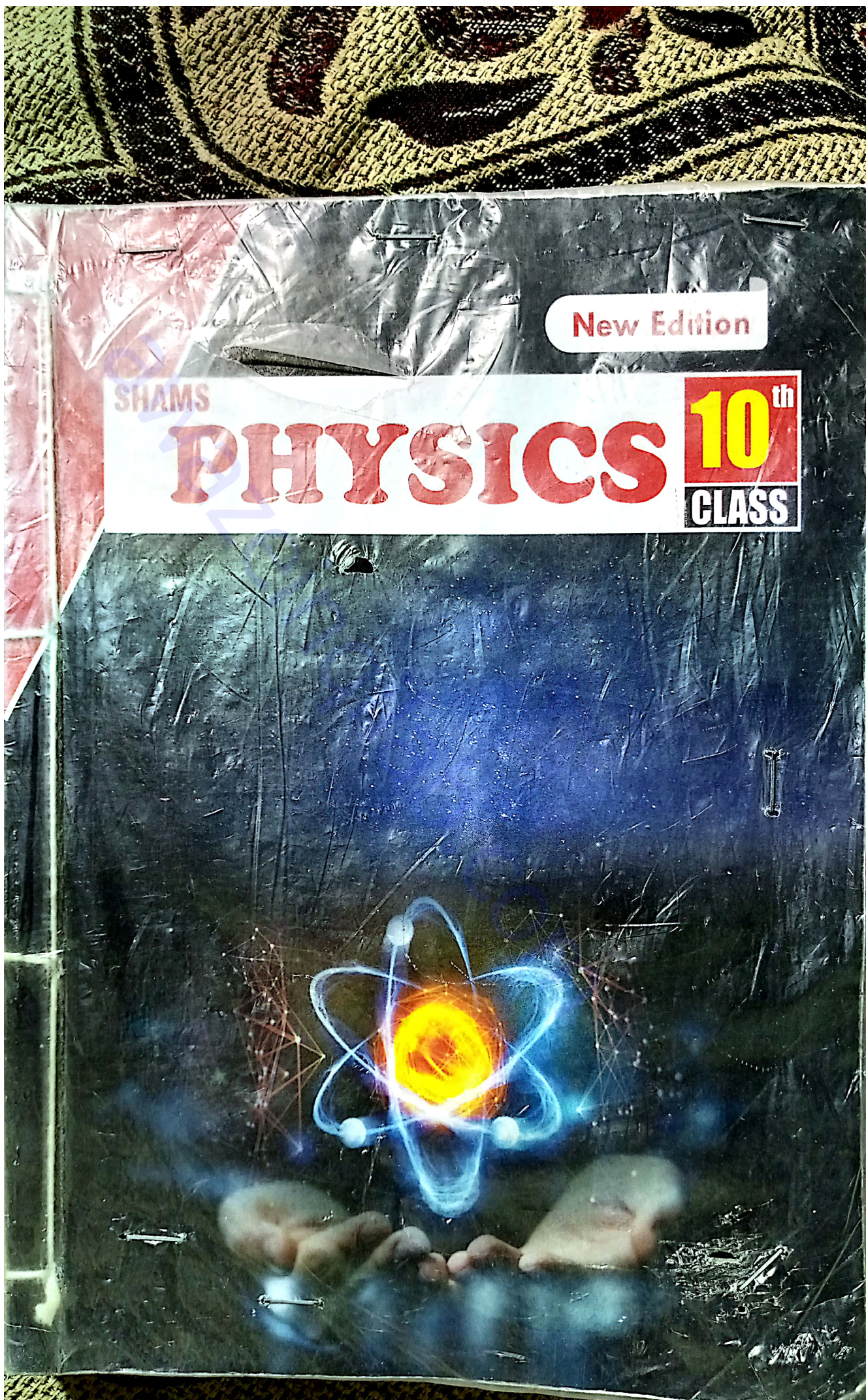




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Preface

All praises and glories to Almighty Allah Who says in the Holy Quran. "And your Allah is most gracious who taught by the pen. Taught man (those things) which he did not know". Countless Darood O Salam on the Prophet of mercy Hazrat Muhammad (Peace Be Upon Him), who showed the path of knowledge to the mankind and gave the lessons of seeking knowledge from cradle to the grave.

These notes are written in accordance with the new syllabus for 10th class students. In presenting these notes, care has been taken to fill a gap which often develops in teaching the students of physics. Very easy sentence has been used which are very easy to understand. I hope it will play a leading role in getting outstanding marks in the examination.

I dedicated my academic success and progress in life to my family whose endless prayers are source of encouragement and determination for me throughout the long years of my education and to my teachers whose guidance and hard work made me such a person whom I could not able to be without them.

While effort has been made to make the book error free, yet some errors and mistake may be present. Author and publisher will be highly obliged to the teachers and students for their constructive, valuable suggestions vital for the improvement of the book.

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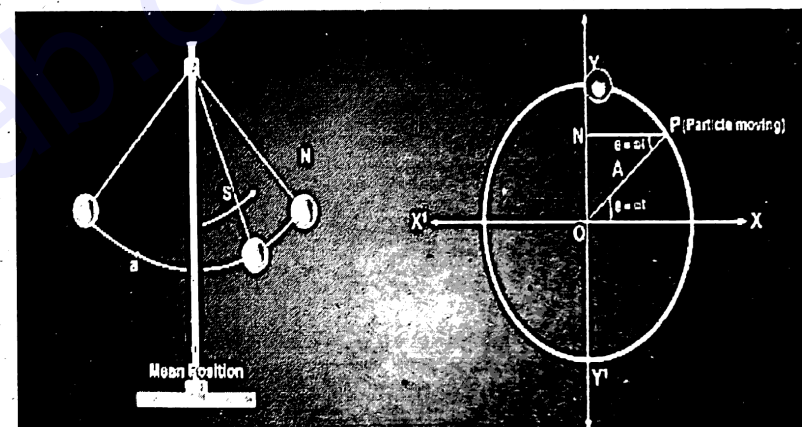
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Chapter No.10

Simple Harmonic Motion & waves

Major Concepts;

- SHM, necessary conditions and examples
- Damped oscillation
- Wave motion
- Types of waves and their examples.
- Waves equations
- Ripple Tank
- Characteristics of Waves
- Solution of problems.



Q 1. Define periodic motion and oscillatory/ vibratory motion? Give examples?

Ans. Periodic Motion:

Definition:

"The motion which repeats itself after regular intervals of time is called periodic motion."

Examples:

1. Motion of the bob of the pendulum f.s.
2. Motion of the mass attached with spring.
3. Oscillations of the steel strip.
4. Motion of the earth around its axis.

Oscillatory / Vibratory Motion:

Definition:

"The to and fro motion of a body about its mean (or) equilibrium position is called oscillatory (or) vibratory motion."

Examples:

- i. Motion of simple pendulum.
- ii. Motion of a swing.
- iii. Motion of steel strip.
- iv. Motion of string of sitar.

Q 2. Define the following terms?

- a) Vibration (or) Oscillation
- b) Time Period
- c) Frequency
- d) Displacement
- e) Amplitude

Ans. Definition of terms:

a) Vibration (or) Oscillation:

"One complete round trip of a vibrating body is called vibration."

b) Time Period:

"The time required for the completion of one round trip is called time period."

c) Frequency:

"The number of vibrations completed by a vibrating body in one second is called frequency."

d) Displacement:

"The distance covered by a vibrating body on either side of the mean position is called displacement. It is denoted by 'x'."

e) Amplitude:

"The maximum displacement covered by a vibrating body on either side of the mean position is called amplitude. It is denoted by 'x₀'."

Q3. Define simple harmonic motion (S.H.M) with examples. Describe its characteristics?

Ans. Simple Harmonic motion:

"The type of periodic motion in which acceleration is directly proportional to displacement from the mean position and always directed toward the mean position is called simple harmonic motion (S.H.M)."

Examples:

- i. Motion of the bob of simple pendulum.
- ii. Motion of mass attached with spring.

Characteristics:

The characteristics of simple harmonic motion are as follows.

- i. In S.H.M, the body oscillates about its mean position.
- ii. In S.H.M, the acceleration of the body is directly proportional to displacement from the mean position and directed toward the mean position & directed toward the mean position i.e. $\vec{a} \propto -\vec{x}$.
- iii. In S.H.M restoring force is always acting upon the body.
- iv. The restoring force and acceleration are Maximum at extreme position and zero at mean position.
- v. The velocity and K.E are maximum at the mean position and zero at extreme position.
- vi. Potential energy is maximum at extreme position and zero at the mean position.

Q 4. Show that the motion of mass attached with spring execute S.H.M. Describe its characteristics?

Ans. Definition:

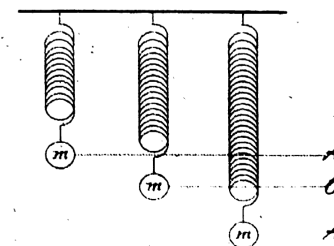
"The type of periodic motion in which acceleration is directly proportional to displacement from the mean position and always directed toward the mean position is called simple harmonic motion (S.H.M)."

Mathematically:

$$\vec{a} \propto -\vec{x}$$

Proof:

To show that the motion of mass attached with spring is S.H.M, let us consider mass "m" is attached to one end of the spring as shown in the figure.



If the mass "m" attached with the spring is stretched by some external force (F_e) downward and then released it, mass "m" will start oscillation between two extreme positions "A" and "A" about the mean position "O" under elastic restoring force ($\vec{F}_r$).

According to Newton's 2nd law;

$$\text{External Applied Force} = ma$$

$$\Rightarrow F_e = ma \text{-----(a)}$$

According to hook's law;

$$\text{Restoring Force} = Kx$$

$$\Rightarrow F_r = Kx \text{-----(b)}$$

Since external applied force and restoring force are equal in magnitude but opposite in direction; therefore,

$$\vec{F}_e = -\vec{F}_r$$

$$\Rightarrow M\vec{a} = -K\vec{x}$$

$$\Rightarrow \vec{a} = -K\vec{x}$$

$$\Rightarrow \vec{a} = -\frac{k}{m}\vec{x}$$

$$\Rightarrow \vec{a} = -(\text{const})\vec{x}$$

$$\vec{a} \propto -\vec{x}$$

The oscillations of mass attached with spring execute S.H.M.

Characteristic:

The characteristic of S.H.M of mass attached to a spring are as follows.

- In S.H.M of mass "m" attached to a spring, mass "m" oscillates about the mean position "O" under elastic restoring force.
- The acceleration of mass attach with spring is directly proportional to displacement from the mean position and directed toward the mean position i.e. $\vec{a} \propto \vec{x}$.
- The acceleration and restoring force are maximum at extreme position and zero at the mean position.
- The velocity and K.E is maximum at the mean position and zero at extreme position.
- The P.E is maximum at the extreme position and zero at mean position.
- The time period of mass attached with spring is given by the relation;

$$T = 2\pi \sqrt{\frac{m}{k}}$$

- The frequency of mass attached with spring is given by the relation;

$$F = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$$

Q.5. What is simple pendulum?

Ans. Simple pendulum:

"An ideal pendulum consists of a small heavy bob of mass 'm' suspended by a light string of length 'L' fixed with a frictionless support."

Motion of a simple pendulum is SHM:

Consider an object of mass 'm' attached with one end of a light string of length 'L' as shown in Fig.

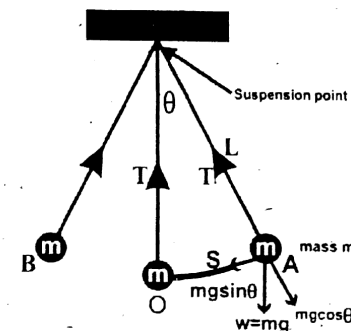
Length of pendulum:

Length of the pendulum 'L' is the distance between the point of suspension and the center of the Bob, when the pendulum is at Equilibrium position 'O', the net force on the bob is zero and the bob is stationary.

Now if we bring the bob to extreme position A, The net force is not zero as shown in fig.

Component of weight:

Weight of the pendulum can be resolved into two components $mg\cos\theta$ and $mg\sin\theta$ as shown in fig.



Q.6. Define simple Harmonic motion (SHM)? What are necessary conditions for a body to execute simple harmonic motion.

Ans. Definition:

"Simple harmonic motion occurs when the net force is proportional to the displacement from the equilibrium position and is always directed toward the equilibrium position." OR

When an object oscillates about mean position, its acceleration is directly proportional to its displacement from mean position and is always directed towards mean position. Its motion is called simple harmonic motion (SHM).

Requirement of SHM:

There are two requirements for oscillations

- Oscillating system has restoring force.
- Oscillating system has inertia.

Necessary conditions for SHM:

There are four main conditions which are necessary for a system executing SHM.

- The oscillating system must have inertia.
- The oscillating system must obey the Hooke's law.
- The oscillating system must have elastic restoring force.
- The system should be frictionless.

Tension in the string:

Third force in this case is the Tension "T" in the string as shown in figure, which is acting toward the support i.e. $mg\cos\theta$ and T are equal and opposite to each other. So they cancelled the effect of each other i.e.,

$$mg\cos\theta = T$$

Hence there is no motion along this direction.

Restoring force and acceleration:

The component of the weight $mg\sin\theta$ is directed towards the mean position and acts as a restoring force. Due to this force the bob will start moving toward 'O' and its speed becomes maximum at 'O' mean position. Due to inertia bob does not stop at 'O' rather it continues to move towards the extreme position 'B'. During its motion toward 'B' its speed decreases due to restoring force and finally it comes to rest when it reaches the point 'B'.

The restoring force $mg\sin\theta$ still acts toward the mean position 'O' and due to this force the bob again starts moving toward mean position 'O'. Hence only the restoring force $mg\sin\theta$ is responsible for "to and fro motion" of simple pendulum. So, the restoring force for the bob is given as:

$$F = -mg\sin\theta \quad (1)$$

Negative sign shows that force is directed towards the mean position 'O'. Also we know that:

$$F = ma \quad (2)$$

Comparing (1) and (2), we get,

$$ma = -mg\sin\theta$$

$$\Rightarrow \frac{a}{1} = -g\sin\theta$$

$$\Rightarrow a = -g\sin\theta \quad (3)$$

From fig,

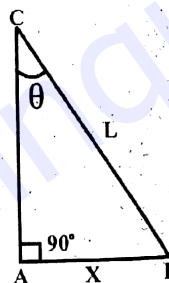
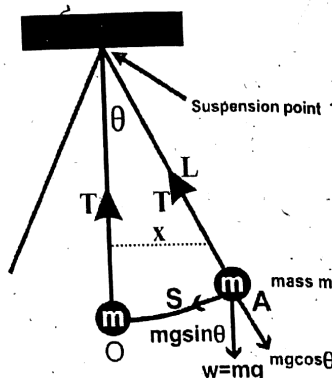
So, equation (3) becomes,

$$\Rightarrow a = -g \frac{x}{L}$$

$$\Rightarrow a = -\frac{g}{L} x$$

$$a = -(\text{constant})x \quad \left[\because -\frac{g}{L} = \text{constant} \right]$$

$$a \propto -x$$



It is clear from above relation that, the acceleration of the bob is also directed towards the mean position as the restoring force acts toward mean position 'O'.

Important points:

- Speed of the bob decreases when it moves from mean position 'O' to extreme position 'A' and 'B' and increases when it moves toward mean position 'O' due to restoring force.
- Acceleration of the bob is directed toward the mean position 'O'.

Q7. Show that the time period of simple pendulum is equal to $\sqrt{\frac{l}{g}}$.

Ans. Time period of simple pendulum:

Time period of the simple pendulum is given by the following Formula.

$$T = 2\pi \sqrt{\frac{l}{g}}$$

This can be derived by using the concept of acceleration and time period of the body performing SHM.

$$a = -\omega^2 x \quad (1)$$

For simple pendulum having SHM.

$$a = -\left[\frac{g}{l}\right] x \quad (2)$$

Comparing (1) and (2)

$$\Rightarrow -\omega^2 x = -\left[\frac{g}{l}\right] x$$

$$\Rightarrow \omega^2 = \frac{g}{l}$$

$$\Rightarrow \sqrt{\omega^2} = \sqrt{\frac{g}{l}}$$

$$\Rightarrow \omega = \sqrt{\frac{g}{l}} \quad (3)$$

Time period SHM can be expressed as,

$$T = \frac{2\pi}{\omega} \quad (4)$$

$$\Rightarrow T = \frac{2\pi}{\sqrt{\frac{g}{l}}}$$

Putting eq.(3) in eq.(4)

$$\Rightarrow T = 2\pi \sqrt{\frac{l}{g}}$$

Dependence of Time period:

Time period of the simple pendulum depend upon the:

- Length of the pendulum (l)
- Gravitational acceleration (g).

Note:

Time period of the pendulum is independent of its mass and amplitude.

Q8. Prove that $V=f\lambda$?

Ans. Since we know that the distance covered by a wave in one oscillation is equal to its wavelength " λ " and the time required to complete one oscillation is called time period " T ".

Now we know that;

$$V = \frac{S}{t}$$

$$\Rightarrow S = vt \dots \dots \dots (1)$$

Put $S=\lambda$ and $t=T$, in equation (1)

$$\Rightarrow \lambda = VT$$

$$\Rightarrow \lambda = V \times \frac{1}{f} \quad (\because T = \frac{1}{f})$$

$$V = f\lambda$$

Hence your required is proved.

Q9. What is wave motion? How waves can be categorized?**Ans. Wave:**

"A source of transferring energy from one place to another place is called wave".

Type of waves:

Waves are mainly classified in to three categories;

i) Mechanical Waves:

"The type of wave which required a material medium for its propagation is called mechanical wave".

Example:

Sound waves, water waves etc.

ii) Electro – magnetic waves:

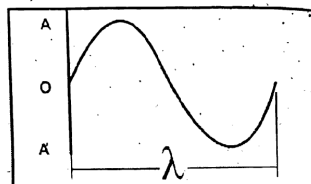
Those waves which do not require a material medium for its propagation are called electromagnetic waves.

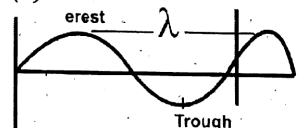
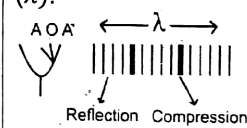
Examples:

X-rays, radio waves, light waves etc.

iii) Matter waves / particle waves:

Those waves which are associated with small particles such as electron, proton and neutron are known as particles waves.

**Type of Mechanical Waves:**

	Transverse Waves	Longitudinal waves
1	"The type of mechanical waves in which the particles of the medium vibrate perpendicular to the direction of propagation of waves is known as transverse wave".	"The type of mechanical waves in which the particles of the medium vibrate parallel to the direction of propagation of wave is known as longitudinal wave".
2	Examples: Water waves, waves produced in stretched string.	Examples: Sound waves, waves produced in long helical spring.
3	Transverse wave consists of Crest and trough. Crest: The portion of transverse wave above the mean position is called crest". Trough: The portion of transverse wave below the mean position is called trough.	Longitudinal wave consists of compression and rarefaction. Compression: The portion of longitudinal wave where particles of medium are more crowded is called compression. Rarefaction: The portion of longitudinal wave where particles of medium are less crowded is called rarefaction.
4	The distance between two consecutive crests (or) troughs is called wave length (λ). 	The distance between two consecutive compression (or) rarefactions is called wave length (λ). 

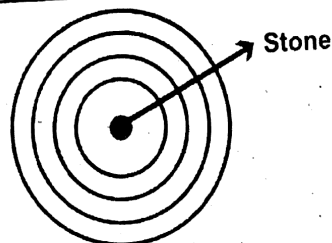
Q10. Discuss generation and propagation of water waves?**Ans. Water waves:**

Water wave is an example of transverse waves in which particles of the medium vibrate perpendicular to the direction of motion of wave.

Generation and propagation of water waves:

When a stone is dropped in a water tank, circular wave are produced called water waves.

Water waves propagate from the point of disturbance in all directions in the form of concentric circles. The water molecules moves up and down, while the waves propagates in all directions from the point disturbance, perpendicular to the direction of vibration of water molecules.



Q 11. Discuss quantitative characteristics of waves?

Ans. Quantitative characteristics of wave:

Quantitative characteristics of wave are as follows.

i. Wave length:

"The distance covered by a wave in one time period "T" is called wave length. It is denoted by (λ)

ii. Time period:

"The time during a single wave passes through a certain point is called time period. It is denoted by "T".

iii. Frequency:

"The number of waves passing through a certain point in one second is called frequency. Time period and frequency are reciprocal of one another i.e. $T = \frac{1}{f}$

iv. Amplitude:

"The maximum displacement of the particle of the medium from the equilibrium position, when wave passes over it, is called amplitude.

v. Velocity of waves:

"The displacement covered by a wave in unit time is called velocity of wave. Mathematically:

$$\vec{V} = \frac{\vec{s}}{T}$$

Q 12: What is ripple tank? Using ripple tank and explain the properties of waves?

Ans. Ripple Tank:

"A device which is used to study the various properties of waves produced on the surface of water is called ripple tank".

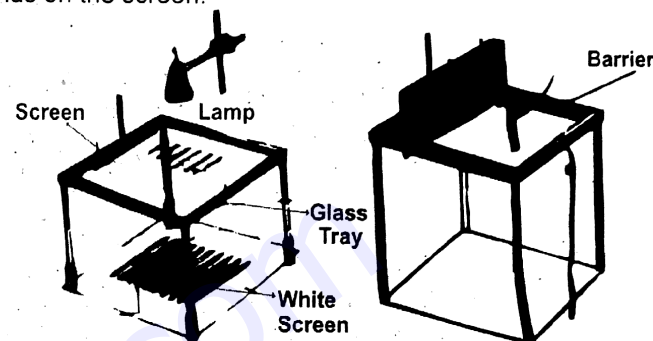
Construction:

A ripple tank consists of a rectangular water tray fitted with transparent glass bottom. A light bulb is fixed above the tray and a viewing screen is placed below the tray.

Working:

Waves can be produced in the ripple tank by disturbing the water in different ways.

When waves are produced, the crests converge the light and form bright bands on the screen, while the troughs diverge the light and form dark bands on the screen.



Demonstration of the properties of waves:

The following properties of wave can be demonstrated with the help of ripple tank.

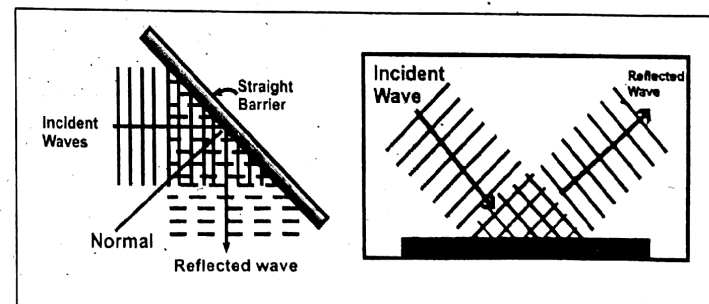
- Reflection of waves.
- Refraction of waves
- Diffraction of Waves.
- Interference of Waves.

i. Reflection of waves:

"The bouncing back of waves in the same medium after striking with the boundary of another medium is called reflection of Waves.

Demonstration:

Reflection phenomena can be demonstrated with the help of ripple tank by placing an upright obstacle in the water tray of ripple tank. The incident waves of water strike with the obstacle and reflect back in to the same medium (water) as shown in the figure.

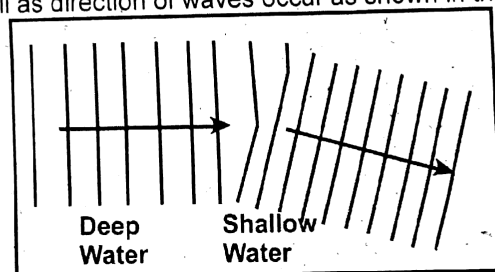


ii. Refraction of Waves:

"The phenomena in which change in speed as well as direction of waves occur, when waves enter from one medium to another medium is called refraction of Waves.

Demonstration:

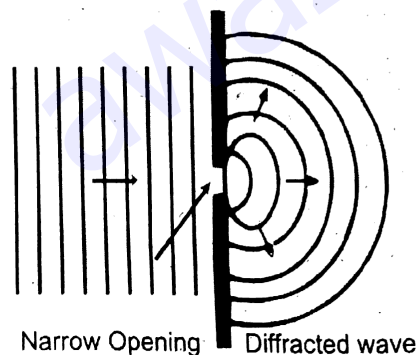
"The refraction of waves can be demonstrated with the help of ripple tank by placing a glass sheet in the bottom of the water tray of ripple tank, so the water in the tray is splitted in to two parts shallower water (denser medium) and deeper water (rare medium). we shall observe that when waves from deeper water enter to the shallower water, the change in speed as well as direction of waves occur as shown in the figure.

**iii. Diffraction of Waves:**

"The bending of waves across the edges of the opening of the obstacles is called diffraction of waves. When Waves passing through an opening whose diameter is equal (or) less than the wavelength of the waves i.e $d \leq \lambda$, then the Waves bend around the opening of the obstacle.

Demonstration:

Diffraction phenomena of Waves can be demonstrated with the help of ripple tank by placing two straight rods with a small opening in between them as shown in the figure.

**vi. Interference of Waves:**

"The Combined effect of two Waves at the region of over lapping is Called interference"

Type of interference:

There are two types of interference

- i. Constructive interference
- ii. Destructive Interference

i. Constructive interference:

When two Waves arrive at the same place, at the same time and in the same phase then they re-inforce each other, such type of interference is known as constructive interference. "OR"

When crest of one Wave meets with the crest of other wave, they re-inforce each other and the amplitude of resultant wave is greater than either of the individual Waves, such type of interference is called constructive interference.

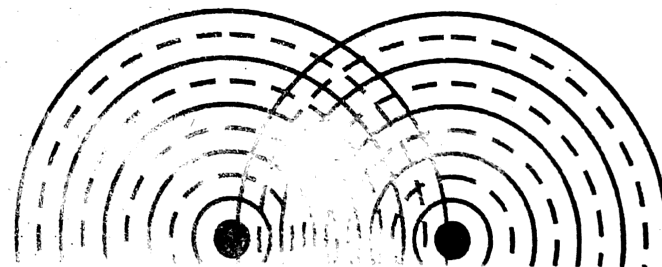
ii. Destructive interference:

When two waves arrive at the same place, at the same time but out of phase, then they cancel the effect of each, such type of interference is known as destructive interference. "OR"

"When crest of one Wave meets with the trough of other wave, they cancel the effect of each other and the amplitudes of resultant wave is less than either of the individual waves.

Demonstration:

Interference phenomena can be demonstrated with the help of ripple tank, when two identical balls with the rod of vibrator touches the water surface periodically. The interference pattern obtained is shown in figure.



EXAMPLE**Example 10.1:**

What is the frequency of oscillation if the time period is 20msec?

Solution:**Given Data:**

Time period = $T = 20 \text{ msec} = 20 \times 10^{-3} \text{ Sec}$

Required:

Frequency of oscillation = $f = ?$

Calculation:

We know that;

$$f = \frac{1}{T}$$

$$\Rightarrow f = \frac{1}{20 \times 10^{-3}}$$

$$\Rightarrow f = 0.05 \times 10^3 \text{ Hz}$$

$$f = 50 \text{ Hz}$$

Conclusion:

Hence, frequency of oscillation is 50Hz.

Example 10.2:

A spring has a spring constant of 48 N/m . This spring is pulled to a distance of 55cm from equilibrium. What is the restoring force?

Solution:**Given Data:**

Spring constant = $k = 48 \text{ N/m}$

Displacement = $x = 55 \text{ cm} = 0.55 \text{ m}$

Required:

Restoring Force = $F = ?$

We know that;

$$F = -kx$$

Putting values, we get;

$$\Rightarrow F = -(48)(0.55)$$

$$\Rightarrow F = -26.4 \text{ N}$$

Where the $-ve$ Sign shows that the restoring force is directed toward the mean position.

Conclusion:

Hence; the restoring force is 26.4 N [left].

Example 10.3: What is the mass of a vertical mass-Spring system if it oscillates with a period of 2.0 Sec and has a spring constant of 20.0 N/m ?

Solution:**Given Data:**

Spring constant = $K = 20 \text{ N/m}$

Time period = $T = 2.0 \text{ Sec}$

Required:

Mass = $m = ?$

Calculations:

We know that;

$$T = 2\pi \sqrt{\frac{m}{k}}$$

Taking square of both sides;

$$T^2 = 4\pi^2 \frac{m}{k}$$

Putting value, we get;

$$\Rightarrow m = \frac{(2^2)(20)}{4(3.14)^2}$$

$$\Rightarrow m = \frac{(4)(20)}{(4)(9.86)}$$

$$m = 2.02 \text{ kg} = 2 \text{ kg}$$

Conclusion:

Hence, the mass of a vertical mass spring system is 2kg.

Example 10.4:

Determine the magnitude of the restoring force for a pendulum bob of mass 100g that has been pulled to an angle 10° from the vertical.

Solution:**Given Data:**

Mass = $m = 100 \text{ g} = 0.1 \text{ kg}$

Acceleration due to gravity = $g = 9.8 \text{ m/sec}^2$

Angle = $\theta = 10^\circ$

Required:

Restoring force = $F_{\text{rest}} = ?$

Calculation:

We know that;

$$F_{\text{rest}} = -mg \sin \theta$$

Putting values, we get;

$$\Rightarrow F_{(\text{rest})} = -(0.1)(9.8) \sin 10^\circ$$

$$\Rightarrow F_{(\text{rest})} = -(0.98)(0.17)$$

$$F_{(\text{rest})} = -0.167 \text{ N}$$

Conclusion:

The magnitude of restoring force acting on the pendulum is 0.167N.

Shams Notes

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Harmonic Motion & waves

Example 10.5:

What is the gravitational field strength on planet mercury, if a 0.5m pendulum swings with a period of 2.30Sec?

Solution:**Given Data:**

Time period = $T = 2.3\text{Sec}$
Length = $l = 0.5\text{m}$

Required:

Gravitational Field strength = $g = ?$

Calculations:

We know that;

$$T = 2\pi \sqrt{\frac{l}{g}}$$

Squaring both sides;

$$T^2 = \frac{4\pi^2 l}{g}$$

Isolating "g", we get

$$\Rightarrow g = \frac{4\pi^2 l}{T^2}$$

$$\Rightarrow g = \frac{4(3.14)^2(0.5)}{(2.3)^2}$$

$$g = \frac{3.73\text{m}}{\text{sec}^2} = 3.73\text{N/kg [down]}$$

Conclusion:

The gravitational field strength on planet mercury is 3.73N/kg.

Example 10.6:

A student vibrates the end of a spring at 2.6Hz. This produces a wave with a wavelength of 0.37m. Calculate the speed of the Wave.

Solution:**Given Data:**

Frequency = $f = 2.6\text{ Hz}$
Wavelength = $\lambda = 0.37\text{m}$

Required:

Speed = $v = ?$

Calculations:

We know that,

$$v = f\lambda$$

Putting value

$$\Rightarrow v = (2.6)(0.37)$$

$$v = 0.962\text{mSec}^{-1}$$

Conclusion:

Hence speed of the Wave v is 0.962m/sec

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Assignment**Assignments 10.1:**

When an object oscillates with a frequency of 0.5 Hz, what is its time period?

Solution:**Given Data:**

Frequency = $f = 0.5\text{ Hz}$

Required:

Time Period = $T = ?$

Calculations:

We know that;

$$f = \frac{1}{T}$$

$$\Rightarrow T = \frac{1}{f}$$

Putting value of "f", we get;

$$\Rightarrow T = \frac{1}{0.5}$$

$$T = 2\text{ Sec}$$

Calculation: Hence;

Time period = $T = 2\text{ Sec}$

Assignment 10.2:

Determine the restoring force of a spring displaced 1.5m, with the spring constant of 30.0N/m.

Calculations:**Given Data:**

Displacement = $x = 1.5\text{m}$
Spring constant = $k = 30.0 \frac{\text{N}}{\text{m}}$

Required:

Restoring Force = $F_{\text{rest}} = ?$

Calculation:

We know that;

$$\vec{F}_{\text{rest}} = k\vec{x}$$

Putting values, we get;

$$\Rightarrow \vec{F}_{\text{rest}} = (30.0)(1.5)$$

$$\vec{F}_{\text{rest}} = -45\text{N}$$

The -ve sign shows that the restoring force is directed toward the meant position.

Assignment 10.3:

A body of mass 0.2kg is attached to a spring placed on a friction less horizontal surface. The spring constant of spring is 4N/m. Find the time period of oscillating mass spring system.

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Solution:**Given Data:**

$$\text{Mass} = m = 0.2 \text{ kg}$$

$$\text{Spring constant} = k = 4 \text{ N/m}$$

Required:

$$\text{Time period} = T = ?$$

Calculations: We know that;

$$T = 2\pi \sqrt{\frac{m}{k}}$$

Putting value, we get;

$$\Rightarrow T = 6.28 \times \sqrt{\frac{0.2}{4}}$$

$$\Rightarrow T = 6.28 \times \sqrt{0.05}$$

$$\Rightarrow T = 6.28 \times 0.22$$

$$T = 1.38 \text{ Sec}$$

Conclusion:

Hence, the time period of oscillating mass-spring system is 1.38 Sec.

Assignment 10.4:

At what angle must a pendulum be displaced to create a restoring force of 4 N on bob with a mass of 600 g?

Solution:**Given Data:**

$$\text{Restoring Force} = F_{\text{rest}} = 4 \text{ N}$$

$$\text{Mass} = m = 600 \text{ gm} = 0.6 \text{ kg}$$

Required:

$$\text{Angle} = \theta = ?$$

Calculations:

We know that;

$$F_{\text{rest}} = mg \sin \theta$$

$$\Rightarrow \sin \theta = \frac{F_{\text{rest}}}{mg}$$

$$\Rightarrow \sin \theta = \frac{4}{(0.5 \times 9.8)}$$

$$\Rightarrow \sin \theta = 0.816$$

$$\Rightarrow \theta = \sin^{-1}(0.816)$$

$$\theta = 54.6^\circ$$

Conclusion: Hence;

$$\text{Angle} = \theta = 54.6^\circ$$

Assignment 10.5:

What is the gravitational field strength at the top of Mount Everest at an altitude of 8954 m, if a pendulum with a length of 1 m has a period of 2.01 Sec?

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Solution:**Given Data:**

$$\text{Length} = l = 1 \text{ m}$$

$$\text{Time period} = T = 2.01 \text{ Sec}$$

Required:

$$\text{Gravitational field strength} = g = ?$$

Calculations:

We know that;

$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$\Rightarrow T^2 = 4\pi^2 \frac{l}{g}$$

$$\Rightarrow g = \frac{4\pi^2 l}{T^2}$$

Putting value, we get;

$$\Rightarrow g = \frac{4((3.14)^2)(1)}{(2.01)^2}$$

$$g = 9.76 \text{ N/kg}$$

Conclusion: Hence;

$$\text{Gravitational field strength} = g = 9.76 \text{ N/kg}$$

Assignment 10.6:A sound of wavelength $1.7 \times 10^{-2} \text{ m}$. Calculate the frequency of sound if its velocity is 343.4 m/sec.**Solution:****Given Data:**

$$\text{Wavelength} = \lambda = 1.7 \times 10^{-2} \text{ m}$$

$$\text{Speed of sound} = V = 343.4 \frac{\text{m}}{\text{Sec}}$$

Required:

$$\text{Frequency} = f = ?$$

Calculations:

We know that;

$$V = f \lambda$$

$$f = \frac{V}{\lambda}$$

Putting values, we get;

$$\Rightarrow f = \frac{343.4}{1.7 \times 10^{-2}}$$

$$\Rightarrow f = \frac{343.4}{1.7} \times 10^2$$

$$\Rightarrow f = 202 \times 10^2$$

$$f = 2.02 \times 10^4 \text{ Hz}$$

Conclusion:

$$\text{Hence, Frequency} = f = 2.02 \times 10^4 \text{ Hz}$$

EXERCISE

Choose the correct answer for each of the following;

- A transverse wave on a string has an Amplitude. A tiny spot on the string is colored red. As one cycle of the wave passes by, what is the total distance travelled by the red spot?
a. A b. 2A c. $\frac{1}{2}A$ d. 4A
- Which of the following does not affect the period of the mass-spring system.
a. Mass
b. spring constant
c. Amplitude of vibration
d. All of above affect the period
- An object of mass m oscillates at the end of a spring. To double the period, replace the object with one of mass:
a. 2m b. $m/2$ c. 4m d. $m/4$
- A car mounted on shock absorbers is like a mass on a spring. If we ignore damping, how will the frequency of the oscillations change if passengers (or a heavy load) are added to the car? The frequency will
a. Increase b. decrease
c. stay the same d. be zero
- If the pendulum completes exactly 12 cycles in 2.0min, what is the frequency of the pendulum?
a. 0.10Hz b. 0.17 Hz c. 6.0 Hz d. 10 Hz
- A certain pendulum has an iron bob. When the iron bob is replaced with lead bob of the same size, its time period will
a. Increase b. decrease
c. stay the same d. be zero
- A wave transports
a. Energy but no matter b. matter but no energy
c. both energy and matter d. air
- The bending of waves around the edges of the obstacle is
a. Reflection b. refraction
c. diffraction d. damping

Conceptual Question

Q1. Is every oscillatory motion simple harmonic? Give Examples.

Ans. No, it is not necessary for an oscillatory motion to be simple harmonic. For SHM, the following conditions must be satisfied by the oscillatory motion.

- The acceleration of an oscillating body must be directly proportional to displacement from the mean position.
- The acceleration must be directed toward the mean position.

Conclusion:

Thus, every SHM is oscillatory motion but every oscillatory motion is not a SHM.

Q2. For a particle with simple harmonic motion, at what point of the motion does the velocity attain maximum magnitude? Minimum magnitude?

Ans. Maximum magnitude of Velocity:

For a particle executing SHM, the magnitude of velocity become maximum at the mean position.

Minimum magnitude of velocity:

For a particle executing SHM, the magnitude of velocity become minimum at the extreme position.

Q3. Is the restoring force on a mass attached to spring in simple harmonic motion ever Zero? If so, Where?

Ans. Restoring force on a mass attached to spring: yes, the restoring force in SHM becomes zero at the mean position.

According to Hook's law,

$$\vec{F} = -k\vec{x}$$

At mean position $x = 0$

Therefore,

$$\text{Eq: (1)} F = -k(0)$$

$$F = 0$$

Hence the restoring force becomes zero at the mean position.

Q4. If we shorten the string of a pendulum to half its original length, what is the effect on its time period and frequency?

Ans. Effect on time period:

We know that;

$$T = 2\pi\sqrt{\frac{l}{g}} \quad \text{----- (1)}$$

Now if we shorten the string of a pendulum to half its original length

i.e. $l = \frac{l}{2}$ then,

$$\Rightarrow T = 2\pi \sqrt{\frac{l}{g}}$$

$$\Rightarrow T = 2\pi \sqrt{\frac{l}{2g}} \quad (\because l = \frac{l}{2})$$

$$\Rightarrow T = \frac{1}{\sqrt{2}} \left[2\pi \sqrt{\frac{l}{g}} \right] \text{----- (2)}$$

Putting eq(1) in eq(2) we get,

$$T = \frac{T}{\sqrt{2}}$$

The time period will decrease by a factor $\frac{1}{\sqrt{2}}$ if we shorten the string of a pendulum to half its original length.

Effect on frequency:

We know that,

$$f = \frac{1}{2\pi} \sqrt{\frac{g}{l}} \text{----- (1)}$$

Now if we shorten the string of a pendulum to half of its original length, i.e. $l = \frac{l}{2}$, then

$$\Rightarrow f = \frac{1}{2\pi} \sqrt{\frac{g}{l}}$$

$$\Rightarrow f = \frac{1}{2\pi} \sqrt{\frac{2g}{l/2}}$$

$$\Rightarrow f = \frac{1}{2\pi} \sqrt{\frac{2g}{l}}$$

$$f = \sqrt{2} \left[\frac{1}{2\pi} \sqrt{\frac{g}{l}} \right] \text{----- (2)}$$

Put equation (1) in equation (2), we get;

$$\text{Equation (2)} \quad f = \sqrt{2} f$$

The frequency will increase by factor $\sqrt{2}$, if we shorten the string of pendulum to half of its original length.

Q5. A thin rope hangs from dark high tower so that its upper end is not visible. How can the length of rope be determined?

Ans. The length of wire hangs from dark high tower can be determined by connecting the metallic bob at its lower end, so that the arrangement becomes like a simple pendulum. The time period of simple pendulum is given,

$$T = 2\pi \sqrt{\frac{l}{g}}$$

$$\Rightarrow T^2 = 4\pi^2 \frac{l}{g}$$

$$\Rightarrow l = \frac{gT^2}{4\pi^2}$$

Knowing the values of "g" and "T", the length of the wire can be determined.

Q6. Suppose you stand on a swing instead of sitting on it. Will your frequency of oscillation increase (or) decrease?

Ans. The swing may be considered as a simple pendulum. The frequency of simple pendulum (Swing) is given by;

$$f = \frac{1}{2\pi} \sqrt{\frac{g}{l}} \text{----- (1)}$$

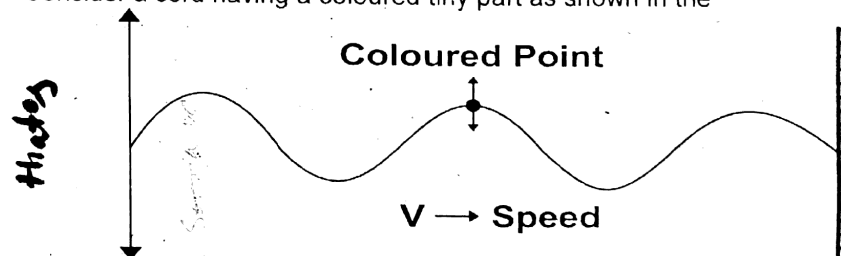
Where L = length of simple pendulum (swing) (Or) L = distance between point of suspension and center of gravity of the person on swing.

Thus the length of simple pendulum (swing) decreases as the person stands up on the swing i.e. the center of gravity of the person rises up. The frequency of oscillation is inversely proportional to the square root of the length of the pendulum (swing). So, frequency of oscillation increases when a person stands on a swing instead of sitting on it.

Q7. Explain the difference between the speed of a transverse wave travelling along a cord and the speed of a tiny colored part of the cord.

Ans. Transverse waves are those in which particles of the medium vibrate perpendicular (right angle) to the direction of propagation of wave motion.

Consider a cord having a coloured tiny part as shown in the



If we move our hand up and down transverse waves are produced moving in the forward direction. Thus transverse waves move in the forward direction while the tiny colored part of the string moves up and down.

Q8. Why waves refract at the boundary of shallow and deep water?

Ans. Refraction:

The change in speed as well as direction of waves as they pass from one medium to another is called refraction.

In refraction, the change occurs in speed and wavelength of waves. The speed of a wave depends on the medium through which it travels. Waves travel fast in deep water as compare to shallow water.

Thus when waves are transmitted from deep water in to shallow water, its speed and wavelength decreases and as a result the change in direction of waves occur which is called refraction of waves.

Q9. What is the effect on diffraction if the opening is made small?

Ans. Diffraction:

The bending (or) spreading of waves around the sharp edges (or) corners of the opening of the obstacles is called diffraction of waves.

Size of the opening in an obstacle:

The amount of bending of waves depends on the relative size of the wavelength of the wave and size of the opening in an obstacle.

Diffraction through large slit:

If the opening is much larger than the wavelength, then very less bending of waves occurs.

Diffraction through small slit:

If the opening is equal (or) smaller than the wavelength i.e, $d \leq \lambda$, then a considerable bending of waves occur. Thus, the wave bends more and more if the opening is made small.

Numerical Problems

P1. A man hung from a spring vibrates 15 times in 12sec. Calculate

(a) The frequency and (b) the time period of the vibration.

Solution:

Given Data:

Number of vibrations = $N=15$

Time for 15 vibrations = $t=12\text{sec}$

Required

(a) Frequency = $f=?$

(b) Time period = $T=?$

Calculations:

(a) Frequency = $f=?$

We know that,

$$f = \frac{N}{T}$$

Putting value we get

$$\Rightarrow f = \frac{15}{12}$$

$$f = 1.25\text{Hz}$$

(b) Time period = $T=?$

We know that,

$$\Rightarrow T = \frac{1}{f}$$

$$\Rightarrow T = \frac{1}{1.25}$$

$$T = 0.8\text{sec}$$

Conclusion: Hence,

(a) Frequency = $f=1.25\text{Hz}$

(b) Time period = $T=0.8\text{sec}$

P2. A spring requires a force of 100N to compress it to a displacement of 4cm. What is its spring constant?

Solution:

Given Data:

Force = $F=100\text{N}$

Displacement = $\chi=4\text{cm}=0.04\text{m}$

Required:

Spring constant = $k=?$

Calculation:

We know that,

$$F = k \chi \quad k = \frac{F}{\chi}$$

Putting value we get,

$$\Rightarrow k = \frac{100}{0.04}$$

$$\Rightarrow k = 2500\text{N/m}$$

$$k = 2.5 \times 10^3 \text{Nm}^{-1}$$

Conclusion: Hence,

Spring constant = $k = 2.5 \times 10^3 \text{Nm}^{-1}$

P3: A second pendulum is a pendulum with period of 2.0sec. How long must a second pendulum be on the earth ($g=9.81\text{m/sec}^2$)? What is the frequency of second pendulum at earth and on moon?

Solution:

Given data:

Time period of second pendulum = $T=2\text{sec}$

Acceleration due to gravity on Earth = $g_e=9.81\text{m/sec}^2$

Acceleration due to gravity on moon = $g_m=1.6\text{m/sec}^2$

Required:

- (a) Length of pendulum at earth $= l_e = ?$
 (b) Length of pendulum on moon $= l_m = ?$
 (c) Frequency at Earth $= f_e = ?$
 (d) Frequency at Moon $= f_m = ?$

Calculation:

- (a) Length of pendulum at Earth $= l_e = ?$

We know that,

$$T = 2\pi \sqrt{\frac{l_e}{g_e}}$$

Taking square of both sides we get,

We know that,

$$\Rightarrow T^2 = 4\pi^2 \frac{l_e}{g_e}$$

$$\Rightarrow l_e = \frac{T^2 g_e}{4\pi^2}$$

Putting values, we get

$$\Rightarrow l_e = \frac{(2)^2 \times 9.8}{4(3.14)^2}$$

$$\Rightarrow l_e = \frac{39.2}{39.44}$$

$$l_e = 0.99m$$

- (b) Length of pendulum on moon $= l_m = ?$

We know that,

$$T_m = 2\pi \sqrt{\frac{l_m}{g_m}}$$

Taking square of both sides

$$T_m^2 = 4\pi^2 \frac{l_m}{g_m}$$

$$\Rightarrow l_m = \frac{T_m^2 g}{4\pi^2}$$

$$\Rightarrow l_m = \frac{(2)^2 \times (1.62)}{4(3.14)^2}$$

$$\Rightarrow l_m = \frac{6.48}{39.44}$$

$$l_m = 0.61m$$

- (c) Frequency of pendulum at Earth $= f_e = ?$

We know that,

$$f_e = \frac{1}{2\pi} \sqrt{\frac{g_e}{l_e}}$$

Putting values, we get,

$$\Rightarrow f_e = \frac{1}{2(3.14)} \sqrt{\frac{9.8}{0.99}}$$

$$\Rightarrow f_e = \frac{3.146}{6.28}$$

$$f_e = 0.5 \text{ Hz}$$

- (iv) The Frequency of pendulum at Moon $= f_m = ?$

We know that,

$$f_m = \frac{1}{2\pi} \sqrt{\frac{g_m}{l_m}}$$

Putting value, we get,

$$\Rightarrow f_m = \frac{1}{2(3.14)} \sqrt{\frac{1.62}{0.16}}$$

$$\Rightarrow f_m = \frac{3.18}{6.28}$$

$$f_m = 0.5 \text{ Hz}$$

P4: Calculate the period and frequency of a propeller on a plane if it completes 250 cycles in 5.0 sec.

Solution:**Given data:**

Number of cycle $= N = 250 \text{ cycles}$

Time for 250 cycle $= t = 5 \text{ sec}$

Required:

- (a) Frequency $= f = ?$

Calculations: We know that

$$f = \frac{N}{T}$$

Putting value we get

$$\Rightarrow f = \frac{250}{5}$$

$$\Rightarrow f = 50 \text{ Hz}$$

- (b) Time period $= T = ?$

We know that

$$T = \frac{1}{f}$$

$$\Rightarrow T = \frac{1}{50}$$

$$\Rightarrow T = 0.02 \text{ sec}$$

Conclusion: Hence

(a) Frequency $= f = 50 \text{ Hz}$

(b) Time period $= T = 0.02 \text{ sec}$

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Harmonic Motion & waves

P5: Water wave with wavelength 2.8m produced in a ripple tank; travel with a speed of 3.80 m/Sec. what is the frequency of the straight vibrator that produced them?

Solution:

Given Data:

Wave length = $\lambda = 2.8\text{m}$
Speed wave = $v = 3.80\text{m/sec}$

Required:

Frequency of vibrator = $f = ?$

Calculation:

We know that;

$$\begin{aligned}\Rightarrow v &= f\lambda \\ \Rightarrow f &= \frac{v}{\lambda} \\ \Rightarrow f &= \frac{3.80}{2.8} \\ f &= 1.36 \text{ Hz}\end{aligned}$$

Conclusions: Hence;

Frequency of vibrator = 1.36Hz

P6: The distance between successive crests in a series of water waves is 4.0m, and the crests travel 9.0m in 4.5sec. What is the frequency of the waves?

Solution:

Given data:

Wavelength = $\lambda = 4\text{m}$
Distance = $S = 9\text{m}$
Time = $T = 4.5 \text{ Sec}$

$$\text{Speed} = v = \frac{s}{t} = \frac{9}{4.5} = \frac{2\text{m}}{\text{sec}}$$

Required:

Frequency of waves = $f = ?$

Calculation: We know that;

$$\begin{aligned}\Rightarrow v &= f\lambda \\ \Rightarrow f &= \frac{v}{\lambda}\end{aligned}$$

Putting value, we get;

$$\Rightarrow f = \frac{2}{4} = 0.5\text{Hz}$$

Conclusion: Hence,

Frequency of waves = $f = 0.5\text{Hz}$

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Harmonic Motion & waves

P7: A station broadcast an AM wave whose frequency is $1230 \times 10^3 \text{ Hz}$ (1230 KHz on the dial) and an FM radio waves whose frequency is 91.910^6 Hz (91.6MHz on dial). Find the distance between adjacent crests in each wave.

Solution:

Given data:

$$f_{(A.M)} = 1230 \times 10^3 \text{ Hz}$$

$$f_{(F.M)} = 91.910^6 \text{ Hz}$$

Speed of radio waves = $v = c = 3 \times 10^8 \text{ m/sec}$

Required:

Distance between adjacent crests in each case i.e.,

(a) $\lambda_{(A.M)} = ?$ and

(b) $\lambda_{(F.M)} = ?$

Calculation:

(a) For A.M waves:

We know that;

$$v = f\lambda$$

$$c = f_{(A.M)} \lambda_{(A.M)}$$

$$\Rightarrow \lambda_{(A.M)} = \frac{c}{f_{(A.M)}}$$

$$\Rightarrow \lambda_{(A.M)} = \frac{3 \times 10^8}{1230 \times 10^3}$$

$$\Rightarrow \lambda_{(A.M)} = 2.44 \times 10^2 \text{ m}$$

$$\lambda_{(A.M)} = 244 \text{ m}$$

(b) For F.M waves:

We know that,

$$\lambda_{(F.M)} = \frac{c}{f_{(F.M)}}$$

$$\Rightarrow \lambda_{(F.M)} = \frac{3 \times 10^8}{91.9 \times 10^6}$$

$$\lambda_{(F.M)} = 0.0326$$

Conclusion: Hence,

$$f_{(A.M)} = 3.26 \text{ m}$$

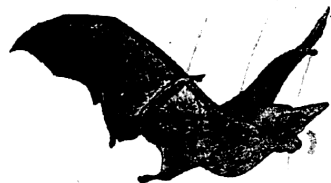
$$\text{And } f_{(F.M)} = 244 \text{ m}$$

Chapter No.11

Sound

Major Concepts

- How sound is produced, nature of sound.
- How sound is propagated.
- Characteristics of sound: loudness, intensity, pitch, quality, music and noise.
- Intensity sound level, its unit and formula
- Echo, speed of sound.
- Noise pollution, importance of acoustics.
- Audible frequency range.
- Ultrasound, uses of ultra sound.
- Solution of problems.



Comprehensive Question

Q1. What is sound? How it is produced, transmitted and received?

Ans. Sound:

The stimulus due to a sounding body capable of producing sensation of hearing is called sound.

Sound is a form of energy that travels through a medium in the form of longitudinal (or) compressional waves. When sound fall on ear membrane it produces a sensation of hearing.

Generation of sound:

Three things are necessary for the generation of sound.

- Vibrating body.
- Transmitting medium.
- Hearing device.

I. Vibrating body:

A vibrating body produces sound, therefore it is must. As the body vibrates it does work on the particles of the medium and set them in to vibration.

II. Transmitting medium:

The vibrating body does work on the particles of the medium and set them in to oscillations. Thus the vibrating body supplies the energy of its vibrations to the particles of the medium transmits this energy from the source to the receiver by means of alternate compression and rarefaction.

III. Hearing Device:

A device which can detect sound waves is known as hearing device (or) receiver. The human ear is the best receiver of sound waves, which converts the sound waves in to sensation of hearing.

Beside the human ears other mechanical and electrical devices have been made to detect and analyze the sound waves.

When the sound waves fall on ear, the energy of sound set the ear membrane of the ear in to vibrations. As ear is connected with brain, therefore hearing of sound occurs.

Q2. Define the terms loudness, intensity, pitch and quality of sound. Explain each term by giving examples?

Ans. In fact there are few fundamental characteristic of sound by means of which we can distinguish one sound from another sound. Following are the important characteristics of sound

- Loudness
- Intensity
- Pitch
- Quality

i. Loudness:

"The magnitude of auditory sensation produced by a sound is known as loudness." "OR"

"The characteristic of sound by which we can distinguish between a loud and faint sound is known as loudness"
Loudness directly depends upon intensity of sound.

ii. Intensity of sound:

The energy transmitted per unit time by sound wave through unit area placed perpendicular to the direction of propagation of waves is known of sound. "OR"

The power delivered by sound waves through unit area is called intensity of sound.

$$\text{Mathematically; } I = \frac{E}{At}$$

Unit:

W/m^2 is the SI unit of intensity of sound.

Factors on which intensity and Loudness Depends:

The intensity and loudness of sound depends on the following factors.

a) Amplitude of vibrating Body:

The increase in amplitude of vibrating body causes an increase in intensity and loudness of sound. For example, A drum produces a loud sound when its membrane is struck strongly while the sound is faint when the membrane is struck gently.

b) Frequency of vibrating Body:

The increase in frequency of vibrating body also causes an increase in the loudness of sound. For example, the sound produce by a thin taut membrane of a drum is louder that the sound produce by thick loose membrane of a drum.

c) Surface Area of vibrating body:

The increase in the surface area of the vibrating body causes an increase in the loudness of sound. For example, a dhool produces a louder sound as compared with dhoolac.

d) Distance between vibrating body and listener:

The loudness of sound also depends upon the distance from vibrating body. If the distance between the source and listener decrease the loudness of sound increase. If the distance between the listener and sources increase then the loudness of sound decrease.

e) Direction of wind:

The loudness of sound is greater when it travels in opposite direction of wind. But it seems faint if it travels in opposite direction of wind.

iii. Pitch of sound:

"The characteristic of sound by which a shrill sound is distinguished from flat (or) grave sound is known as pitch of sound."

Explanation:

The pitch sound directly depends upon the frequency of sound. Greater the frequency of sound, higher will be the pitch of sound and it will be a shriller sound.

For example:

Sound produce by birds, cats, children and women are of high pitch. While the sounds produce by dogs, frogs and men etc. are of low pitch.

iv. Quality of sound:

The characteristic of sound by mean of which we can distinguish between two sounds of same pitch and loudness, but originating from different instruments. Quality of sound depends on the resultant wave form of individual sound waves.

Example:

The note played by piano is quite different from the note played by clarinet of same loudness and pitch. Because the wave form of clarinet sound is rich in harmonics and of higher quality than that of piano. The wave form of clarinet and piano are given below.

Clarinet



Piano



Q3. What is intensity level? Describe the decibels scale for the intensity of different sound levels?

Ans. Intensity level:

The difference between the loudness "L" of unknown sound and the loudness "L₀" of the faintest audible Sound is called the intensity level of the unknown sound"

Notation:

Intensity level (or) sound level is denoted by " β "

Mathematical formula:

$$\beta = \log \frac{I}{I_0} (\text{bel})$$

$$\Rightarrow \beta = 10 \log \frac{I}{I_0} (\text{dB}) \quad (\because 1\text{bel}=10\text{dB})$$

Unit of intensity level:

The term intensity level was introduced by Alexander Graham Bell. Hence the unit of intensity level is derived from his name i.e. bel.

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Sound

"bel" is very large unit of intensity level. Generally a small unit called decibel (dB) is used.

$$1\text{ bel} = 10\text{ db}$$

The loudness (L) of a sound is directly proportional to the logarithm of intensity.

$$\begin{aligned} L &\propto \log I \\ \Rightarrow L &= (\text{constant}) \log I \\ \Rightarrow L &= k \log I \text{----- (1)} \end{aligned}$$

Where "k" is constant of proportionality. Let "L₀" be the loudness of the faintest audible sound of intensity "I₀" and "L" be the loudness of an unknown sound of intensity "I".

Equation (1) can be written as;

$$L_0 = k \log I_0 \text{----- (2)}$$

Subtracting eq (2) from eq (1);

$$\begin{aligned} L - L_0 &= k \log I - k \log I_0 \\ \Rightarrow L - L_0 &= k \log \frac{I}{I_0} \end{aligned}$$

$$\text{Sound level} = K \log \frac{I}{I_0}$$

$$\begin{aligned} \Rightarrow \beta &= K \log \left(\frac{I}{I_0} \right) \\ \Rightarrow \beta &= K \log \frac{I}{I_0} \quad (\because K=1) \\ \Rightarrow \beta &= K \log \frac{I}{I_0} (\text{Bel}) \text{----- (3)} \end{aligned}$$

Since; 1Bel=10db. So eq(3) becomes;

$$\Rightarrow \beta = 10 \log \frac{I}{I_0} (\text{db}) \text{----- (4)}$$

Thus by using eq(4) we can construct a scale for measuring the intensity of sound. Such scale is known as "decibel scale."

Table 11.2 : Logarithmic intensity levels and sound intensity:

Source	Intensity level (db)	Intensity (w/m ²)
Threshold of hearing	0	10 ⁻¹²
Normal breathing	10	10 ⁻¹¹
Average whisper at 2 m	20	10 ⁻¹⁰
Empty theatre	30	10 ⁻⁹
Residential area at night	40	10 ⁻⁸
Quiet restaurant	50	10 ⁻⁷
Two person conversation	60	10 ⁻⁶

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Busy street traffic	70	10 ⁻⁵
Vacuum cleaner	80	10 ⁻⁴
Loud stereo in average room	90	10 ⁻³
Maximum level in concert hall (13 th row)	100	10 ⁻²
Pneumatic chisel	110	10 ⁻¹
Maximum level at some rock concerts	120	10 ⁰
Propeller plane taking off	130	10 ⁺¹
Threshold of pain	140	10 ⁺²
Military jet taking off	150	10 ⁺³
Wind tunnel	160	10 ⁺⁴
Instant perforation of the eardrum	170	10 ⁺⁵

Q 4. What is the speed of sound?

Ans. Speed of sound:

The speed of sound is defined as,

"The distance covered by the sound waves in unit time is called speed of sound."

Mathematical formula:

$$\text{speed} = \frac{\text{Distance}}{\text{Time}}$$

$$\text{Or } V = \frac{S}{T}$$

Sound, like all waves, travel at a certain speed and has the properties of frequency and wavelength. At 20°C, the speed of sound in air is 343m/sec. Sound can be transmitted through any medium-gas, liquid or solid.

The speed of sound in Air:

The speed of sound in air depends upon the density of air and its compressibility. As temperature increases, these properties change causing the speed of sound in air to increase with temperature. At a temperature of °C and a pressure of 101KPa (1atm pressure), the speed of sound in dry air is 331m/sec and for each 1°C rise in temperature, the speed of sound increases approximately by 0.6 m/sec.

Mathematically;

$$V = 331 + 0.6T \text{----- (1)}$$

If T= 20°C, then,

$$\Rightarrow V = 331 + (0.6) (20)$$

$$\Rightarrow V = 343 \text{ m/sec}$$

We know that;

$$V = f\lambda \text{----- (2)}$$

Equation (2) implies that, the speed of sound is the same for all frequencies. For example, if the frequency of a wave is doubled, its wavelength is halved, so that the speed of sound "V" stays the same.

Table 11.3: The speed of sound

State	Materials	Speed at 0°C (m/s)
Solid	Aluminum	5104
	Glass	5050
	Steel	5050
	Maple wood	4110
	Bone (human)	4040
	Pine wood	3320
Solid / liquid	Brain	1530
Liquid	Fresh water	1493(at 25°C)
	Sea water	1470
	Alcohol	1241
Gas (at atmospheric pressure)	Hydrogen	1270
	Helium	970
	Nitrogen	350(at 20°C)
	Air	332
	Oxygen	317
	Carbon dioxide	258

Q 5: Differentiate between musical sound and noise?

Ans. Musical sound:

Definition:

"Sounds which have pleasing effect on our ears are called musical sounds".

- ❖ For example, Sounds produced by musical instruments such as flute, harmonium, Violin, drum etc.
- ❖ Musical sounds have regular wave form.
- ❖ Musical sounds have definite amplitude and frequency which make them pleasant.



Noise:

Definition:

"Sound which has jarring and unpleasant effect on our ears are called noise".

- ❖ For example, the sound produces by the rattling of heavy machinery and buses in big cities. The sound produce by hammering in factories has jarring effect.
- ❖ Noise corresponds to irregular and sudden vibrations produced by some sounds.
- ❖ Wave form of noise is very irregular and is sudden change.
- ❖ Changing in frequency and amplitude is also sudden and irregular.



Q 6. What is noise? Explain why noise is nuisance?

Ans. Noise:

"Noise is an undesirable sound that is harmful for health of human and other species." (OR)

"Noise is that sound which disrupts the normal functioning of life."

Effect of Noise:-

Noise has negative effects on human health such as;

- (i) Hearing loss
- (ii) Sleep disturbance
- (iii) Aggression
- (iv) Hypertension,
- (v) High stress levels, restlessness depression and insomnia
- (vi) Anxiety increase with increase of noise which effect badly temper and emotional stress.

Sources Noise pollution:

Noise pollution has become a major issue of concern in big cities. Main sources of noise pollution are as follows,

- i. Transportation equipment and heavy machinery in industrial areas.
- ii. Loud vehicle horns, hooters and alarms.
- iii. Air planes, trains and ships are loud sounds transport model.
- iv. Work on construction sites in urban areas i.e. grilling and piercing sound

Recommended level of Noise:

Recommended level of noise in most countries is usually 85-90dB over an eight hour work day. The WHO (world health organization) has recommended that noise during sleep should be limited to a level of 35dB.

Q7: Define and explain term ECHO (reflection of a sound) and reverberation? Also calculate the minimum distance for echo to be heard?

Ans. Echo (Reflection a sound):

"The repetition of a sound by reflection of sound waves from a surface is known as echo."

Explanation:

When a person shouts in a big empty hall, we first hear his original sound. After a little while, we hear the reflected sound of the shout. This reflected sound is an echo. This when we hear an echo, we are actually hearing a reflected sound. Hence an echo is simply a reflected sound.

Factors:

Echo depends on the following factors.

- Echo depends upon the nature of reflecting surface
- Echo depends upon the temperature of the medium in which sound waves travel.
- Echo depends upon distance between source of sound and reflecting surface.

Reverberation:

"The presence of sound after the sounding source has stopped is known as reverberation."

The reverberation causes a general confusion to the sound impressions on the ear. To avoid such problem we should use sound absorbing things in the halls and rooms.

Minimum Distance for an echo to be heard:

The sensation of sound persists in our brain for about 0.1 second. To ear a clear echo the time interval between our sound and the reflected sound must be at least 0.1s. If we consider the speed of sound in air at normal temperature is 340ms^{-1} , then we hear echo after 0.1s.

Total distance covered by sound from the point of generation to the reflecting surface and back should must be 34m i.e

$$\begin{aligned} S &= vt \\ \Rightarrow S &= (340\text{ms}^{-1})(0.1\text{s}) \\ \Rightarrow S &= 34\text{m}. \end{aligned}$$

Thus for hearing distinct echoes, the minimum distance of the reflecting surface (obstacle) from the source of sound must be half of this distance i.e.

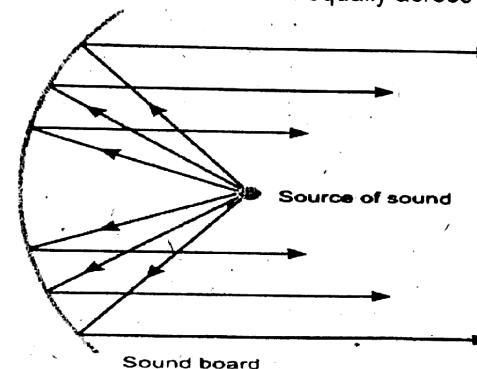
$$\begin{aligned} d &= \frac{S}{2} \\ \Rightarrow d &= \frac{34\text{m}}{2} \\ \Rightarrow d &= \frac{34\text{m}}{2} \\ d &= 17\text{m} \end{aligned}$$

Q8. Define acoustic protection. Explain the importance of acoustics?**Ans. Acoustic protection:**

The technique or method used to absorb undesirable sounds by soft and porous surface is called acoustic protection.

Importance of acoustics:

- Reflection of sound is more prominent if the surface is rigid and smooth.
- Reflection of sound is less if the surface is soft and irregular.
- Soft porous material such as draperies and rugs absorb large amount of sound energy and thus quit echoes and softening noises.
- By using soft and sound insulating materials such as curtains, carpets and double glazed windows we can reduce the level of noise pollution.
- If surface of the class rooms and public halls are too absorbent, then sound level is low for audience.
- If the surface of class rooms and public halls is reflective then sound becomes garbled.
- Garble sound is the result of multiple reflection which is called reverberations.
- In the design of lecture halls, auditorium, theater halls, a balance must be achieved between absorption and reverberation.
- It is useful to place reflective surfaces behind the stage to direct sound to the audience.
- Generally the ceilings of lecture halls, Conference halls and theater halls are curved so that sound after reflection may reach to all corners of the hall.
- Sometime curved sound boards are placed behind the stage so that sound after reflection distributed equally across the hall.



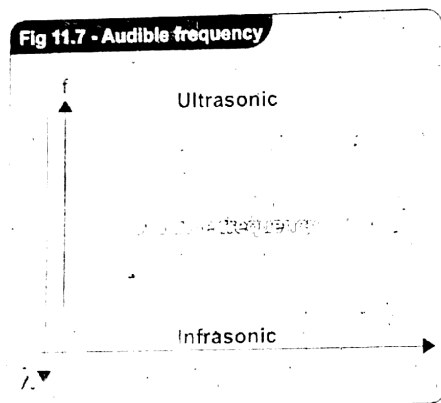
Q 9. What is audible frequency range?

Ans. Audible Frequency range:

"The frequency range to which a normal human ear is sensitive is known as audible frequency range"

A typical human ear can hear only those sounds whose frequency ranges from 20Hz to 20,000Hz (20KHz).

Physicists have established a three-part classification of sound, based on the range of human hearing. Sound frequency lower than 20Hz are referred to as infrasonic, those in the 20Hz to 20,000Hz range are audible, and those higher than 20,000Hz are ultrasonic as shown in figure.



Q10. What are Ultrasound and infrasound? Write the uses of ultrasound?

Ans. Ultrasound:

Definition:

"Sound of frequency higher than 20,000Hz which is inaudible to normal human ear are called ultrasound or ultrasonic."

Infrasound:

Definition:

"Sound of frequency less than 20Hz are called infrasound or infrasonic."

Uses of Ultrasound:

- Ultrasonic Waves carry more energy and higher frequency than audible sound waves. Therefore, according to the wave equation $v = f\lambda$ the wave length of ultrasonic waves is very small and is very useful for detecting very small objects.

- Ultrasonic are utilized in medical and technical fields.
- In medical field ultrasonic waves are used to diagnose and treat different ailments. For diagnosis of different diseases ultrasonic waves are made to enter the human body through transmitters. These waves are reflected differently by different organs, tissues or tumors etc. the reflected waves are then amplified to form an image of the internal organs to the body on the screen. Such an image helps in detecting the defects in these organs.
- Powerful ultrasound is now being used to remove blood clots formed in the arteries.
- Ultrasound can also be used to get the pictures of thyroid gland for diagnosis purposes.
- Ultrasound is used to locate underwater depths or is used for locating objects lying deep on the ocean floor etc. the technique is called SONAR (sound navigation and ranging). The sound waves are sent from a transmitter, and a receiver collects the reflected sound. The time lapse is calculated knowing the speed of sound in water, the distance of the object from the ocean surface can be estimated.
- SONAR ranging is also used to see the shape and the size of the object.

Cracks appear in the interior of moving parts of high speed heavy machines such as turbines, engines of ships and airplanes due to excessive use. These cracks are not visible from outside but they can be very dangerous. Such cracks can be detected by ultrasound. A powerful beam of ultrasound is made to pass through these defective parts. While passing these waves are reflected by the surface of these cracks and flaws. The comparison of the ultrasonic waves reflected from cracks and from the surfaces of these parts can give a clue of the existence of the cracks.

- Germes and bacteria in liquids can also be destroyed by using high intensity ultrasonic wave.

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Examples

Example 11.1: Show that if one sound is twice as intense as another. About what factor is the sound level (in dB) higher?

Solution:

Given: intensity of 1st sound = $I_1 = I$
Intensity of 2nd Sound = $I_2 = 2I$

Required:

Intensity level = $\Delta\beta = ?$

Calculation:

We know that;

$$\begin{aligned}\Delta\beta &= 10 \log \frac{I_2}{I_1} \\ \Rightarrow \Delta\beta &= 10 \log \frac{2I}{I} \\ \Rightarrow \Delta\beta &= 10 \log 2 \\ \Rightarrow \Delta\beta &= 10 \times 0.301 \\ \Delta\beta &= 3.01 \text{ dB}\end{aligned}$$

Conclusion: Hence;

Intensity level = 3.01 dB

Example 11.2:

You are standing at 1.5 Km from the cannon with a stop watch. You start the stopwatch when you see the cannon flash and stop it when the sound is heard. The time recorded on your stopwatch is 4.4 sec, what is the speed of sound? What is this speed in km/hr.

Solution:

Given:

Distance "S" = 1.5 km = 1500 m
Time "T" = 4.4 sec

Required:

- (a) Speed of sound "V" = ?
(b) Speed of sound in Km/h = ?

Calculation:

(a) Speed of sound "V":

We know that;

$$V = \frac{S}{T}$$

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Putting value;

$$\Rightarrow V = \frac{1500}{4.4}$$

$$\Rightarrow V = 340.90 \text{ m/sec}$$

$$\Rightarrow V = 341 \text{ m/sec}$$

(b) Speed in km/h:

$$\Rightarrow V = 341 \times \frac{3600}{1000}$$

$$\Rightarrow V = 341 \times 3.6$$

$$V = 1227.6 \text{ Km/h} = 1228 \text{ Km/h}$$

Conclusion: Hence;

(a) Speed of sound in m/sec = 341 m/Sec

(b) Speed of sound in Km/h = 1228 km/h

Example 11.3:

What is the wavelength of the sound in dry air if its frequency is 590 Hz on a hot day with temperature of 40°C?

Solution:

Given:

Temperature = $T = 40^\circ\text{C}$

Frequency "f" = 590 Hz

Required:

Wavelength = $\lambda = ?$

Calculation:

Since speed of sound at 0°C is 331 m/sec and for each one degree Celsius rise in temperature, the speed of sound increases by 0.6 m/sec. Therefore,

$$V = 331 + 0.6T$$

$$\Rightarrow V = [331 + 0.6 \times 40] \text{ m/Sec}$$

$$\Rightarrow V = [331 + 24] \text{ m/Sec}$$

$$\Rightarrow V = 355 \text{ m/Sec}$$

Now;

$$V = f\lambda$$

$$\Rightarrow \lambda = \frac{V}{f}$$

$$\Rightarrow \lambda = \frac{355}{590}$$

$$\lambda = 0.6 \text{ m}$$

Conclusion:

Hence;

Wavelength of wave = $\lambda = 0.6 \text{ m}$

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Example 11.4

During a winter camp on pipe line track from Donga Gali to Ayubia Aalia shouts at a cliff and hears her echo after 15 Sec. She records the temperature on her personal thermometer as 3C° . How far is the cliff from her?

Solution:**Given:**

Time = $\Delta t = 1.5\text{Sec}$
Temperature = $T = 3\text{C}^\circ$

Required:

Distance of cliff from Aalia = $S = ?$

Calculation:

We know that;

$$\begin{aligned} V &= 331 + 0.6T \\ \Rightarrow V &= 331 + 0.6 \times 3 \\ \Rightarrow V &= 331 + 1.8 \\ \Rightarrow V &= 332.8 \\ \Rightarrow V &= 333\text{m/sec} \end{aligned}$$

Now;

$$V = \frac{d}{t} \text{----- (1)}$$

For an echo; $d = 2S$ put in (1)

$$\begin{aligned} \Rightarrow V &= \frac{2S}{t} \\ \Rightarrow S &= \frac{V \times t}{2} \\ \Rightarrow S &= \frac{333 \times 1.5}{2} \\ \Rightarrow S &= 249.75 \\ S &= 250\text{m} \end{aligned}$$

Conclusion:

Hence distance of cliff from Aalia = $S = 250\text{m}$

Assignment

Assignment 11.1: Suppose that when a certain sound intensity level (dB) triples, the sound intensity (in W/m^2) also triples. Determine this sound intensity level

Solution:**Given:**

$$I = 3I_0$$

Required:

$$\text{Intensity level} = \Delta\beta = ?$$

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Calculation:

We know that;

$$\begin{aligned} \Delta\beta &= 10 \log\left(\frac{I}{I_0}\right) \\ \Rightarrow \Delta\beta &= 10 \log\left(\frac{3I_0}{I_0}\right) \quad (\because I = 3I_0) \\ \Rightarrow \Delta\beta &= 10 \log(3) \\ \Rightarrow \Delta\beta &= 10 \times 0.477 \\ \Delta\beta &= 4.77\text{dB} \end{aligned}$$

Conclusion: Hence;

Sound intensity level = $\Delta\beta = 4.77$

Assignment 11.2: If the time between seeing lightning and hearing the thunder is 5.0sec. The speed of sound is 343m/sec; How far away is the lightning?

Solution:**Given:**

Time = $T = 5.0\text{Sec}$
Speed of sound = $V = 343\text{m/sec}$

Required:

Distance of lightning = $S = ?$

Calculation:

We know that;

$$\begin{aligned} \Rightarrow V &= \frac{S}{T} \\ \Rightarrow S &= VT \\ \Rightarrow S &= (343)(5) \\ S &= 1715\text{m} = 1.715\text{km} \end{aligned}$$

Conclusion: Hence,

Distance of lightning = $S = 1715\text{m} = 1.715\text{km}$

Assignment 11.3: What is the frequency of sound with wave length 0.25m in air with temperature of 32C° ?

Solution:**Given:**

Wavelength = $\lambda = 0.25\text{m}$
Temperature = $T = 32\text{C}^\circ$

Required:

Frequency " f " = ?

Calculation:

We know that;

$$\begin{aligned} \Rightarrow V &= 331 + 0.6T \\ \Rightarrow V &= 331 + 0.6 \times 32 \end{aligned}$$

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$$\Rightarrow V = 331 + 19.2$$

$$\Rightarrow V = 350.2 \text{ m/Sec}$$

$$\Rightarrow V = 350 \text{ m/Sec}$$

Now,

$$V = f\lambda$$

$$\Rightarrow f = \frac{V}{\lambda}$$

Putting value, we get,

$$\Rightarrow f = \frac{350}{0.25}$$

$$f = 1400 \text{ Hz}$$

Conclusion: Hence,Frequency of sound $= f = 1400 \text{ Hz}$

Assignment 11.4: A man stands in between two parallel cliffs and fires a gun; he hears two successive echoes after 3sec and 5sec. What is the distance between Cliffs?

Solution:**Given:**Time for 1st echo $= t_1 = 3 \text{ Sec}$ Time for 2nd echo $= t_2 = 5 \text{ Sec}$ Speed of sound $= V = 330 \text{ m/sec}$ **Required:** Distance between man and 1st cliff: $S_1 = ?$ Distance between man and 2nd cliff: $S_2 = ?$ Distance between the two cliff $= S = ?$ **Calculation:****(a) Distance between man and 1st Cliff:**

We know that,

$$\Rightarrow S_1 = \frac{V \times T_1}{2}$$

$$\Rightarrow S_1 = \frac{330 \times 3}{2}$$

$$\Rightarrow S_1 = 295 \text{ m}$$

(b) Distance between man and 2nd Cliff:

We know that,

$$\Rightarrow S_2 = \frac{V \times T_2}{2}$$

$$\Rightarrow S_2 = \frac{330 \times 5}{2}$$

$$\Rightarrow S_2 = 825 \text{ m}$$

(c) Distance between the two cliff:

$$\Rightarrow S = S_1 + S_2$$

$$\Rightarrow S = 295 + 825$$

$$\Rightarrow S = 1120 \text{ m}$$

Conclusion: Hence,Distance between the two Cliffs $= S = 1120 \text{ m}$

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EXERCISE

1. Choose the correct answer for each of the following;

- The intensity of a sound wave increase by 1000 W/m^2 . What is this increase equal to in decibels?
a. 10 b. 20 c. 30 d. 40
- An echo occurs when a sound wave is
a. Absorbed b. transmitted
c. refracted d. **reflected**
- Compared with a sound of 60 decibels, a sound of 80 decibels has an intensity _____ times Greater.
a: 10 b. **100** c. 1000 d. 10000
- The loudness of a sound is most closely related to its _____.
a. Frequency b. period c. wavelength d. **amplitude**
- Various instruments sound different even when they play the same note due to different in _____.
a. Pitch b. loudness c. **quality** d. intensity
- Humans can hear sound that is _____.
a. Less than 20 Hz b. **between 20 Hz and 20 kHz**
c. greater than 20 kHz d. none
- The speed of sound on a warm day when the outdoor temperature is 38°C is _____.
a. 331 m/s b. 345 m/s c. **354 m/s** d. 362 m/s
- Minimum echo distance is reduced in _____.
a. Summer b. **winter** c. spring d. space
- Which of the following cannot transmit sound _____.
a. Solid b. liquid c. gas d. **vacuum**

Conceptual Questions

Q1. Why sound produced by a simple pendulum is not heard?**Ans. Sound produce By a Simple pendulum:**

The sound produce by a simple pendulum is not heard because the frequency of sound produced by simple pendulum is less than 20Hz and human ear drum cannot vibrate with sounds whose frequency is less than 20Hz and greater than 20KHz. Therefore the sound produce by a simple pendulum not heard.

Q2. If a ringing bicycle bell is held tightly by hand, it stops producing sound, why?

Ans. Sound produces by ringing bicycle bell:

A ringing bicycle bell produces sound due to vibrations. If the ringing bicycle bell is held tightly by hand, the vibrations of the bicycle bell stop which stops to produce sound. Thus the ringing bicycle bell stops to produce sound, when a ringing bicycle bell is held tightly by hand.

Q3. Why is the intensity of an echo less than that of the original sound?

Ans. Intensity of an Echo:

The intensity of an echo is less than that of the original sound.

Reason:

When the sound strikes with wall, it transfers some of its energy to the wall. Thus the reflected sound possesses less energy and becomes less intense. Therefore the intensity of an echo is less than that of the original sound.

Q4. In which medium air (or) water an echo is heard sooner. Why?

Ans. An echo is heard sooner in water as compare to air.

Reason:

An echo is heard sooner in water as compare to air because the speed of sound in water is greater than the speed of sound in air. Therefore the sound Waves travel faster in water as compare to air. Hence an echo can be heard sooner in water than air.

Q5. Why sound cannot be heard on moon?

Ans. Sound cannot be heard on Moon due to the following reason.

Reason:

Sound waves are longitudinal waves, which require a material medium for propagation. As in Moon, there is no material medium, therefore sound cannot travel through moon atmosphere and thus sound cannot be heard on moon.

Q6: If a person places his ear on rails of railroad for determination of coming train, why is this done and how does it work?

Ans: A person can hear the sound of coming train by placing ear on the railway track even if it is quite far away.

Reason:

Sound waves travel faster in solids as compare to gases. At STP[0c°(or)32F°, 100 Kpa(or)1bar], the speed of sound in air is 332m/sec while the speed of sound in steel (railway track) is about 5100m/sec. Thus the speed of in railway track (steel) is 15 times faster than air. Therefore, if a person places ear on the rails of railroads, he can hear the sound of coming train long before he sees it.

Q7. When you watch a thunderstorm, you see the lighting first, and you hear the thunder afterward. Why is the thunder delayed?

Ans. When we watch a thunderstorm, we see the lightning first, and we hear the thunder afterward due to the following reason.

Reason:

The lightning and thunder occur at the same time in a thunder storm but we see the lighting first and we hear the thunder afterward because light travels much faster than sound in air. The speed of light in air is $3 \times 10^8 \text{ m/sec}$ while that of sound is 340 m/sec. Therefore, when we watch a thunderstorm; we see the lightning first and hear the thunder afterward.

Q8. If the speed of sound is dependent on frequency, would music from marching band be enjoyed?

Ans. The speed of sound in an ideal gas depends only on temperature and properties of the medium. The important property of sound is that, its speed is nearly independent of frequency. This independence is true in open air for sounds in the audible range of 20Hz to 20000Hz.

If this independence were not true, we would certainly notice it for music played by a marching band. Thus, it will not be possible for us to enjoy the music played by a marching band, if the speed of sound is dependent of frequency.

Q9. Why does your voice sound fuller in the shower?

Ans. The sound in a shower is fuller due to the following reasons.

- (i) Most showers are made up of tiles, plastic (or) other non- absorbent surfaces. The multiple reflections from these non-absorbent surfaces enrich the sound and make our voice sound fuller.
- (ii) Reverberation occurs when our ear picks many echoes in a very short interval of time. This reverberation makes our voice sound fuller.
- (iii) Resonance occurs when the frequency of sound waves matches the frequency of the shower and as a result we hear loud sound. This resonance makes our voice sound fuller

Q10. Why is it so quiet after a snowfall?

Ans. Snow absorbs sound. When light, fluffy and porous accumulates on the ground, it acts as a sound absorber. Due to its porous nature, a very little sound energy is reflected when sound waves hit against the snow surface. Sound waves enter in to snow surface and make multiple reflections, due to which a substantial amount of sound energy is absorbed. Thus there is so quiet after a snowfall.

Numerical Problems

P1: The sound intensity 3m from a jackhammer is $8.2 \times 10^{-2} \text{ W/m}^2$. What is the sound intensity level in decibels? Use the useful reference level of $I_0 = 1 \times 10^{-12} \text{ W/m}^2$.

Solution:

Given:

Intensity of sound = $I = 8.2 \times 10^{-2} \text{ W/m}^2$
Reference of intensity = $I_0 = 1 \times 10^{-12} \text{ W/m}^2$

Required: Intensity level = $\Delta\beta = ?$

Calculation:

We know that;

$$\begin{aligned}\Rightarrow \Delta\beta &= 10 \log \frac{I}{I_0} \\ \Rightarrow \Delta\beta &= 10 \log \left(\frac{8.2 \times 10^{-2}}{1 \times 10^{-12}} \right) \\ \Rightarrow \Delta\beta &= 10 \log (8.2 \times 10^{10}) \\ \Rightarrow \Delta\beta &= 10 \times 10.9138 \\ \Delta\beta &= 109.138 \text{ dB}\end{aligned}$$

Conclusion: Hence;

Intensity level = $\Delta\beta = 109.138 \text{ dB}$

P2: A ship is anchored where the depth of water is 120m. An ultrasonic signal sent to the bottom of the lake returns in 0.16Sec. What is the speed of sound in water?

Solution:

Given:

Depth of water = $S = 120 \text{ m}$

Total Time = $T = 0.16 \text{ Sec}$

Time taken by the ultrasonic signals to reach the bottom of water = $t = \frac{T}{2}$

$$\Rightarrow t = \frac{0.16}{2}$$

$$\Rightarrow t = 0.08 \text{ sec}$$

Required:

Speed of sound = $V = ?$

Calculation:

We know that;

$$\Rightarrow V = \frac{S}{t}$$

$$\Rightarrow V = \frac{120}{0.08}$$

$$\Rightarrow V = 1500 \text{ m/sec}$$

Conclusion: Hence;

Speed of sound in water = $V = 1500 \text{ m/sec}$

P3: A gun shoot from 9.22rimfire rifle has an intensity of about $I = (2.5 \times 10^{13}) I_0$. Do we need to wear ear protection? (Considering that prolonged exposure to sounds above 85 decibels can cause hearing damage or loss.)

Solution:

Given:

Intensity = $I = 2.5 \times 10^{13} I_0$

Safe intensity level limit = 85 dB

Required:

(a) Intensity level = $\Delta\beta = ?$

(b) Do we need to wear ear protection = ?

Calculation:

(a) Intensity level:

We know that;

$$\text{Intensity level} = \Delta\beta = 10 \log \frac{I}{I_0}$$

Putting values, we get;

$$\Rightarrow \Delta\beta = 10 \log \frac{2.5 \times 10^{13} I_0}{I_0}$$

$$\Rightarrow \Delta\beta = 10 \log (2.5 \times 10^{13})$$

$$\Rightarrow \Delta\beta = 10 \times 13.39$$

$$\Rightarrow \Delta\beta = 133.9$$

$$\Delta\beta = 134 \text{ dB}$$

(b) Ear protection:

Since safe intensity level limit is 85 dB , this 134 dB is too greater than 85 dB . Therefore we need to wear ear protection.

P4: What sound intensity level is dB is produced by earphones that create an intensity of $4.00 \times 10^{-2} \text{ W/m}^2$? Use the usual reference level of $I_0 = 1.00 \times 10^{-12} \text{ W/m}^2$

Solution:

Given:

$I = 4 \times 10^{-2} \text{ W/m}^2$

$I_0 = 1 \times 10^{-12} \text{ W/m}^2$

Required:

Intensity level = $\Delta\beta = ?$

Calculation:

We know that;

$$\Delta\beta = 10 \log \frac{I}{I_0}$$

Putting value, we get;

$$\Rightarrow \Delta\beta = 10 \log \left(\frac{4 \times 10^{-2}}{1 \times 10^{-12}} \right)$$

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$$\Rightarrow \Delta\beta = 10 \log (4 \times 10^{10})$$

$$\Rightarrow \Delta\beta = 10 \times 10.602$$

$$\Delta\beta = 106.02 \text{ dB}$$

Conclusion:

Hence; Intensity level of sound = $\Delta\beta = 106.02 \text{ dB}$

P5: What is the speed of sound in air at -20°C ?

Solution:

Given: Temperature = $T = -20^\circ\text{C}$

Required:

Speed of sound = $V = ?$

Calculation:

We know that;

$$\Rightarrow V = 331 + 0.6T$$

$$\Rightarrow V = [331 + (0.6)(-20)]$$

$$\Rightarrow V = 331 - 12$$

$$V = 319 \text{ m/sec}$$

Conclusion: Hence;

Speed of sound at $-20^\circ\text{C} = V = 319 \text{ m/sec}$

P6: Army man wearing binoculars to see the flash from enemy tank fire "5 Sec" before the fire heard, he records 26°C Temperature on his personal thermometer. What is the distance of the tank from him?

Solution:**Given:**

Time = $T = 5 \text{ Sec}$
Temperature = $T = 26^\circ\text{C}$

Require:

Distance of the tank = $S = ?$

Calculation:

We know that;

$$\Rightarrow V = \frac{S}{t}$$

$$\Rightarrow S = vt$$

$$\Rightarrow S = (331 + 0.6T)t \quad (\because V = 331 + 0.6T)$$

$$\Rightarrow S = \{331 + (0.6)(26)\}(5)$$

$$\Rightarrow S = 346.6 \times 5$$

$$\Rightarrow S = 1733 \text{ m}$$

$$\Rightarrow S = 1.733 \text{ Km}$$

Conclusion: Hence;

Distance of tank = $S = 1.7 \text{ Km}$

Shams Notes

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Sound

P7: Calculate the wavelengths of sounds at the extremes of the audible range, 20Hz and 20000Hz, at normal room temperature of 20°C ?

Solution:**Given:**

Minimum Audible frequency = $f_1 = 20 \text{ Hz}$

Maximum Audible Frequency = $f_2 = 20000 \text{ Hz}$

Temperature = $T = 20^\circ\text{C}$

Required:

(a) Maximum Audible Wave length = $\lambda_1 = ?$

(b) Minimum Audible wavelength = $\lambda_2 = ?$

Calculation:

(a) Maximum Audible Wavelength(λ_1):

We know that;

$$\Rightarrow V = f\lambda$$

$$\Rightarrow \lambda = \frac{V}{f}$$

$$\Rightarrow \lambda_1 = \frac{V}{f_1}$$

$$\Rightarrow \lambda_1 = \frac{331 + 0.6T}{f_1} \quad (\because V = 331 + 0.6T)$$

Putting values, we get;

$$\Rightarrow \lambda_1 = \frac{331 + (0.6)(20)}{20}$$

$$\Rightarrow \lambda_1 = \frac{331 + 12}{20}$$

$$\Rightarrow \lambda_1 = \frac{343}{20}$$

$$\Rightarrow \lambda_1 = 17.15 \text{ m} \quad \text{OR} \quad \lambda_1 = 17 \text{ m}$$

(b) Minimum Audible Wavelength(λ_2):

We know that;

$$\Rightarrow V = f\lambda$$

$$\Rightarrow \lambda = \frac{V}{f}$$

$$\Rightarrow \lambda_2 = \frac{V}{f_2}$$

$$\Rightarrow \lambda_2 = \frac{331 + 0.6T}{20000}$$

$$\Rightarrow \lambda_2 = \frac{331 + (0.6)(20)}{20000}$$

$$\Rightarrow \lambda_2 = \frac{331 + 12}{20000}$$

$$\Rightarrow \lambda_2 = \frac{343}{20000}$$

$$\Rightarrow \lambda_2 = 0.017 \text{ m} \quad \text{OR} \quad \lambda_2 = 1.7 \text{ cm}$$

Conclusion:

Hence:

(a) Maximum Audible Wavelength = $\lambda_1 = 17m$

(b) Minimum Audible wavelength = $\lambda_2 = 1.7cm$

P8: Ishfaq stands between two high rise buildings "A" and "B", such that he is at 33m distance from building "A" when he blows the whistle, he hears the first echo after 0.2 sec and second echo after 0.8sec. Calculate

- (a) The speed of sound and
(b) Distance of building "B" from him.

Solution:**Given:**

Time for 1st echo = $T_1 = 0.2Sec$

Time for 2nd echo = $T_2 = 0.8Sec$

Distance of Ishfaq from building "A" = $S_1 = 33m$

Required:

- (a) Speed of sound = $V = ?$
(b) Distance of Ishfaq from building "B" = $S_2 = ?$

(a) Speed of sound (V):

Time taking by sound of whistle to reach building "A"

$$\Rightarrow t_1 = \frac{T_1}{2} = \frac{0.2}{2} = 0.1$$

$$\Rightarrow t_1 = 0.1$$

Now, we know that

$$V = \frac{S_1}{t_1}$$

$$\Rightarrow V = \frac{33}{0.1}$$

$$V = 330m/Sec$$

(b) Distance of Ishfaq from Building "B":

Time taken by sound of whistle to reach building "B"

$$t_2 = \frac{T_2}{2} = \frac{0.8}{2} = 0.4Sec$$

$$\Rightarrow t_2 = 0.4Sec$$

Now, we know that:

$$\Rightarrow V = \frac{S_2}{t_2}$$

$$\Rightarrow S_2 = Vt_2$$

$$\Rightarrow S_2 = (330)(0.4)$$

$$\Rightarrow S_2 = 132m$$

Conclusion: Hence:

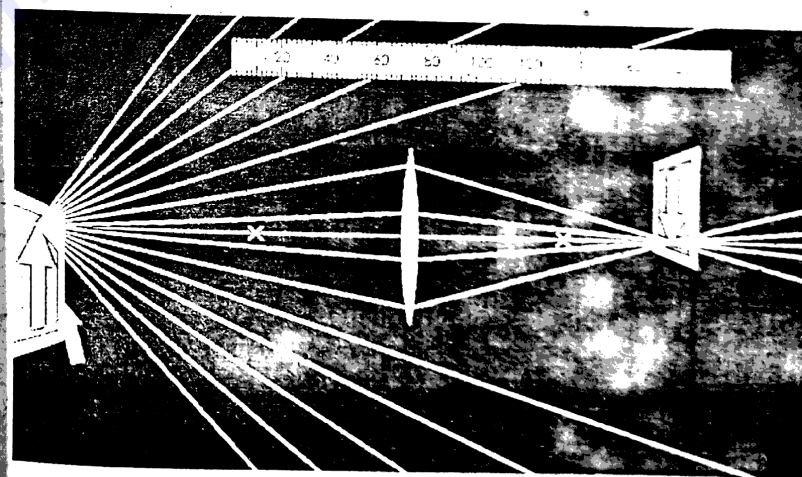
- (a) Speed of sound = $V = 330m/sec$
(b) Distance of Ishfaq from Building "B" = $S_2 = 132m$

Chapter No.12

Geometrical Optics

Major Concepts

- Reflection of light
- Spherical mirrors and their types
- Important terms related to mirrors
- Sign conventions
- Refraction of light
- Total internal reflection of light
- Refraction through prism
- Ray diagram of lenses
- Application of lenses
- Totally reflecting prism and optical fibre
- Simple microscope
- Compound microscope
- Telescope
- The human eye
- Accommodation, near point and far point
- Defects of vision (myopia and Hypermetropia)
- Solution of problems



Comprehensive Question

Q1. What is meant by reflection of light? State and explain laws of reflection with diagram?

Ans. Reflection of light:

The bouncing back of light rays from the surface of a certain medium is called reflection of light.

Explanation:

Consider a plane surface "MM'" as shown in the figure.

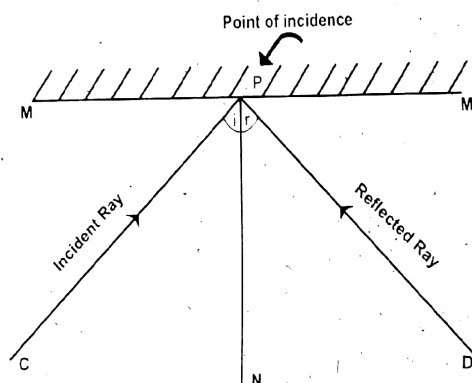


Fig: Reflection of light

Let a ray of light coming from the point "C" is allowed to fall on point "P" of the plane surface. This ray "CP" is known as incidence ray. The angle made by the incidence ray is known as angle of incidence ($\angle i$). During this process some light rays reflect from the surface at point "P" which is known as reflected ray. The angle made by the reflected ray with normal is known as angle of reflection ($\angle r$).

Now from the figure it is clear that; The angle of incidence is equal to the angle of reflection.

- The incident ray, reflected ray, and the normal lies in the same plane.

Law of reflection of light:

History:

The laws of reflection of light were first discovered by a Muslim scientist named Ibn-al-Haitham. There are two laws of reflection which are given below.

a) 1st Law of reflection light:

This law states that "The angle of incidence " $\angle i$ " is equal to the angle of reflection " $\angle r$ " i.e., $\angle i = \angle r$

b) 2nd Law of Reflection:

This law states that, "The incident ray, reflected ray and normal at the point of incidence all lies in the same plane."

Q2: What is mirror? Describe types of spherical mirrors?

Mirror:

The smooth and polished surface of a medium which reflect rays of light is called mirror.

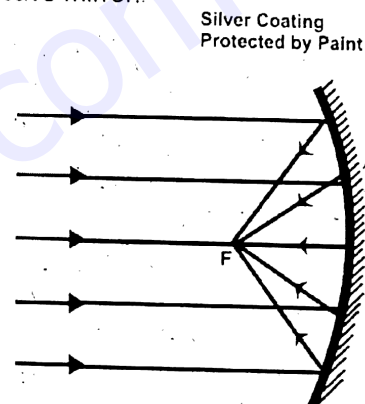
Spherical mirror:

A portion of spherical shell (or) sphere whose inner (or) outer surface is shining and reflectable to light is known as spherical mirror.

Type of spherical mirror:

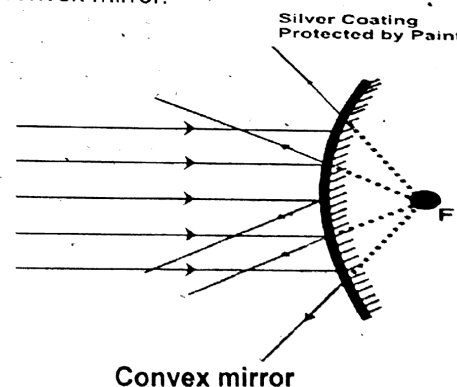
i) Concave mirror:

A spherical mirror whose inner surface is shining and reflectable to light is known as concave mirror.



ii) Convex mirror:

A spherical mirror whose outer surface is shining and reflectable to light is known as convex mirror.

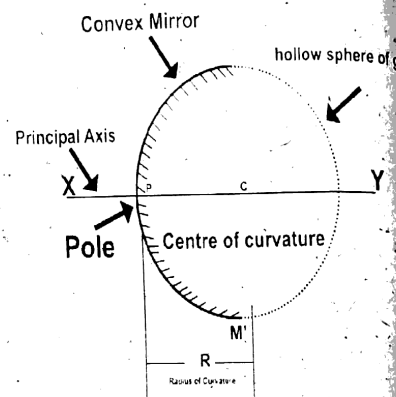
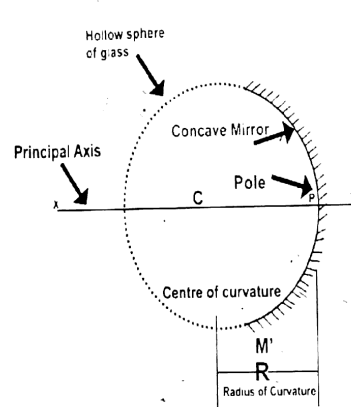


3. Define the terms related to spherical mirrors?

Ans. Terms related to spherical mirror:

i. Center of curvature:

The Center of sphere of which the mirror is a part is known as center of curvature. It is denoted by "C".



ii. Radius of curvature:

The radius of sphere of which the mirror is a part is called radius of curvature (R).

iii. Pole of Mirror:

The geometrical Central point of a spherical mirror is called pole and is denoted by "P".

iv. Aperture of the spherical mirror:

The diameter of the circular boundary of spherical mirror is called aperture. (OR)

The size of spherical mirror is known as aperture.

v. Principal Axis:

"The straight line passing through pole and center of curvature of spherical mirror is known as principal axis."

Focal length:

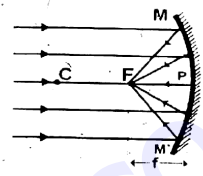
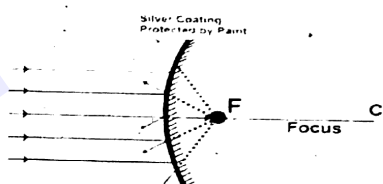
The straight distance between pole and principal focus of spherical mirror is called focal length. It is denoted by "f".

Principal Focus (Or) Focal point:

A point on the principal axis of the spherical mirror at which parallel rays of light after reflection converge (in case of concave mirror) or appear to diverge (in case of convex mirror) is called principal focus.

Q4. Write characteristics of focus of concave and convex mirror.

Ans. Characteristics of concave and convex mirror:

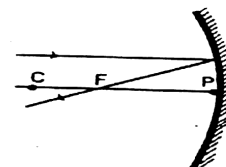
Convex Mirror	Concave Mirror
Focus lie behind the mirror	Focus is in-front of the mirror
The focus is virtual as the reflected rays appear to come from focus.	The focus is real as the rays of light after reflection converge at the focus.
The focus of convex mirror is a diverging point of reflected rays.	The focus of concave mirror is a converging point of reflected rays.
	

Q 5: Discuss reflection of light rays by spherical mirrors?

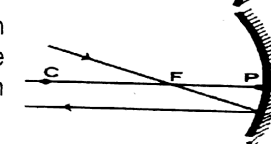
Ans: Reflection of light rays from spherical mirror:

The inner (or) outer surface of the mirror is smooth and polished, so the spherical mirror has the ability to reflect light rays. Some special types of reflection of light from the mirror are given below.

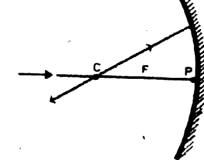
Case 1: If rays of light are parallel to the principal axis. Then after reflection from the spherical mirror these rays of light will pass through the principal focus as shown in figure.



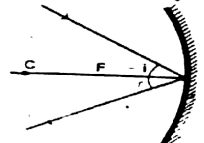
Case (2): If the incident rays of light pass through the principal focus. Then such rays will become parallel to the principal axis after reflection from the spherical mirror as shown in fig.



Case (3): If the incident rays of light pass through the center of curvature, then such rays will reflect back along the same path as shown in figure.



Case 4: If the incident ray falls on the pole at an angle θ with the principal axis. Then such a ray of light will make the same angle θ with the principal axis after reflection as shown in figure.



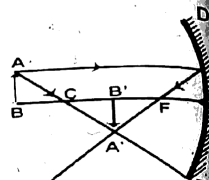
Q6. Discuss the formation of image by concave mirror. Support your answer by drawing figures?

Ans. Image formation by concave mirror:

The position, size and nature of the image of an object placed in front of a concave mirror depend on the location of object with respect to mirror.

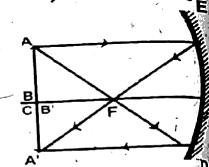
i) Object placed beyond "C":

If an object is placed beyond the center of curvature in front of concave mirror. The image is formed between Centre of curvature and principal focus. The image is real, inverted and diminished.



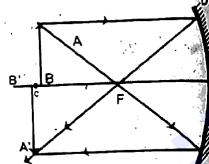
ii) Object is placed "C":

If an object is placed on the Centre of curvature. The real, inverted and same size image is formed on the Centre of curvature "C".



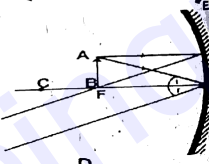
iii) Object placed between "C" and "F":

If the object is placed between Centre of curvature and focal point in front of concave mirror. The image is formed beyond "C". This image is real inverted and magnified.



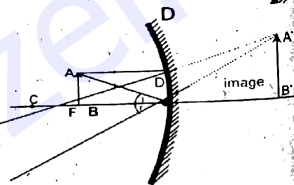
iv) Object placed at "F":

If an object is placed at principal focus "F" in front of concave mirror, the real inverted and highly magnified image is formed at infinity.



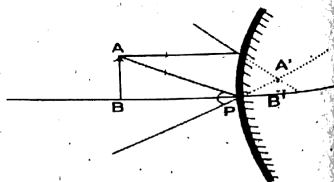
v) Object placed between "F" and "P":

If the object is placed in front of a concave mirror between the principal focus "F" and pole "P" the virtual, erect and magnified image is formed behind the mirror.



Q 7: Discuss the formation of image by convex mirror?

Ans: In case of a convex mirror, for all distances of the object, the image is formed behind the mirror between principal focus "F" and pole "P". It is always diminished and erect.



Q8. Differentiate between the images formed by concave and convex mirrors?

Ans. Image by concave mirror:

- A concave mirror forms an image that is real and inverted for all object which are placed between Centre of curvature and the principal focus.
- The image formed by concave mirror is virtual and upright for all objects which are placed between focus point and pole (p).

Image by convex Mirror:

- In convex mirror, the image is always appears smaller, upright and behind the mirror which is virtual image.
- When object moves closer to closer to convex mirror image also moves closer to the mirror and becomes larger, but stay virtual, upright and diminished.

Q 9: Derive spherical mirror formula?

Ans. Spherical mirror formula:

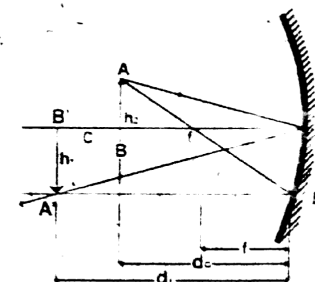
"An equation which shows the relationship between focal length of spherical mirror "f", distance of object from the mirror "p" and distance of image from the mirror "q" is known as spherical mirror formula".

Mathematically;

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

Derivation:

Let us consider an object "AB" is placed in front of a concave mirror between focal point "F" and Centre of curvature "C", the real inverted and magnified image "A'B'" is formed beyond the Centre of curvature "C" as shown in figure.



From the figure we see that $\triangle ABP$ and $\triangle A'B'P$ are similar, therefore:

$$\frac{AB}{A'B'} = \frac{BP}{B'P} \quad \text{--- (a)}$$

Also from the figure we see that $\triangle ABP$ and $\triangle A'B'P$ are similar, therefore:

$$\frac{AB}{A'B'} = \frac{BP}{B'P} \quad (\triangle EP = AB)$$

$$\frac{AB}{A'B'} = \frac{d_o - f}{f} \quad \text{--- (b)}$$

Comparing equ (a) and equ (b), we have;

$$\frac{d_o}{d_i} = \frac{d_o - f}{f}$$

By crossing multiplication, we get;

$$d_o f = d_i (d_o - f)$$

$$\Rightarrow d_o f = d_i d_o - d_i f$$

Dividing each term by " $d_o d_i f$ ", we get;

$$\frac{d_o f}{d_o d_i f} = \frac{d_o d_i}{d_o d_i f} - \frac{d_i d_o}{d_o d_i f}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

This is known as spherical mirror formula. It gives the relationship between the image distance " d_i " object distance " d_o " and focal length " f " of a spherical mirror.

Q10. What is meant by linear magnification?

Ans. Linear magnification

"The ratio of size of image to the size of an object is known as linear magnification."

Mathematically;

$$M = \frac{-h_i}{h_o} \quad \text{--- (i)}$$

Also,
$$M = -\frac{d_i}{d_o} \quad \text{--- (ii)}$$

$$\Rightarrow \frac{-h_i}{h_o} = \frac{-d_i}{d_o}$$

$$\Rightarrow \frac{h_i}{h_o} = \frac{d_i}{d_o}$$

$$\Rightarrow h_i = \frac{d_i}{d_o} \times h_o$$

Q11. Write sign convention for spherical mirror?

Ans. Sign convention:

The following sign convention is adopted to obtain the correct result in a given problem of image formation by a spherical mirror.

- All distances are measured from the pole of the mirror.
- Distance of real objects and real images are taken positive.
- Distances of virtual objects and virtual images are taken negative.
- The focal length of Concave mirror is taken positive and that of convex mirror is taken negative.
- For upright image magnification is +ve while magnification is -ve for vertically inverted image.

Q12. Write uses of spherical mirrors?

Ans. Uses of spherical Mirrors:

There are several important applications of spherical mirrors. A few of them are given below.

- Convex mirrors are used in vehicles to observe rear view.
- Convex mirrors are also used at dangerous road bends for safe drive.
- Concave mirrors are used by doctors to examine ear, nose, throat and eyes.
- Concave mirrors are used in head-lights of automobiles and search lights.
- Concave dish is used to collect microwave signals from satellites to a focus.
- Concave mirrors are used to concentrate light on the slides of microscope so that the slide can be viewed more clearly.

Q13. What is meant by refraction of light? State and explain laws of refraction with diagrams?

Ans. Refraction of light:

"The change in speed and direction of light when light enter from one medium to another is called refraction of light." OR

"The phenomena in which change in speed as well as direction of light rays occurs, when light rays enter obliquely from one medium to another medium is known as refraction of light."

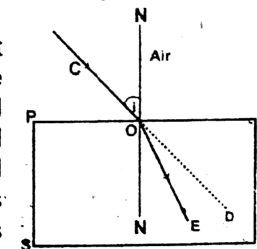
Explanation:

As we know that in a homogeneous transparent medium (having the same density throughout) light travels in a straight line with uniform velocity but when a ray of light enter from one medium to another medium, it undergoes a change in speed as well as in direction.

This change of speed and direction of light rays when enters from one medium to another medium is known as refraction of light.

From rarer to denser medium:

Let's a ray of light "CO" be incident at point "O" of the surface "PQ". Upon entering the second medium, the ray changes its path. Instead of traveling along "OD", the ray is refracted and travel along "OE". The ray "OE" is called refracted ray. Draw a normal "NON", the angle $\angle CON = \angle i$ is called angle of incidence and angle $\angle EON = \angle r$ is called the angle of refraction. The refracted ray bends towards normal i.e. the angle of refraction is smaller than the angle of incidence.



From denser to rarer medium:

If the light ray travels from denser medium to rarer medium, then the ray is bent away from normal.

i.e. the angle of refraction is greater than the angle of incidence as shown in figure.

Law of Refraction:

The refraction of light obeys the following two laws.

i) First law:

This law states that "The incident ray, refracted ray and normal at the point of incident, all lies in the same plane".

ii) Second Law:

This law states that; "The ratio of sine of angle of incidence to the sine of angle of refraction is constant for a given pair of media."

Mathematically;

$$\frac{\sin \angle i}{\sin \angle r} = n$$

When "n" is constant and is known as refractive index. This law is also called Snell's law.

Q14. What is meant by index of refraction (refractive index)?**Ans. Refractive index:**

"The ratio of sine of angle of incidence to the sine of angle of refraction is known as refractive index."

$$n = \frac{\sin \angle i}{\sin \angle r}$$

"OR"

"The ratio of speed of light in vacuum to the speed of light in the given medium is called refractive index."

$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in a given medium}}$$

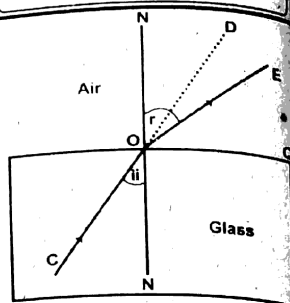
$$n = \frac{c}{v}$$

"OR"

"The ratio of real depth to the apparent depth is called refractive index."

$$n = \frac{\text{Real Depth}}{\text{Apparent Depth}}$$

The refractive index of a substance depends on the nature of the material of the medium and on the wavelength of light used. It is a characteristic property of a substance.



Q 15. What is meant by critical angle? Also describe total internal reflection. Derive relation of critical angle and refractor index?

Ans. Critical Angle:**Definition:**

"The angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90° , is called critical angle". It is denoted by "C".

Examples:

Critical angle for glass = 42°

Critical angle for diamond = 24.4°

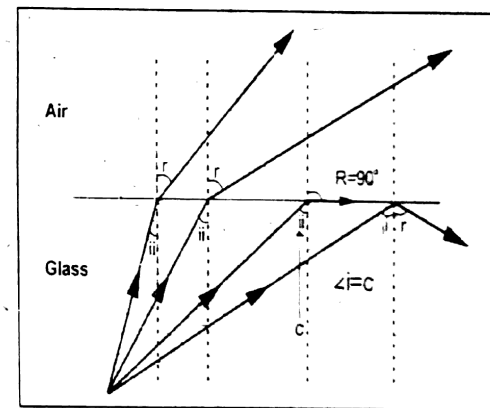
Critical angle for water = 48° etc.

Total internal reflection:**Definition:**

When the angle of incidence in the denser medium becomes greater than the critical angle "C", then there is no refraction, only reflection phenomena take place, such a reflection is known as total internal reflection.

Explanation:

Whenever light enter from an optically denser medium to a rarer medium it bends away from normal. Therefore the angle of refraction " $\angle r$ " is greater than the angle of incidence " $\angle i$ ". If we increase the angle of incidence gradually, then the angle of refraction " $\angle r$ " also increases until for a certain angle of incidence, the angle of refraction become " 90° " is known as critical angle. When



the angle of incidence in the denser medium becomes greater than the critical angle "C", there is no refracted beam. All the rays are internally reflected back in the optically denser medium. Such a reflection is called total internal reflection.

Necessary conditions for total internal reflection:

The necessary conditions for total internal reflection are as follows;

- The incident light must be entering from denser medium to a rarer medium.
- The angle of incidence " $\angle i$ " in denser medium must be greater than critical angle i.e. $\angle i > C$.

Relationship between refractive index and critical Angle:

We know that;

$$\frac{n_{rare}}{n_{denser}} = \frac{\text{sine of angle in denser medium}}{\text{sine of angle in rare medium}}$$

$$\Rightarrow \frac{1}{n} = \frac{\sin C}{\sin 90^\circ} \quad (\because n_{rare} = 1 \text{ and } n_{denser} = n)$$

$$\Rightarrow n = \frac{\sin 90^\circ}{\sin C} \quad (\because \sin 90^\circ = 1)$$

$$\Rightarrow n = \frac{1}{\sin C}$$

Which is the required relationship between refractive index and critical angle.

Q16. What is optical fiber? Describe how total internal reflection is used in light propagating through fiber?

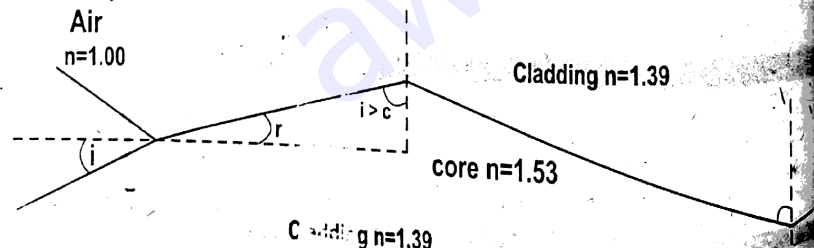
Ans. Optical Fiber:

"A thin hair like rod of glass having central portion of high refractive index called core, which is surrounded by a glass layer having low refractive index called cladding." OR

"A thin hair like glass rod through which light propagates by total internal reflection."

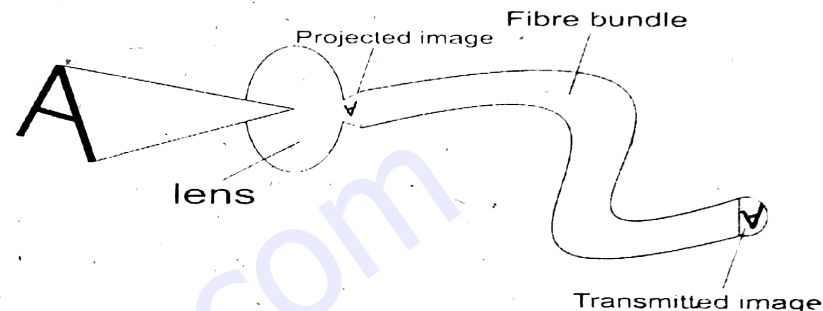
Explanation

Total internal reflection is used in fibre optics which has number of advantages in telecommunication field. Fibre optics consists of hair size threads of glass or plastic through which light can be travelled (see in fig). The inner part of the fibre optics is called core that carries the light and an outer concentric shell is called cladding. The core is made from glass or plastic or reflectively high index of refraction. The cladding is made of glass or plastic, but of relatively low refractive index. Light entering from one end of the core strikes the core - cladding boundary at an angle of incidence greater than critical angle and is reflected back in to the core (see in fig). In this way light travels many kilometers with small loss of energy. In Pakistan, optical fibre is being used in telephone and advanced telecommunication systems. Now we can listen thousands of phone calls without any disturbance.



Q17. Write the application of optical fibers?

Ans. The light pipe is a bundle of thousands optical fibers bounded together through a flexible pipe jacket. The light pipes are used by doctors and engineers to illuminate those inaccessible places which otherwise are not possible to examine. Light pipes also used to transmit data (image, calls, Movies) from one place to another.

**Endoscope:**

Endoscope is a medical instrument used for viewing and photographing of internal structure of human body. Due to small size the endoscope is inserted through the mouth and illuminates the internal parts viewed by another bundle of optical fiber. A video camera is fitted outside of this bundle and it makes the interior parts visible to doctors which help them to diagnose easily.

Q18. What is endoscopy? Describe the type of endoscope.

Ans. Endoscope:

A medical procedure in which any type of endoscope is used called endoscopy.

Type of Endoscope

The endoscope is divided in to different types on the bases of use in medical filed.

i. Gastroscope:

Gastroscope is an instrument used to diagnose the stomach.

ii. Cytoscope:

Cytoscope is an instrument used to diagnose the bladder.

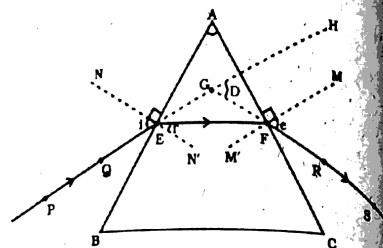
iii. Bronchoscope:

Bronchoscope is an instrument used to diagnose the bladder and sore throat.

Q19. Describe the behavior of a ray of light after passing through a prism?

Ans. A transparent body having three rectangular and two triangular surfaces is called prism. The angle between two refracting rectangular surfaces opposite to the base is called the angle of prism ($\angle A$).

The refraction of light through a glass prism is as shown in the figure.



The incident ray "EF" makes an angle $\angle EFN = \angle i$ with surface "AB". The incident ray "EF" on entering the glass prism is refracted towards the base "BC" of the prism. When this refracted ray "FG" emerges out of the prism it bends away from the normal.

The inclination of the surface "AC" with "AB" causes the emergent ray "GH" to bend more towards the base as shown in figure. Thus the emergent ray "GH" has been as shown in figure. Thus the emergent ray "GH" has been deviated from its original path EFI. The angle through which the emergent ray has been deviated is called the angle of deviation "D" ($\angle IOH$). The value of angle of deviation depends upon the following factors.

- ❖ Angle "A" of the prism.
- ❖ The refractive index of the material of the prism.
- ❖ The angle of incidence.

Experimentally it is verified that when the refracted ray becomes parallel with the base "BC" of the prism then the angle of deviation becomes minimum and is called the angle of minimum deviation " D_m ". The refractive index of the material of the prism can be determined by the relation

$$n = \frac{\sin\left(\frac{A+D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Q20. Define lens? Describe types of lenses?

Ans. Lens:

A portion of transparent medium like glass which is bounded by at least one curved surface is called lens.

Types of lens:

There are two types of lens which are as follows.

a) Convex lens (or) converging lens:

"A lens which is thicker at the middle and thinner at the edges is called converging lens (or) convex lens."

(OR)

A lens which converge parallel rays of light to a single point is called converging lens (or) converging lens.

b) Concave lens (or) Diverging lens:

"A lens which diverge parallel rays of light is called diverging lens (or) concave lens."

Sub types of convex lens:

There are three types of convex lens which are given below.

i) Double convex lens:

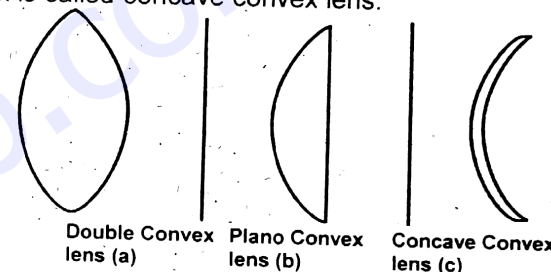
"A convex lens whose both bounding surfaces are convex is called double convex lens."

ii) Plano convex lens:

"A Convex lens in which one bounding surface is plane and the other is convex is called plano-convex lens."

iii) Concave-convex Lens:

"A convex lens whose one bounding surface is concave and the other is convex is called concave convex lens."



Sub types of concave Lens:

There are three types of concave lens which are given below.

i) Double Concave lens:

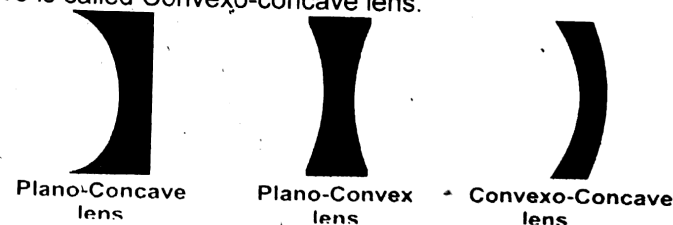
"A concave lens whose both bounding surfaces are concave is called double concave lens."

ii) Plano - concave lens:

"A concave lens whose one bounding surfaces is plane and other is concave is called plano- concave lens."

iii) Convexo -concave lens:

"A concave lens whose one bounding surface is convex and other is concave is called Convexo-concave lens."



Q 21. Define special terms related with lenses?

Ans. Definitions of special terms:

i) Centre of Curvature:

The Centre of sphere of which the lens is a part is called Centre of curvature, denoted by "C".

ii) Principal Axis:-

The straight line joining optical center with center of curvature of lens is known as principal axis.

iii) Optical center:

A single point inside or outside the lens, through which a ray of light passes un-deviated is called optical center. "OR"

The geometrical Centre of a lens is called optical Centre.

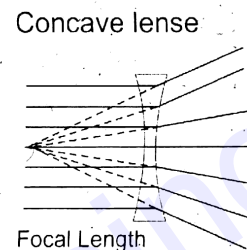
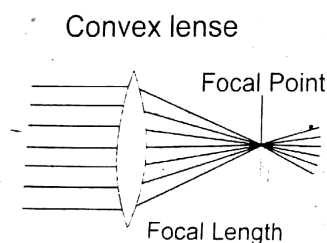
iv) Aperture:

The geometrical diameter of lens is called aperture. "OR"

"The size of lens is called aperture".

v) Principal Focus:

The point where all rays parallel to the principal axis converge after passing through a convex lens (or) appear to diverge after passing through a concave lens, is called principal focus, denoted by "F".



vi) Radius of Curvature:

The radius of sphere of which the lens is a part is called radius of Curvature, denoted by "R".

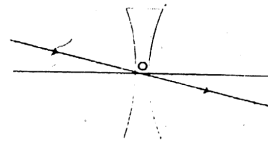
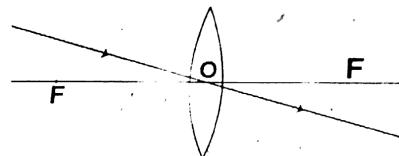
vii) Focal length:

The straight distance between optical Centre and principal focus is called focal length. It is denoted by "f".

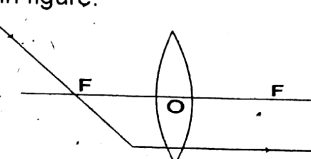
Q 22: Discuss the refraction of light rays by lens?

Ans: Refraction of special Rays:

Ray(1): An incident ray of light passes through optical Centre "O" of lens without bending as shown in figure.

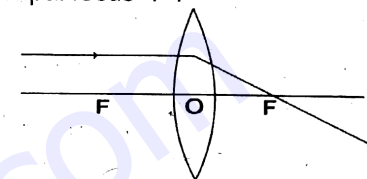


Ray (2): An incident ray passes through "F" is refracted parallel to the principal axis as shown in figure.



Ray (3): A ray parallel to principal axis after refraction from a convex lens passes through the principal focus.

In case of a concave lens this ray diverges and appears to be coming from the principal focus "F".



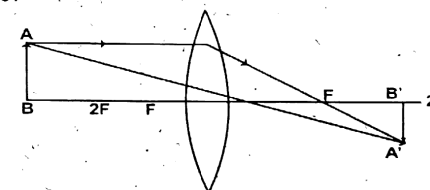
Q23. Discuss the formation of image by Concave and convex lenses?

Ans. Image formation by Convex Lens:-

The position, nature and size of the image of an object that is formed by a convex lens depend on the distance of the object from the lens:

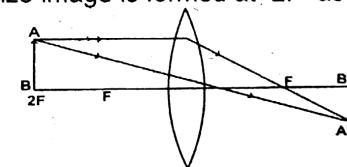
a) Object placed beyond "2F" OR "C":

When an object is placed beyond "2F" (Or) "C" in front of a convex lens, the real, inverted and diminished image is formed between F and 2F, as shown in figure.



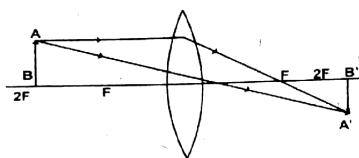
b) Object placed at "2F":

When an object is placed at "2F" in front of a convex lens, the real, inverted and same size image is formed at "2F" as shown in fig.

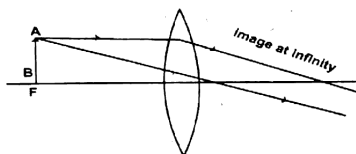


c) Object between "2F" and "F":

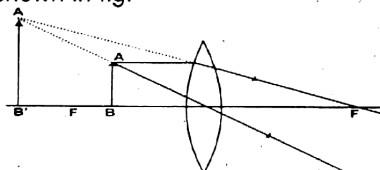
When an object is placed between "2F" and "F", the real, inverted and magnified image is formed beyond "2F" as shown in fig.

**d) Object placed at "F":**

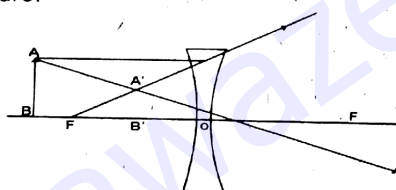
When an object is placed at principal focus "F" of convex lens, the real, inverted and highly magnified image is formed at infinity as shown in figure.

**e) Object placed "F" and "O":**

When an object is placed between "F" and "O" the virtual, erect and magnified image is formed on the same side of the lens at which the object is placed as shown in fig.

**Image formation by concave Lens:**

In case of concave lens, for all positions of the object from concave lens, the virtual, erect and diminished image is formed between "F" and "O" as shown in figure.

**Q24. Describe lens formula equation?**

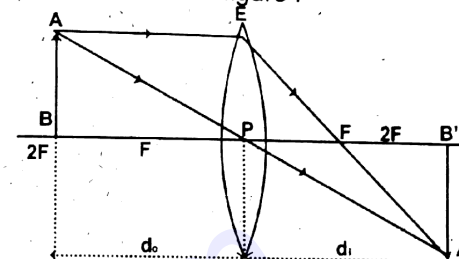
Ans. An equation which shows the relationship between focal length "f", distance of object from the lens "P" and distance of image from the lens "q" is called lens formula.

Mathematically,

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

Deviation:

Let us consider an object "AB" is placed in front of a convex lens between the principal focus "F" and Centre of Curvature "C", the real, inverted and magnified image "A'B'" is formed beyond the Centre of curvature "2F" (or) "C" as shown in figure.



From the figure we see that $\triangle ABC$ and $\triangle A'B'C$ are similar, therefore,

$$\frac{AB}{A'B'} = \frac{BC}{B'C} = \frac{d_o}{d_i} \Rightarrow \frac{AB}{A'B'} = \frac{d_o}{d_i} \quad \text{--- (a)}$$

Also from the figure we see that $\triangle CEF$ and ABC are similar, therefore;

$$\frac{CE}{A'B'} = \frac{CF}{B'C} = \frac{CF}{B'C - CF} \Rightarrow \frac{CE}{A'B'} = \frac{CF}{B'C - CF}$$

Hence, $CF = f$, $CE = AB$ and $B'C = d_i$

Therefore, Eq(b)

$$\Rightarrow \frac{AB}{A'B'} = \frac{f}{d_i - f} \quad \text{--- (c)}$$

Comparing equ(a) and equ(c), we get,

$$\Rightarrow \frac{d_o}{d_i} = \frac{f}{d_i - f}$$

But cross multiplication, we have:

$$d_i f = d_o (d_i - f) \Rightarrow d_i f = d_o d_i - d_o f$$

Dividing each term by " $d_o d_i f$ ", we have;

$$\frac{d_i f}{d_o d_i f} = \frac{d_o r}{d_o d_i f} - \frac{d_o f}{d_o d_i f} \Rightarrow \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$$

$$\text{Or } \Rightarrow \frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

Which is the required thin lens formula.

Q25. What is meant by resolving power?

Ans. Resolving power:

The ability of an imaging device to separate points of an object that are located at a small angular distance is called resolving power.

The resolution (or) minimum resolvable distance between distinguish objects in an image, although the term is loosely used by many users of microscopes and telescope to describe resolving power. The term resolution is used to describe the precision with which any instrument measure and records any variable in the sample under study.

Q26. Describe power of lens? What is its unit?

Ans. Power of lens:

"The reciprocal of focal length of lens expressed in meters is called power of lens, denoted by "D".

Mathematically;

$$D = \frac{1}{\text{Focal length of the lens in (meters)}}$$

$$D = \frac{1}{f(\text{meters})} \quad (\text{or}) \quad D = \frac{1}{f(\text{m})}$$

Unit:

Diopetre is the unit of power of lens and is defined as "The power of a lens whose focal length is one meter is called one diopetre.

The power of a lens can be measured directly by using an instrument called diopetre meter. It is used by the opticians to test the power of spectacle lenses.

Q 27. What is a simple Microscope? Describe a ray diagram explaining its working and magnifying power?

Ans. Simple microscope (or) magnifying Glass:

A double convex lens of short focal length used to view the enlarged, upright image of small object, is called simple microscope (or) magnifying glass.

Working principle:

When an object is placed inside the focal length of a convex lens, a virtual, enlarged and erect image is formed on the same side on which the object is located.

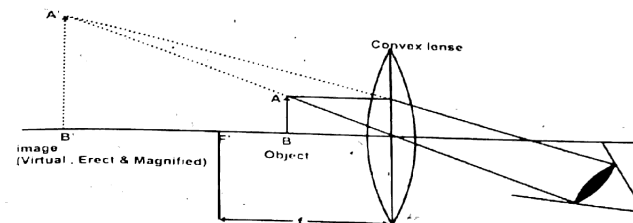
Working principle:

When an object is placed inside the focal length of a convex lens, a virtual, enlarged and erect image is formed on the same side on which the object is located.

Explanation:

A normal person can see an object clearly which is at a distance of 25cm. This distance is known as least distance of distinct vision and denoted by "d". A normal person cannot see clearly an object if it is closer than the least distance of distinct vision i.e. 25cm. When an object

placed within the focal length of a convex lens, the virtual, erect and magnified image is formed on the same side of object. The image formation of an object by simple microscope is as shown in figure.



Magnifying power (or) Magnification:

The ratio of angle of image seen through a magnifying glass to the angle made by the object when placed at 25cm from an unaided eye is called magnifying power of magnifying glass.

Mathematically;

$$M = \frac{\beta}{\alpha}$$

$$\Rightarrow M = \frac{\tan \beta}{\tan \alpha}$$

$$\Rightarrow M = \frac{A'B'}{AB} \cdot \frac{N}{N}$$

$$(\because \tan \beta = \frac{A'B'}{N})$$

$$\Rightarrow M = \frac{A'B'}{AB} \quad \text{----- (a)}$$

$$\text{and } \tan \alpha = \frac{AB}{N}$$

From the figure we see that $\triangle ABC$ and $\triangle A'B'C$ are similar, therefore,

$$\frac{A'B'}{AB} = \frac{d_i}{d_o}$$

$$\Rightarrow \frac{A'B'}{AB} = \frac{N}{d_o}$$

$$(\because d_i = N = 25 \text{ cm})$$

Putting equation (a)

$$M = \frac{N}{d_o} \quad \text{----- (b)}$$

According to lens formula;

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{d_o} - \frac{1}{N}$$

$$(\because d_i = -N, \text{ i.e., image is virtual})$$

$$\Rightarrow \frac{1}{f} = \frac{1}{d_o} - \frac{1}{N}$$

Multiplying each term by "N"

$$\Rightarrow \frac{N}{f} = \frac{N}{d_o} - \frac{N}{N}$$

$$\Rightarrow \frac{N}{f} = \frac{N}{d_o} - 1$$

$$\Rightarrow \frac{N}{d_o} = 1 - \frac{N}{f} \text{----- (c)}$$

Putting equ (b) in equ (c);

$$\text{Equ (c)} \Rightarrow M = 1 + \frac{N}{f}$$

$$\Rightarrow \frac{d}{f} = \frac{d}{d_o} - 1$$

$$\Rightarrow \frac{d}{f} = \frac{d}{d_o} + 1$$

Putting equation (b)

$$M = 1 + \frac{d}{f}$$

For normal human eye, $N=25\text{cm}$

$$\text{Therefore, } M = 1 + \frac{25}{f}$$

Hence, shorter the focal length of convex lens higher will be magnifying power of lens and vice versa.

Q 28. What is a compound microscope? Using ray diagram for a compound microscope mention its magnifying power?

Ans. Compound microscope:

Definition:

An optical instrument which helps us to see the magnified images of very small object is called compound microscope.

Construction:

A compound microscope consists of two convex lens which are fitted at each end of two metal tubes whose length is adjustable. The lens near object is called objective and the lens near eye is called eye piece. The focal length of objective is less than the focal length eye piece i.e. $f_o > f_e$.

Working:

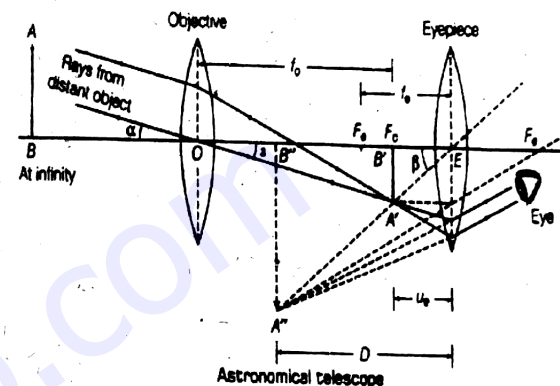
An object "AB" is placed at a point whose distance "P" is slightly greater than the focal length f_o of objective. A real, inverted and magnified image $A'B'$ of the object is formed after refraction from the objective at distance "r" from objective. The eye piece is adjusted in such a way that the image $A'B'$ should fall inside its focal length.

The eye piece acts like a magnifying glass and so the final image $A''B''$ of $A'B'$ is formed at a distance equal to the least distance of distinct vision "d".

Magnifying power:

"The ratio of size of final image seen through compound microscope to the ratio of size of object seen without compound microscope is called magnification (or) magnifying power of compound microscope."

$$M = \frac{\text{size of final image seen through compound microscope}}{\text{size of object seen without compound microscope}}$$



$$\Rightarrow M = \frac{A'B''}{AB} = \frac{A'B''/A'B'}{AB/A'B'}$$

$$\Rightarrow M = \frac{A'B''}{AB} \times \frac{A'B'}{AB}$$

$$\Rightarrow M = M_e \times M_o \text{----- (a)}$$

$$\text{Now, } M_o = \frac{d_i}{d_o} \quad M_e = 1 + \frac{N}{f}$$

$$\text{Therefore, } M = \frac{d_i}{d_o} \left(1 + \frac{N}{f_o}\right)$$

As the object "AB" is situated near the principal focus of the objective so;

$$d_o = f_o \text{ and } d_i = L = \text{The length of microscope}$$

$$\text{Thus, } M = \frac{L}{f_o} \left(1 + \frac{N}{f_o}\right)$$

This is the magnifying power of compound microscope eye.

Q 29. What is a telescope? Using a ray diagram explain its working and magnifying power?

Ans. Astronomical telescope:

An optical instrument which is used to see heavenly bodies and other distant objects clearly is called astronomical telescope.

Construction:

The astronomical telescope consists of two convex lenses which are fitted at each end of two metal tubes.



tubes whose length is adjustable. The lens toward the object is called objective and the lens near the eye is called eye piece. The focal length of eye piece is less than the focal length of objective i.e. $f_e < f_o$

Working:

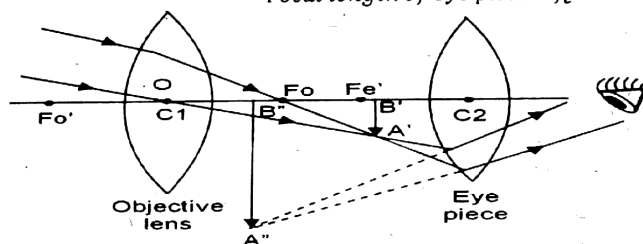
The objective forms a real, inverted and diminished image $A'B'$ of distant object AB . This image $A'B'$ behaves as an object for the eye piece which is lying within focal length of eye piece. The eye piece produces virtual, inverted w.r.t the object and magnified image $A''B''$.

When the telescope is focused at infinity (or) in normal adjustment then the distance between objective and the eye piece is equal to $f_o + f_e$ i.e. $L = f_o + f_e$.

Magnifying power:

The magnifying power of astronomical telescope is given by:

$$\text{Magnification } M = \frac{\text{Focal length of objective}}{\text{Focal length of eye piece}} = \frac{f_o}{f_e}$$



Q 30. Define the defect of vision. What is meant by the short sightedness and long sightedness? How these defects can be corrected.

Defect of vision (sightedness):

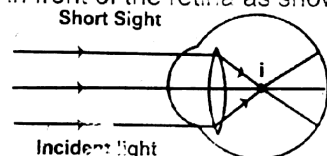
The inability of the eye lens to produce sharp images at the retina is called defect of vision, the main defects of vision are as follows.

- Short sightedness (Myopia)
- Long sightedness (Hypermetropia)

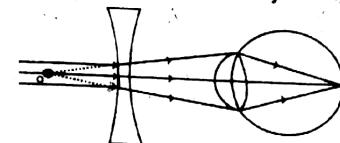
a) Short sightedness (myopia):

"The defect of eye lens in which a person can see near objects clearly but cannot see distant objects clearly is called shortsightedness

The lens of such an eye is more convergent than that of the normal eye. Due to greater converging power of lens the eye ball becomes too long for the lens system suffering myopia. The parallel rays from the object are focused just in front of the retina as shown in figure

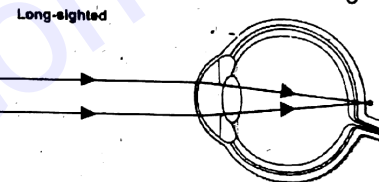
**Removal:**

This defect of eye can be removed by using spectacles containing concave lenses.

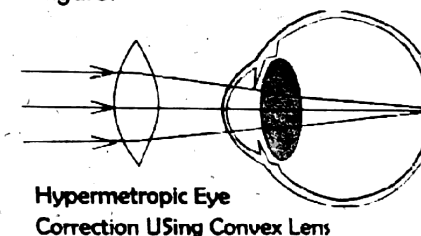
**b) Long sightedness:**

"The defect of eye lens in which a person can see distant objects clearly but cannot see near objects clearly is called long sightedness.

The lens of such eye is less convergent than that of normal eye. The eye ball becomes too small for the lens system suffering long sightedness. Due to low converging power of lens the parallel rays from the object are focused beyond retina as shown in figure.

**Removal:**

To remove this defect a convex lens is placed in front of the eye in the form of spectacles. The combination of convex lenses forms the image at retina as shown in figure.



Q 31. How human eye works? How the defects in the eye like short sightedness and long sightedness be corrected by using lenses?

Ans. Human Eye:

In many respects the Human eye is similar to Camera. It has white wall called sclerotic in the front of eye there is a lens

Parts of human eye:**Retina:**

The light passing through the lens crosses the vitreous humour to form an image on specific wall which is called retina. Retina records the picture and works as film in camera

Shams Notes

Geometrical Optics

Lens:

There is converging lens in the front of eye. Naturally, this lens has ability to change the focal length.

Iris:

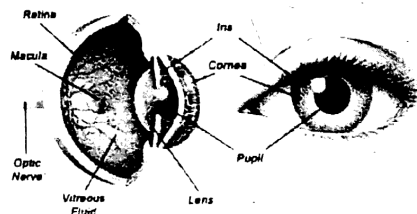
The iris is the Coloured part of eye which automatically adjust the size of pupil and controls the amount of light reaching the retina.

Pupil:

Pupil is circular in the center according to intensity of light falling on it. When white light passes, the iris contracts the size of pupil while in dim light pupil is enlarged.

Cornea:

The light enters the eye through transparent membrane called Cornea.

**Formation of image:**

The image formation in human eye is shown in fig. Human eye acts like a camera. In place of the film, the retina records the picture. The eye has a refracting system containing a converging lens. The lens forms an image on the retina which is a light sensitive layer at the back of the eye, the lens changes focal length. Light enters the eye through a transparent membrane called is the cornea. The iris is the coloured portion of the eye and controls the amount of light reaching the retina. It has an opening at its Centre called the pupil. The iris controls the size of the pupil. In bright light, iris contracts the size of the pupil while in dim light pupil enlarged. The lens of the eye is flexible and accommodates objects over a wide range of distances.

Accommodation:

The variation of the focal length of eye lens is called accommodation.

OR

"The sharpness of image formed in retina for objects at different distances from the eye is controlled by an alternation an alternation in the focal length of eye lens. This is called accommodation."

For Object:

If the object is far away from eye,

- The ciliary muscles relax.

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Geometrical Optics

- The curvature of lens is decreased.
- The focal length decreased.
- The divergent rays from mean object are thus bent more and come to focus on retina.

Nearer Object: If an object close to eye

- The ciliary muscles contract.
- The curvature of lens increased.
- The focal length decreased.
- The divergent rays from near object are thus bent more and come to focus on retina.

Accommodation is larger of healthy eye in young people while it goes on decreasing with increasing the age. Defects in accommodation be corrected by using different types of lens in eyeglasses.

Examples

Example 12.1: The concave side of a spoon has a focal length of 5.00cm find the image distance for this 'mirror' when the object distance is (a) 12.0 cm, (b) 10.0cm, (c) 7.50cm, (d) 5.00cm and (e) 2.00cm.

Given:

Focal length ' $f = 5.00\text{cm}$.

- (a) Object Distance ' $d_o = 12.0\text{cm}$,
- (b) Object Distance ' $d_o = 12.0\text{cm}$,
- (c) Object Distance ' $d_o = 12.0\text{cm}$,
- (d) Object Distance ' $d_o = 12.0\text{cm}$,
- (e) Object Distance ' $d_o = 12.0\text{cm}$,

Required:

- (a) Image Distance ' $d_i = ?$
- (b) Image Distance ' $d_i = ?$
- (c) Image Distance ' $d_i = ?$
- (d) Image Distance ' $d_i = ?$
- (e) Image Distance ' $d_i = ?$

Solution:

By mirror equation

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \text{ or } \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

Taking LCM

$$\frac{1}{d_i} = \frac{d_o - f}{f d_o} \text{ or } d_i = \frac{f d_o}{d_o - f} \text{-----(1)}$$

Putting the values in equation 1

$$d_i = \frac{f d_o}{d_o - f}$$

$$\Rightarrow d_i = \frac{5.00\text{cm} \times 12.00\text{cm}}{12.00\text{cm} - 5.00\text{cm}}$$

$$\Rightarrow d_i = \frac{60.0\text{cm}^2}{7.00\text{cm}}$$

Therefore,

$$d_i = 8.6\text{cm} \text{ ----- Answer}$$

b) Putting value in equation 1

$$d_i = \frac{f d_o}{d_o - f_o}$$

$$\Rightarrow d_i = \frac{5.00\text{cm} \times 10.00\text{cm}}{10.00\text{cm} - 5.00\text{cm}}$$

$$\Rightarrow d_i = \frac{50.0\text{cm}^2}{5.00\text{cm}}$$

Therefore,

$$d_i = 10.0\text{ cm} \text{ ----- Answer}$$

c) Putting value in equation 1

$$d_i = \frac{f d_o}{d_o - f_o}$$

$$\Rightarrow d_i = \frac{5.00\text{cm} \times 7.50\text{cm}}{7.50\text{cm} - 5.00\text{cm}}$$

$$\Rightarrow d_i = \frac{37.5\text{cm}^2}{2.50\text{cm}}$$

Therefore,

$$d_i = 15.0\text{cm} \text{ ----- Answer}$$

d) Putting value in equation 1

$$d_i = \frac{f d_o}{d_o - f_o}$$

$$\Rightarrow d_i = \frac{5.00\text{cm} \times 5.00\text{cm}}{5.00\text{cm} - 5.00\text{cm}}$$

$$\Rightarrow d_i = \frac{25.0\text{cm}^2}{0\text{cm}}$$

Therefore,

$$d_i = \infty \text{ ----- Answer}$$

e) Putting value in equation 1

$$d_i = \frac{f d_o}{d_o - f_o}$$

$$\Rightarrow d_i = \frac{5.00\text{cm} \times 2.00\text{cm}}{2.00\text{cm} - 5.00\text{cm}}$$

$$\Rightarrow d_i = \frac{10.0\text{cm}^2}{-3.00\text{cm}}$$

Therefore,

$$d_i = -3.33\text{cm} \text{ ----- Answer}$$

Example 12.2: An external rearview car mirror is convex with a radius of curvature of 16.0m (fig). Determine (a) the focal length of the mirror, (b) location of the image and (c) its magnification for an object 10.0m from the mirror.

Given:Object distance ' d_o ' = 10mRadius of curvature = R = 16.0m**Required:**(a) focal length ' f ' = ?(b) Image distance ' d_o ' = ?(c) magnification ' m ' = ?**Solution:**(a) Focal length ' f ' = ?

We know that;

$$f = -\frac{1}{2} R$$

Putting values

$$f = -\frac{1}{2} 16\text{m}$$

$$f = -8.0\text{m} \text{ ----- Answer}$$

(b) By mirror equation

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$\text{Or } \Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

Taking LCM

$$\Rightarrow \frac{1}{d_i} = \frac{d_o - f}{f d_o}$$

$$\Rightarrow d_i = \frac{f d_o}{d_o - f} \text{ (1)}$$

Putting the values

$$\Rightarrow d_i = \frac{-8.0\text{m} \times 10.0\text{m}}{10\text{m} - (-8.0\text{m})}$$

$$\Rightarrow d_i = \frac{80.0\text{m}^2}{18.0\text{m}}$$

Therefore,

$$d_i = -4.4\text{m} \text{ ----- Answer}$$

(c) Magnification ' m ' = ?

$$m = -\frac{d_i}{d_o}$$

Putting values

$$m = -\frac{-4.4\text{m}}{10\text{m}}$$

$$m = +0.44 \text{ ----- Answer}$$

Example 12.3: What is speed of light in water having index of refraction as 1.33?

Given:

Speed of light in vacuum ' C ' = 3.00×10^8 m/s
Index of refraction for water ' n ' = 1.33

Required:

Speed of light in water ' v ' = ?

Solution:

We know that:

$$n = \frac{c}{v} \text{ or } v = \frac{c}{n}$$

Putting values $v = \frac{3.00 \times 10^8 \text{ m/s}}{1.33}$

Therefore, $v = 2.26 \times 10^8$ m/s ----- **Answer**

Conclusion:

Therefore, the speed of light in water is 2.26×10^8 m/s

Example 12.4: Light travels from crown glass ($n_g = 1.52$) into water ($n_w = 1.33$). The angle of incidence in crown glass is 40.0° . What is the angle of refraction in water?

Given:

Index of refraction for crown glass ' n_g ' = 1.52
Index of refraction for water ' n_w ' = 1.33
Angle of incidence $\theta_g = 40.0^\circ$

Required:

Angle of refraction $\theta_w = ?$

Solution:

By Snell's law

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Or

$$n_g \sin \theta_g = n_w \sin \theta_w$$

$$\sin \theta_w = \frac{n_g}{n_w}$$

Putting the value

$$\sin \theta_w = \frac{1.52}{1.33} \sin 40^\circ$$

Or

$$\Rightarrow \sin \theta_w = 0.735 \text{ and } \theta_w = \sin^{-1} 0.735$$

Hence,

$$\Rightarrow \theta_w = 47.3^\circ \text{ ----- Answer}$$

Example 12.5: Find the critical angle for light traveling from glass ($n = 1.502$) to (a) air ($n = 1.002$) and (b) water ($n = 1.332$)

Given:

Index of refraction for ordinary glass ' n_g ' = 1.502
Index of refraction for air ' n_a ' = 1.002
Index of refraction for water ' n_w ' = 1.002

Required:

Critical Angle $\theta_c = ?$

Solution:

The critical angle is

$$\sin \theta_c = \frac{n_1}{n_2} \text{ or } \theta_c = \sin^{-1} \frac{n_1}{n_2}$$

(a) When light goes from glass to air the critical angle

$$\Rightarrow \theta_c = \sin^{-1} \frac{n_a}{n_g}$$

Putting the value,

$$\Rightarrow \theta_c = \sin^{-1} \frac{1.00}{1.50}$$

$$\Rightarrow \theta_c = 41.8^\circ$$

(b) When light goes from glass to water the critical angle is

$$\theta_c = \sin^{-1} \frac{n_w}{n_g}$$

Putting the value,

$$\Rightarrow \theta_c = \sin^{-1} \frac{1.33}{1.50}$$

$$\theta_c = 62.5^\circ$$

Example 12.6: A converging lens of focal length 10.0 cm forms images of an object situated at various distances. (a) if the object is placed 30.0 cm from the lens, locate the image, state whether it's real or virtual, and find its magnification. Repeat the problem (b) when the object is at 20.0 cm and (c) when the object is 15.0 cm from the lens (d) when the object is 10.0 cm from the lens and (e) when the object is 5.00 cm from lens

Given:

Focal length ' f ' = 10.00 cm.

(a) Object Distance ' d_o ' = 30.0 cm,

(b) Object Distance ' d_o ' = 20.0 cm,

(c) Object Distance ' d_o ' = 15.0 cm,

(d) Object Distance ' d_o ' = 10.00 cm,

(e) Object Distance ' d_o ' = 5.00 cm,

Required:

(a) Image Distance ' d_i ' = ?

Magnification m = ?

(b) Image Distance ' d_i ' = ?

Magnification m = ?

(c) Image Distance ' d_i ' = ?

Magnification m = ?

(d) Image Distance ' d_i ' = ?

Magnification m = ?

(e) Image Distance ' d_i '=?
Magnification m =?

Solution:

By mirror equation

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

Or $\Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$

Taking LCM

$$\Rightarrow \frac{1}{d_i} = \frac{d_o - f}{f d_o}$$

$$\Rightarrow d_i = \frac{f d_o}{d_o - f} \quad (1)$$

(a) To get image distance putting values in equation 1
Putting value

$$d_i = \frac{10.0\text{cm} \times 30.0\text{cm}}{30.0\text{cm} - 10.0\text{cm}}$$

$$\Rightarrow d_i = \frac{300\text{cm}^2}{20\text{cm}}$$

Therefore, $\Rightarrow d_i = +15.0\text{cm}$ -----Answer

The magnification formula is

$$m = \frac{d_i}{d_o}$$

$$\Rightarrow m = -\frac{15\text{cm}}{30\text{cm}}$$

Therefore

$$m = -0.500$$

(b) To get image distance putting values in equation 1

$$d_i = \frac{10.0\text{cm} \times 20.0\text{cm}}{20.0\text{cm} - 10.0\text{cm}}$$

$$\Rightarrow d_i = \frac{200\text{cm}^2}{10.0\text{cm}}$$

Therefore, $\Rightarrow d_i = +20.0\text{cm}$ -----Answer

The magnification formula is

$$m = \frac{d_i}{d_o} \quad m = \frac{20\text{cm}}{20\text{cm}}$$

Therefore,

$$-1.00$$

(c) To get image distance putting values in equation 1

$$d_i = \frac{10.0\text{cm} \times 15.0\text{cm}}{15.0\text{cm} - 10.0\text{cm}}$$

$$\Rightarrow d_i = \frac{150\text{cm}^2}{5.00\text{cm}}$$

Therefore $\Rightarrow d_i = 30\text{cm}$ -----Answer

The magnification formula is

$$m = -\frac{d_i}{d_o} \quad m = \frac{30\text{cm}}{15\text{cm}}$$

$$m = -2.00$$

Therefore

Therefore, when in a object distance is less than twice the focal length but greater than the focal length ($2f$)

(d) To get image distance putting values in equation 1

$$d_i = \frac{10.0\text{cm} \times 10.0\text{cm}}{10.0\text{cm} - 10.0\text{cm}}$$

$$\Rightarrow d_i = \frac{100\text{cm}^2}{0\text{cm}}$$

Therefore $\Rightarrow d_i = \infty$ -----Answer

The magnification formula is

$$\Rightarrow m = \frac{d_i}{d_o}$$

$$\Rightarrow m = \frac{\infty}{20\text{cm}}$$

Therefore

$$m = \infty$$

(e) To get image distance putting values in equation 1

$$d_i = \frac{10.0\text{cm} \times 5.00\text{cm}}{5.00\text{cm} - 10.0\text{cm}}$$

$$\Rightarrow d_i = \frac{50\text{cm}^2}{-5\text{cm}}$$

Therefore, $\Rightarrow d_i = -10\text{cm}$ -----Answer

The magnification formula is

$$\Rightarrow m = -\frac{d_i}{d_o} \quad m = \frac{-10\text{cm}}{5\text{cm}}$$

Therefore,

$$m = +2$$

Example 12.7: A biologist with a near-point distance of $N=26\text{cm}$, examines an insect wing through a magnifying glass whose focal length is 4.3cm . Find the angular magnification when the image produced by the magnifier is (a) at the near point and (b) at infinity.

Given:

Focal length of magnifying glass ' f '= 4.3cm .

Near -point distance of $N=26\text{cm}$

Object Distance ' d_o '= 1.1cm

Required:

Angular magnification ' m_θ '=?

Solution:

The magnification when the image is at near point for magnifying glass is

$$m_n = \frac{N}{f} + 1$$

Putting the values

$$\Rightarrow m_n = \frac{26\text{cm}}{4.3\text{cm}} + 1$$

$$\Rightarrow m_n = 7$$

The magnification when the image is at infinity for magnifying glass is

$$m_\theta = \frac{N}{f}$$

Putting the values

$$\Rightarrow m_\theta = \frac{26\text{cm}}{4.2\text{cm}}$$

$$\Rightarrow m_\theta = 6$$

Example 12.8: In biology class, a student with a near point distance of $N=25\text{cm}$ uses a microscope to view an amoeba. If the objective has a focal length of 1.0cm , the eyepiece has a focal length of 2.5cm , and amoeba is 1.1cm from the objective, what is the magnification produced by the microscope?

Given:

Focal length of eye piece ' f_e ' = 2.5cm .

Focal length of objective ' f_o ' = 1.0cm .

Near point distance of $N = 25\text{cm}$

Object distance ' d_o ' = 1.1cm

Required:

Total magnification ' m ' = ?

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

Or $\Rightarrow \frac{1}{d_i} = \frac{1}{f_o} - \frac{1}{d_o}$

Taking LCM

$$\Rightarrow \frac{1}{d_i} = \frac{d_o - f_o}{f_o d_o}$$

$$\Rightarrow d_i = \frac{f_o d_o}{d_o - f_o} \quad (1)$$

Putting values

$$\Rightarrow d_i = \frac{1.1\text{cm} \times 1.0\text{cm}}{1.0\text{cm} - 1.1\text{cm}}$$

$$\Rightarrow d_i = \frac{1.1\text{cm}^2}{-0.1\text{cm}}$$

$$\Rightarrow d_i = 11\text{cm}$$

The magnification formula for compound microscope is

$$\Rightarrow m = \frac{d_i}{f_o} \times \frac{N}{f_e}$$

Putting values

$$\Rightarrow m = \frac{11\text{cm}}{1.0\text{cm}} \times \frac{25\text{cm}}{2.5\text{cm}}$$

Therefore,

$$m = -110$$

Example 12.9: The largest optical refracting telescope in the world is located at the Yerkes observatory in Wisconsin. The objective lens has a focal length of 19m , and the eye piece has a focal length of 10cm . (a) calculate the total magnifying power of this telescope. (b) Estimate the focal length of the telescope.

Given:

Focal length of objective ' f_o ' = 10cm

Focal length of eye piece ' f_e ' = 11m .

Required:

(A) Angular magnification m_θ = ?

(B) Approximate length ' L ' = ?

Solution:

(a) The magnification of telescope is

$$m_\theta = -\frac{f_o}{f_e}$$

Putting values,

$$\Rightarrow m_\theta = -\frac{19\text{m}}{0.10\text{m}}$$

Therefore,

$$\Rightarrow m_\theta = -190 \quad \text{Answer}$$

b) For a relaxed eye, the image is at the focal point of both the eye piece and the objective lenses. The distance between the two lenses is thus

$$L \approx f_o + f_e \approx 19\text{m} + 0.10\text{m}$$

Therefore, $L \approx 19\text{m}$ Answer

Which is essentially of the length of telescope.

Assignment

Assignment 12.1: A dentist uses a concave mirror with focal length 2.0cm to examine some teeth. If the tooth under examination is 1.2 cm high and mirror is placed at 0.9cm. Calculate the distance of image formed, the height of the image and magnification.

Solution:

Given:

Focal length $= f = 2\text{cm}$

Object (tooth) Height $= h_o = 1.1\text{cm}$

Distance of object (tooth) $= d_o = 0.9\text{cm}$

Required:

(a) Distance of image $= d_i = ?$

(b) Height of image $= h_i = ?$

(c) Magnification $= m = ?$

Calculation:

(a) Distance of image $= d_i$:

We know that;

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} \text{----- (1)}$$

Putting value in eq(1), we get

$$\frac{1}{d_i} = \frac{1}{2} - \frac{1}{0.9}$$

$$\Rightarrow \frac{1}{d_i} = \frac{0.9 - 2}{(2)(0.9)}$$

$$\Rightarrow \frac{1}{d_i} = \frac{-1.1}{1.8}$$

$$d_i = \frac{1.8}{-1.1} = -1.64$$

(b) Height of image:

We know that;

$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

$$h_i = \frac{d_i \times h_o}{d_o}$$

Putting value in eq(2), we get

$$\Rightarrow h_i = \frac{-1.64 \times 1.1}{0.9}$$

$$\Rightarrow h_i = -2.0 \text{ cm}$$

The -ve sign shows that the image is virtual.

(c) Distance of object (tooth) d_o :

We know that;

$$m = \frac{h_i}{h_o}$$

$$\Rightarrow m = \frac{-2}{1.1}$$

$$m = -1.8 \text{----- Answer}$$

The -ve sign shows that the image is vertically inverted.

Assignment 12.3: A convex security mirror in a warehouse has a -0.50 m focal length. A 2.0 m tall forklift is 5.0 m from the mirror. What is the image position and image height?

Solution

Given:

Focal length of convex mirror $= f = -0.5\text{m}$

Height of object $= h_o = 2\text{m}$

Distance of object from the mirror $= 5\text{m}$

Required:

(a) Image position $= d_i = ?$

(b) Height of image $= h_i = ?$

Calculation:

(a) Image position (d_i):

We know that;

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{-0.5} - \frac{1}{5}$$

$$\Rightarrow \frac{1}{d_i} = -\frac{1}{0.5} - \frac{1}{5}$$

$$\Rightarrow \frac{1}{d_i} = \frac{-5 - (0.5)}{2.5}$$

$$\Rightarrow \frac{1}{d_i} = \frac{-5.5}{2.5}$$

$$\Rightarrow d_i = -\frac{2.5}{5.5}$$

$$\Rightarrow d_i = -\frac{2.5}{5.5}$$

$$d_i = -0.45\text{m} \text{----- Answer}$$

The -ve sign show that the image is virtual.

(b) Height of image (h_i):

We know that;

$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

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$$\Rightarrow h_i = \frac{d_i}{d_o} \times h_o$$

Putting value

$$\Rightarrow h_i = \frac{-0.5}{5} \times 2$$

$$\Rightarrow h_i = \frac{-0.9}{5}$$

$$\Rightarrow h_i = -0.18\text{m} \text{----- Answer}$$

The -ve sign show that the image is vertically inverted.

Assignment 12.3: If the speed of light in kerosene oil is $2.08 \times 10^8 \text{ m/sec}$. Calculate the index of refraction?

Solution:**Given:**

$$\text{Speed of light in kerosene oil} = v = 2.08 \times 10^8 \text{ m/sec}$$

$$\text{Speed of light in vacuum} = c = 3 \times 10^8 \text{ m/sec}$$

Required:

$$\text{Index of refraction} = n = ?$$

Calculation:

We know that;

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

$$\Rightarrow n = \frac{3 \times 10^8 \text{ m/sec}}{2.08 \times 10^8 \text{ m/sec}}$$

$$\Rightarrow n = 1.44$$

Conclusion: Hence;

$$\text{Index of refraction of kerosene oil} = 1.44$$

Assignment 12.3: Find the index of refraction for medium -2, if medium -1 is air with index of refraction $n_a = 1.00$, the incident angle is $(30.0)^\circ$ and the angle of refraction is $(22.0)^\circ$. Compare the result with the table and identify the nature of medium -2

Given:

$$\text{Refractive index of medium -1 (air)} = n_1 = 1.00$$

$$\text{Angle of incident} = \theta_1 = (30.0)^\circ$$

$$\text{Angle of refraction} = \theta_2 = (22.0)^\circ$$

Required:

$$\text{Refractive index of medium -2} = n_2 = ?$$

Calculation:

We know that;

$$\frac{n_2}{n_1} = \frac{\sin \theta_1}{\sin \theta_2}$$

$$\Rightarrow n_2 = \frac{\sin \theta_1}{\sin \theta_2} \times n_1$$

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Geometrical Optics

$$\Rightarrow n_2 = \frac{\sin 30^\circ}{\sin 22^\circ} \times 100$$

$$\Rightarrow n_2 = \frac{0.5 \times 1.00}{0.375}$$

$$\Rightarrow n_2 = 1.33$$

Comparison:

If we compare the refractive index of medium -2 i.e. $n_2 = 1.33$ with the table, this value match with the refractive index of water. This medium -2 is water.

Assignment 12.5: What is the critical angle for light traveling in polystyrene (a type of plastic with index of refraction for polystyrene as 1.49) pipe surrounded by air take index of refraction for air to be 1.00?

Solution:**Given:**

$$\text{Refractive index of polystyrene} = n_1 = 1.49$$

$$\text{Refractive index of air} = n_2 = 1.00$$

Required:

$$\text{Critical angle} = \theta_c = ?$$

Calculate:

We know that,

$$\sin \theta_c = \frac{n_2}{n_1}$$

$$\Rightarrow \sin \theta_c = \frac{1.00}{1.49}$$

$$\Rightarrow \sin \theta_c = 0.671$$

$$\Rightarrow \theta_c = \sin^{-1}(0.671) = 42.2^\circ$$

$$\theta_c = 42.2^\circ \text{----- Answer}$$

Assignment 12.6: An object is placed 30.0cm in front of a converging lens and then 12.5 cm in front of a diverging lens. Both lenses have a focal length of 10.0cm. for both cases; find the image distance and the magnification. Describe the images.

Solution:**(a) lens = converging lens = convex lens:****Given:**

$$\text{Object distance} = d_o = 30\text{cm}$$

$$\text{Focal length} = f = +10\text{cm (convex lens)}$$

Required:

$$\text{Image distance} = d_i = ?$$

$$\text{Magnification} = m = ?$$

(b) Lens = Diverging lens = concave lens:**Given:**

$$\text{Object Distance} = d_o = 12.5\text{cm}$$

$$\text{Focal length} = f = -10\text{cm (concave lens)}$$

Required:Image distance = $d_i = ?$ Magnification = $M = ?$ **Calculation:****(a) Lens = converging lens = convex lens $d_i = ?$**

We know that;

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} \text{----- (1)}$$

Putting value in eq(1), we get,

$$\frac{1}{d_i} = \frac{1}{10} - \frac{1}{30}$$

$$\Rightarrow \frac{1}{d_i} = \frac{3-1}{30}$$

$$\Rightarrow \frac{1}{d_i} = \frac{2}{30}$$

$$\Rightarrow d_i = \frac{30}{2}$$

$$\Rightarrow d_i = +15 \text{ cm}$$

$$\text{Magnification} = m = \frac{d_i}{d_o}$$

$$\Rightarrow m = -\frac{15}{30}$$

$$m = -0.5$$

(1) The image is real (Distance positive)

(2) The image is vertically inverted (magnification $-v3$)

(3) The image is smaller than the object (magnification is less than "1")

(b) lens = Diverging lens = concave lens $d_i = ?$

We know that;

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} \text{----- (1)}$$

Putting value in eq (1), we get

$$\frac{1}{d_i} = \frac{1}{-10} - \frac{1}{12.5}$$

$$\Rightarrow \frac{1}{d_i} = -\frac{1}{10} - \frac{1}{12.5}$$

$$\Rightarrow \frac{1}{d_i} = \frac{-12.5-10}{(12.5)(10)}$$

$$\Rightarrow \frac{1}{d_i} = \frac{-22.5}{125}$$

$$\Rightarrow d_i = \frac{125}{-22.5}$$

$$\Rightarrow d_i = -5.56 \text{ cm}$$

$$\text{Magnification} = m = -\frac{d_i}{d_o}$$

$$m = -\frac{(-5.56)}{12.5}$$

$$\Rightarrow m = -\frac{+5.56}{12.5}$$

$$\Rightarrow m = +0.445$$

The image is virtual (distance negative)

The image is upright. (magnification +ve)

The image is smaller than the object (magnification is less than 1)

Conclusion: Hence;Image Distance (in case of convex lens) = $d_i + 15 \text{ cm}$ Image Distance (In case of concave lens) = $d_i = -5.56 \text{ cm}$ Magnification (in case of convex lens) = $m = -0.5$ Magnification (in case of concave lens) = $m = +0.445$ **Assignment.12.7:** An 8 cm focal length converging lens is used as "Jeweler's loupe" which is a magnifying glass. Estimate the magnification (a) when the eye is relaxed and (b) if the eye is focused its near point.**Solution:****Given:**

Lens = converging lens = convex lens.

Focal length of converging lens = $f = +8 \text{ cm}$ Near -point distance = $N = 25 \text{ cm}$ (least Distance of Distinct vision)**Required:**(a) Magnification (when eye is relaxed) = $m = ?$ (b) Magnification (when eye is focused at near point) = $m = ?$ **Calculation:**Magnification (when eye is relaxed) = $m = ?$

We know that;

$$m = \frac{n}{f}$$

$$\Rightarrow m = \frac{25}{8}$$

$$\Rightarrow m = 3.12$$

Magnification (when eye is focused at near point) = $m = ?$

$$\text{We know that, } m = 1 + \frac{n}{f}$$

Putting value,

$$\Rightarrow m = 1 + \frac{25}{8}$$

$$\Rightarrow m = 1 + 3.12$$

$$m = 4.12$$

Conclusion: Hence;

- (a) 3 times magnified image is formed when the eye is relaxed.
 (b) 4 times magnified image is formed when the eye is focused at its near point.

Assignment 12.8: If the focal length of eye piece is increased, does the magnitude of the magnification increase (or) decrease? Check your response by calculating the magnification when the focal length of the eye piece is 3.6 cm

Solution:

Given: Focal length of objective = $f_o = 1.0\text{cm}$
 Near -point Distance = $N = 25\text{cm}$
 Image distance = $d_i = 11\text{cm}$
 Focal of eye -piece = $f_e = 3.5$

Required:

- (a) Effect on magnification=?
 (b) Magnification=?

Calculation:

Magnification of compound microscope and eye piece focal length:
 The magnification of compound microscope is given by;

$$m = -\frac{d_i}{f_o} \times \frac{N}{f_e} \text{----- (1)}$$

From eq(1) ,it is clear that the magnification of compound microscope is inversely proportional to the focal length of eye - piece (f_e) i.e. increase in focal length of eye - piece causes decrease in magnification of compound microscope and vice versa.

(b) Magnification when $f_e = 3.5\text{cm}$:

We know that;

$$m = -\frac{d_i}{f_o} \times \frac{N}{f_e}$$

Putting value

$$\Rightarrow m = -\frac{11}{1.0} \times \frac{25}{3.5}$$

$$\Rightarrow m = -78.6 = -79$$

$$\Rightarrow m = -79$$

The magnification of compound microscope is decreased when eye piece focal length is increased

Assignment 12.9: Astronomical telescope has the following specifications?
 $f_o = 985\text{mm}$ and $f_e = 5.00\text{mm}$. From these data points, find

- (a) The angular magnification and
 (b) The approximate length of this telescope.

Given: Focal length of objective = $f_o = 985\text{mm}$
 Focal length of eye piece = $f_e = 5\text{mm}$

Required:

- (a) Angular magnification = $m_\theta = ?$
 (b) Length of telescope = $L = ?$

Calculation:

(a) **Angular magnification:**

The angular magnification of an astronomical telescope is given by;

$$m_\theta = -\frac{f_o}{f_e}$$

$$\Rightarrow m_\theta = -\frac{985}{5}$$

$$\Rightarrow m_\theta = -197$$

(b) **Length of telescope:**

The length of an astronomical telescope is given by;

$$L = f_o + f_e$$

$$\Rightarrow L = 985 + 5$$

$$\Rightarrow L = 990\text{mm}$$

Conclusion: Hence;

Angular magnification = $m_\theta = -197$

Length of telescope = $L = 990\text{mm}$

EXERCISE

1. Choose the correct answer for each of the following;

- If the angle of incidence is 30° the angle of reflection will be
 a. 30° b. 45° c. 90° d. 210°
- When is the radius of curvature of concave mirror. Real diminished image will be formed when the object is at
 a. $D_o > r$ b. $d_o = r$ c. $r > d_o > f$ d. $d_o = f$
- The focal length of convex mirror with radius of curvature 10cm is
 a. +10cm b. +5cm c. -10cm d. -5cm
- An object is placed 7cm from a concave mirror whose radius of curvature is 10cm, the image formed will be
 a. Real and upright b. virtual and upright
 c. real and inverted d. virtual and inverted
- Which one of the following materials will refract light more
 a. Water b. glass c. air d. diamond
- A convex lense with focal length 8.00 cm has the power of lens
 a. 2.05 D b. 4.00D c. 12.5 D d. 16.0D
- If the distance from your eye's lense to the retina is shorter than for a normal eye, you will struggle to see object that are

- a. Nearby b. colorful c. far way d. moving fast
- viii. Who benefit more from using a magnify glass, a person whose near point is located at a distance away from the eye ball of
- a. 75cm b. 50cm c. 35cm d. 25cm
- ix. The human eye forms the image of an object at its
- a. Iris b. retina c. pupil d. cornea

Conceptual Question

Q1. Which type of lense would you use to start fire from light from light from sun concave (or) convex, would work best? At what distance from the lens should the paper be held for the best result?

Ans. Type of lense:

We will use a convex lens to start fire with the help of sun rays because the convex lens converges the parallel sun rays to a single point (principle focus "F") after refraction.

Procedure:

Take a convex lens and place a paper at a distance equal to focal length of the lens. The lens converges sun rays to the principle focus (on the paper). After some time the paper heat up and catches the fire.

For best results:

For the best results, the paper should be placed at the principle focus of a lens of large size should be used because larger lenses collect more sun rays.

Q2. If a concave mirror produces a real image, is the image necessarily inverted? Explain.

Ans. Real Image:

In image formed when light rays actually pass through the point where the image is formed is called real image.

Real Image Formed By Concave Mirror:

Real image can be produced by concave mirror when an object at principle focuses "F" (Or) beyond the principal focus of concave mirror. This real image formed by concave mirror will always be vertically inverted.

Conclusion:

Hence, the real image formed by concave mirror will be necessarily inverted.

Q3. Are rearview mirror using in cars concave (Or) Convex?

Ans. Rearview Mirrors Using in Cars:

Convex mirrors are used as rear view mirror in cars and other vehicles.

Field of view:

Convex mirror has a large field of view as compared to concave mirror. The convex forms virtual, erect and diminishes.

Conclusion:

Hence, for wider field of view, erect and clear images convex mirror is used as rearview. Mirror in cars and other vehicles.

Q4. A magician during a show makes a glass lens with $n=1.47$ disappear in a trough of liquid. What is the refractive index of the liquid? Could the liquid be water?

Ans. Refractive Index of Liquid Used to Disappear Glass:

Lens:

If a transparent object is surrounded by a transparent medium having the same refractive index as the object, then no reflection and no refraction take place and the object becomes invisible (disappear). Thus the glass lens with $n=1.47$ must be inserted in a liquid with the same refractive index i.e. $n=1.47$.

Water with $n=1.47$:

Since the refractive index of water is 1.33, so water cannot be used for the disappearance of the glass lens with $n=1.47$. It may be glycerin (Or) turpentine (Both have refractive index equal to 1.47)

Conclusion:

a) Hence, the glass lens must be inserted in a liquid having refractive index $= n=1.47$ for disappearance.

b) Water cannot be used for the disappearance of glass lens with $n=1.47$.

Q5. Suppose that you were handed a lens and a ruler and told to determine the focal length of the lens. How would you proceed?

Ans. Determination of Focal Length of Lens:

By Ruler (Or) Meter Rod:

Yes, we can determine the focal length of convex lens with the help of ruler (Or) meter rod.

Procedure:

In open atmosphere, make the sun rays focused on the wall and measure the distance between the lens and wall. This will be the focal length of the given convex lens.

Conclusion:

Hence, the focal length of convex lens can be determined with help of ruler by focusing sun rays on the wall.

Q6. Can we achieve total internal reflection from optically rare medium to optically dense medium?

Ans. No, we cannot achieve total internal reflection from optically rare medium to optically dense medium. The total internal reflection will take place when the following conditions are satisfied.

- The light rays must be enter from denser medium to the rare medium.
- The angle of incidence in the denser medium must be greater than critical angle.

Conclusion: Hence, we cannot achieve total internal reflection from optically rare medium to optically dense medium.

Q7. Will a nearsighted person who wears corrective lenses in her glasses be able to see clearly underwater when wearing those glasses.

Ans. No, a near sighted person who wears corrective lenses in her glasses will not be able to see clearly under water when wearing those glasses.

Explanation:

The lenses used by a near sighted person in her glasses are designed to work with the difference in refractive indices of air and glass but when the air is replaced with water, the difference in refractive indices is less. Thus the light will refract between "water and glass" as compare "air and glass", means these glasses would not correct your vision underwater these would not focus the light on correct spot in the eyes to create a clear image.

Conclusion:

Hence, a near sighted person who wears corrective lenses in her glasses will not be able to see clearly under water when wearing those glasses.

Q 8. When you use a simple magnifying glass, does it matter whether you hold the object to be examined closer to the lens than its focal length (Or) farther away? Explain

Ans. Yes, it matters whether we hold the object to be examined closer to the lens than its focal length (Or) farther away.

Magnifying Glass (Or) Simple Microscope:

A double convex lens is called magnifying glass (Or) Simple microscope.

Working Principle:

Simple magnifying glass works on the principle that "An object must be placed within the focal length of magnifying glass in order to get a magnified image this when we hold an object to a magnifying glass closer than its focal length, the image will be virtual erect and magnified.

Conclusion:

Hence, the magnification of magnifying glass depends on whether we hold the object to be examined.

Q 9. In blind turns on hilly roads, mirrors are used to help drivers. Are these mirrors plane mirrors, concave mirrors (Or) convex mirror? Explain.

Ans. Convex mirrors are used in blind turns on hilly roads to help drivers.

Explanation: Convex mirrors are used at blind corners. Convex mirror has a wider field of view. They also form virtual, erect and diminished images of objects. Thus convex mirror has larger field of view as compared to plane and concave mirror. Therefore convex mirrors are used in blind corners on hilly roads.

Numerical Problems

P 1: A 1.50 cm high object placed 20.0 cm from a concave mirror with radius of curvature 30.0 cm. Determine (a) the position of the image, and (b) is size, also draw the ray diagrams.

Solution:

Given: Mirror = Concave Mirror

Height of object = $h_o = 1.50$ cm

Position of object = $d_o = 20.0$ cm

Radius of Curvature = $R = 30.0$ cm

Focal length of concave mirror = $f = \frac{R}{2} = \frac{30}{2} = +15$ cm (concave mirror)

Required:

(a) Position of image = $d_i = ?$

(b) Height of image = $h_i = ?$

Calculation:

(a) Position of image (d_i):

We know that;

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{f} + \frac{1}{d_o}$$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{15} + \frac{1}{20}$$

$$\Rightarrow \frac{1}{d_i} = \frac{20+15}{(15)(20)}$$

$$\Rightarrow \frac{1}{d_i} = \frac{5}{300}$$

$$\Rightarrow d_i = \frac{300}{5}$$

$$d_i = 60 \text{ cm} \text{ ----- Answer}$$

(b) Height of image (h_i):

We know that;

$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

$$\Rightarrow h_i = \frac{d_i}{d_o} \times h_o$$

Putting values, we get;

$$\Rightarrow h_i = \frac{60}{20} \times 1.50$$

$$h_i = 4.5 \text{ cm} \text{ ----- Answer}$$

Conclusion: Hence;

a) Position of image = $d_i = 60$ cm

b) Height of image = 4.5 cm

P 2. A candle of height 8.0 cm is located at a distance of 300 mm from a concave mirror; its virtual image is formed behind the mirror at a distance f 3.0 cm from the pole (or vertex). Find the focal length of the mirror and height of the mirror formed.

Solution:

Given:

Mirror = Convex mirror
 Height of object = $h_o = 8.0$ cm
 Position of object = $d_o = 300.00$ mm = 30.0 cm
 Position of image = $d_i = -3.0$ cm

Required:

- Focal length = $f = ?$
- Height of image = $h_i = ?$

Calculations:

a) Focal length (f):

We know that;

$$\begin{aligned} \frac{1}{f} &= \frac{1}{d_o} + \frac{1}{d_i} \\ \Rightarrow \frac{1}{f} &= \frac{1}{30} + \frac{1}{-3} \\ \Rightarrow \frac{1}{f} &= \frac{1}{30} - \frac{1}{3} \\ \Rightarrow \frac{1}{f} &= \frac{1-10}{30} \\ \Rightarrow \frac{1}{f} &= \frac{-9}{30} \\ \Rightarrow f &= \frac{-30}{9} \end{aligned}$$

$$f = -3.33 \text{ cm} \text{----- Answer}$$

The -ve sign show that the mirror is convex.

b) Height of image:

We know that;

$$\begin{aligned} \frac{h_i}{h_o} &= \frac{d_i}{d_o} \\ \Rightarrow h_i &= \frac{d_i}{d_o} \times h_o \end{aligned}$$

Putting values, we get;

$$\Rightarrow h_i = \frac{-30}{30} \times 8$$

$$h_i = -0.8 \text{ cm} \text{----- Answer}$$

The -ve sign show that the image is virtual

Conclusion:

- Focal length = $f = -3.33$ cm
- Height of image = $h_i = -0.8$ cm

P 3. Calculate the speed of light in zircon with index of refraction $n = 1.923$, a material is used in jewelry to replicate diamond?

Solution:

Given:

Speed of light in vacuum = $c = 3 \times 10^8$ m/sec
 Refractive index of zircon = $n = 1.923$

Required:

Speed of light in zircon = $v = ?$

Calculation:

We know that;

$$\begin{aligned} n &= \frac{c}{v} \\ \Rightarrow v &= \frac{c}{n} \end{aligned}$$

Putting the values

$$v = \left(\frac{3 \times 10^8}{1.923} \right) \text{ m/sec}$$

$$v = 1.56 \times 10^8 \text{ m/sec}$$

Conclusion:

Hence; the speed of light in zircon (v) is 1.56×10^8 m/sec

P 4: A light ray strike in air / water surface at an angle of 26° with respect to the normal. The refractive index of water is 1.33. Find the angle of refraction when the direction of the rays is (a) from air to water (b) from water to air.

Solution:

Given:

Angle of incidence = $\theta_1 = 46^\circ$

Refractive index of air = $n_{\text{air}} = 1$

Refractive index of water = $n_w = 1.33$

Required:

(a) Angle of refraction (from air to water) = $\theta_{r1} = ?$

(b) Angle of refraction (from water to air) = $\theta_{r2} = ?$

(a) From air to water:

According to snell's law;

$$\begin{aligned} \frac{n_{\text{air}}}{n_{\text{water}}} &= \frac{\sin \theta_{r1}}{\sin \theta_i} \\ \Rightarrow \sin \theta_{r1} &= \frac{n_{\text{air}}}{n_{\text{water}}} \times \sin \theta_i \end{aligned}$$

Putting value we get,

$$\sin \theta_{r1} = \frac{1 \times \sin 46^\circ}{1.33}$$

$$\Rightarrow \sin \theta_{r_1} = \frac{1 \times \sin 0.72}{1.33}$$

$$\Rightarrow \sin \theta_{r_1} = 0.54$$

$$\Rightarrow \theta_{r_1} = \sin^{-1}(0.54)$$

$$\theta_{r_1} = 33^\circ \text{----- Answer}$$

(b) From water to Air:

According to snell's law;

$$\frac{n_{\text{water}}}{n_{\text{air}}} = \frac{\sin \theta_{r_2}}{\sin \theta_i}$$

$$\Rightarrow \sin \theta_{r_2} = \frac{n_{\text{water}}}{n_{\text{air}}} \times \sin \theta_i$$

Putting value we get;

$$\sin \theta_{r_2} = \frac{n_{\text{water}}}{n_{\text{air}}} \times \sin \theta_i$$

$$\Rightarrow \sin \theta_{r_2} = \frac{1.33 \times \sin 46^\circ}{1}$$

$$\Rightarrow \sin \theta_{r_2} = 0.96$$

$$\Rightarrow \theta_{r_2} = \sin^{-1}(0.96)$$

$$\theta_{r_2} = 74^\circ \text{----- Answer}$$

Conclusion: Hence;(a) Angle of refraction (from air to water) $= \theta_{r_1} = 33^\circ$ (b) Angle of refraction (from water to air) $= \theta_{r_2} = 74^\circ$

P 5: An optical fiber is made from flint glass with index of refraction 1.66 and is surrounded by a cladding made of crown glass with index of refraction 1.52. What is the critical angle?

Solution:**Given:**Refractive index of flint glass $= n_{F.G} = 1.66$ Refractive Index of crown glass $= n_{C.G} = 1.52$ **Required:**Critical Angle $= Q_c = ?$ **Calculation:**

We know that;

$$\sin Q_c = \frac{n_2}{n_1}$$

$$Q_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

Putting value, we get;

$$\Rightarrow Q_c = \sin^{-1} \frac{1.52}{1.66}$$

$$Q_c = 66.3^\circ \text{----- Answer}$$

Conclusion: Hence;Critical Angle $= Q_c = 66.3^\circ$

P 6: Suppose the book page is held 7.50 cm from a concave lens of focal length 10.0 cm. What magnification is produced in each case?

Solution:**Given:**

- (a) Lens = convex lens
Focal length $= f = 10.0 \text{ cm}$
Position of object $= d_o = 7.50 \text{ cm}$
- (b) Lens = concave lens
Focal length $= f = -10.0$
Position of object $= d_o = 7.50 \text{ cm}$

Required:

- (a) Magnification for convex lens $= M = ?$
(b) Magnification for concave lens $= M = ?$

Calculation:**(a) Magnification for convex lens (M):**

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

Putting value, we get;

$$\frac{1}{d_i} = \frac{1}{10} - \frac{1}{7.5}$$

$$\Rightarrow \frac{1}{d_i} = \frac{10 - 7.5}{7.5 \times 10}$$

$$\Rightarrow \frac{1}{d_i} = \frac{-2.5}{75}$$

$$\Rightarrow d_i = \frac{-75}{2.5}$$

$$\Rightarrow d_i = -30 \text{ cm}$$

Now;

$$M = \frac{-d_i}{d_o}$$

$$\Rightarrow M = -\frac{(-30)}{7.5}$$

$$M = +4 \text{----- Answer}$$

The +ve sign shows that the image is upright

(b) Magnification for Concave Lens:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

Putting values, we get;

$$\Rightarrow \frac{1}{d_i} = \frac{1}{-10} - \frac{1}{7.5}$$

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$$\Rightarrow \frac{1}{d_i} = -\frac{1}{10} - \frac{1}{7.5}$$

$$\Rightarrow \frac{1}{d_i} = \frac{-7.5-10}{(10)(7.5)}$$

$$\Rightarrow \frac{1}{d_i} = \frac{-17.5}{75}$$

$$\Rightarrow d_i = \frac{-75}{17.5}$$

$$d_i = -5.56 \text{ cm}$$

The -ve sign shows that the image is virtual,
Now;

$$M = -\frac{d_i}{d_o}$$

Putting value we get;

$$M = -\frac{-5.56}{7.5}$$

$$\Rightarrow M = +\frac{5.56}{7.5}$$

$$\Rightarrow M = +0.445 \text{----- Answer}$$

The +ve sign shows that the image is upright.

P 7: Gulalai is viewing a flea using a magnifier with $f = 3.0 \text{ cm}$ if her near point is at $N = 25 \text{ cm}$ then calculate the maximum magnification she can get.

Solution:

Given:

Focal length of magnifier = $f = 3 \text{ cm}$
Near point distance = $N = 25 \text{ cm}$

Required:

Maximum magnification = $M_{\max} = ?$

Calculation:

We know that

$$M_{\max} = \frac{N}{f} + 1$$

Putting values, we get;

$$\Rightarrow M_{\max} = \frac{25}{3} + 1$$

$$\Rightarrow M_{\max} = 8.33 + 1$$

$$\Rightarrow M_{\max} = 9.33$$

Conclusion: Hence;

Maximum magnification = $M_{\max} = 9.33$

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P 8: A telescope has a magnification of 40.0 and a length of 1230 mm. What are the focal lengths of the objective and eyepiece?

Solution:

Given:

Magnification of telescope = $M = 40$
Length of telescope = $L = 1230 \text{ mm}$

Required:

- (a) Focal length of objective = $f_o = ?$
(b) Focal length of eyepiece = $f_e = ?$

Calculation:

We know that,

$$M = \frac{f_o}{f_e}$$

$$\Rightarrow f_o = M f_e \text{----- (1)}$$

Also;

$$L = f_o + f_e$$

Putting equation(1) and Equation (2) we get;

$$L = M f_e + f_e$$

$$\Rightarrow L = (M + 1) f_e$$

$$\Rightarrow f_e = \frac{L}{M+1}$$

Putting value we get;

$$\Rightarrow f_e = \frac{1230}{40+1}$$

$$\Rightarrow f_e = \frac{1230}{41}$$

$$f_e = 30 \text{ mm} \text{----- Answer}$$

Putting eq(3) in eq(1)

$$f_o = (M)(30)$$

$$\Rightarrow f_o = (40)(30)$$

$$f_o = 1200 \text{ mm} \text{----- Answer}$$

Conclusion: Hence;

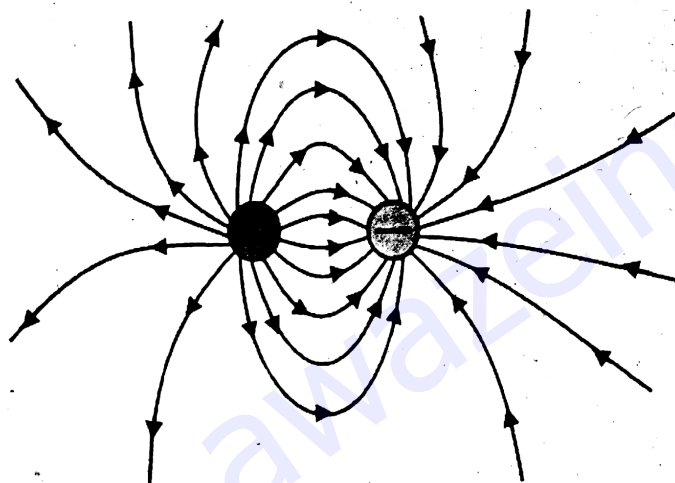
- (a) Focal length of objective = $f_o = 1200 \text{ mm}$
(b) Focal length of eyepiece = $f_e = 30 \text{ mm}$

Chapter No.13

Electrostatics

Major Concepts

- Production of electric charges
- Electrostatic induction
- Electroscope and its uses
- Coulomb's law
- Electric field and electric field intensity
- Electric field lines
- Electrostatic potential
- Capacitors and capacitance
- Combination methods of capacitors
- Types and uses of capacitors
- Solution of problems



Comprehensive Question

Q1. Define electrostatics and electric charge? How objects can be electrified? Describe with the help of experiments?

Electrostatics:

Electrostatics is composed of two words, Electro and statics, Electro mean charge and static mean rest. So it is defined as,

The branch of physics which deal with the study of charges at rest is called electrostatics.

Electric charge:

The deficiency (or) excess of electrons on an object is called electric charge.

If there is excess of electrons on an object, then the object is called negatively charged. If there is deficiency of electrons on an object, then the object is called positively charged.

The properties of electric charge can be understood with the help of different experiments discussed as follows.

Experiments No.1:

Take glass rod and rub it with silk cloth, we will observe that the glass rod will attract small pieces of paper toward itself.

Similarly the same type of behavior is observed by the silk cloth. If we suspend glass rod and bring the silk cloth near it, they will attract each other.

Experiment No.2:

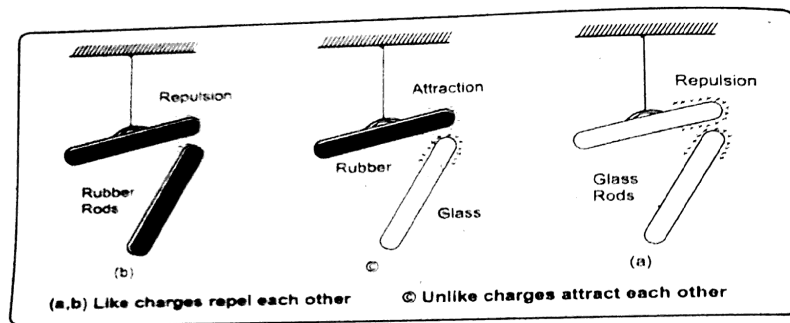
Take a rubber rod and rub it with woolen cloth, again we observe that the rubber rod and woolen cloth, attract small pieces of paper toward itself. If we suspend the rubber rod and bring the woolen cloth near it, they will attract each other.

Conclusion:

Before these experiments we observe that both the rods and both the cloths did not have this property of attraction. Since gravitational force is also attractive in nature. But the property of attraction in these two experiments is not due to gravitational force because gravitational force was present before rubbing of rods with the cloths but it was not strong enough to attract clothes toward the rods. The attraction is due to electrical force between the charges placed on rods by cloths due to rubbing.

Experiment No. 3:

Suspend glass rod rubbed with silk cloth and bring another glass rod rubbed with silk cloth near to the first glass rod. We will observe that these glass rods repel each other. Now suspend rubber rod rubbed with woolen cloth and bring a glass rod rubbed with silk cloth near to it, we will observe that these two rods attract each other. By bringing rubber rod rubbed with woolen cloth to the suspended rubber rod, we will observe that they also repel each other as shown in figure.



Q2. Define conductor and insulator. Give examples?

Ans. Conductor:

The substances through which electric current can flow easily are called conductors.

Explanation:

In a metallic substances such as solid copper, iron, aluminum etc. the valance electrons are not bound to any particular nucleus. They can move freely. They are called free electrons. Those substances which have a large number of free electrons per unit volume can easily conduct electric current are known as good conductors.

Insulators:

The substances through which electric current cannot flow easily are called insulators.

Examples:

Dry wood, plastic, glass, rubber etc.

In insulators the valance electrons are tightly bounded with the respective nucleus. Therefore, electric current cannot flow easily through insulator.

Q 3. A material is neither a perfect conductor nor perfect insulator, explain it?

Ans. A material is neither a perfect conductor nor perfect insulator because under certain cases an insulator may behave like a conductor and conductor may behave like an insulator. For example air is an insulator, but due to strong electric forces it may becomes a conductor temporarily.

Similarly the air between ground and charged clouds becomes a conductor and allow the flow of current.

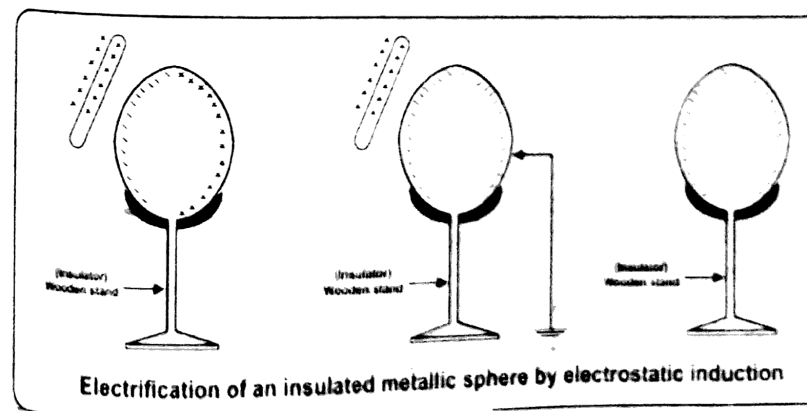
Q 4. Explain the phenomena of electrostatic induction. How a conductor is charged by electrostatic induction?

Ans. Electrostatic induction:

The modification in the distribution of electric charge on one material under the influence of an electric charge on a nearby object is called electrostatic induction.

Charging a conductor by electrostatic induction:

Fix a metallic sphere on an insulating stand. Bring a positively charge rod near the sphere, the free electrons in the metallic sphere will move toward the charge rod. Negative charge will accumulates on the surface of the sphere toward the positively charge rod. Keeping the rod in its place, earth the conductor by touching it for short time with your finger. Now by removing the rod, the conductor is negatively charge. Due to mutual repulsion, the electrons spread uniformly on the surface of metallic sphere. The method of charging a conductor in this manner is called charging by induction as shown in the figure below.



Q 5. Describe a gold leaf electroscope. By using an electroscope, how can we find the:

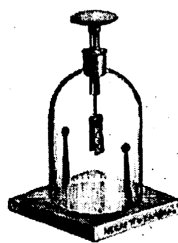
- The presence of charge on a body.
- The nature of charge present on a body.

Ans. Electroscope:

An instrument which is used for the detecting and testing the nature of charge is called electroscope.

Construction:

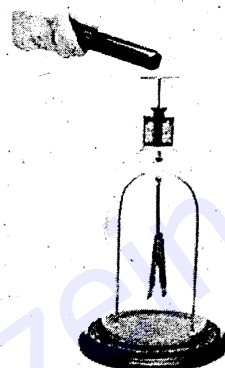
A gold leaf electroscope consists of a metal rod which has small metallic sphere at the upper end while the two gold metal leaves are attached to the lower end of the rod. The rod is fixed in a glass jar and is well insulated from the case, as shown in the figure.



Simple leaf electroscope

i) Detecting of charge:

In order to detect the presence of charge on a body, bring it near the disk of an uncharged electroscope as shown in figure.



Gold leaf electric scope

If the body is charge, the leaves of the electroscope diverge to a definite extent otherwise they would remain in their normal position. The divergence between the leaves of electroscope is due to electrostatic induction. For example when a negatively charged body is brought near the electroscope, due to induction positive charge will appear on the disc and negative charge on the leaves. As like charges repel each other, therefore due to the force of repulsion between negative Charges on the two leaves, the leaves will move away from each other as show in the above figure.

ii)Testing the nature of Charge:

To test the nature of charge on a body, we need to charge the electroscope first. In order to charge the electroscope positively, touch its disc with positively charged body. Similarly if we Charge the electroscope negatively, touch its disc with negatively charged body. In this process

some of the charges present on the body are transferred to the disc and leaves of electroscope.

After charging electroscope bring the body under test near the disc of electroscope. If the divergence of leaves increases, the body has the same kind of charge as on the electroscope. On the other hand if the divergence decreases, the charge on the body will be opposite to the charge present on the electroscope.

Q 6. State Coulomb's Law. Explain and also define the unit of charge?

Ans. Coulomb's Law:

History:

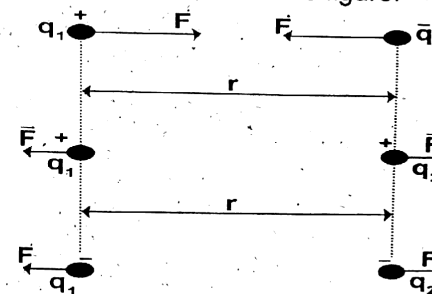
In 1785 French physicist Charles Coulomb formulated his law of electrostatics known as Coulomb law of electrostatics.

Statement:

This law states that; "the force of attraction (or) repulsion between two point charges is directly proportion to the product of charges and inversely proportional to the square of the distance between them."

Mathematical form:

Let us consider two point charges q_1 and q_2 are placed at a distance "r" from each other as shown in the figure.



According to the statement of coulomb's law, we have

$$F \propto q_1 q_2 \text{ ----- (1)}$$

$$\Rightarrow F \propto \frac{1}{r^2} \text{ ----- (2)}$$

Combining (1) and (2), we get,

$$\Rightarrow F = k \frac{q_1 q_2}{r^2} \text{ ----- (3)}$$

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Where "k" is constant of proportionality the value of "K" depends on the nature of the medium between the charges and the system of units in which F, r and q are measured.

In SI system the value of "k" for air (or) free space is given by;

$$K = k_0 = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \frac{N.m^2}{C^2}$$

Where "ε" is the permittivity of air (or) vacuum.

Thus equation (3) becomes;

$$F = \frac{1}{4\pi\epsilon_0} \times \frac{q_1 q_2}{r^2}$$

Unit of charge:

In SI system, coulomb is the unit of charge.

Definition:

One coulomb is the quantity of charge which when placed one meter apart from an equal and same charge in vacuum repel it with a force of $9 \times 10^9 N$.

Numerically:

$$1C = 6.25 \times 10^{18} \text{ electrons}$$

Sub units of charge:

The commonly used sub unit of charge is micro coulomb.

$$1\mu C = 10^{-6} C$$

Q7. What do you mean by electric field? Illustrate how is it represented by lines of force?

Ans. Electric Field:

The region (or) space around a source charge in which a test charge, brought in to the region would experience an electric force is called electric field.

Electric field is a vector quantity because at each point in the electric field a test charge experiences a directed electric force.

Electric Lines of Force:

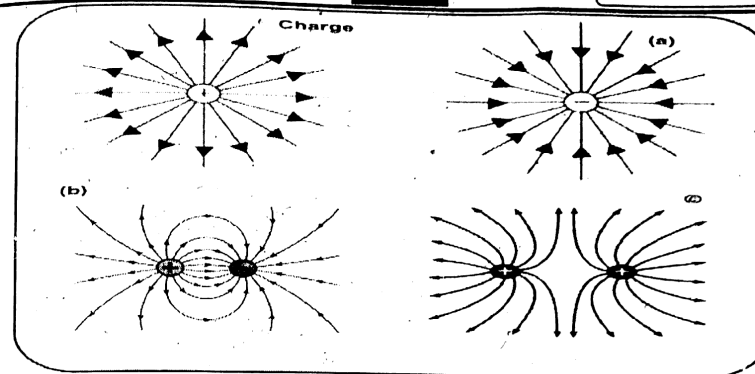
"The path followed by a test charge when a source charge exerts a force on it is called electric line of force."

The electric lines of force represent the direction of the electric field. The electric lines of force originating from positive charge and terminate at the negative charge as shown in figure.

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Electrostatics



Q 8. Define electric field intensity. Explain its magnitude and direction by providing figures for illustration?

Ans. Electric Field intensity:

The force per unit positive test charge is called electric field intensity. It is denoted by " $\vec{E}$ ".

Mathematically:

$$\vec{E} = \frac{\vec{F}}{q_0}$$

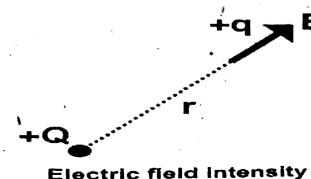
Unit:

The unit of electric field intensity is N/C .

Direction and magnitude of electric field:**Intensity:**

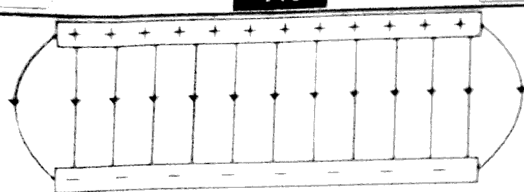
Electric field intensity is a vector quantity which gives the strength and direction of the electric field at point of consideration.

The direction of electric field intensity is the same in which the test charge moves.

**Uniform Electric Field:**

The electric field of constant magnitude and unchanging direction is called uniform electric field.

The electric field lines of force for oppositely charge pair of large and closely spaced plates as shown below.



Uniform electric field between a pair of charged plate

In this case, the lines are parallel and uniformly spaced. Such a field of uniformly spaced parallel lines is called uniform electric field.

Q 9. Explain electrostatic potential?

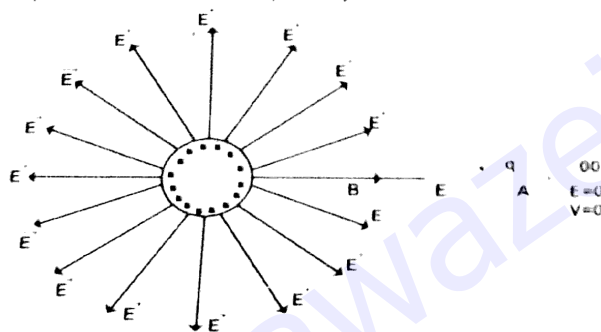
Ans. Electrostatic potential:

The electrostatic potential at any point in the electric field is defined as, "The potential energy gained by a unit positive charge when brought from infinity to a field point".

If "w" is the amount of work done in bringing a test charge "+q" from infinity to a certain point in the field, the electrostatic potential "V" at this point is given by,

$$V = \frac{W}{q}$$

Electrostatic potential is a scalar quantity. Its SI unit is volt.



Definition of volt:

The electrostatic potential is said to be one volt, if the potential energy of one coulomb positive charge at a point is one joule. "OR"

The potential difference is said to be one volt if one Joule work is required to move a unit positive charge of one coulomb from one point to another point against the electric field intensity.

Potential Difference:

The potential difference between two points is defined as,

The energy supplied by a unit positive charge as it moves from a point of higher to a point of lower potential is called potential difference.

A unit positive test charge " q_0 " is moved from point "A" to point "B", the potential difference

$$\Delta V = V_A - V_B = \frac{W_{AB}}{q_0}$$

Q10 Give some practical applications in which electric field is useful?

Ans. Application of Electrostatics:

Some important applications of electrostatics are as follows.

(i) Electro painting:

Electro painting is used in applying paints on the surface of different articles. Electro – painting of the bodies of automobiles, refrigerator, metallic furniture etc. has become a standard technology. The body of the car to be painted is earthed. The particles of the paint emerge out of the nozzle of the spray machine, they acquire a positive charge as shown in the figure.



When these positively charged particles reach near the body of the car, they induce negative charges. Due to the force of attraction a very firm coating of the paint is formed on the surface of the car. This method is very effective, efficient and cheap. It also requires less paint as compared to other methods.

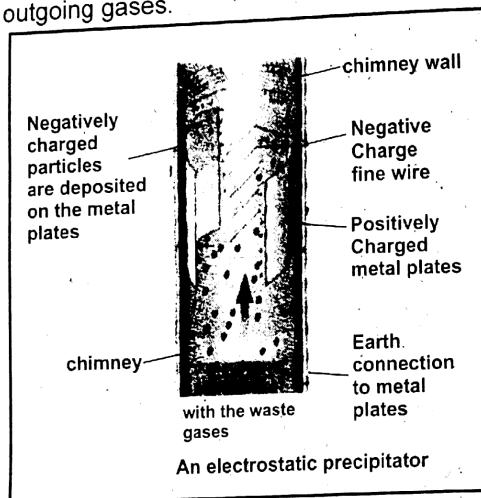
(ii) Dust extraction:

Electrostatic phenomena is also used for separation of smoke and dust particles from a modern coal-burning power station by means of an electrostatic precipitator. If it is not separated it would cause a serious air pollution.

In a chimney wire gauze is fixed between two metallic plates. The plates are electrically earthed and the wire gauze is highly charged with

positive charges. So the wire gauze induces negative charges on the inner surfaces of the plates. In this way strong electric field is produced between the wire gauze and the plates.

When gases exit through the chimney, they acquire positive charge by coming in contact with the wire gauze. So they are attracted to the negatively charged plate on reaching the plates, the smoke and other particles are deposited there. The dust and smoke particles are thus removed from the outgoing gases.



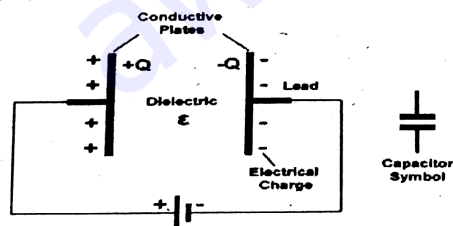
Q11. What is a capacitor? Define and explain capacitance. Also define the unit of capacitance?

Ans. Capacitor:

"An electrical device which is used for storage of electrical charge and hence energy, is known as capacitor".

Construction:

Capacitor consists of two parallel metal plates separated by some insulator like air, paper, mica etc.



Parallel Plate capacitor

Charging of a capacitor:

When the plates of a capacitor are connected with the terminals of a battery, the positive terminal of a battery charges the plate "A" positively while negative terminal charges the plate "B" negatively. In this way some electrons are transferred through the battery from positive plate to the negative plate. Mutual attraction between the plates keeps them bound on the two plates. The Charges remain stored in the capacitor even, after the removal of battery.

Capacitance of a capacitor:

The capacity of a capacitor to store charge is called capacitance of the capacitor.

Experimentally, it has been observed that the charge "Q" on the plates of a capacitor is directly proportional to the potential difference "V" applied. i.e.

$$\begin{aligned} Q &\propto V \\ \Rightarrow Q &= CV \\ \Rightarrow C &= \frac{Q}{V} \end{aligned}$$

Where "C" is constant known as capacitance of the capacitor. Its value depends upon the area of the plates. Distance between the plates and medium between the plates.

The larger the plates, closer the plates and more insulating the medium between them, the higher is the capacitance of the capacitor.

Unit of capacitance:

Farad is the unit of capacitance of capacitor in the honour of Micheal faraday.

Since capacitance is given by;

$$\Rightarrow C = \frac{Q}{V}$$

If $Q = 1\text{c}$ and $V = 1\text{volt}$, then capacitance of capacitor is;

$$C = \frac{1\text{C}}{1\text{V}} = 1 \text{ Farad}$$

The capacitance of a capacitor is said to be 1 Farad, if it stores one coulomb charge when one volt potential difference is applied.

Convenient Sub multiples of farad are;

$$1\mu\text{F} = 10^{-6}\text{Farad}$$

$$1 \text{ Pico Farad} = 10^{-12} \text{ Farad}$$

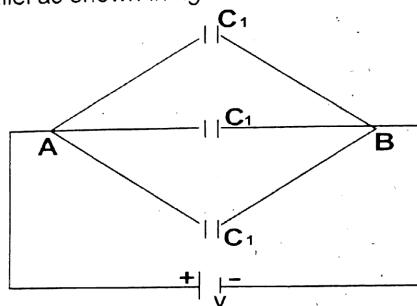
Q 12. How are the capacitors connected in parallel? Describe the characteristic features of this combination.

Ans. Parallel combination of capacitors:

When two (or) more capacitors are connected in such a way that the potential difference across the plates of each capacitor is the same while the charge stored on the plates of each capacitor is different, then the combination is known as capacitors in parallel.

Explanation:

Let us consider three capacitors having capacitances C_1 , C_2 , C_3 are connected in parallel as shown in figure.



Parallel combination of capacitors

Since in case of parallel combination, the potential difference across the plates of each capacitor is the same while different charge is stored on the plates of each capacitor i.e. Q_1 , Q_2 and Q_3 respectively.

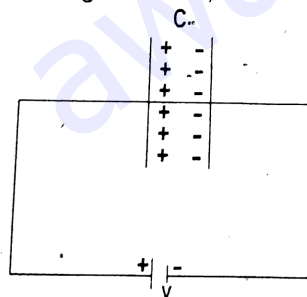
So;

$$Q = Q_1 + Q_2 + Q_3$$

$$\Rightarrow Q = C_1V + C_2V + C_3V \quad (\because v_1 + v_2 + v_3 = v)$$

$$\Rightarrow Q = V(C_1 + C_2 + C_3) \quad \text{-----(1)}$$

Let the three Capacitors are replaced by an equivalent capacitor of capacitance " C_{eq} " which can store the amount of charge " Q " under the same condition as shown in figure below;



Now;

$$Q = C_{eq}V \quad \text{----- (2)}$$

Comparing equation (1) and equation (2), we get;

$$\Rightarrow C_{eq}V = V(C_1 + C_2 + C_3)$$

$$\Rightarrow C_{eq} = C_1 + C_2 + C_3 \quad \text{----- } C_n$$

Thus it is concluded that the capacitance of the equivalent capacitor is equal to the sum of the capacitances of all the capacitors which are connected in parallel.

Characteristic Features of parallel combination:

Parallel combination of capacitors has the following characteristics features.

- In case of parallel combination the potential difference (V) across each of the capacitor is same i.e. $V_1 = V_2 = V_3 = V$
- In case of parallel combination of capacitors the charge stored on the plates of each capacitor is different.
- In case of parallel combination of capacitors the capacitance of the equivalent capacitor is equal to the sum of all the capacitors which are connected in parallel. i.e. $C_{eq} = C_1 + C_2 + \dots + C_n$
- The equivalent capacitance of parallel Combination is greater than the greatest capacitance of capacitor connected in parallel.

Q 13. How are the capacitors connected in series? Describe the characteristic features of this combination?

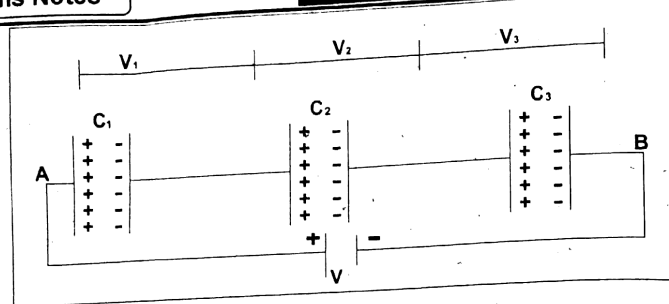
Ans. Series combination of capacitors:

When two or more capacitors are connected in such a way that the same charge is stored on the plates of each capacitor, while potential difference across the plates of each capacitor is different, such combination of capacitors is known as series combination of capacitors.

Explanation:

Let us consider three capacitors having capacitances C_1 , C_2 , and C_3 are connected in series. They are connected plate to plate. A battery of voltage V supplies $+Q$ charge to the left plate of the capacitor " C_1 ". Due to induction " $-Q$ " charge is induced on its right plate.

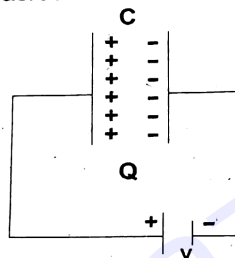
The electrons which produce the negative charge on C_1 must come from the left plate of " C_2 " and leave it with charge $+Q$ ". This charging process continues to capacitor " C_3 " as shown below.



Since the charge on each capacitor is the same i.e., $Q = Q_1 = Q_2 = Q_3$ while the voltage across C_1 , C_2 and C_3 are V_1 , V_2 and V_3 respectively. So,

$$\begin{aligned} V &= V_1 + V_2 + V_3 \\ \Rightarrow V &= \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3} \\ \Rightarrow V &= Q \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right) \quad (1) \end{aligned}$$

Now we are replacing these three capacitors by an equivalent capacitor of capacitance " C_{eq} " which can store equal amount of charge " Q " when voltage V is applied across it as shown in figure.



Now,

$$\begin{aligned} Q &= C_{eq} V \\ \Rightarrow V &= \frac{Q}{C_{eq}} \quad (2) \end{aligned}$$

Comparing equation (1) and equation (2);

$$\begin{aligned} \Rightarrow \frac{Q}{C_{eq}} &= Q \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right) \\ \Rightarrow \frac{1}{C_{eq}} &= \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \right) \end{aligned}$$

Thus it is concluded that the reciprocal of the capacitance of equivalent capacitor is equal to the sum of the reciprocal of individual capacitances of the capacitors which are connected in series.

Characteristic Features of series combination:

Series combination has the following Characteristic features.

- In series combination of capacitors the charge stored on the plates of each capacitor is the same i.e. $Q_1 = Q_2 = Q_3 = Q$
- In series combination of capacitors the potential difference across the plates of each capacitor is different.
- In series combination of capacitors the reciprocal of the capacitance of equivalent capacitor is equal to the sum of the reciprocal of individual capacitances of the capacitors connected in series. i.e. $\frac{1}{C_{eq}} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n} \right)$
- The equivalent capacitance of series combination is smaller than the smallest capacitance of capacitor connected in series.

Q 14. What are the types of capacitors?

Ans. Type of capacitor:

There are two type of capacitor which are given below.

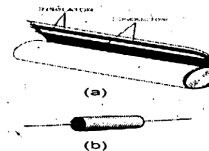
i) Fixed Capacitor:

A capacitor of constant capacitance is called Fixed Capacitor.

In Fixed capacitor the plates are immovable.

Examples:

Paper capacitor and mica capacitor are examples of fixed capacitor.



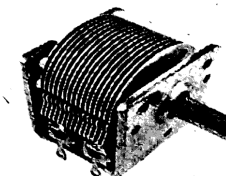
ii) Variable Capacitor:

A capacitor of variable capacitance is called variable capacitor.

In parallel plates a capacitor some arrangements are made that the area of the plates facing each other can be change then it is called variable capacitor as shown in figure.

For example:

The capacitors used in tuning of a radio frequency.



Examples

Examples 13.1: The two protons and two neutrons in the nucleus of the helium atom are held together by the strong force, which is required to overcome the electrostatic repulsion between the protons. The charge of each proton is $q_p = +1.6 \times 10^{-19} \text{ C}$. A distance of approximately $r = 2 \times 10^{-15} \text{ m}$ separates the two protons. Calculate the magnitude of the electrostatic force between the protons.

Given:

Charge on proton $q_p = +1.6 \times 10^{-19} \text{ C}$

Distance $r = 2 \times 10^{-15} \text{ m}$

Coulomb Constant ' K ' = $9 \times 10^9 \text{ Nm}^2/\text{C}^2$

Required: Force ' F_E '=?

Solution:

Using Coulomb's Law, we can find the force

$$F_E = k \frac{q_p \times q_p}{r^2}$$

Putting the value

$$F_E = \frac{(1.6 \times 10^{-19} \text{ C}) \times (1.6 \times 10^{-19} \text{ C})}{(2 \times 10^{-15})^2} = 57.6 \text{ N} \text{----- Answer}$$

Conclusion: Hence,

The magnitude of the electrostatic force between the protons is **57.6 N**.

Example 13.2: A positive test charge of $30 \mu\text{C}$ is placed in an electric field. Force on it is 0.600 N . What is the magnitude of electric field at the location of test charge?

Given:

Test charge $q_o = 30 \mu\text{C} = 30 \times 10^{-6} \text{ C}$

Force ' F_E ' = 0.600 N

Required:

Electric field intensity ' E '=?

Solution: By definition of electric field intensity

$$\vec{E} = \frac{\vec{F}_E}{q_o}$$

Putting the value

$$\vec{E} = \frac{0.600 \text{ N}}{30 \times 10^{-6} \text{ C}} = 2.00 \times 10^4 \text{ NC}^{-1} \text{----- Answer}$$

Conclusion: Hence,

The magnitude of electric field is **$\vec{E} = 2.00 \times 10^4 \text{ NC}^{-1}$**

Example 13.3: Work done

How much work must be done to increase the potential of a charge $2.5 \times 10^{-7} \text{ C}$ by 100 V ?

Given:

Charge ' q ' = $2.5 \times 10^{-7} \text{ C}$

Change in potential ' ΔV ' = 100 V

Required:

Work done ' W '=?

Solution:

By definition of electric potential

$$V = \frac{W}{q} \quad \text{or} \quad W = qV$$

Putting values

$$W = 2.5 \times 10^{-7} \text{ C} \times 100 \text{ V}$$

$$W = 2.5 \times 10^{-5} \text{ J} \text{----- Answer}$$

Conclusion: Hence,

The work done is **$W = 2.5 \times 10^{-5} \text{ J}$** .

Example 13.4: Capacitor of MP3 Player

A typical capacitor in an MP3 player has $C = 0.10 \mu\text{F}$. If a charge $5.0 \mu\text{C}$ is placed on the plates, what is the voltage across the capacitor?

Given:

Charge $q = 5 \mu\text{C} = 5 \times 10^{-6} \text{ C}$

Capacitance ' C ' = $0.10 \mu\text{F} = 0.10 \times 10^{-6} \text{ F}$

Required:

Voltage ' V '=?

Solution:

The capacitance of capacitor is $C = \frac{Q}{V}$ Or $V = \frac{Q}{C}$

$$\text{Putting values} \quad V = \frac{5 \times 10^{-6} \text{ C}}{0.10 \times 10^{-6} \text{ F}}$$

$$\text{Or} \quad V = \frac{5 \times 10^{-6} \text{ C}}{0.10 \times 10^{-6} \text{ C/V}}$$

$$V = 50 \text{ V} \text{----- Answer}$$

Conclusion: Hence,

The voltage across the capacitor is **$V = 50 \text{ V}$** .

Example 13.5:

Two capacitors of $5\mu F$ and $10\mu F$ are connected in series with the external source of voltage is $100V$. Calculate the total capacitance and the potential drop across each capacitor.

Given:

$$\text{Capacitor } C_1 = 5\mu F = 5 \times 10^{-6} F$$

$$\text{Capacitor } C_2 = 10\mu F = 10 \times 10^{-6} F$$

$$\text{Voltage } V = 100 V$$

Required:

$$(a) \text{ Equivalent capacitance } C_{eq} = ?$$

$$(b) \text{ Potential drops } V_1 \text{ and } V_2 = ?$$

Solution:

(a) Equivalent capacitance $C_{eq} = ?$

For series combination the equivalent capacitance is

$$\frac{1}{C_e} = \frac{1}{C_1} + \frac{1}{C_2} \quad \text{or} \quad \frac{1}{C_e} = \frac{C_2 + C_1}{C_1 C_2} \quad \text{or} \quad C_e = \frac{C_1 C_2}{C_2 + C_1}$$

$$\text{Putting value} \quad C_e = \frac{5 \times 10^{-6} F \times 10 \times 10^{-6} F}{5 \times 10^{-6} F + 10 \times 10^{-6} F}$$

$$\text{Or} \quad C_e = \frac{50 \times 10^{-12} F^2}{15 \times 10^{-6} F}$$

$$C_e = 3.33 \times 10^{-6} F = 3.33 \mu F \text{ ----- Answer}$$

(b) Potential drops V_1 and $V_2 = ?$

In series combination, the charge remains the same $q_1 = q_2 = Q$

The charge on each capacitor is $Q = C_e V$

$$\text{Putting values} \quad Q = 3.33 \times 10^{-6} F \times 100 V$$

$$\text{Hence} \quad Q = 3.33 \times 10^{-4} C$$

$$\text{Therefore} \quad q_1 = q_2 = Q = 3.33 \times 10^{-4} C$$

However, series combination of circuit elements the voltage splits, the voltage across capacitor C_1 and capacitor C_2 as V_1 and V_2 , respectively

$$\Rightarrow V_1 = \frac{Q}{C_1}$$

$$\text{Putting value} \quad \Rightarrow V_1 = \frac{3.33 \times 10^{-4} C}{5 \times 10^{-6} F}$$

$$\Rightarrow V_1 = 0.666 \times 10^2 V$$

$$V_1 = 66.6 V \text{ ----- Answer}$$

$$\Rightarrow V_2 = \frac{Q}{C_2}$$

$$\text{Putting value} \quad \Rightarrow V_2 = \frac{3.33 \times 10^{-4} C}{10 \times 10^{-6} F}$$

$$\Rightarrow V_2 = 0.333 \times 10^2 V$$

$$V_2 = 33.3 V \text{ ----- Answer}$$

Conclusion:

$$(a) C_e = 3.33 \times 10^{-6} F = 3.33 \mu F$$

$$(b) \text{ That } V_1 + V_2 = 66.6 + 33.3 = 100 = V, \text{ That is the battery voltage is split between the two capacitors.}$$

Example 13.6: Parallel combination of Capacitor

Two capacitors of $4\mu F$ and $8\mu F$ are in parallel. In each case the external source of voltage is $100 V$. Calculate the total capacitance and the charge on each capacitor.

Given:

$$\text{Capacitor } C_1 = 4\mu F = 4 \times 10^{-6} F$$

$$\text{Capacitor } C_2 = 8\mu F = 8 \times 10^{-6} F$$

Required:

$$(a) \text{ Equivalent capacitance } C_{eq} = ?$$

$$(b) \text{ Charge } q_1 \text{ and } q_2 = ?$$

Solution:

(a) Equivalent capacitance $C_{eq} = ?$

For Parallel combination, the equivalent capacitance is,

$$C_e = C_1 + C_2$$

Putting values,

$$C_e = 4 \times 10^{-6} F + 8 \times 10^{-6} F$$

Therefore,

$$C_e = 12 \times 10^{-6} F = 12 \mu F \text{ ----- Answer}$$

(b) Charge q_1 and $q_2 = ?$

In parallel combination the voltage remains the same $V_1 = V_2 = V$

Since the applied voltage $V = 100 V$, Therefore $V_1 = V_2 = V = 100 V$

In parallel combination the charge splits, the charge stored in first capacitor C_1 is

$$q_1 = C_1 V$$

Putting values

$$q_1 = 4 \times 10^{-6} C \times 100 V$$

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$$q_1 = 400 \times 10^{-6}$$

$$q_1 = 400 \mu\text{C} \text{----- Answer}$$

In parallel combination the charge splits, the charge stored in second capacitor C_2 is,

$$q_2 = C_2 V$$

Putting values

$$q_2 = 8 \times 10^{-6} \text{C} \times 100 \text{V}$$

$$q_2 = 800 \times 10^{-6} \text{C}$$

$$q_2 = 800 \mu\text{C} \text{----- Answer}$$

Conclusion:

(a) Equivalent capacitance $C_{eq} = 12 \times 10^{-6} \text{F} = 12 \mu\text{F}$

(b) Charge q_1 is $400 \mu\text{C}$ and charge of q_2 is $400 \mu\text{C}$

Assignments

Assignment 13.1: A small metal sphere with a charge of $-2.10 \times 10^{-6} \text{C}$ is brought near an identical sphere with a positive charge of $1.5 \times 10^{-6} \text{C}$ so that the distance between the Centres of the two spheres is 3.30cm. Calculate the magnitude of the force that each charge exerts on the other?

Solution:

Given:

Charge on 1st sphere $q_1 = -2.10 \times 10^{-6} \text{C}$

Charge on 2nd sphere $q_2 = 1.5 \times 10^{-6} \text{C}$

Distance between the Centres of the sphere = $r = 3.30 \text{cm} = 0.033 \text{m}$

Coulomb constant = $k = 9 \times 10^9 \text{Nm}^2/\text{C}^2$

Required:

$$\text{Force} = F_E = ?$$

Calculation:

$$F_E = \frac{k q_1 q_2}{r^2}$$

Putting values, we get;

$$F_E = \frac{(9 \times 10^9)(-2.10 \times 10^{-6})(1.5 \times 10^{-6})}{(0.033^2)}$$

$$\Rightarrow F_E = 26033 \times 10^{-3} \text{N}$$

$$F_E = -26 \text{N} \text{----- Answer}$$

The -ve sign shows that the force is attractive.

Conclusion: Hence;

Electrostatic attractive force $F_E = 26 \text{N}$

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Assignment 13.2: If a charge of $4 \mu\text{C}$ is placed in a uniform field of strength 2NC^{-1} , what force will it experience?

Solution:

Given:

Charge = $q_0 = 4 \mu\text{C} = 4 \times 10^{-6} \text{C}$

Electric field intensity = $E = 2 \text{N/C}$

Required:

$$\text{Force} = F_E = ?$$

Calculation:

$$\Rightarrow E = \frac{F_E}{q_0}$$

$$\Rightarrow F_E = E \times q_0$$

Putting the value, we get;

$$\Rightarrow F_E = (4 \times 10^{-6})(2)$$

$$\Rightarrow F_E = 8 \times 10^{-6}$$

$$F_E = 8 \mu\text{N} \text{----- Answer}$$

Conclusion: Hence;

Force experienced by charge = $F_E = 8 \mu\text{N}$

Assignment 13.3: How much work is done in moving a charge of 3C from a point at 118V to a point at 138v in an electric field?

Solution:

Given:

Charge = $q = 3 \text{C}$

Change in potential = $v = 138 - 118 = 20 \text{V}$

Required:

$$\text{Work done} = W = ?$$

Calculation:

We know that:

$$W = \frac{W}{q}$$

$$W = qv$$

Putting values; we get

$$W = (3)(20)$$

$$W = 60 \text{J} \text{----- Answer}$$

Conclusion: Hence;

Work done = $W = 60 \text{J}$

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Assignment 13.4: The potential difference across the plates of the capacitor is 500V. The charge on each plate is 0.02C. What is the capacitance of the capacitor?

Solution:

Given:

$$\begin{aligned}\text{Charge } q &= 0.02\text{C} \\ \text{Electric potential } V &= 500\end{aligned}$$

Required:

$$\text{Capacitance } C = ?$$

Calculation:

We know that;

$$C = \frac{Q}{V}$$

$$C = \frac{0.02}{500}$$

$$C = 0.00004\text{F} \text{----- Answer}$$

Conclusion: Hence;

$$\text{Capacitance of capacitor } C = 0.00004\text{ F Or } 4 \times 10^{-5}\text{ F}$$

Assignment 13.5: Two capacitors of capacitance $3\mu\text{F}$ and $6\mu\text{F}$ are connected in series to a 100V battery. Calculate the equivalent capacitance and the voltage across each capacitor.

Solution: Combination = series

Given:

$$\begin{aligned}C_1 &= 3\mu\text{F} \\ C_2 &= 6\mu\text{F} \\ V &= 100\text{V}\end{aligned}$$

Required:

(a) Equivalent capacitance = $C_{eq} = ?$

(b) Voltage across $C_1 = V_1 = ?$

(c) Voltage across $C_2 = V_2 = ?$

(a) Equivalent capacitance = $C_{eq} = ?$

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

Putting the value;

$$\Rightarrow \frac{1}{C_{eq}} = \frac{1}{3} + \frac{1}{6}$$

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$$\Rightarrow \frac{1}{C_{eq}} = \frac{2+1}{6}$$

$$\Rightarrow \frac{1}{C_{eq}} = \frac{3}{6}$$

$$C_{eq} = 2\mu\text{F} \text{----- Answer}$$

Change of each capacitor:

In series combination, same charge is stored on the plates of each capacitor i.e. $Q_1 = Q_2 = Q$ this the "Q" on each capacitor is given by;

$$Q = C_{eq}V$$

$$\Rightarrow Q = (2\mu\text{F})(100\text{V})$$

$$Q = 2.10 \times 10^{-4}\text{C}$$

Voltage across C_1 and C_2 :

In series combination voltage across each capacitor is different therefore;

$$\Rightarrow V_1 = \frac{Q}{C_1}$$

$$\Rightarrow V_1 = \frac{2 \times 10^{-4}}{3 \times 10^{-6}}$$

$$V_1 = 66.6\text{V} \text{----- Answer}$$

and

$$V_2 = \frac{Q}{C_2}$$

$$\Rightarrow V_2 = \frac{2 \times 10^{-4}}{6 \times 10^{-6}}$$

$$V_2 = 33.3\text{V} \text{----- Answer}$$

Conclusion: Hence;

(a) Equivalent capacitance = $C_{eq} = 2\mu\text{F}$

(b) Voltage across $C_1 = V_1 = 66.6\text{V}$

(c) Voltage across $C_2 = V_2 = 33.3\text{V}$

Assignment 13.6: Two capacitors of capacitance $3\mu\text{F}$ and $6\mu\text{F}$ are connected in parallel to a 800V battery. Find the equivalent capacitance and charge across each capacitor.

Solution:

Given:

Combination = parallel

$$\text{Capacitance } C_1 = 3\mu\text{F} = 3 \times 10^{-6}\text{F}$$

$$\text{Capacitance } C_2 = 6\mu\text{F} = 6 \times 10^{-6}\text{F}$$

$$\text{Voltage } V = 800\text{V}$$

Required:

- (a) Equivalent capacitance $= C_{eq} = ?$
 (b) Change Q_1 and $Q_2 = ?$

Calculation:**(a) $C_{eq} = ?$**

For parallel combination, the equivalent capacitance is given;

$$C_{eq} = C_1 + C_2$$

$$\Rightarrow C_{eq} = 3\mu F + 6\mu F$$

$$C_{eq} = 9\mu F$$

(b) Change Q_1 and $Q_2 = ?$

In parallel combination of capacitors, voltage remains constant i.e.
 $V_1 = V_2 = V = 800V$ this Change Q_1 and Q_2 is given by;

$$Q_1 = C_1 V$$

$$\Rightarrow Q_1 = (3 \times 10^{-6})(800)$$

$$\Rightarrow Q_1 = 2400 \times 10^{-6} C$$

$$\Rightarrow Q_1 = 2.4 \times 10^{-3} C$$

$$\Rightarrow Q_1 = 2.4mc \text{----- answer}$$

and

$$Q_2 = C_2 V$$

$$\Rightarrow Q_2 = (6 \times 10^{-6})(800)$$

$$\Rightarrow Q_2 = 4800 \times 10^{-6} C$$

$$\Rightarrow Q_2 = 4.8 \times 10^{-3} C$$

$$Q_2 = 4.8mc \text{----- answer}$$

Conclusion: Hence;

- (a) Equivalent capacitance $= C_{eq} = 9 F$
 (b) $Q_1 = 2.4mc$ and $Q_2 = 4.8mc$

EXERCISE**1. Choose the correct answer for each of the following;**

- When combing our hair, we shift electrons from our hair onto the comb. The charge on our hairs is:
 a. **Positive** b. negative c. zero d. infinite
- The unit of charge is
 a. Farad b. **coulomb** c. volt d. electron volt
- Initially, sphere A has a charge of $-50e$ and sphere B has a charge of $+20e$. The spheres are made of conducting material and are identical in size. If the spheres then touch, what is the resulting charge on sphere A?
 a. $+15e$ b. **$-15e$** c. $+35e$ d. $-35e$
- If the distance between two charged particles is halved, the coulomb force between the two charged particles become
 a. Half b. one quarter c. double d. **four times**
- The value of coulomb constant k , depend on
 a. Value of charges b. **material medium**
 c. separation between charges d. all of these
- An additional capacitor is added to a group of capacitors already connected in series, the equivalent capacitance
 a. Increase b. stay the same c. **decrease** d. goes to zero
- The unit of electric potential is
 a. Farad b. coulomb c. **volt** d. NC^{-1}
- Four identical $1\mu F$ capacitors are connected together electrically. What is the least possible capacitance of the combination?
 a. $4\mu F$ b. $1\mu F$ c. **$1/4\mu F$** d. $1/8\mu F$
- A capacitor C 'has a charge Q'. the actual charges on its plates are:
 a. Q, Q b. $Q, 0$ c. **$Q, -Q$** d. $Q/2, -Q/2$

Conceptual Questions

Q1. Normally, objects with large number of electrons are electrically neutral. Why?

Ans. Objects with large Number of electrons:

Objects with large number of electrons are electrically neutral because they have the same number of positively charged protons and negatively charged electrons.

Explanation:

Electrically neutral objects contain the same number of positively charged protons and negatively charged electron. Therefore no net charge exists on such objects.

Every object is a combination of a large number of atoms. Every atom has positively charged nucleus and negatively charged electrons revolving around the nucleus. As the number of electrons increases. The number of protons also increases. They balance the charge and the body as a whole becomes electrically neutral.

Q2. How does shuffling feet across a carpet cause hair to stand on our body?

Ans: Shuffling Feet across a carpet:

Shuffling feet across a carpet cause hair to stand on your body because static charge produces due to friction.

Explanation:

The transferring of electrons takes place as a result of rubbing of certain materials against one another. The body which loses electrons becomes positively charged and the body which gains electrons becomes negatively charged. For example, when you shuffle (rub) your feet across a carpet, you are allowing electrons to transfer to you. These electrons are accumulate on our body's hair and these negatively charged hair try to repel each other. That is why the hair stands on our body when we shuffle feet across a carpet.

Q 3: Why neutral objects are always attracted by charged object? Not repelled.

Ans: Neutral objects Attracted By charged objects:

Neutral objects are always attracted by charged objects because opposite charges come toward the charged body and same charges to the other end.

Explanation:

When a charged body is brought near a neutral body, then due to electrostatic induction, opposite charge is appeared on the neutral body toward the charged body.

For example, if a negatively charged rod is brought near a neutral sphere. Positive charges inside the neutral sphere came toward negatively charged rod while negative charges to the other end. As we know that opposite charges attract each other. Therefore the negatively charge rod attract positively charged side of the neutral body

Conclusion:

Hence, neutral objects are always attracted by charged objects.

Q4: Why the pieces of paper initially attracted by charged comb fly away when they touch it?

Ans: Pieces of paper attracted by charged comb:

The charged comb when gets closer to some pieces of paper, the paper pieces are initially attracted by the comb due to electrostatic induction. The part of paper pieces with positive charge is attracted by the comb, some of the excess negative in the comb is transferred to the paper pieces and paper pieces become negatively charged particles. As similar charges repel each other, therefore these paper pieces will now be repelled by the charged comb due to electrostatic induction and fly away when they touch the comb.

Conclusion:

Hence, the pieces of paper initially attracted by charged comb due to electrostatic induction and fly away when they touch the comb.

Q 5: Is it necessary for a charged body actually to touch the ball of the electroscope for the leaves to diverge? Defend your answer.

Ans: Charge body and ball of electroscope:

No, it is not necessary for the charged body to touch the ball of an electroscope.

Dependence:

If we bring negative charge body near the ball of an electroscope, some electrons in the ball are repelled and driven to the gold leaves, leaving the ball positively charged. Similarly, if we bring positively charge near the ball, some electrons will attracted and move up to the ball to make the ball negative and leaving the leaves positively charged. Tis charge separation takes pace due to electrostatic induction.

Conclusion:

Hence, it is not necessary for a charged body to actually touch the ball of the electroscope for the leaves to diverge.

Q6: How electrostatic painting is better than conventional spray painting?

Ans: Electrostatic painting:

Electrostatic painting is better than conventional spray painting because it reduces the paint usage, helps to distribute paint particles uniformly and get uniform coverage.

Explanation:

Electrostatic painting is a method in which electrically charged paint is applied. In electrostatic painting, when the paint leaves the nozzle of the spray gun, it is given a positive charge. The grounded object (the object being painted) is negatively charged in order to attract the positively charged paint particles to its surface. By creating this electrostatic field, the grounded object acts like a magnet, pulling the paint particles to its surface. This makes the particles less likely to stay in the air.

Q7: Why are lightning rods normally at a higher elevation than the buildings they protect?

Ans: Position of lightning Rods:

The lightning rods are normally at higher elevation than the buildings they protect because lightning (composed of huge amount of charge) first hit rods and not the buildings.

Explanation:

Lightning occurs when the electric field between clouds and ground gets high to overcome the resistance of the air between them. The lightning rods give an easy path to the charge, so buildings become safe. Lightning hits the tallest objects in its path e.g. trees, high rise buildings etc. therefore, lightning rods should be taller in order to be hit first by the lightning leaving the building safe. If the lightning rods were shorter than the building, then the lightning will hit the building first causing damage to it.

Conclusion:

Hence, the lightning rods are normally at a higher elevation than the buildings they protect.

Q 8: What would happen if two insulating plates were used instead of conducting plates to construct a capacitor?

Ans: It will be the same capacitor with slight changes as we will need high potential battery to charge it and the dielectric material between the plates must be different from that of the plates material.

In case of insulating material plates a high potential will be needed to deposit charges on the plates. The other change we need to do is that the dielectric material (insulator) between the plates must be different from the material of the plates.

Q9: The sum of the charge on both plates of a capacitor is zero. What does a capacitor store?

Ans: Storage of capacitor:

The capacitor actually stores energy in the form of an electric field between its plates.

Explanation:

Capacitor stores energy in the form of an electric field between its plates. Because the plate's equal but oppositely charged, a potential difference exists between them which mean that there is energy available to do work. Since there is a potential difference between the plates of a capacitor. This implies that there is an electric field which points from the positive plate to the negative plate.

Conclusion:

Hence, the capacitor actually stores energy in an electric field.

Q10: If you wish to store a large amount of energy in a capacitor bank, would you connect capacitors in series or parallel? Explain.

Ans: If I wish to store a large amount of energy in a capacitor bank, I will connect all the capacitors in parallel.

Explanation:

In parallel combination of capacitor, the equivalent capacitance is equal to the sum of capacitances of capacitors connected in parallel i.e. the capacitance become large and energy storage goes in proportion. In case of a given fixed voltage, parallel combination is the only way to store a large amount of energy in a capacitor bank.

Conclusion:

Hence, the capacitors must be connected in parallel, to store a large amount of energy in a capacitor bank.

Numerical Problem

P1: A $5\mu\text{C}$ point charge is placed 20 cm from the $10\mu\text{C}$ point charges. (a) Calculate the force experienced by the $5\mu\text{C}$ charge. (b) What is the force on $10\mu\text{C}$ charges? (c) What is the field strength 20 cm from the $10\mu\text{C}$ point charges?

Solution:

Given:

$$\begin{aligned} 1^{\text{st}} \text{ Charge} &= q_1 = 5\mu\text{C} = 5 \times 10^{-6} \text{C} \\ 2^{\text{nd}} \text{ Charge} &= q_2 = 10\mu\text{C} = 10 \times 10^{-6} \text{C} \\ \text{Separation between the charge} &= r = 20 \text{cm} = 0.2 \\ \text{Coulomb constant} &= k = 9 \times 10^9 \text{Nm}^2/\text{C}^2 \end{aligned}$$

Required:

- Force on 1st charge = $F_1 = ?$
- Force on 2nd charge = $F_2 = ?$
- Electric field strength = $E = ?$

Calculation:

(a) Force on 1st charge = $F_1 = ?$

According to coulomb's law;

$$F_1 = \frac{kq_1q_2}{r^2}$$

Putting values, we get;

$$F_1 = \frac{(9 \times 10^9)(5 \times 10^{-6})(10 \times 10^{-6})}{(0.2)^2}$$

$$\Rightarrow F_1 = 11.25 \text{N}$$

$$\Rightarrow F_E = -26 \text{N}$$

(b) Force on 2nd charge = $F_2 = ?$

Since both the charges exert an equal and oppositely directed forces on each other therefore, force on 2nd charge is also 11.25N.

$$F_2 = 11.25 \text{N}$$

(c) Electric field strength = $E = ?$

We know that;

$$E = k \frac{q}{r^2}$$

$$\Rightarrow E = \frac{(9 \times 10^9)(10 \times 10^{-6})}{(0.2)^2}$$

$$\Rightarrow E = 2.25 \times 10^6 \text{N/C}$$

Conclusion: Hence;

(a) Force on 1st charge = $F_1 = 11.25 \text{N}$

(b) Force on 2nd charge = $F_2 = 11.25 \text{N}$

(c) Electric field strength = $E = 2.25 \times 10^6 \text{N/C}$

P2: Determine the magnitude of the electric force on the electron of a hydrogen atom is exerted by the single proton that is the atom's nucleus. Assume the average distance between the electron and proton is $r = 5.3 \times 10^{-11} \text{m}$ and charge on electron and proton is $1.6 \times 10^{-19} \text{C}$.

Solution:

Given:

$$\begin{aligned} \text{Charge on proton} &= q_p = +1.6 \times 10^{-19} \text{C} \\ \text{Charge on electron} &= q_e = -1.6 \times 10^{-19} \text{C} \\ \text{Separation between the charges} &= r = 5.3 \times 10^{-11} \text{m} \\ \text{Coulomb constant} &= k = 9 \times 10^9 \text{Nm}^2/\text{C}^2 \end{aligned}$$

Calculation:

According to coulomb's law;

$$\Rightarrow F = \frac{kq_pq_e}{r^2}$$

Putting values, we get;

$$\Rightarrow F = \frac{(9 \times 10^9)(+1.6 \times 10^{-19})(-1.6 \times 10^{-19})}{(5.3 \times 10^{-11})^2}$$

$$\Rightarrow F = 8.2 \times 10^{-8} \text{N}$$

The -ve sign shows that the force is attractive in nature.

Conclusion: Hence;

The attractive force between electron and proton = $F = 8.2 \times 10^{-8} \text{N}$
P3: In a certain region of space, a uniform electric field has a magnitude of $4.60 \times 10^4 \text{N/C}$ and point in the position x-direction. Find the magnitude and direction of force this field exert on a charge of (a) $+2.80 \mu\text{C}$ (b) $9.30 \mu\text{C}$.

Solution:

Given:

$$\begin{aligned} 1^{\text{st}} \text{ Charge} &= q_1 = +2.8\mu\text{C} = +2.8 \times 10^{-6} \text{C} \\ 2^{\text{nd}} \text{ Charge} &= q_2 = -9.30\mu\text{C} = -9.30 \times 10^{-6} \text{C} \\ \text{Electric field strength} &= E = 4.6 \times 10^4 \text{N/C} \\ \text{Coulomb constant} &= k = 9 \times 10^9 \text{Nm}^2/\text{C}^2 \end{aligned}$$

Required:

(a) Force on 1st charge = $F_1 = ?$

(b) Force on 2nd charge = $F_2 = ?$

Calculation:

(a) Force on 1st charge = $F_1 = ?$

$$E = \frac{F_1}{q_1}$$

$$\Rightarrow F_1 = Eq_1$$

Putting values, we get;

$$\Rightarrow F_1 = (4.6 \times 10^4)(2.8 \times 10^{-6})$$

$$\Rightarrow F_1 = +0.13 \text{N}$$

Direction:

Since the force is positive, thus the force and electric field have the same direction i.e. force also points toward the positive

(b) Force on 2nd charge = F_2 = ?

We know that;

$$E = \frac{F_2}{q_2}$$

$$\Rightarrow F_2 = Eq_2$$

Putting value, we get;

$$F_2 = (4.6 \times 10^4) (-9 \times 10^{-6})$$

$$\Rightarrow F_2 = -0.43 \text{ N}$$

Direction:

Since the force is negative, thus force and electric field are oppositely directed i.e. force points in the negative x- direction.

P4: The potential difference between two points is 110 V. when the unknown charge is moved between these points, the work done 550 J. What is the amount of charge?

Solution:

Given:

$$\text{Work done} = W = 550 \text{ J}$$

$$\text{Electric potential} = v = 110 \text{ V}$$

Required:

$$\text{Charge} = q = ?$$

Calculation:

We know that;

$$V = \frac{W}{q} \quad \text{Or} \quad q = \frac{W}{V}$$

Putting the value, we get;

$$q = 5 \text{ C}$$

Conclusion: Hence;

Amount of charge is 5C.

P 5: The capacitor of capacitance is $1 \mu\text{F}$, $2 \mu\text{F}$ and $3 \mu\text{F}$ are connected in series to a 110V battery. Calculate the equivalent capacitance and voltage of each capacitor.

Solution:

Given:

$$\text{Electrical potential} = V = 220 \text{ V}$$

$$\text{Capacitance} = C = 3200 \text{ PF} = 3200 \text{ PF} = 3200 \times 10^{-12} \text{ F}$$

Required:

$$\text{Charge} = Q = ?$$

Calculation:

We know that;

$$Q = CV$$

Putting the value;

$$Q = (3.2 \times 10^{-9})(220)$$

$$\Rightarrow Q = 704 \times 10^{-9}$$

$$\Rightarrow Q = 7.04 \times 10^{-7} \text{ C}$$

Conclusion: Hence;

Charge on each plate of the capacitor = $Q = 7.04 \times 10^{-7} \text{ C}$

P 6: The capacitor of capacitance is $1 \mu\text{F}$, $2 \mu\text{F}$ and $3 \mu\text{F}$ are connected in series to a 110V battery. Calculate the equivalent capacitance and voltage of each capacitor.

Solution:

Given:

$$\text{Electric potential} = V = 110 \text{ V}$$

$$C_1 = 1 \mu\text{F} = 1 \times 10^{-6} \text{ F}$$

$$C_2 = 2 \mu\text{F} = 2 \times 10^{-6} \text{ F}$$

$$C_3 = 4 \mu\text{F} = 3 \times 10^{-6} \text{ F}$$

Required:

(a) Equivalent capacitance = $C_{eq} = ?$

(b) Potential Drops V_1 , V_2 and $V_3 = ?$

Calculation:

In series combination, we have;

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Putting the value

$$\frac{1}{C_{eq}} = \frac{1}{1 \mu\text{F}} + \frac{1}{2 \mu\text{F}} + \frac{1}{3 \mu\text{F}}$$

$$\Rightarrow \frac{1}{C_{eq}} = \frac{6+3+2}{6}$$

$$\Rightarrow \frac{1}{C_{eq}} = \frac{11}{6}$$

$$\Rightarrow C_{eq} = \frac{6}{11}$$

$$\Rightarrow C_{eq} = 0.54 \mu\text{F}$$

In series combination of capacitors, charge on the plates of each capacitor is the same i.e. $q_1 = q_2 = q$

Now;

$$Q = C_{eq} V$$

Putting values, we get;

$$Q = (0.54 \times 10^{-6})(110)$$

$$\Rightarrow Q = 59.4 \times 10^{-6} \text{ C}$$

Shams Notes

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Electrostatics

Since, series combination splits voltage across capacitors. Therefore,

$$\text{voltage across } C_1 = V_1 = \frac{Q}{C_1} = \frac{59.4 \times 10^{-6}}{1 \times 10^{-6}} \\ \Rightarrow V_1 = 59.4V$$

$$\text{Voltage across } C_2 = V_2 = \frac{Q}{C_2} = \frac{59.4 \times 10^{-6}}{2 \times 10^{-6}} \\ \Rightarrow V_2 = 29.7V$$

$$\text{Voltage across } C_3 = V_3 = \frac{Q}{C_3} = \frac{59.4 \times 10^{-6}}{3 \times 10^{-6}} \\ \Rightarrow V_3 = 19.8V$$

Conclusion: Hence;

(a) Equivalent capacitance = $0.54 \mu F$

(b) Voltage across $C_1 = V_1 = 59.4V$

Voltage across $C_2 = V_2 = 29.7V$

Voltage across $C_3 = V_3 = 19.8V$

P7: Two capacitor of capacitance $2\mu F$ and $3\mu F$ are connected in parallel to a $9V$ battery. Calculate the equivalent and the charge on each capacitor.

Solution:

Given: Electric potential $= V = 9V$
 $C_1 = 2\mu F$ and $C_2 = 3\mu F$

Required:

- (a) Equivalent capacitance = $C_{eq} = ?$
 (b) Charge Q_1 and $Q_2 = ?$

Calculation:

(a) Equivalent capacitance = $C_{eq} = ?$

In parallel combination of capacitors, we have;

$$C_{eq} = C_1 + C_2 \\ \Rightarrow C_{eq} = 2\mu F + 3\mu F = 5\mu F \\ C_{eq} = 5\mu F \text{----- answer}$$

(b) Charge Q_1 and $Q_2 = ?$

In parallel combination voltage remain constant. i.e. $V_1 = V_2 = V = 9V$

Now;

$$\text{Charge of capacitor "C1"} = Q_1 = C_1 V \\ \Rightarrow Q_1 = (2\mu F)(9V) \\ Q_1 = 18\mu C \text{----- answer}$$

$$\text{Charge on Capacitor "C2"} = Q_2 = C_2 V \\ \Rightarrow Q_2 = (3\mu F)(9V) \\ Q_2 = 27\mu C \text{----- answer}$$

Conclusion: Hence;

(a) Equivalent capacitance = $C_{eq} = 5\mu F$

(b) $Q_1 = 18\mu C$ and $Q_2 = 27\mu C$

Shams Notes

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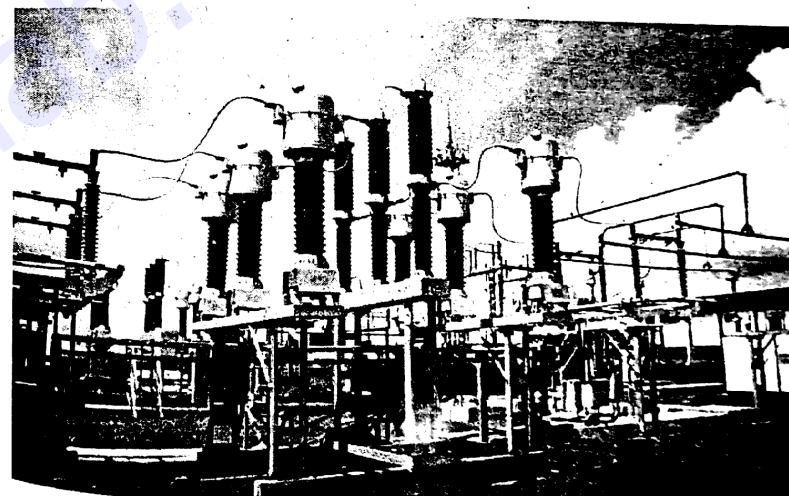
Current Electricity

Chapter No.14

Current Electricity

Major concepts

- Electric current and conventional current
- Potential difference and e.m.f
- Ohm's law
- Specific resistance
- Conductors and insulators
- Combination methods of resistors
- Electric energy and joule's law
- Electric power
- DC and AC current
- Hazards of electricity and safety devices
- Solution of problems



Comprehensive Question

Q1. Define electric current. In what unit it is measured? Explain the mechanism of the flow of current through a conductor:-

Ans. Electric Current:

"The time rate of flow of charges across any cross section of a conductor is called current.

If "Q" amount of charge is passing through certain cross section of a conductor in time "T" then the current "I" is given by;

$$I = \frac{Q}{T}$$

Unit:

In SI system the unit of current is ampere which is denoted by "A"

One Ampere:

"The flow charge at a rate of one coulomb per second through certain cross section of a conductor is called one ampere current."

$$1 \text{ Ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

"OR"

"The current is said to be one ampere when one coulomb charge flows across certain cross section of a conductor in one second.

Sub unit:

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

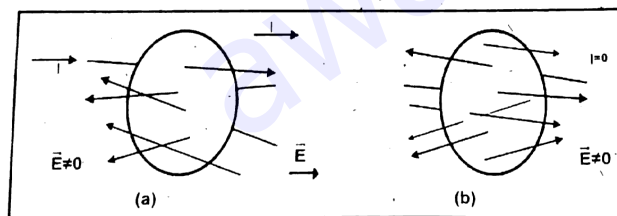
$$1 \mu \text{ A} = 10^{-6} \text{ A}$$

Instrument used for the Measurement of Current:

Ammeter is used for measuring electric current in a circuit.

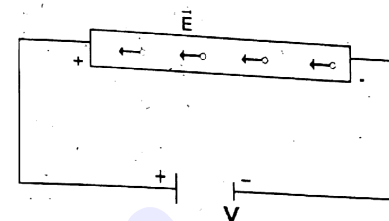
Flow of Current through a Conductor:

In the absence of an external electric field the free electrons in a conductor are moving randomly so the rate of flow of free electrons across any cross section to the left is the same as the rate of free electrons toward the right as show figure.



The number of electrons moving left is same as the number of electrons moving toward right. But when one end of a conducting wire is connected to +ve terminal of a battery (or) cell and other end is connected

to the -ve terminal, then there is produced a potential difference between the ends of wire. An electric field is set up at every point within the conductor. The electric intensity $\vec{E}$ is directed from +ve to -ve end. The free electron in the conductor experience an electric force due to electric field against the electric intensity. In this way the flow of current take place in a conductor as shown below.



Conventional Current:

"The current carried by the flow of equivalent positive charges in a direction opposite to the motion of negative charge is known as conventional current." **"OR"**

"The current due to the flow of equivalent positive charges in the circuit is called conventional current."

Earlier scientist's thoughts that electric current is produced only due to the flow of positive charges because at that time the concept of free electrons was not known. But today it is well known that in metals (or) vacuum tubes current is produced due to flow of free electrons (negative charges). In electrolytic solution it is produced due to flow of both positive and negative charges and in unclear accelerator it is produced due to flow of positive charges (protons).

Experiments shows, that the magnetic effects of an electric current due to flow of negative charges in one direction are the same as that of the current due to flow equivalent positive charges in the opposite direction. Thus for all practical purposes as far as current is concerned, a positive charge moving in opposite direction. Due to this reason, for the sake of simplicity and convenience, it is possible to use the old convention to express the electric current in terms of an equivalent current due to flow of positive charges. This current equivalent positive charge is called conventional current. Its direction is taken from positive towards negative terminal of the battery.

Q 2. What is potential difference and emf?

Ans. Electromotive Force (emf):

"The maximum potential difference produce by an electric generator (or) cell is called electromotive force (emf)". **OR**

"The potential difference between the terminals of a battery (or) generator (or) dry cell when it is giving no current to the circuit is known as electromotive force (emf)."

As we know that current is produced due to the flow of charges and when charges are flowing through conductor they lose their electric potential energy therefore to maintain a steady flow of current in a resistance a continuous source of electric energy is required which maintain a constant voltage across the ends of the conductor. The source must supply energy at the rate at which it is dissipated due to flow of charges in the form of heat.

Thus electromotive force can also be defined as.

"The energy required to drive the charge around the circuit is called electromotive force (emf)."

Potential Difference:

The difference of potential between any two points in a circuit is called potential difference.

The potential difference is produced by the source of emf.

Q3. State and explain Ohm's law. What are its limitations?

Ans. History:

This law was presented by German scientist George Simon ohm in 1826.

Statement:

This law states that "the current 'I' flowing in a conductor is directly proportional to the voltage 'V' applied across it, provided the temperature and other physical conditions remain constant". Mathematically;

$$\begin{aligned} I &\propto V \\ \Rightarrow I &= k V \quad (k = 1/R) \\ \Rightarrow I &= V/R \\ \Rightarrow V &= IR \end{aligned}$$

Where "R" is constant of proportionality and is known as resistance of conductor.

Experiment:

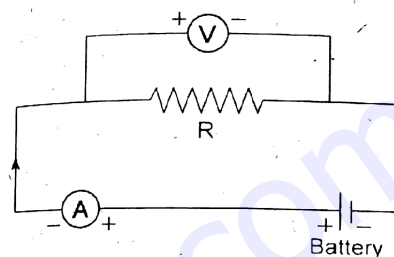
Take a thin wire of uniform cross sectional area and one meter long. Connect two (or) more electric cells in series to make batteries of different voltages.

Connect ammeter in series and voltmeter in parallel. Connect one end of the wire to the negative terminal and the other to the positive terminal of the battery.

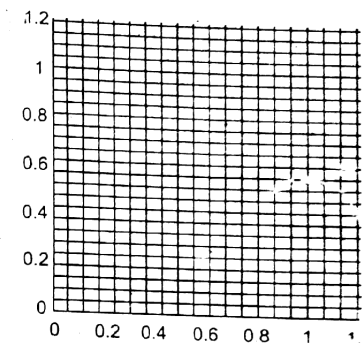
Measure the voltage across the wire by a voltmeter and the current in the wire by ammeter as shown in figure.

Change the position of rheostats and again measure the current I and voltage by moving the slider of the rheostats. Now a graph drawn between current "I" and voltage "V" is a straight line which shows the direct proportionality between the two physical quantities.

The value of $R = \frac{V}{I}$ has a constant value for each reading. The graph is shown below.



Circuit
Experimental verification of Ohm's law



Graph of V versus I

Limitations of Ohm's Law:

The substances which obey Ohm's law are called Ohmic substances while the substance which does not obey ohm's law are called non-Ohmic substances.

The Ohm's law is valid for metallic conductors but for certain conductors like electronic tubes, transistors, ionic plasma etc. the Ohm's law is invalid.

Q4. What is resistance, and on what factors resistance of a conductor depends?

Ans. Resistance:

"The property of a substance due to which it opposes the flow of current through itself is called resistance, denoted by 'R'."

According to Ohm's law the resistance of a conductor is the ratio of the potential difference between its ends to the current "I" produced in it.

Mathematically;

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

Unit of Resistance:

SI unit of resistance is Ohm. It is defined as "the resistance of a conductor through which current of one ampere flows when the potential difference across its ends is one volt is called one ohm." It is denoted by Ω (omega).

$$1 \text{ Ohm} = \frac{1 \text{ Volt}}{1 \text{ ampere}}$$

Factors on which Resistance Depends:

The resistance depends upon the nature, dimension (length and cross section) and the temperature of the conductor.

i) Length of the conductor:

The resistance of a conductor is directly proportional to the length of the conductor. Greater the length of a conductor, greater will be the resistance of the conductor and vice versa.

$$\text{i.e. } R \propto L \text{----- (1)}$$

ii) Cross sectional Area of the Conductor:

Resistance of a conductor is inversely proportional to its cross section area. Greater the cross section area, lesser will be the possibilities of collisions of free electrons with lattice atoms and smaller will be the resistance i.e.

$$R \propto \frac{1}{A} \text{----- (2)}$$

Combining (1) and (2)

$$\Rightarrow R \propto \frac{L}{A}$$

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

Where ρ (Rho) is the resistivity of specific resistance.

Resistivity (or) specific Resistance:

The resistivity (or) specific resistance of a material is defined as "the resistance of a conductor having unit cross section area and unit length". Mathematically;

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

If $A = 1\text{m}^2$ and $L = 1\text{m}$

Then; $\rho = R$

Unit:

$\Omega\cdot\text{m}$ is the unit of specific resistance.

Effect of temperature on Resistance:

The free electrons in a conductor move randomly and the lattice atoms present there vibrate about their mean position. If the temperature is increased, then the positive ions vibrate with larger amplitude. This causes an increase in the rate of collisions of free electrons with lattice ions and hence an increase in the resistance takes place. Experimentally it is verified that increase in resistance is directly proportional to its original resistance " R_0 " at 0°C .

$$\Delta R \propto R_0 \text{----- (1)}$$

The change in resistance is also directly proportional to rise in temperature.

$$\Delta R \propto t \text{----- (2)}$$

Combining (1) and (2)

$$\Delta R \propto R_0 t$$

$$\Rightarrow \Delta R = \alpha R_0 t$$

$$\Rightarrow \Delta R = R_t - R_0$$

$$\Rightarrow R_t - R_0 = \alpha R_0 t$$

$$\Rightarrow R_t = R_0 + \alpha R_0 t$$

$$\Rightarrow R_t = (1 + \alpha t) R_0$$

$$\text{Also, } \Rightarrow \frac{R_t - R_0}{R_0 t} = \alpha$$

$$\Rightarrow \alpha = \frac{R_t - R_0}{R_0 t}$$

Where " α " is the constant of proportionality and is known as temperature co-efficient of resistance of the given conducting wire.

Temperature Co-efficient of Resistance:-

"The increase in resistance per degree rise in temperature per unit original resistance at 0°C is called temperature co-efficient of resistance, denoted by α . Mathematically;

$$\alpha = \frac{\Delta R}{R_0 t}$$

$$(\therefore \Delta R = R_t - R_0)$$

Unit:

Unit of temperature co-efficient of resistance is $^\circ\text{C}^{-1}$ (or) K^{-1} .

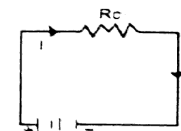
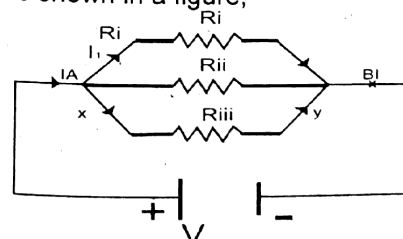
Q5. Three resistors R_1 , R_2 and R_3 are connected in parallel. Derive the formula for their equivalent resistance. Describe the characteristics of this combination of resistors?

Ans: Parallel combination of Resistor:

When two (or) more resistor are connected in circuit in such a way that the voltage across each resistor is the same while different current flows through each resistor, such a combination of resistors is known as parallel combination of resistors.

Formula For Equivalent Resistance:-

Let us consider three resistors R_1 , R_2 and R_3 are connected in parallel as shown in a figure,



Parallel combination of resistors

Since in parallel combination of resistors different current flows through each resistor, therefore;

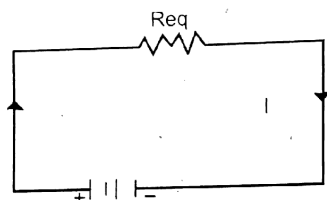
$$I = I_1 + I_2 + I_3 \text{----- (1)}$$

$$\Rightarrow I = \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} \text{ (}\because \text{ In parallel combination } V_1 = V_2 = V_3 = V \text{)}$$

$$\Rightarrow I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\Rightarrow I = V \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right)$$

Let " R_{eq} " be the equivalent resistance of all the three resistors connected in parallel.



According to ohm's Law;

$$\Rightarrow V = R_{eq} I$$

$$\Rightarrow I = \frac{V}{R_{eq}} \text{----- (b)}$$

Comparing equ (a) and equ(b);

$$\Rightarrow \frac{V}{R_{eq}} = V \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \right)$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Which is the required formula for equivalent resistance.

Characteristics of parallel combination of Resistors:

- In parallel combination of resistors, the voltage drop across the ends of each resistor is the same.
- Different current flows through each resistor i.e. the total current is equal to the sum of individual current.
 $I = I_1 + I_2 + I_3$
- There are various paths for the flow of current.
- The equivalent resistance of parallel combination is smaller than the smallest resistance of resistor connected in parallel.
- The reciprocal of equivalent resistance is equal to the sum of reciprocals of the resistances of all the individual resistors which are connected in parallel i.e.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

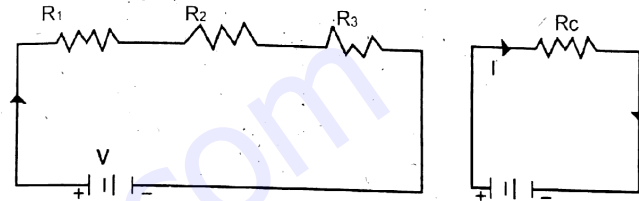
Q 6. Three R_1 , R_2 and R_3 are connected in series. Derive the formula for their equivalent resistance. Describe the characteristics of this combination of resistors?

Ans. **Series combination of Resistors:**

When two (or) more resistors are connected in such a way that the same current flows through each resistor while the voltage drop across each resistor is different, such a combination of resistors is known as series combination.

Formula for equivalent resistance:

Let us consider three resistors R_1 , R_2 and R_3 are connected in series as shown in figure.



Since in series combination of resistors, the voltage drop across each resistor is different therefore;

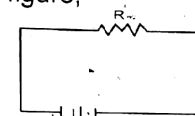
$$V = V_1 + V_2 + V_3$$

$$\Rightarrow V = I_1 R_1 + I_2 R_2 + I_3 R_3$$

($\because$ In series combination $I_1 + I_2 + I_3 = I$)

$$V = I(R_1 + R_2 + R_3) \text{----- (a)}$$

Let " R_{eq} " be the equivalent resistance of the series combination of R_1 , R_2 and R_3 as shown in figure;



$$V = I R_{eq} \text{----- (b)}$$

Comparing eq(a) and eq(b), we get;

$$\Rightarrow I R_{eq} = I(R_1 + R_2 + R_3)$$

$$\Rightarrow R_{eq} = R_1 + R_2 + R_3$$

In series combination the equivalent resistance is equal to the sum of resistance of individual resistors.

Characteristics of Series combination of Resistors:

- In series combination of resistors same current flows through each resistor.
- The potential difference at the ends of each resistor is different in series combination.

- iii. In series combination of resistors, there is only one path for the flow of current.
- iv. The equivalent resistance of series combination is greater than the greatest resistance of resistor connected in series.
- v. The equivalent resistance of series combination is equal to the sum of resistance of individual resistors. i.e.

$$R_{eq} = R_1 + R_2 + \dots + R_n$$

Q7. Explain the concept of electric energy and electric power. Discuss their units?

Ans. Electric Energy:

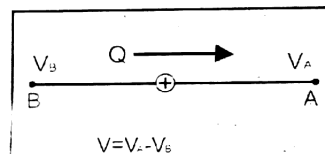
The energy of a moving charge is called electric energy.

Explanation:

Electric energy is commonly obtained from mechanical, chemical (or) heat energy.

Electrical devices work only when voltage is applied across it, which drives current "I" through the devices.

Now to derive a relationship between current "I" and Voltage "V" and work "W" consider the diagram in which the potential difference $V = V_A - V_B$ is applied between the two points "A" and "B" of a wire. Here " V_A " is greater than " V_B ".



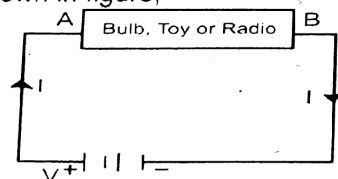
Since the potential difference is defined as the work required to carry one coulomb of charge from one point to another point against the electric field intensity is called potential difference.

The work done to move "Q" coulombs of charge from "B" to A is given by;

$$W = QV \text{----- (1)}$$

This work is stored in the charge "Q" as an electric potential energy at point "A". This potential energy converts in to kinetic energy and the charge "Q" moves toward point "B". This energy of a moving charge is called electric energy.

When an electric device such as electric fan, bulb radio, etc. are placed in the path of flowing charges then the K.E of the charges turn then on to work, as shown in figure,



Since the charge "Q" moves from point "A" to "B" due to the potential difference "V" applied and due to which current "I" is flowing through the circuit. If "T" is the time during which the charge "Q" moves from "A" to "B", then the current "I" given by;

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

$$Q = I t$$

Putting this value in equation (1);

$$\text{Eq(1)} \quad W = (It) (V)$$

$$W = Vit \text{----- (3)}$$

By using ohm law $V = IR$ put the value of V in above equation

$$W = Vit$$

$$W = (IR)(It)$$

$$W = I^2 Rt$$

This equation gives the energy gained by the charge "Q" when moved from "B" to "A" that is available which should be consumed.

Unit of electric Energy (OR) commercial unit of consumption of electrical energy:

This unit of electric energy is called kilowatt- hour which is defined as; "the amount of energy consumed in one hour when a power of one kilowatt is maintained, is known as one kilo-watt-hour (1Kwh) As we know that;

$$P = \frac{W}{t}$$

$$\Rightarrow W = P \times t$$

When

$$\Rightarrow R = 1\text{kw} = 1000\text{w}$$

And

$$\Rightarrow t = 1\text{hour} = 3600\text{sec}$$

Then,

$$\Rightarrow w = 1000 \times 3600\text{sec}$$

$$\Rightarrow w = 3600000\text{j}$$

$$\Rightarrow w = 3.6 \times 10^6\text{j}$$

Kilowatt hour (kwh) is the biggest unit of electric energy.

Electric power:

Electric power is defined as; "the time rate of doing work (or) the time rate of expending energy is called power, denoted by "P".

The electric power "P" is obtained when the electrical energy "W" expended is divided by the time "T" taken;

$$P = \frac{W}{t}$$

If "I" is the current supplied by a generator of voltage "V" in time "t" then the energy supplied is given by;

$$W = Ivt$$

Putting the value in eq. (1)

$$\Rightarrow P = \frac{IVt}{t} = VI$$

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This equation is called watt's law of electric power.

Units of power:

The units of power are as follows.

i) Watt:

The unit of power in SI system is watt, which is defined as; "when work is done (or) energy is consumed at a rate of one joule per second, then the power is called one watt.

ii) Kilo watt:

The bigger unit of power is kilo watt which is equal to 1000watts.
 $1\text{kw} = 1000\text{watts}$

iii) Horse power:

In F.P.S system the unit of power called horse power and is defined as: "When work is done (or) energy is consumed at a rate of 550 foot pound per second, then the power is called one horse power.

$$1\text{hp} = 746\text{w}$$

Q 8. What is Joules law of heating?**Ans. Joule's Law of Heating:**

Joule's law states that when a current passes through a resistance for a certain time, then the heat dissipated in the resistance is equal to the product of the square of the current resistance and the time "T". i.e.,
 $H = I^2 R t$

Derivation:

The electrical appliances offer some resistance "R" to the flow of electric current through them. Now from ohm's law we know that;

$$V = IR \text{----- (1)}$$

Since the heat energy dissipated in the conductor is equal to the energy of the charges consumed which is,

$$H = W = IVt$$

$$H = IVt \text{----- (2)}$$

Put equation (1) and equation (2)

$$\text{Eq(2)} \quad H = I(I R)t$$

$$H = I^2 R t$$

This equation is known as joule's law.

Q9. Write a comprehensive note on D.C and A.C?**Ans. Direct current (D.C):**

The electric current which always flows in a wire in one direction is called direct current. "OR"

"The current which maintains its unidirectional flow in a wire is known as direct current (D.C)."

Explanation:

As we know that, when the terminals of a dry cell (or) battery are connected by a conducting wire then the current starts flowing from the

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positive terminal to the negative terminal of the battery. Such a current which does not change its direction is known as direct current.

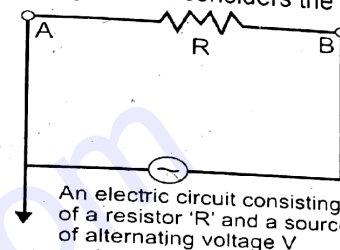
Alternating current (A.C):

"The electric current which changes its direction in a circuit to a number of times in one second is called alternating current (A.C)".

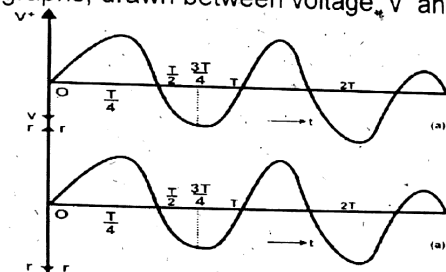
The current applied to houses, factories, offices etc. is alternating current (A.C).

Explanation:

To explain alternating current considers the diagram;



In this diagram alternating current source is connected across the ends "A" and "B" of resistor "R" the end "B" is connected to earth which is at zero potential. The end "A" is at potential "V" that varies with time in a way as shown in graphs, drawn between voltage "v" and time "t".



At starting when $t=0$, the voltage v is also zero. As the time passes voltage increases, at $\frac{T}{4}$ the voltage become maximum V which is also called the peak value.

From time $\frac{T}{4}$ to $\frac{T}{2}$ the voltage reduces from maximum to zero in the positive direction. From time $\frac{T}{2}$ to $\frac{3T}{4}$, the voltage increases from zero to maximum V in the -ve direction.

From $\frac{3T}{4}$ to time period "T", the voltage again reduces to zero in the -ve direction. After time "T" the graph repeat itself. The time duration "T" the graph repeat itself. The time duration "T" is called time period in which one cycle is completed.

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For V^+ the current is I^+ and flow from "A" to "B"

i.e. $A \xrightarrow{I^+} B$

For V^- the current is I^- which flow from "B" to "A"

i.e. $B \xrightarrow{I^-} A$

From time $t=0$ to $T = \frac{T}{2}$ the voltage is V^+ and current is I^+ that flows from A to B from $T = \frac{T}{2}$ to $t = T$, the voltage is V^- and current is I^- that flows from "B" to "A". I^+ and I^- are unidirectional but their values vary with time. The voltage, across "A" and "B" is known as alternating voltage, while the current flowing through the circuit is called alternating current.

Cycle:

The changes through which A.C voltage and current go in one period " T " is called one cycle.

Frequency:

The number of cycles complete by A.C in one second is called frequency of A.C. the frequency of A.C used in our houses is 50 cycles per second.

Energy formula For A.C:

The value of alternating current " I " varies with time so we have to know the average value of " I^2 ". Therefore the alternating current is measured by the square root of average value of " I^2 " which is known as root mean square value (rms), which is given by;

$$I_{rms} = \sqrt{\text{average value of } I^2} \quad (1)$$

But average value of I^2 in one cycle is given by;

$$\text{Average value of } I^2 = \frac{I_{max}^2 + (0)^2 + (I_{max})^2 + (0)^2}{4}$$

$$\text{Average value of } I^2 = \frac{2 I_{max}^2}{4}$$

$$\text{Average value of } I^2 = \frac{I_{max}^2}{2}$$

$$\sqrt{\text{average value of } I^2} = \sqrt{\frac{I_{max}^2}{2}} \quad (2)$$

$$\Rightarrow I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

$$\Rightarrow I_{rms} = \frac{1}{\sqrt{2}} I_{max}$$

$$\Rightarrow I_{rms} = (0.707) I_{max}$$

Thus the heat dissipated in a resistor " R " during time " T " in case of A.C is given by;

$$\Rightarrow H = I_{rms}^2 RT$$

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$$\Rightarrow H = (0.707 I_{max})^2 RT$$

$$I_{rms} = 0.707 I_{max}$$

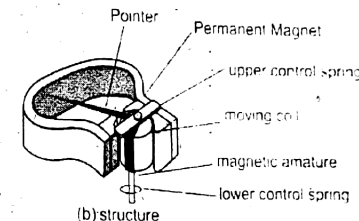
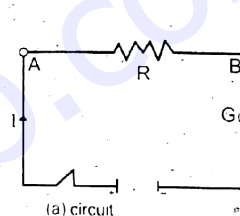
Thus $0.707 I_{max}$ is equivalent to direct current " I ", which produce the same heat in given resistor as produced by the value of $0.707 I_{max}$ is called effective value (or) rms value of alternating current.

Q 10. Discuss electrical measuring instruments in detail?

Ans. Measuring instruments:

A) Galvanometer:

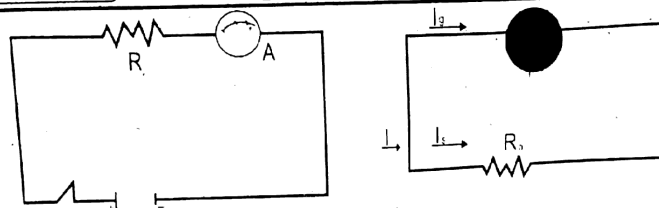
Galvanometer is a sensitive electrical instrument for the detection. Basically it consists of a coil, which is suspended between the poles of a u-shaped magnet by means of a fine metallic wire. It is based on the principle that when current passes through the coil suspended in a magnetic field, this turns is measured by a light pointer, which moves over a dial. The current enters and leaves the coil by means of the suspension wire. The whole system is enclosed in a box with a glass window for the pointer and the dial.



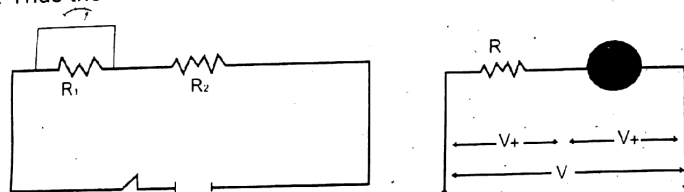
B) Ammeter:

A current-measuring instrument is called ammeter. It is essentially a galvanometer, which is modified for measuring large current. The modification is accomplished by connecting a suitable low resistance (R_s) in parallel with terminals of the galvanometer. R_s is called the resistance. Ammeter is connected in series with a circuit. The reason is that the current in the circuit to be measured must pass totally through the ammeter. This is only possible if the ammeter is connected in series with the rest of the circuit.

By requirement, an ammeter must have low resistance. The reason is that its insertion in to circuit introduces an additional resistance in the circuit. So its resistance must be so small that it does not disturb the original current to be measured. One necessary precaution must be taken before connecting an ammeter in to a circuit. A positive mark (+) is written on one terminal of the ammeter. The positive terminal of the current supply must be connected to the positive terminal of the galvanometer. A mismatch in the connection may let the current to flow in opposite direction that may damage the galvanometer.

**C) Voltmeter:**

A voltmeter is a voltage-measuring instrument. It is essentially a galvanometer so modified to measure voltage to a desired range. The modification is accomplished by connecting a high resistance R_h in series with the galvanometer. The value of this resistance is several thousand ohms. Thus the resistance of a voltmeter is very high.



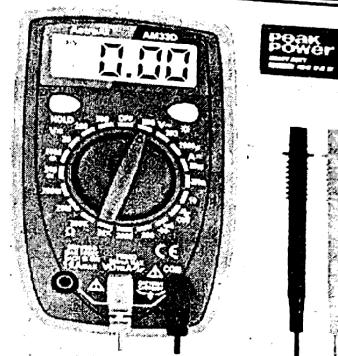
(a) Conversion of galvanometer to voltmeter
(b) use of voltmeter parallel

Voltmeter is always connected in parallel with the resistance across which the potential difference is to measure. Higher the resistance of the voltmeter, more reliable would be its readings. If the resistance of the voltmeter is comparatively low, it will draw more current across the resistance that was to be measured would drop. Therefore, a good voltmeter should have such a high resistance so that only a negligible current would pass through it.

When a voltmeter is connected in a circuit, care must be taken to connect its terminal marked positive (+) to that end of the resistance which is at higher potential

D. Multimeter:

In practice, measurements of current and potential difference are made with a digital multimeter that can switch between functioning as an ammeter and functioning as a voltmeter. It displays the results with an auto-ranging numerical digital display, which includes the sign of the potential difference of current. Most digital multimeters can also measure the resistance of a circuit component; that is, they can function as an ohmmeter.



Q11. What are the hazards of electricity? What safety measures are taken in household electricity to safeguard for these hazards?

Ans. Electricity Hazards:

Hazards:

A person can be electrocuted by touching a live wire, while in contact with the ground. This commonly happens because of damage insulation, overheating of cables, damp condition etc. the ground contact might be made either by the person touching a water pipe or by standing on ground with wet feet. Since polluted water (pure water is a bad conductor) is a good electric conductor.

Electric shock can result in fatal burns, or it can cause the muscles of organs, such as the heart, to malfunction. The degree of damage to the body depends on the magnitude of current, the length of time it acts, and the part of body through which it passes. Current of 5 mA or less can cause a sensation of shock but ordinarily do little or no damage. If the current is larger current will paralyze the respiratory muscles and prevent breathing. In some cases, current of 1A through the body may produce serious burns.

Safe use of electricity in Homes:

The electricity supplied to our homes is alternating current A.C. A.C means that the current in the supply line changes its direction many times in one second. Its frequency is 50Hz and its voltage is 220V. For the safe use of electricity the following devices should be used in the house circuit.

i) Fuse:

It is always in the line of the live wire. A fuse consists of a thin piece of metal wire which has a low melting temperature. When too much of current flows through the fuse wire piece of metal gets hot and melt. This opens the circuit. The fuse will melt before the copper wires in the circuit get hot enough to do and damage.

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ii) Circuit Breakers:

These are now used in consumer units instead of fuse. They contain an electromagnet which when the current exceeds the rated value of the circuit breaker, become strong enough to separate a pair of contacts and break the circuit. Their advantage is that the circuit is broken much more quickly than a fuse. Also they are closed again (reset) by simply pressing a button. This is its major advantage over a fuse.

iii) Earth wire:

This is a wire, which goes to the top connection on all power sockets and is earthed by being connected either to a metal water pipe in the house or to an earth connection on the supply cable. This wire is a safety precaution to prevent electric shock when an appliance develops a fault. The earth pin on a three pin plug is connected to the metal case of the appliance which is thus joined to earth by a path of almost zero resistance. For example, the element of an electric fire breaks and touches the case, large current flows to earth and blows the fuse. Otherwise the case would become live and anyone touching it would receive a shock which might be fatal, especially if they were earthed, say, standing on a concrete floor or holding a water tap.

Examples

Example 14.1: A new battery is at the battery shop charging station using a current of 6.7A for 5.0 h. How much charge passes through to the battery?

Given:

$$\text{Current 'I' = 6.7A}$$

$$\text{Time '}\Delta t\text{' = 5hrs = }5 \times 60 \times 60 = 18000\text{s}$$

Required:

$$\text{Charge '}\Delta Q\text{'=?}$$

Solution: By definition of electric current

$$I = \frac{\Delta Q}{\Delta t} \quad \text{or} \quad \Delta Q = I \times \Delta t$$

Putting values

$$\Delta Q = 6.7\text{C/s} \times 18000\text{s}$$

$$\Delta Q = 120600\text{C}$$

$$\Delta Q = 1.2 \times 10^5\text{C} \text{----- Answer}$$

Conclusion:

The total charge pass through the battery is $1.2 \times 10^5\text{C}$.

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Example 14.2: A 30.3V battery is connected to a 10.0Ω resistor. What is the current in the circuit?

Given:

$$\text{Potential difference 'V' = 30.0v}$$

$$\text{Resistance 'R' = } 10.0\Omega$$

Required:

$$\text{Current 'I'=?}$$

Solution:

$$\text{By Ohm's law } I = \frac{V}{R}$$

Putting values

$$I = \frac{30.0\text{V}}{10.0\Omega}$$

$$I = 3.00\text{A} \text{----- Answer}$$

Conclusion:

The current in the circuit is 3.00A.

Example 14.3: A small flashlight bulb draws 300ma from its 1.5V battery. What is the resistance of the bulb?

Given:

$$\text{Potential difference 'V' = 1.5V}$$

$$\text{Current 'I' 300mA = 0.3A}$$

Required:

$$\text{Resistance 'R'=?}$$

Solution: By definition of resistance $R = \frac{V}{I}$

Putting values

$$R = \frac{1.5\text{V}}{0.3\text{A}}$$

Therefore

$$R = 5\Omega$$

Conclusion:

The resistance of the bulb is 5Ω .

Example 14.4: Four resistors $R_1=5\Omega$ $R_2=12\Omega$ $R_3=13\Omega$ and $R_4=96\Omega$ are connected in series across a 90v battery. What is the current in the circuit?

Given:

$$\text{Resistance } R_1=5\Omega$$

$$\text{Resistance } R_2=12\Omega$$

$$\text{Resistance } R_3=13\Omega$$

$$\text{Resistance } R_4=96\Omega$$

Required:

$$\text{Circuit current 'I'=?}$$

Solution:

$$R_{eq} = R_1 + R_2 + R_3 + R_4$$

$$\Rightarrow R_{eq} = 5\Omega + 12\Omega + 13\Omega + 96\Omega$$

$$\Rightarrow R_{eq} = 126\Omega$$

By Ohm's law

$$\Rightarrow I = \frac{V}{R_{eq}}$$

Putting values

$$\Rightarrow I = \frac{90V}{126\Omega}$$

Therefore

$$I = 0.71A \text{ -----Answer}$$

Conclusion:

The current through the circuit is 0.71A

Example 14.5: Three resistors $R_1=5.0\Omega$, $R_2=10.0\Omega$ and $R_3=20.0\Omega$ are connected in parallel across a 90.0V battery. What is the current in the circuit?

Given:Resistance $R_1=5.0\Omega$ Resistance $R_2=10.0\Omega$ Resistance $R_3=20.0\Omega$

Potential difference 'V' 90V

Required:

Circuit current 'I'=?

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{5.0\Omega} + \frac{1}{10.0\Omega} + \frac{1}{20.0\Omega}$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{1 \times 4 + 1 \times 2 + 1 \times 1}{20.0\Omega}$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{7}{20.0\Omega}$$

$$R_{eq} = 2.9\Omega$$

Hence

By Ohm's law

$$\Rightarrow I = \frac{V}{R_{eq}}$$

Putting values

$$\Rightarrow I = \frac{90V}{2.9\Omega}$$

Therefore

$$I = 31.03A \text{ -----Answer}$$

Conclusion:

The current through the circuit is 31.0A

Example 14.6: If a current of 10.0 A takes 5 minutes to boil. A kettle of water required 3.6×10^5 J of energy, what is the potential difference [in voltage] across the kettle?

Solution:**Given:**

$$\text{Energy} = E = 3.6 \times 10^5 \text{ J}$$

$$\text{Time} = t = 5.0 \text{ min} = 300\text{s} = 3.0 \times 10^2 \text{ s}$$

$$\text{Current} = I = 10.0 \text{ A}$$

Required:

$$\text{Voltage} = V = ?$$

Calculation:

We know that,

$$E = VIt$$

$$\Rightarrow V = \frac{E}{It} \text{ ----- (1)}$$

Putting the value in equation (1), we get,

$$\Rightarrow V = \frac{3.6 \times 10^5}{10 \times 3 \times 10^2}$$

$$\Rightarrow V = 0.12 \times 10^3 \text{ v}$$

$$\Rightarrow V = 1.2 \times 10^2 \text{ v}$$

$$V = 1.2 \times 10^2 \text{ v} \text{ -----Answer}$$

Conclusion:The potential difference in voltage across the kettle is $1.2 \times 10^2 \text{ v}$.

Example 14.7: In the flashlight the current is 0.40 A, and the voltage of 3.0 V is delivered by cell. Find the power delivered to the bulb.

Solution:**Given:**

$$\text{Current} = I = 0.40 \text{ A}$$

$$\text{Voltage} = V = 3.0 \text{ A}$$

Required:

$$\text{Electric power} = p = ?$$

Calculation:

We know that,

$$P = IV \text{ ----- (1)}$$

Putting the values in equation (1), we get,

$$\Rightarrow P = (0.40 \times 3) \text{ watt}$$

$$\Rightarrow P = 1.2 \text{ watt.}$$

$$P = 1.2 \text{ watt.} \text{ -----Answer}$$

Conclusion:

The power delivered to the bulb is 1.2 watt.

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Example 14.8: You are arranging night cricket tournament, you have arranged five 1000W light bulbs. These bulbs will remain lit for 6 hours for 29 days. Estimate the cost of electricity consumption if the cost of electricity is 8.11 Rs/ kWh.

Solution:

Given:

$$\begin{aligned}\text{Power of one bulb} &= 1000 \text{ W} \\ \text{Power of bulbs} &= P = 5 \times 1000 \text{ W} = 5000 \text{ W} = 5 \text{ kW} \\ \text{Time} &= t = 29 \times 6 \text{ h} = 174 \text{ h} \\ \text{Tariff rate} &= T.R = 8.11 \text{ Rs/kWh}\end{aligned}$$

Required:

- (a) Energy consumed = $E_{(\text{kWh})} = ?$
(b) Cost of electricity = $C = ?$

Calculation:

(a) Energy consumed = $E_{(\text{kWh})} = ?$

$$E = P \times t \text{ ----- (1)}$$

Putting the value of "P" and "t" in equation (1), we get,

$$\Rightarrow E = (5 \times 174) \text{ kW.hr}$$

$$E = 870 \text{ kW.hr ----- Answer}$$

(b) Cost of electricity = ?

$$\text{Cost of electricity} = \text{energy consumed} \times \text{tariff rate}$$

$$C = E \times T.R$$

$$\Rightarrow C = (870 \times 8.11) \text{ Rs}$$

$$\Rightarrow C = 7055.7 \text{ Rs}$$

$$C = 7055.7 \text{ Rs ----- Answer}$$

Conclusion:

- (a) Energy consumed = $E_{(\text{kWh})} = 870 \text{ kW.hr}$
(b) Cost of electricity = 7055.7 Rs

Assignment

Assignment # 14.1: Truck Starter Current

While starting an engine of a truck, its battery sets 720 C of charge in motion for 4.00 s. How much current is flowing?

Given:

$$\text{Charge time } \Delta t = 4.00 \text{ s}$$

Required:

$$\text{Current 'I' = ?}$$

Solution:

By definition of electronic current:

$$I = \frac{\Delta Q}{\Delta t}$$

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Putting values

$$I = \frac{720}{4.00}$$

$$I = 180 \text{ A}$$

Conclusion:

The current flowing is 180A.

Assignment # 14.2: Current through Electric Range

A heating element on an electric range operating on 240 V has a resistance of 30.0 Ω . What current does it draw?

Given:

$$\text{Potential difference } V = 240 \text{ V}$$

$$\text{Resistance } R = 30.0 \Omega$$

Required:

$$\text{Current 'I' = ?}$$

Solution:

By ohm's law:

$$V = IR$$

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

Putting values

$$\Rightarrow I = \frac{240}{30}$$

$$\Rightarrow I = 8.0 \text{ A}$$

Conclusion:

The current passes is 8.0 A.

Assignment # 14.3: Resistance of Wire

Calculate the resistance of wire when the current through it is 2.0A and the voltage across its ends is 3.0 V.

Given:

$$\text{Potential difference } V = 3.0 \text{ V}$$

$$\text{Current } I = 2.0 \text{ A}$$

Required:

$$\text{Resistance 'R' = ?}$$

Solution:

By ohm's law:

$$V = IR$$

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

Putting the values

$$\Rightarrow R = \frac{3.0}{2.0}$$

$$R = 1.5 \Omega \text{ ----- answer}$$

Conclusion:

Thus, the resistance of the bulb is 5 Ω

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Assignment # 14.4: Resistors in Series

Four resistors all having same resistance of 15Ω are connected in series across a 30 V battery. What is the current in the circuit?

Given:Potential difference $V=30\text{ V}$ Resistance $R_1=R_2=R_3=R_4=15\Omega$ **Required:**Current ' I ' = ?**Solution:**

For series combination as shown in the figure, the equivalent resistance is given by:

$$R_{eq}=R_1+R_2+R_3+R_4$$

Putting the values

$$R_{eq}=15\Omega+15\Omega+15\Omega+15\Omega$$

$$\Rightarrow R_{eq}=60\Omega$$

By ohm's law:

$$\Rightarrow V=IR$$

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

Putting the values:

$$\Rightarrow I=\frac{30.0}{60}$$

$$\Rightarrow I=0.5\text{ A}$$

Conclusion:The current through the circuit is 0.5 A .**Assignment # 14.5: Resistors in Parallel**

Three resistors $R_1=60\Omega$, $R_2=30\Omega$, $R_3=20\Omega$ are connected in parallel across a 90 V battery. What is the current in the circuit?

Given:Potential difference $V=90\text{ V}$ Resistance $R_1=60\Omega$ Resistance $R_2=30\Omega$ Resistance $R_3=20\Omega$ **Required:**Current ' I ' = ?**Solution:**

For parallel combination as shown in the figure, the equivalent resistance is given by:

$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

putting values,

$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{60} + \frac{1}{30} + \frac{1}{20} \Rightarrow \frac{1}{R_{eq}} = \frac{1+2+3}{60}$$

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$$\Rightarrow \frac{1}{R_{eq}} = \frac{6}{60}\Omega$$

$$\Rightarrow R_{eq} = 6\Omega$$

By ohm's law

$$\Rightarrow V = IR$$

$$\Rightarrow I = \frac{V}{R_{eq}}$$

putting values,

$$\Rightarrow I = \frac{90}{6}$$

$$I = 15\text{ A} \text{----- answer}$$

Conclusion:The current through the circuit is 15 A .**Assignment # 14.6: Clothes Dryer**

For how long a clothes dryer is operated, if it uses 32 kJ of energy to dry clothes at 220 V , running 16 A of current through it?

Given:Energy ' E ' = $32\text{ kJ} = 3.2 \times 10^4\text{ J}$ Current $I = 16\text{ A}$ Potential difference $V=220\text{ V}$ **Required:**Time $t = ?$ **Solution:**

The electrical energy is given by:

$$E = I \times t \times V$$

$$\Rightarrow t = \frac{E}{I \times V}$$

Putting values

$$\Rightarrow t = \frac{3.2 \times 10^4}{16 \times 220}$$

$$t = 9.09\text{ s}$$

Conclusion:The time taken by clothes dryer is 9.09 s .**Assignment # 14.7: Automobile Headlight**

Calculate the resistance of a 40 W automobile head light designed for 12 V .

Given:Potential difference $V=12\text{ V}$ Electric power ' P ' = 40 W **Required:**Resistance $R = ?$

Solution:

The electric power is given by:

$$P = I \times V$$

From ohm's law,

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

$$P = \frac{V}{R} \times V = \frac{V^2}{R}$$

$$\Rightarrow R = \frac{V^2}{P}$$

Putting values

$$\Rightarrow R = \frac{(12)^2}{40}$$

$$R = 3.6\Omega$$

Conclusion:

The resistance of automobile head light is 3.6Ω .

Assignment # 14.8: Winter Cost

A 100 W bulb is left on, in an outdoor storage room to keep paint from freezing. The 100 W rating refers to the power dissipated in the bulb's filament, which is a resistor. If electricity costs 8.11/kWh, about how much does it cost to burn the light bulb for three months during winter?

Given:

Electric power $P = 100W = 0.1 \text{ kW}$

Time $t = 3 \times 30 \text{ days} = 90 \times 24 \text{ h} = 2,160 \text{ h}$

Tariff rate = 8.11 Rs / kWh

Required:

- (a) Energy Consumed $E_{\text{kWh}} = ?$
 (b) Cost of electricity 'C' = ?

Solution:**(a) Energy Consumed $E_{\text{kWh}} = ?$**

The electric power is given by:

$$\Rightarrow P = \frac{E}{t}$$

$$\Rightarrow E = P \times t$$

Putting value $\Rightarrow E = 0.1 \text{ kW} \times 2,160 \text{ h}$

$$E = 216 \text{ kWh} \text{----- answer}$$

(b) Cost of electricity 'C' = ?

$$\text{Cost} = E \times \text{Tariff rate}$$

Putting values,

$$\text{Cost} = 216 \times 8.11$$

$$\text{Cost} = 1751.76 \text{ Rs}$$

Conclusion:

The total consumed energy is 216 kWh and the cost of electricity is Rs.1752.

EXERCISE**1. Choose the correct answer for each of the following;**

- Batteries are rated with unit 'ampere-hour', it is the unit of
 a. **Charge** b. current c. power d. energy
- When connected to a battery, a lightbulb glows brightly. If the battery is reversed and reconnected to the bulb, the bulb will glow
 a. Brighter b. dimmer
 c. **with the same brightness** d. and fuse
- The resistance of wire will decrease by increasing
 a. Temperature b. length
 c. **diameter** d. both A and B
- The wire made from which of the following material is a conductor
 a. Glass b. rubber c. **silver** d. silk
- The current which reverse direction after regular interval of time is
 a. DC b. **AC**
 c. conventional current d. both A and B
- Electricity main supply meters measure it in units of 'kilowatt- hour' it is the unit of
 a. Charge b. current c. power d. **energy**
- The device that is used to protect a circuit against overload is
 a. Heater b. **fuse** c. lamp d. all of these
- Which of the following represent one ohm
 a. **VA^{-1}** b. JS^{-1} c. WA^{-1} d. JC^{-1}
- Two resistance of 1 ohm are connected in parallel, the equivalent resistance is
 a. **2Ω** b. 1.5Ω c. 1Ω d. **0.5Ω**
- $1\text{kWh} =$
 a. 36000W b. 1000J c. **$3.6 \times 10^6 \text{ J}$** d. 0.36hrs

Conceptual Question

Q 1. As water is made of atoms having protons (charge +ve) and electrons (charge -ve), does the water flowing through pipe carry an electric current? Explain.

Ans: No, the water does not carry an electric current because water molecules as whole is neutral having equal number of protons and electrons.

Explanation:

Atom as a whole is neutral i.e. the number of protons inside the nucleus is equal to the number of electrons outside the nucleus of an

atom. Similarly water molecule is composed of one oxygen and two hydrogen atoms. All these atoms are neutral, that's why water molecule is a neutral molecule. So water flowing through a pipe does not carry any current, as no net charge flows in it.
Conclusion: Hence, water flowing through a pipe does not carry any current.

Q 2. A car has two headlights, when the filament in one headlight burns out, the other headlight stays on. Are the headlights connected in series or in parallel?

Ans. Yes, the headlights are connected in parallel.

Explanation:

In parallel combination there are more than one path flows of an electric current. The headlights of car are connected in parallel, therefore they will be independent of each other. Thus burning the filament of one headlight does not affect the other.

Conclusion: Hence, the headlight are connected in parallel.

Q3. Qurat-ul-Ain needs a 100-Ω resistor for a circuit, but she only has a box of 300-Ω resistors. What can she do?

Ans. This is possible; if she takes three resistors of 300Ω and connected them in parallel the equivalent resistance in this case will be exactly equal to 100Ω. We know that the equivalent resistance of three resistors connected in parallel is given by,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{300} + \frac{1}{300} + \frac{1}{300}$$

$$\frac{1}{R_{eq}} = \frac{1+1+1}{300} = \frac{3}{300} = \frac{1}{100}$$

$$R_{eq} = 100\Omega$$

Conclusion:

Thus, the parallel combination of three resistors each of 300 Ω is equivalent to 100 Ω

Q 4. A number of light bulbs are connected to a single power outlet. Will they provide more illumination when connected in series or in parallel? Why?

Ans. To provide more aluminum from a number of bulbs connected to a single power outlet, they should be connected in parallel.

Explanation:

The bulbs should be connected in parallel for getting aluminum because in parallel circuit, each circuit element gets uniform potential difference across it while in series combination the total potential

difference is divided among all circuit elements. Therefore we connected a number of bulbs in parallel to provide more aluminum.

Conclusion: Hence, the bulbs should be connected in parallel to provide more illumination.

Q5. Explain why light bulbs almost always burn out just as they are turned on and not after they have been on for some time.

Ans. Lights bulbs almost always burn out just as they are turned on because at that time maximum current flows through the filament of the light bulb which decrease after some time when the filament heats up.

When the lights bulb is switched on, its filament had low resistance at room temperature due to which large current flows through the filament of the light bulb.

But when the tungsten wire in the filament of the bulb heat up causes increase in its resistance, which decreases current in the filament.

Conclusion:

Hence; the light bulbs almost always burn out just as they are turned on and not after they have been on for some time due to low resistance of the filament in the beginning, which (resistance) after some time decreases when the filament heats up.

Q 6. Explain why is it possible for birds to perch safely on high tension wires without being electrocuted?

Ans. It is possible for birds to perch safely on high tension wires without being electrocuted because they touch only one wire at a time causing no potential difference between its two legs and hence no current flows through its body.

The whole body of the birds sitting on a high voltage wire is at the same potential as that of the high voltage wire and the potential difference is zero due to which no current passes through the body of the bird. Therefore the bird is not electrocuted.

Q7. An electrician working on "live" circuits wears insulated shoes and keeps one hand behind his or her back. Why?

Ans. Wearing insulated shoes increase the overall resistance of the worker which reduces the danger of electric shock. The electrician working on live wire keeps his other hand behind for safety purposes. If he keeps one hand conducting material (e.g earth) he will get an electric shock. The possibility of touching ground or other conductor, the electrician keeps his one hand on his back. In this way, he can work safely without any danger of electric shock.

Q 8. Explain why is it dangerous to turn on a light bulb when you are in a bath tub?

Ans: The human body is a good conductor of electricity. Heavy current may pass through his/her body when touches a live wire. Therefore when

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a person in a bath tub, tries to turn ON the switch of a bulb, he may get an electric shock. Thus for safety measures, he should not do so.

Q9. Why circuit breaker fuses and switches are installed to 'live wire'?

Ans. Circuit breakers and fuses are used to protect an electrical circuit from damage caused by an excess current flow due to a fault or short circuit.

As basic function is to stop the current flow after a fault is detected. As in case of fire, if we want to control the fire we have to control it from its source. In the similar way, if we want to have a better control over electricity we have to control it from its source, i.e., live wire.

Live wire has a potential difference of 230 volt with respect to neutral wire of zero potential. Electric current enters our homes through live wire and leave through neutral. Therefore, circuit breakers and fuses should be installed on the live wires to control current at the very beginning.

Numerical Problems

P1: A small electric heater has a resistance of 15 ohms when the current in it is 2 amperes. What voltage is required to produce this current?

Solution:

Given: Resistance $= R = 15\Omega$
Current $= I = 2 \text{ amperes}$

Required: Voltage $= V = ?$

Calculation: We know that;
 $V = IR$

Putting values

$$\Rightarrow V = 2 \times 15 = 30$$

$$V = 30 \text{ v} \text{-----Answer}$$

Conclusion:

The voltage required to produce current is 30v.

P2: If a potential difference is 10 V is maintain across a 1 m length of the nichrome wire having resistance of 3.1Ω what is the current in the wire?

Solution:

Given: Potential difference $= V = 10 \text{ v}$
Length of wire $= L = 1 \text{ m}$
Resistance $= R = 3.1\Omega$

Required:

Current in the wire $= I = ?$

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Calculation:

We know that;

$$V = IR$$

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

Putting values

$$\Rightarrow I = \frac{10}{3.1}$$

$$I = 3.2 \text{ A} \text{-----Answer}$$

Conclusion:

Current in the wire is 3.2 A.

P3: What resistor would have a 15 mA current, if connected across the terminal of a 9.0 V battery?

Solution:

Given:

Current $= I = 15 \text{ mA} = 15 \times 10^{-3} \text{ A}$
Voltage of battery $= V = 9.0 \text{ v}$

Required:

Resistance $= R = ?$

Calculation:

We know that;

$$V = IR \quad R = \frac{V}{I}$$

Putting values

$$\Rightarrow R = \frac{9}{15 \times 10^{-3}} = 15 \times 10^{-3} \Omega$$

$$R = 600 \Omega \text{-----Answer}$$

Conclusion:

The resistance would be 600 Ω

P4: Consider a circuit with three resistor $R_1 = 250\Omega$, $R_2 = 150\Omega$, $R_3 = 350.0\Omega$, connected in parallel with a 24.0-V battery. Find the total current supplied by the battery?

Solution:

Given:

Resistance $R_1 = 250\Omega$
Resistance $R_2 = 150\Omega$
Resistance $R_3 = 350\Omega$

Required:

Total current $= I = ?$

Calculation:

We know that;

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

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Putting values

$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{250} + \frac{1}{150} + \frac{1}{350}$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{21+35+15}{5250} = \frac{71}{5250}$$

$$\Rightarrow R_{eq} = \frac{5250}{71}$$

$$R_{eq} = 73.9\Omega \quad \text{Or} \quad R_{eq} = 74\Omega$$

Now we know that

$$\Rightarrow V = IR_{eq}$$

$$\Rightarrow I = \frac{V}{R_{eq}}$$

Putting values

$$\Rightarrow I = \frac{24}{74} = 0.3 \text{ A} \text{----- answer.}$$

Conclusion: Hence,

The total current is 0.3 A.

P5: An electric hair dryer is rated at 1,875 watts when operating on 120 volts. What is the current flowing through it? If the hair dryer is used for 3 minutes, how much energy is consumed?

Solution:

Given: Power of dryer = $p = 1875 \text{ watt}$
 Voltage = $V = 120 \text{ V}$
 Time = $t = 3 \text{ min} = 3 \times 60 \text{ sec} = 180 \text{ sec}$

Required:

- (i) Current = $I = ?$
 (ii) Energy consumed = $E = ?$

Calculation:**(i) Current = $I = ?$** We know that; $P = IV$ OR $I = \frac{P}{V}$

Putting values,

$$I = \frac{1875}{120} = 15.625 \text{ A} = 15.6 \text{ A}$$

$$I = 15.6 \text{ A}$$

(ii) Energy consumed = $E = ?$ We know that; $E = P \times T$

Putting the value,

$$E = 1875 \times 180$$

$$E = 337500.0 \text{ J}$$

$$E = 337.5 \times 10^3 \text{ J}$$

$$E = 337.5 \text{ kJ}$$

$$E = 337.5 \text{ kJ}$$

Conclusion:

Total current flowing is 15.6 A and energy consumed is 337.5 kJ

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P6: A battery with an emf of 12 V is connected to a 454Ω resistor. How much energy is dissipated in the resistor in 65s?

Solution:**Given:**Battery emf = $V = 12 \text{ V}$ Resistance = $R = 454\Omega$ Time = $t = 65 \text{ sec}$ **Required:**Energy dissipated = $E = ?$ **Calculation:**

We know that;

$$E = P \times T$$

We also know that,

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

Putting equation (2) and equation (1).

$$P = \frac{V^2}{R} \times t$$

Putting values

$$E = \frac{(12)^2}{545} \times 65$$

$$E = 17.1 \text{ J} \text{----- Answer}$$

Conclusion:

The total energy dissipated in the resistor is 17 J.

P7: If the unit of electricity cost 8.11 Rs/kwh, what is the cost of running two 160 W fans and four 100 W light bulb for 6 hours in school?

Solution:**Given:**Tariff rate = $T.R. = 8.11 \text{ Rs/Kwh}$ Power of two 160W fans = $P_1 = 160 \times 2 = 320 \text{ w}$ Power of four 100 watt bulbs = $p_2 = 100 \times 4 = 400 \text{ w}$ Total power = $P = P_1 + P_2 = (320 + 400) \text{ w} = 720 \text{ w} = 0.72 \text{ kw}$ Time = $t = 6 \text{ hour}$ **Required:**Cost of electricity = $C = ?$ **Calculation:**

$$C = P \times t \times T.R. \text{----- (1)}$$

We know that;

$$E = P \times t \text{----- (2)}$$

Putting equation (2) and equation (1), we get,

$$E = P \times t \times T.R. \text{----- (3)}$$

Putting the values in equation (3), we get,

$$C = 0.72 \times 6 \times 8.11$$

$$C = 35.0 \text{ Rs} \text{----- Answer}$$

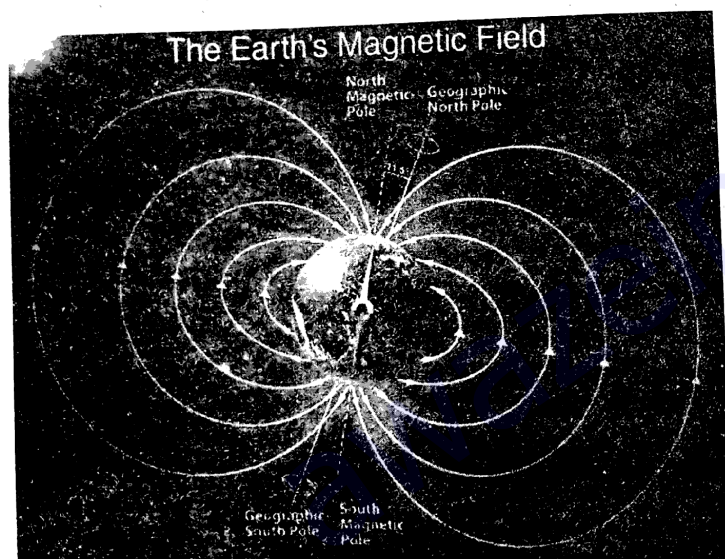
Conclusion:

The cost of electricity is 35.0 Rs.

Chapter No.15 Electromagnetism

Major Concepts

- Magnetic effect of steady current
- Direction of magnetic field
- Fleming's left hand rule
- D.C motor
- Electromagnetic induction
- Faraday's law of electromagnetic induction
- Len's law
- A.C Generator
- Mutual induction
- Transformer
- Relay circuit
- Solution of problems



Comprehensive Question

Q1. What is the magnet? Write properties of a magnet. Also define magnetism.

Ans. Magnetism and Electromagnetism:

Magnet:

"An object which attracts small pieces of iron and pointing towards north south direction when freely suspended is known as magnet".

The end of a magnet pointing towards north is called North Pole while the end pointing towards the south is known as South pole.

Properties of a Magnet:-

Following are the some important properties of a magnet.

- A magnet attracts small pieces of iron.
- Like poles of two magnets repel while unlike poles of two magnets repel each other.
- A freely suspended magnet always points in the north south direction.
- The magnetism of a magnet concentrated in its poles.
- The two poles of a magnet cannot be separated from each other. If a magnet is broken in to two pieces, then two new magnets are obtained.
- There is a magnetic field around a magnet. A test magnet or a current carrying conductor experiences force in a magnetic field.

Magnetism:

"The study of the properties associated with a magnet is called magnetism."

Magnetism derives its name from magnesia (turkey), where it was found in the form of lumps of certain iron ore. These lumps have the property of attracting small pieces of iron. It was also known as a lodestone.

Q2. Define compass needle, magnetic field and electromagnetism?

Ans. Compass Needle:

"A magnetized iron needle which is so pivoted that it can turn freely in a horizontal plane is called a magnetic compass needle". This needle comes to rest along the north south direction.

Uses:

- ❖ A compass needle is often used to investigate a magnetic field.
- ❖ It can also be used to detect a current in a conductor.

Magnetic Field:

"The space around a magnet in which its magnetic effect can be felt by another magnet is called magnetic field".

Explanation:

In general any region in which magnetic effect is felt is called magnetic field. Magnetic field is represented by the magnetic lines of force which can be traced by means of a small test magnet such as compass needle.

Intensity and Direction:

The intensity and direction of magnetic field at any field point is determined by the force which the field exerts on a test magnet placed at that point.

The magnetic field of a bar magnet is represented by lines of force. The magnet field lines are directed from North Pole to South Pole.

Electromagnetism:

"A magnet formed due to flow of electric current in a conducting coil is called electromagnet".

The study of the properties associated with an electromagnet is known as electromagnetism.

As we know that the electric and magnetic effects are produced by electric charge.

- The static charge produces electrostatic effects.
- While a moving charge that is current produces both electric and magnetic effect (electric and magnetic fields are produced around it).

Q3. Discuss magnetic field due to current. Describe an experiment to show that the steady current carrying wire produce a magnet field around. What is the direction of this magnetic field?

Ans. Magnetic Field due to current:-

A magnetic field produced around a conductor due to flow of electric current in it, is known as magnetic field due to current.

In 1820, it was Hans Oersted who first of all determined that a magnetic field is produced around a wire carrying current "I". He also got the following conclusion.

- The magnetic field is strong near the conductor and become weaker and weaker as we move away from the conductor.
- The magnetic field exists as long as the current is flowing through the conductor.
- The magnetic lines of force are circular around the conductor.

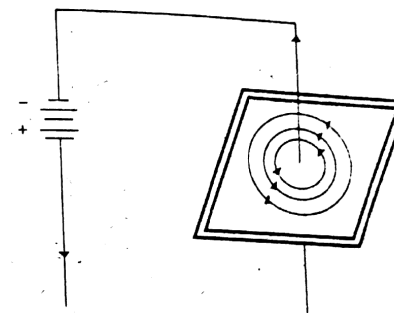
Magnetic Field of a straight current carrying wire:

"A magnetic field produced around a conductor due to flow of electric current in it, is known as magnetic field due to current".

Experiment:

The magnetic field due to current demonstrated by considering a straight conductor passed vertically through a horizontal

card board. The iron filings are sprinkle over the card board around the conducting wire.

**Explanation:**

When the switch is on and the current I is allowed to pass through the conductor, the iron filings arrange themselves in concentric circles around the wire in the direction of the magnetic field by taping the card board gently. This shows that the magnetic field is produced around a current carrying conductor. The magnetic field lines are circular around the current carrying conductor as shown;

Direction:

The direction of magnetic field due to current can be determined by "Right Hand Rule". If the current flowing upward in the wire, the magnetic field will be anticlockwise. But if the current is flowing downward in the wire, the magnetic field will be clockwise.

Q 4. What are magnetic lines of force? Represent the field pattern of a bar magnet by lines of force.

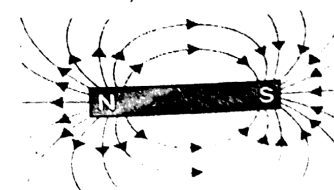
Ans. Magnetic Field lines:

"The path along which an isolated north pole of a magnet moves in a magnetic field is called a magnetic field line of force".

Explanation:

The magnetic lines of force are curve path originating from the North Pole and terminating at the South Pole outside a magnet. Inside the magnet they start from South Pole and ends at North pole.

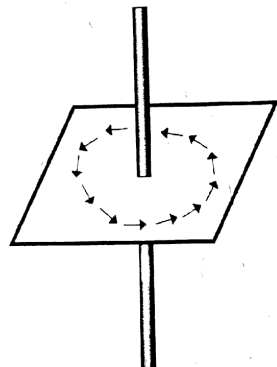
In this way the magnetic lines form a close path. The magnetic field lines of a bar magnet are shown;



The magnetic field strength at a certain point can be determined by using the density of the magnetic field lines. The density of magnetic lines of force near the poles of a magnet is greater. The magnetic field lines don't intersect each other.

Tracing of magnetic lines:

We can trace the magnetic lines of force by placing compass needles. When a compass needle is moved around a current carrying conductor, its direction changes from point to point. If we put dots in front of the ends of a compass needle, we shall get magnetic field lines. The lines of force are anticlockwise when current is flowing upward and vice versa.



Q5. State the right hand rule of electromagnetism. Illustrate by a diagram.

Ans. Right Hand Rule:

Statement:

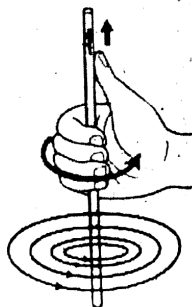
According to Right Hand Rule;

"If the current carrying wire is grasped by the right hand with the thumb in the direction of the current, then the fingers encircle the wire in the direction of magnetic field".

Explanation:

As we know that when current is flowing through a conductor, magnetic field is produced around it. Right hand rule relates the direction of the magnetic field with the direction of the current flowing in the wire.

If the current is flowing upward in the wire then the magnetic line of force are anticlockwise according to the right hand rule. But when the current is flowing downward then the magnetic line of force is clockwise.



Q6. Write a note on atomic magnetism?

Ans. Atomic Magnetism:-

It was first of all amperes who gave the idea that all magnetic effects may be due to circulating currents (moving charges).

Discovery of the internal structure of the atom

After discovery the internal structure of atom the amperes view appears to be basically correct.

As atom is composed of three kinds of basic particles i.e. electron, proton and neutrons. Since protons and neutrons reside inside the nucleus while the negatively charged electrons are revolving around the nucleus in different orbits. Moreover the electrons also have spinning motion.

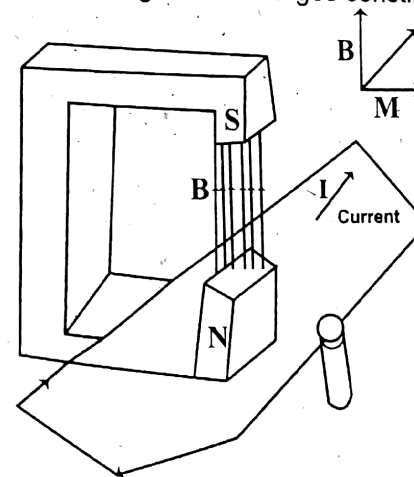
Magnetic field Due to motion of Electrons:-

The rotation and the spin motion of electron both give rise to a magnetic field. Since there are a number of electrons in an atom, their spin may be so oriented as to cancel the magnetic effects mutually or strengthen the effect of each other.

An atom in which there is a resultant magnetic field, behaves like a tiny magnet, and is known as magnetic dipoles.

Q7. Explain the force on a current carrying wire in a magnetic field?

Ans. Since electric current is regarded as a drift of charge (electrons) in the same direction. Each electron moves with a drift velocity V in a conductor. When this conductor is placed in a magnetic field of strength B , every electron is acted upon by a magnetic force F_m . Since the electrons are confined inside the wire. Therefore, the magnetic force experienced by a current carrying conductor in a magnetic field is the resultant of the forces acting on the charges constituting the current.



Shams Notes

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Electromagnetism

The magnetic force F_m on a wire of length L carrying current places perpendicular to the magnetic field of intensity B is given by;

$$F_m = ILB\theta$$

If the conductor makes an angle θ with the magnetic field then the above equation can be written as

$$F_m = ILB \sin \theta$$

Demonstration of magnetic Force:

The magnetic force on a current carrying wire can be demonstrated experimentally, as shown.

A conducting wire is placed between the poles of U-shaped magnet, while its ends are connected to the terminals of a battery through switch s .

When the current is allowed to pass through the wire, the current carrying wire is immediately pushed to a side. Increasing the current in the wire increases the push. Reversing the current in the wire, the direction of the push is also reversed. Similarly exchanging the North and South poles of the magnet, the magnetic force on the wire is also reversed.

Q8. State Fleming's right hand rules for $\vec{B}$, I and L ?

Ans. Fleming's right hand rules.

Statement:

This rule states that

"If we stretch the thumb, fore finger and the middle finger of our left hand in such a way that they are mutually perpendicular. If we point the fore finger in the direction of magnetic field " $\vec{B}$ " the middle finger in the direction of the current " I ". Then the thumb will point in the direction of the magnetic force " $\vec{F}$ " above the current carrying conductor."

Q9. Illustrate by a diagram the magnetic field of a current carrying solenoid. Identify the polarity of a magnet so formed. Discuss the intensity and the direction of the field

Ans. Magnetic field due to current in a solenoid:

A solenoid is a closely wound cylindrical coil of insulated wire. It is constructed when a conducting wire is wound on a certain cylindrical support as shown



Shams Notes

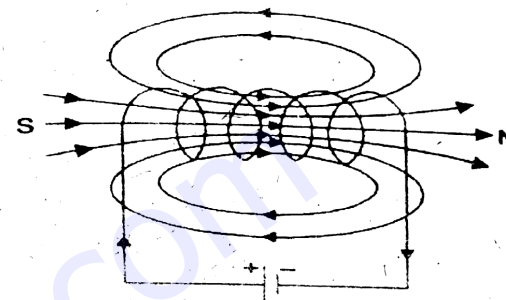
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Electromagnetism

When current is allowed to flow through a solenoid the magnetic field produced is uniform and strong in the middle of the turn and negligibly weak outside the solenoid. The field due to solenoid current is in fact the sum of the field due to current in each circular turn of the solenoid.

Using right hand rule on each turn of the solenoid, we can find inside the coil the magnetic lines of force are in the same direction as shown in figure.

The magnetic field strength at a certain point inside a solenoid is given by:



Intensity of the field:

The intensity of the field within the solenoid increases with increasing the current " I " in a solenoid. The intensity also increases with the increase in number of turn of the solenoid.

Identification of polarity:

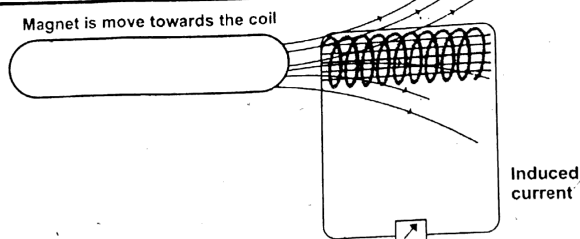
The polarity of the magnet depends upon the direction of the current passing through the solenoid. The polarity can be determined by means of a compass needle. It can also be determined by right hand rules, stated below

Grasp the solenoid in a right hand by circulating the fingers in the direction of the current. The stretched thumb will be towards the north pole of the solenoid.

Q10. Describe the phenomena of electromagnetic induction. List the factors effecting electromagnetic induction.

Ans. "The current produced by the relative motion between the loop of wire and the magnetic field is called induced current and the emf thus produced is known as induced emf".

i. Faraday observed that a galvanometer connected to the end of a coil deflects when a magnet is moved towards or away from the coil. This deflection of the galvanometer shows that current is set up in the coil.



- ii. In the figure; when north pole is moved towards the coil the current flows in one direction. But when the magnet is moved away from the coil, the current flows in the opposite direction. Now if South Pole the coil, the current is in the opposite direction. Now if South Pole the coil, the current is in the away from the coil, the current flows in opposite direction.
- iii. If the magnet is held stationary and coil is move towards the magnet, the current flow is one direction. If the coil is moved away from the stationary magnet, the current flows in the other direction.
- iv. When magnet and the coil are held stationary with respect to each other. The galvanometer shows no deflection.
- v. Thus induced current and induced emf are produced by the relative motion of the magnet and the current carrying loop.

Factors:

If "I" is the induced current produced and "R" is the resistance of the loop when magnet is pushed towards it, then the induced emf denote by "ε" is given by,

$$\varepsilon = IR$$

So;

- The induced current I depends upon the strength of the magnetic field provided by the magnet.
- The value of the induced emf depends upon the relative motion of the loop.

Q 11. State faraday law of electromagnet induction?

Ans. Faraday's Law of electromagnetic induction

Statement:-

This law states that,

"The emf induced in a close circuit is equal to the rate of change of magnetic flux through it".

Mathematically;

$$\varepsilon = - \frac{\Delta \phi}{\Delta t}$$

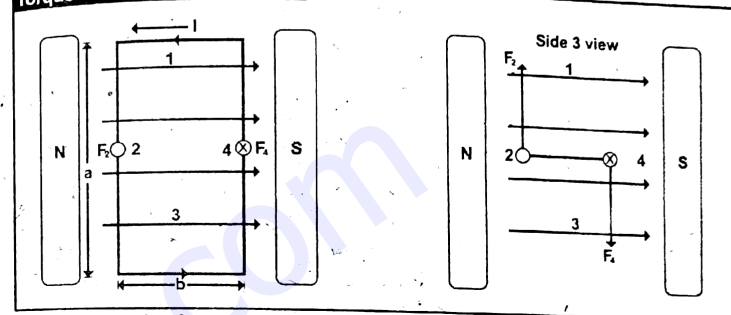
For N-loops;

$$\varepsilon = -N \frac{\Delta \phi}{\Delta t}$$

Q 12. Explain the torque on current carrying coil in magnetic field?

Ans. Turning effect on a current carrying coil in a magnetic field:

When a current carrying coil or loop is placed in uniform magnetic field it experiences a new force, this force can exert torque on a coil or loop of wires. Consider a rectangular coil having four [1, 2, 3 and 4] sides of length a and b carrying a current "I" in the presence of a uniform magnetic field B directed parallel to the plane of the loop as shown in figure.

Torque on current carrying coil

No magnetic forces act on sides 1 and 3 because these wires are parallel to the field $\theta = 0^\circ$; the length of sides 1 and 3 is b, therefore magnetic force F_1 and F_3 is,

$$F_1 = F_3 = I(L \times B)$$

$$F_1 = F_3 = ILB \sin \theta$$

$$\theta = 0$$

$$F_1 = F_3 = ILB \sin 0 \quad (\sin 0 = 0)$$

$$\sin 0^\circ = 0$$

$$F_1 = F_3 = 0$$

However, maximum magnetic force act on sides 2 and 4, because these sides are perpendicular to the field $\theta = 90^\circ$, the length of sides 2 and 4 is a, therefore magnetic force is,

$$F_2 = F_4 = I(L \times B) \sin \theta$$

$$F_2 = F_4 = I(L \times B) \sin \theta \quad (\because \sin \theta = \sin 90^\circ = 1)$$

$$F_2 = F_4 = BIL \sin 90^\circ \quad (\because \sin 90^\circ = 1)$$

$$F_2 = F_4 = BIL \quad (2)$$

We see the view shown in figure (b) the two magnetic force F_2 and F_4 point in opposite directions having same magnitude (Bia) such that they form a couple. If the loop is pivoted so that it can rotate about point O, these two forces produce a torque to rotate the loop (in this case clockwise).

Q13. Explain the working of a D.C motor?

Ans. D.C motor:

A device which converts an electrical energy in to mechanical energy is called D.C motor.

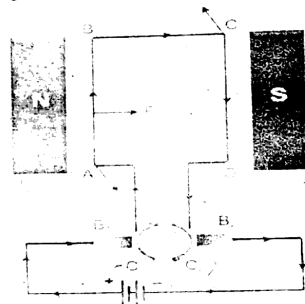
Principle:

When a current carrying coil is placed in a magnetic field, a torque acts on it which caused the coil to rotate.

Construction:

An electric motor consists of a coil of N -turns wound on an iron core which is known as armature. The armature can rotate about an axis perpendicular to the magnetic field provided by an electromagnet.

The terminals of the coil are connected to split rings (Commutators). Brushes b_1 and b_2 supplying current from the battery or D.C source. The split ring system reverses the sense in which the current is supplied to the rotating coil in every half revolution.



Working:

When current I is passed through the coil, the coil is acted upon by the torque until the plane of the coil is perpendicular to the field where torque becomes zero. At this instant the split ring system reverses the direction of the current and the armature continues to rotate. The rotating armature provides mechanical power.

Uses:

Electric motor is one of the basic device for converting electrical energy in to mechanical energy. Its applications are fan, water pumps, electric drill and washing machines.

Electric motors are also used in communication devices such as telephone, television, tape recorder and recorders.

Construction, working and working of moving coil loud speaker.

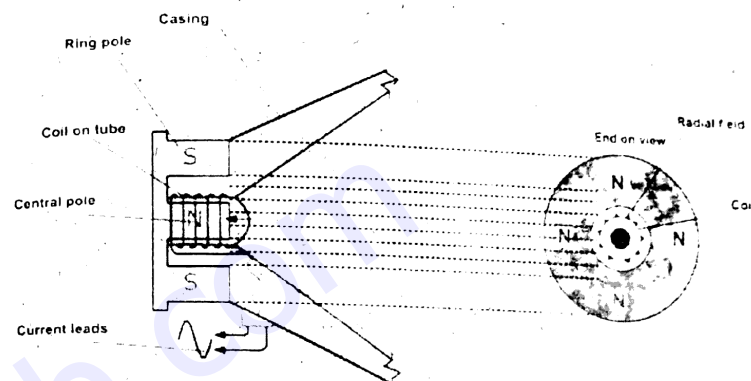
Ans. Moving coil loud speaker:

Principle:

The basic principle of moving coil loud speaker is a current carrying conductor experiences a force in a magnetic field.

Construction:

Moving coil loud speaker consists of a permanent magnet with a central cylindrical pole and a surrounding ring pole. This arrangement creates a strong magnetic field in the gap between the poles. It has a short cylinder with a coil wound on it, which moves backward and forward. Also a paper cone is attached to the coil which produces sound when moves backward and forward.



Working:

When an alternating current from a radio or a record player passes through the coil. It forces the paper cone to move in or out, depending on the current direction.

This motion of the paper cone thus sets up sound waves in the surrounding air of the same frequency as that of the alternating current.

Q15. Explain the direction on induced emf and show its relation to conservation of energy?

Ans. Lenz's Law:

The direction induce emf can be determined by using lens's law.

Statement:

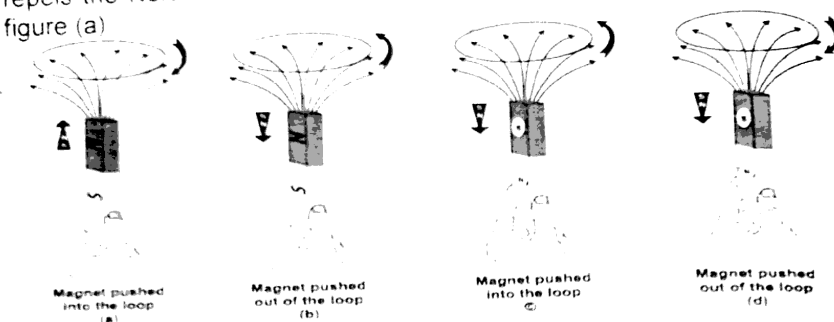
This law states that

"The direction of an induced ϵ will be such that it opposes the cause producing it".

Direction of induced emf and conservation of energy:

Whenever there is a change of magnetic flux, there will be induced emf and current will flow in such a direction so as to oppose the cause producing it. The induced current around a coil produces its own magnetic field. This field may be weak compared with the external magnetic field. It cannot prevent the magnetic flux through the coil from changing, but its directions are always such that it tries to prevent the flux from changing.

Consider pushing the bar magnet's North pole in to the loop, it causes the magnetic field to increase in the upward direction. To oppose the change, the loop itself needs to generate the downward-pointing magnetic field (acting as a magnet with its North Pole at the bottom which repels the North Pole of the bar magnet moving towards it) as shown in figure (a)



Direction of induced current:

The induced magnetic field at the center of the loop will point downward (using right hand rule II) only if the current is clockwise (cw) as seen from above. Now suppose the north pole of bar magnet is pulled away from the loop, as shown in figure (b). There is a upward magnetic field through the loop, but the magnetic field is decreasing as the magnet is moving away. Thus, the induced magnetic field of the loop opposes this decrease, therefore, the induced field needs to point in the upward direction, and the induced current is counter clockwise (CCW) as seen from above.

Similar effects can also be observed with the south pole of a magnet pushed in and out of the loop figure (c, d), it is seen that the induced current setup a magnetic field of its own. From the above discussion, it is clear that the motion of magnet is always opposed by the magnetic field generated from induced current. The mechanical energy spent in overcoming this opposition is converted in to electrical energy. If the induced current were in the opposite direction, the magnetic force would have accelerated it with no external energy source, even though electric energy would have been dissipated in the circuit. This would have been a clear violation of the law of conservation of energy, which doesn't happen in nature

Q16. Sketch and describe the construction and working of A.C generator?

Ans. **A.C Generator:**

"A device which converts mechanical energy in to electrical energy is known as A.C generator".

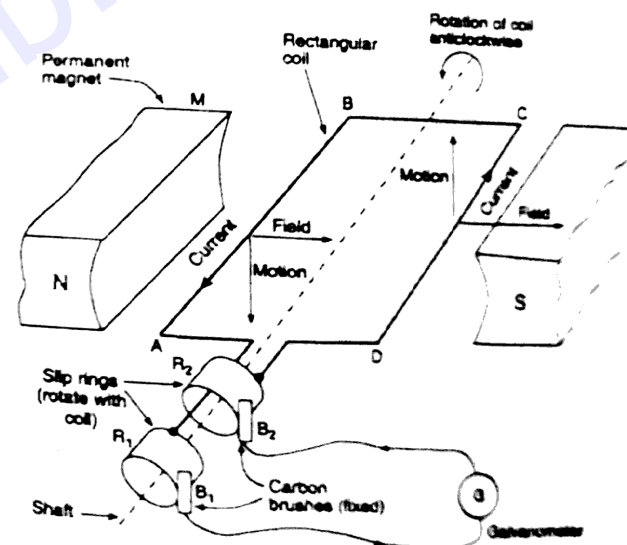
Principle:

A.C generator is based on the principle of electromagnetic induction, i.e. An induced emf is produced by changing the magnetic flux through a coil.

Construction:

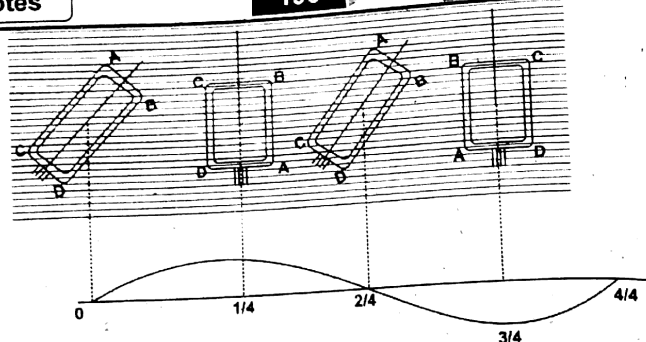
A simple A.C. generator consists of a closely-wound Rectangular coil ABCD of N - Turns which can rotate about an axis OO' perpendicular to a uniform magnetic field $\vec{B}$.

The terminals of the coil are connected to slip rings R and R' . The slip ring is also connected with the axis of the coil and rotates with it. The brushes b and b' are sliding along the rings and connected the coil to the external circuit. The magnetic field of intensity $\vec{B}$ is applied by an electromagnet or two poles of a magnet. The coil is wound on an iron core and is called armature.



Working:

When the coil ABCD is rotated by any means the magnetic flux linked with it changes and an induced emf is produced in it. Now to investigate the direction and magnitude of the produced emf when the coil rotates, consider the figure.



- In figure (a) the plane of coil is perpendicular to the magnetic field. The sides AB and CD are moving parallel to the magnetic field hence induced emf is zero.
- As the coil rotates, the sides AB and CD cross the field and their velocity perpendicular component increases that becomes maximum when the coil attains the position (b). So the induced emf increases from zero to maximum. i.e. $\text{emf} = LVB$.
- When the coil further rotates the sides AB moves down while the side CD moves upward. So their velocity components perpendicular to the field decreases and becomes zero when the coil gains the position (c). Thus the induced emf decreases from maximum to zero in the same direction i.e. $\text{emf} = 0$.
- When the coil further rotates the side CD moves downward, the induced emf increased from zero to maximum in opposite direction, when the coil attains the position (d). $\text{emf} = -LVB$.
- But when the coil rotates from position d to position e, the induced emf reduces to zero.

Thus it is clear that at the beginning of rotation, the emf is zero and reaches to maximum value in +ve direction during $\frac{1}{4}$ rotations.

After $\frac{1}{2}$ rotations the emf again reduces to zero in the same direction. After $\frac{3}{4}$ rotations the induced emf increases to maximum but in -ve direction.

The emf reduced to zero after one rotation. In this way the rotation of the coil in a magnetic field produces an alternating induced emf.

Uses:

The uses of A.C generator are countless. A.C generators are used to convert kinetic energy of water falls to electrical energy. Huge A.C generators are installed at Turbella, Mangla, and Worsak etc.

In petrol and diesel operated A.C. generators, that convert chemical energy is converted in to electrical energy.

Q17. Describe the phenomena of mutual induction?

Ans. **Mutual induction:-**

"The phenomenon in which induced emf is produced in secondary coil when current is changing the primary coil is known as mutual induction, denoted by M"

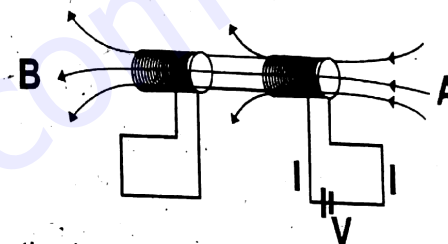
Mathematically;

$$M = \frac{\epsilon_s \Delta t}{\Delta I_p / \Delta t}$$

$$\Rightarrow M = \frac{\epsilon_s}{\Delta I_p}$$

Explanation:

To describe mutual induction consider the coils placed near each other;



The coil in the battery circuit is called primary coil while coil in a galvanometer circuit is known as secondary coil.

The magnetic flux induced due to flow of current in the primary coil is linked with secondary coil. When a current in the primary coil is change by varying the resistance of the rheostat, the magnetic flux through the secondary coil is also changed. So according to Faraday's law induced emf is produced in the secondary coil.

Unit:

The unit of mutual induction is henry [H]. Mutual induction of two coil will be on a henry [H], if the current is changing at the rate of one ampere per second in the primary coil and causes an induce emf of one volt in the secondary coil.

$$1H = \frac{1V \times 1s}{1A}$$

$$1H = \frac{Vs}{A}$$

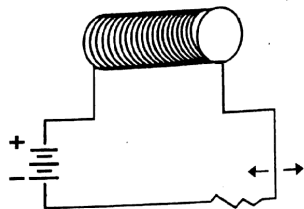
Q 18: Describe the phenomenon of self-induction?

Self induction:

The emf induced in a coil when magnetic flux linked with it is changed by changing the current flowing through it is known as self induced emf and the phenomenon is called self-induction. It is denoted by L.

Explanation:

Consider a coil Connected to a battery through a rheostat R as shown in figure;



When a key is closed current flowing through the coil produces magnetic flux which links with the coil itself.

Now if the current through the coil is changed by rheostat, the magnetic flux linked with the coil is also changed. Thus according to Faraday law induced emf is produced in the coil.

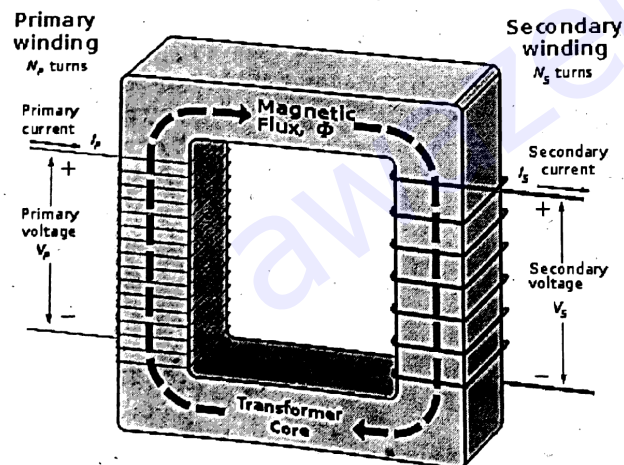
Q19. What is transformer? Explain its construction, working principle and types.

Ans. Transformer:

"Transformer is an electrical device which is used to increase or decrease the value of alternating voltage".

Construction:

A transformer has two coils, electrically insulated from each other, but wound around the same iron core. One coil is called the primary coil. The other coil is called the secondary coil. Number of turns on the primary and the secondary coils are represented by N_p and N_s respectively.

**Working principle**

When the primary coil is connected to a source of A.C. voltage, the changing current creates a changing magnetic field, which is carried through the core to the secondary coil. In the secondary coil, the changing field induces a varying e.m.f. This effect is called mutual inductance.

Voltage and number of turns of coil

The e.m.f induced in the secondary coil is called the secondary voltage V_s is proportional to the primary voltage V_p . The secondary voltage also depends on the ratio of the number of turns on the secondary coil to the number of turns on the primary coil, as shown by the following expressions.

According to Faraday law of electromagnetic induction.

$$\mathcal{E}_s = -N \frac{\Delta \phi}{\Delta t}$$

So,

$$V_s = -N \frac{\Delta \phi}{\Delta t} \quad \text{----- (1)}$$

$$V_p = -N \frac{\Delta \phi}{\Delta t} \quad \text{----- (2)}$$

Dividing equ (1) by equ (2)

$$\frac{V_s}{V_p} = \frac{-N_s \Delta \phi / \Delta t}{-N_p \Delta \phi / \Delta t}$$

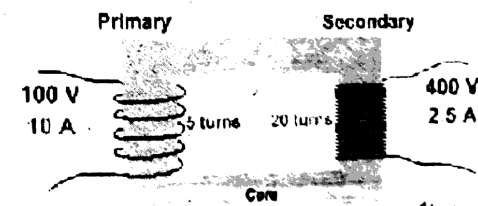
$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

Type

There are two types of transformer.

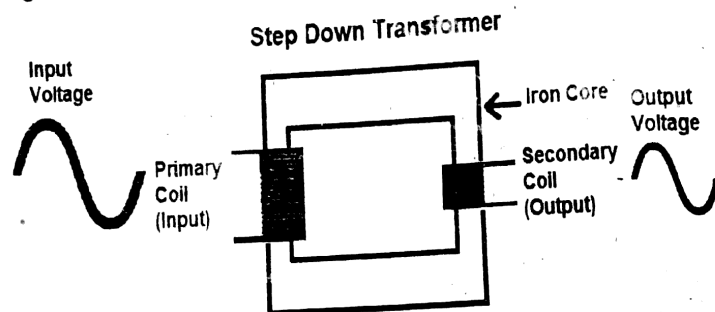
- i. Step-up transformer
 - ii. Step-down transformer
- i. **Step-up transformer**

If $N_s > N_p$, then secondary voltage is larger than the primary voltage, then the transformer is called a step-up transformer.

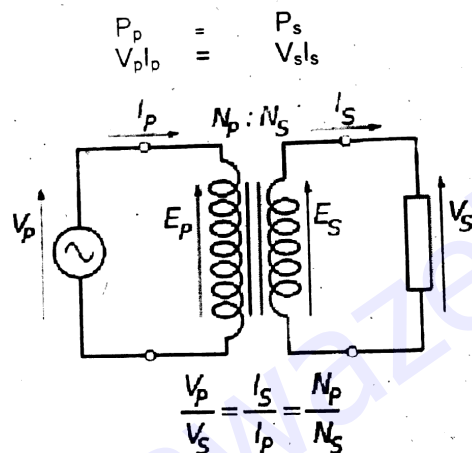


ii. **Step-down transformer:**

If $N_p > N_s$, then the secondary voltage is smaller than the primary voltage, then transformer is called a step-down transformer.

**An ideal transformer:**

In an ideal transformer, the electric power delivered to the secondary circuit equals the power supplied to the primary circuit. An ideal transformer dissipates no power itself and for such a transformer we can write:

**Uses of transformer:**

Transformer are used to increase or decrease AC voltages. Usage of **transformers** is common because they change voltages with relatively little loss of energy. In fact, many of the devices in our homes, such as game systems, printers and stereos have transformers inside their casings or as part of their connecting cords.

Q 20. How high voltage transmissions reach from power station to consumer? (OR)

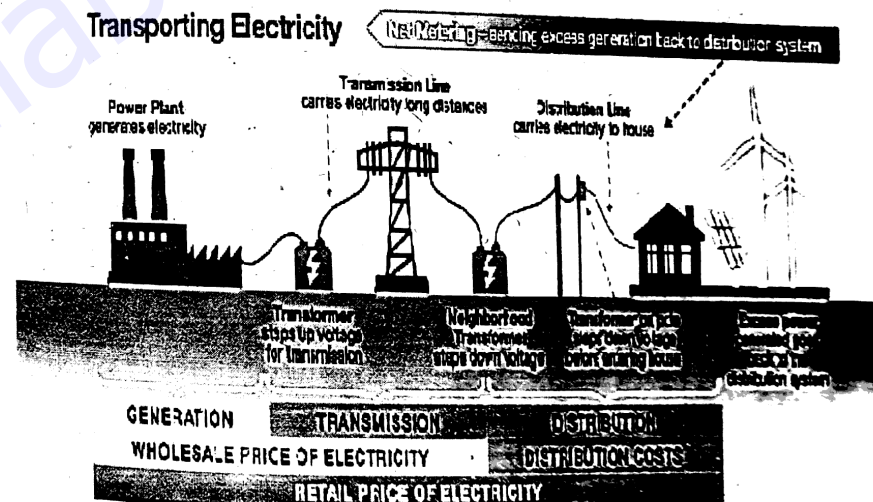
Why alternating voltage is stepped up at the generating station?

Ans. **Why heat dissipated in transmission?**

Electric power is usually generated at places where it is consumed. The power is transmitted over long distances at high voltage to minimize the loss of energy in the form of heat during transmission. As heat dissipated in the transmission cable of resistance R is $I^2 R T$. Hence by reducing the current through the cable, power loss in the form of heat dissipation can also be reduced. So the alternating voltage is stepped up at generating station.

How voltages are stepped down?

High voltages are transmitted to the main sub-station. This voltage is stepped down and is transmitted to the switching transformer station or the city sub-station. At the city sub-station it is further stepped down to 220v and supplied to the consumer. A Schematic diagram of high voltage transmission is shown in fig.

Transporting Electricity

Examples

Example 15.1: Can the magnetic force on a current-carrying wire be large enough to suspend the wire against gravity? Consider a wire having mass of 6.24×10^{-4} kg and length 3.5cm placed perpendicular to a 2.4 T magnetic field. How large a current must the wire carry in order to be suspended against gravity?

Given:

Mass 'm' = 6.24×10^{-4} kg
Length 'L' = 3.5cm = 0.035m
Magnetic field 'B' = 2.4T
Acceleration due to gravity 'g' = 9.8 m/s^2

Required:

Current 'I' = ?

Calculation:

Therefore,
Putting values,

$$F_B = W \quad \text{Here } F_B = ILB \text{ and } W = mg$$

$$ILB = mg \quad \text{or } I = \frac{mg}{LB}$$

$$I = \frac{6.24 \times 10^{-4} \text{ kg} \times 9.8 \text{ ms}^{-2}}{0.035 \text{ m} \times 2.4 \text{ T}}$$

$$I = \frac{6.24 \times 10^{-4} \text{ kg} \times 9.8 \text{ ms}^{-2}}{0.035 \text{ m} \times 2.4 \text{ kg s}^{-2}}$$

Hence,

$$I = 0.073 \text{ A} = 73 \text{ mA} \text{-----Answer}$$

Conclusion:

The current passes in the wire is 73mA.

Example 15.2: If the mutual inductance of two coils is 3.5mH and the current through primary coil changes from 0A to 10A in 0.03s, how much emf is induced in the secondary coil.

Given:

Mutual inductance 'm' = $3.5 \text{ mH} = 3.5 \times 10^{-3} \text{ H}$
Initial current $i = 0 \text{ A}$
Final current $I = 10 \text{ A}$
Time taken for change ' Δt ' = 0.03s

Required:

Induced emf in secondary coil ' ε_s ' = ?

Solution:

The emf induced in the secondary coil is given by the equation

$$\varepsilon_s = m \times \frac{\Delta I_p}{\Delta t}$$

$$\varepsilon_s = -m \times \frac{I_f - I_i}{\Delta t}$$

Putting values

$$\varepsilon_s = -3.5 \times 10^{-3} \text{ H} \frac{10 \text{ A} - 0 \text{ A}}{0.03 \text{ s}}$$

$$\varepsilon_s = -3.5 \times 10^{-3} \frac{\text{Vs}}{\text{A}} \times \frac{10 \text{ A}}{0.03 \text{ sec}}$$

Hence,

$$\varepsilon_s = -1.17 \text{ V} \text{-----Answer}$$

Conclusion:

Induced emf in secondary coil ' ε_s ' is -1.17V.

Example 15.3: A portable x-ray unit has a step-up transformer, the 220v input of which is transformed to the 100kv output needed the x-ray tube. The primary has 50 loops, what is the number of loops in the secondary?

Given:

Primary voltage ' V_p ' = 220V

Secondary voltage ' V_s ' = 100kv = 10^5 V

Number of turns in the primary ' N_p ' = 50

Required:

Number of turns in the secondary ' N_s ' = ?

Solution:

By transformer equation

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$N_s = \frac{V_s}{V_p} \times N_p$$

Putting values

$$N_s = \frac{10^5 \text{ V}}{220 \text{ V}} \times 50 \text{ turns}$$

Hence

$$N_s = 2.27 \times 10^4 \text{ turns} \text{-----Answer}$$

Conclusion:

Number of turns in the secondary ' N_s ' 2.27×10^4 turns.

Assignment

Assignment 15.1: A wire carrying a steady (dc) 30A current has a length of 0.12m between the pole faces of a magnet. The wire is at an angle $\theta = 60^\circ$ to the field. The magnetic field is approximately uniform at 0.90T. Determine the magnitude of the force on the wire.

Given:

Current $= I = 30A$

Length of wire $= L = 0.12m$

Angle $= \theta = 60^\circ$

Strength of magnetic field $= B = 0.90T$

Required:

Magnitude of magnetic force $= F_m = ?$

Calculations:

We know that;

$$F_m = BIL \sin \theta$$

Putting the values;

$$F_m = (30)(0.12)(30) \sin 60^\circ$$

$$F_m = 2.8N \text{ -----Answer}$$

Conclusion: Hence;

Magnitude of magnetic force is **2.8N**.

Assignment 15.2: If the current through the primary coil changes from 0A to -10A in 0.02s, such that the induced emf is 4.3v. What is the mutual inductance?

Given:

Inductance emf $\varepsilon_s = 4.3V$

Initial current ' I_i ' = 0A

Final current ' I_f ' = 10A

Time ' Δt ' = 0.02Sec

Required:

Mutual inductance $= M = ?$

Calculation:

We know that;

$$\varepsilon_s = -M \times \frac{\Delta I_p}{\Delta t}$$

$$\varepsilon_s = -M \times \frac{I_f - I_i}{\Delta t}$$

$$M = -\frac{\varepsilon_s \Delta t}{I_f - I_i}$$

Putting values

$$M = \frac{-4.3 \times 0.02}{-10 - 0}$$

$$M = \frac{-4.3 \times 0.02}{10}$$

$$M = 0.0086H$$

$$M = 8.6mH \text{ -----Answer}$$

Conclusion: Hence;

Mutual inductance $= M = 8.6mH$

Assignment 15.3: A step -up transformer has a primary coil consisting of 200 turns and a secondary coil consisting of 3000 turns. The primary coil is supplied with an effective AC voltage of 90.0V. What is the voltage in the secondary circuit?

Given:

Number of turns in Primary coil ' N_p ' = 200V

Number of turns in Secondary Coil ' N_s ' = 3000

Primary voltage (Input) ' V_p ' = 90v

Required:

Secondary Voltage (output) ' V_s ' = ?

Calculation:

According to transformer equation;

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$V_s = \frac{N_s}{N_p} \times V_p$$

Putting values

$$V_s = \frac{3000}{200} \times 90$$

$$V_s = 1350V$$

Conclusion:

Secondary voltage (output) is **1350V**.

EXERCISE

1. Choose the correct answer for each of the following;

- A current carrying wire in which current flow in northward direction is deflected towards the east by a magnetic force. The direction of the magnetic field is
 (a) **Straight up** (b) straight down
 (c) South (d) west
- Which derived unit is equivalent to tesla T?
 (a) Nm/A (b) NA/m
 (c) **N/Am** (d) Am/N
- The unit of inductance, the Henry, is equivalent to
 (a) **Vs/A** (b) VA/m
 (c) As/V (d) V/A
- When the speed at which a magnet is move through a coil is increased, the induced voltage
 (a) **Increase** (b) remain the same
 (c) decrease (d) goes to 0
- Slip rings are a part of
 (a) DC motor (b) **AC generator**
 (c) transformer (d) magnet
- A transformer is used for
 (a) Both DC and AC (b) **AC voltage**
 (c) DC voltage (d) farming
- A step-up transformer increases
 (a) Power (b) energy
 (c) **voltage** (d) current
- A certain transformer has a primary winding with 500 turns and a secondary winding with 250 turns. The turns ratio is
 (a) **0.5** (b) 2 (c) 250 (d) 750
- If the turns ratio is 5, the secondary voltage is greater than the primary voltage by a factor of
 (a) 0.2 (b) 0.5 (c) 2.5 (d) **5**

Conceptual Questions

Q1. Differentiate between electric and magnetic fields.

Ans. Difference between Electric and magnetic fields:

	Electric Field	Magnetic field
(i) Definition	the region (or) space around a charge where its electric effect can be felt by test charge is called electric field	(1) the region (or) space around a magnet where its magnetic effect can be felt by test magnet is called magnetic field
(ii) Force	In electric field there exists an electric force on the test charge.	In magnetic field there exists a magnetic force on the test magnet.
(iii) Medium	An electric field depend on the medium between charges.	Magnetic field is independent of the medium
(iv) Monopole and Dipole	Electric field exists due to monopole (or) dipole.	magnetic field exists only due to dipole. Magnetic monopole does not exist.
(v) Unit	Electric field is measured in newton per meter (v/m)	Magnetic field is measured in gauss (or) tesla.

Q2. Can an electron at rest be set in to motion with a magnetic field?

Ans. Electron at Rest and magnetic field:

No, an electron at rest cannot be set in to motion with a magnetic field.

Explanation:

The magnetic force on a charged particle is given by;

$$F_m = qVB\sin\theta$$

For an electron at rest, we have $V=0$

$$F_m = q(0)B\sin\theta$$

$$F_m = 0$$

Therefore;
This implies that a charged particle at rest experiences no force in a magnetic field.

Conclusion:

Hence; an electron at rest cannot be set in to motion with a magnetic field.

Q 3. Which is more likely to show deflection in compass needle, AC current or DC current? Explain.

Ans. DC current is more likely to show deflection in compass needle.

Explanation:

D.C current is a unidirectional current. It flows along a single direction. The magnetic field produced by D.C will have only one direction and the compass needle will be deflected along that direction. In case of A.C, current changes its direction continuously and hence the magnetic field also changes continuously, due to which the compass will show almost no deflection

Q 4. A constant magnetic field is applied to a current carrying conductor. What angle should the wire make with the field for the force to be (a) maximum, (b) minimum?

Ans. Angle for maximum magnetic force:

The magnetic force on a current carrying conductor will be maximum when the angle between magnetic field (B) current (I) carrying conductor is equal to "90°". the magnetic force on a current carrying conductor placed in magnetic field is given by;

$$F_{B(max)} = BIL \sin \theta \text{-----(1)}$$

For maximum force $\theta = 90^\circ$, put in eq(1)

$$F_{B(max)} = BIL \sin 90^\circ$$

$$F_{B(max)} = BIL \quad (\because \sin 90^\circ = 1)$$

(b) Angle for minimum magnetic force:

The magnetic (F_B) on a current carrying conductor placed in magnetic field (B) will be minimum when the angle between magnetic field (B) and current (I) is equal to "0". The magnetic force (F_B) on a current carrying conductor placed in magnetic field is given

$$F_{B(max)} = BIL \sin \theta \text{-----(2)}$$

For minimum magnetic for $\theta = 0^\circ$, So equation (2) becomes;

$$F_{B(min)} = BIL \sin 0^\circ$$

$$F_{B(min)} = BIL (0) \quad (\because \sin 0^\circ = 0)$$

$$F_{B(min)} = 0$$

Conclusion: Hence;

For maximum magnetic force the angle should be "90°" and for minimum magnetic force the angle should be "0°".

Q 5. Why does a compass needle points north?

Ans. Statement:

A compass needle always points north.

Reason:

A compass needle always points to North because there is a small magnet inside the compass which interacts with the earth's magnetic field. Compass needle is a tiny suspended magnet while the earth behaves like a giant bar magnet the earth's magnetic field interacts with magnets lying on it. Thus the north end of compass needle is drawn by the pole of earth magnet

Conclusion:

Hence; the magnetic force of earth magnet compels a compass needle to point to North always.

Q6. How can a magnetic field be used to generate electric current?

Ans. Electric current generated by magnetic field:

Magnetic field can generate electric current by the phenomena of electromagnetic induction i.e. Change in magnetic field produces an induced emf causing electric current in closed loop. According to Faraday's law, whenever magnetic flux linking a coil changes induced current is produced in the coil the rate of change of magnetic flux induces current in a closed loop (coil).

Conclusion:

Hence; magnetic field can generate electric current by the principle of electromagnetic induction.

Q 7. What would happen if we use a slip ring to drive a DC motor?

Ans. Uses of slip Ring to Drive A D.C motor:

Slip ring cannot drive a D.C motor uniformly.

Explanation:

In D.C motor, if we use slip rings instead of split rings, the continuous rotations of the coil of the D.C motor will not be possible. A slip ring is a continuous ring which provides a continuous transfer of power. Slip rings are not suitable to used in D.C motors. Thus, if we use slip rings to drive a D.C motor, the coil will not rotate along a single direction.

Conclusion:

Hence; if we use slip rings to drive a D.C motor, there will be no complete rotation and it will vibrate between half cycles.

Shams Notes

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Electromagnetism

Q8. The primary coil of a transformer is connected to a DC battery. Is there an emf induced in the secondary coil? Why?

Ans. No, emf will be induced in the secondary coil if the primary coil of transformer is connected to a D.C battery.

Explanation:

A transformer work on the principle of mutual induction i.e, changing current in the primary coil will produce an induced emf in the secondary coil

The D.C Voltage from a battery produces a D.C current in the primary coil. Since D.C current does not change, therefore no change occurs in the magnetic flux produced by it. The magnetic flux linking the secondary coil also does not change, thus no emf is induced in the secondary coil.

Conclusion:

Hence, if we connect the primary coil to a D.C battery, no secondary voltage will be produced.

Numerical Problems

P1: A 1.5 m long wire carries a current of 5A, at right angle to a uniform magnetic field of 0.04 T. determine the force exerted on the wire.

Solution:

Given: Current in wire $= I = 5A$
Length $= L = 1.5m$
Magnetic field $= B = 0.04T$
Angle, $\theta = 90^\circ$

Required:

Force $= F_B = ?$

Calculation:

We know that;

$$F_B = BIL \sin \theta$$

Putting the values;

$$\begin{aligned} \Rightarrow F_B &= (1.5) \times (5) (0.04) \sin 90^\circ \\ \Rightarrow F_B &= (7.5) (0.04) (1) \sin 90^\circ \quad \therefore \sin 90^\circ = 1 \\ \Rightarrow F_B &= 0.3N \text{ ----- Answer} \end{aligned}$$

Conclusion: Hence;

Magnetic force exerted on current carrying wire $F_B = 0.3N$.

P2: A wire carrying a direct current of 10.0 A is suspended 5.0 m east between a house and a garage perpendicular to the earth magnetic field of $5.0 \times 10^{-5} T$. what is the magnitude of the force that act on the conductor.

Shams Notes

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Electromagnetism

Solution:

Given: Current in the wire $= I = 10A$
Length of wire $= L = 5m$
Strength of magnetic field $= B = 5 \times 10^{-5} T$
Angle $\theta = 90^\circ$

Required:

Magnetic force $= F_B = ?$

Calculation:

We know that;

$$F_B = BIL \sin \theta$$

Putting the values;

$$\begin{aligned} F_B &= (5 \times 10^{-5}) (10) (5) \sin 90^\circ \\ F_B &= 250 \times 10^{-5} \times 1 \quad \sin 90^\circ = 1 \\ F_B &= 2.5 \times 10^{-3} N \end{aligned}$$

Conclusion: Hence;

Magnetic force $= F_B = 2.5 \times 10^{-3} N$

P3: A 10 cm wire at 30° to uniform magnetic field of 0.06T is exerted by a force of 0.024 N. what is the current flowing in the wire?

Solution:

Given: Magnetic force $= F_B = 0.024N$
Length $= L = 10cm = 0.1m$
Angle $\theta = 30^\circ$
Magnetic field $= B = 0.06T$
Angle $\theta = 30^\circ$

Required:

Current through wire $= I = ?$

Calculation:

We know that;

$$F_m = BIL \sin \theta \quad I = \frac{F_m}{BL \sin \theta}$$

Putting the values;

$$\begin{aligned} I &= \frac{0.024}{(0.06)(0.1) \times \sin 30^\circ} \\ \Rightarrow I &= \frac{0.024}{(0.06)(0.1)(0.5)} = 8 \\ \Rightarrow I &= 8A \end{aligned}$$

Conclusion: Hence;

Current flowing through the wire $I = 8A$

P4: If the current through the primary coil changes from -5A to +5A in 0.05 s, such that the induced emf is 2.8V. what is the mutual inductance?

Solution:

Given:

Initial current $= I_i = -5A$
Final current $= I_f = 5A$

Induced emf $\varepsilon_{ind} = 2.8V$
Time $\Delta t = 0.05$

Required:

Mutual inductance $M = ?$

Calculation:

We know that;

$$\varepsilon_{ind} = -M \frac{\Delta I_p}{\Delta t}$$

$$\Rightarrow M = \frac{-\varepsilon_{ind} \Delta t}{\Delta I_p}$$

Putting the values;

$$\Rightarrow M = \frac{-2.8 \times 0.05}{5 - (-5)}$$

$$\Rightarrow M = \frac{-2.8 \times 0.05}{10}$$

$$\Rightarrow M = -0.014H$$

$$\Rightarrow M = -14mH$$

Conclusion: Hence;

Mutual inductance $= 14mH$

P5: A transformer connected to a 120-V AC line to supply 9600 V for a neon sign. (a) What are the ratio primary and secondary turns of the transformer? (b) If the transformer consisted of 275 primary winding, how many secondary winding would there be?

Given: Primary voltage (input) $V_p = 120v$
Secondary voltage (output) $V_s = 9600V$
Number of turns in the primary $N_p = 275$

Required:

(a) Turns ratio $= \frac{N_s}{N_p} = ?$

(b) Number of secondary loops $N_s = ?$

Solution:

(a) Turns ratio $= \frac{N_s}{N_p} = ?$

We know that

$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$\Rightarrow \frac{N_s}{N_p} = \frac{9600}{120}$$

$$\Rightarrow \frac{N_s}{N_p} = 80$$

(b) Number of secondary loops $N_s = ?$

We know that

$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$\Rightarrow N_s = \frac{V_s}{V_p} \times N_p$$

Putting values

$$\Rightarrow N_s = \frac{9600}{120} \times 275$$

$$\Rightarrow N_s = 22000$$

Conclusion: Hence;

(a) Turns ratio $= \frac{N_s}{N_p} = 80$

(b) Number of secondary loops $N_s = 22000$

P6: How many turn would you want in the secondary coil of a transformer having 400 turns in the primary, if it wire to reduce the voltage from 220V AC to 3.0 V AC?

Given:

Primary voltage (input) $V_p = 220v$
Secondary voltage (output) $V_s = 3V$
Number of turns in the primary $N_p = 400$

Required:

Number of secondary Coils $N_s = ?$

Solution:

We know that,

$$\frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$\Rightarrow N_s = \frac{V_s}{V_p} \times N_p$$

Putting values

$$\Rightarrow N_s = \frac{3}{220} \times 400$$

$$\Rightarrow N_s = 5.45$$

Conclusion: Hence;

Number of secondary Coils $N_s = 5.45$

P7: A transformer steps down a main supply of 220 V AC to operate a 12 V AC lamp. Calculate the turn's ratio of the windings.

Given:

Primary voltage (input) $V_p = 220v$
Secondary voltage (output) $V_s = 12V$

Required:

Turns ratio $= \frac{N_s}{N_p} = ?$

Calculation:

We know that

$$\Rightarrow \frac{N_s}{N_p} = \frac{V_s}{V_p}$$

$$\Rightarrow \frac{N_s}{N_p} = \frac{12}{220}$$

$$\frac{N_s}{N_p} = 0.05 \text{----- Answer}$$

Conclusion: Hence;

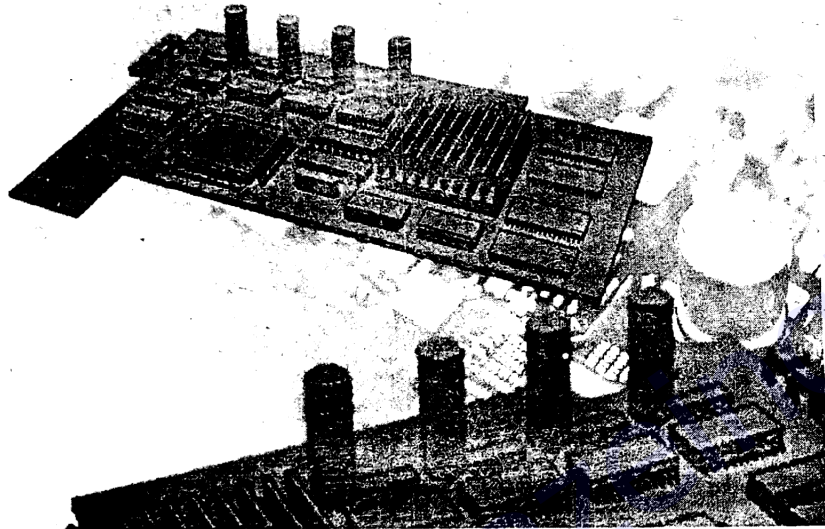
Turns ratio $= \frac{N_s}{N_p} = 0.05$

Chapter No.16

Introductory electronics

Major Concepts

- Thermionic emission
- Properties of electrons
- Electron gun
- Cathode-ray oscilloscope
- Analogue and digital electronics
- Logic gates



Comprehensive Question

Q1. Define electronics? Discuss the main branches of electronics?

Ans. Electronics:

"The branch of applied physics which we deals with the study of electron emitting devices, their use and control is called electronics." "OR"

"The branch of physics which deals with the development of electron emitting devices, their Utilization and controlling electrons flow in electrical circuits designed for various purposes is called electronics."

Branch of Electronics:

Electronics can be divided in two main branches.

- i) Analogue Electronics.
- ii) Digital Electronics.

i) Analogue Quantities:

The branch of electronics which consisting of such circuits which processes analogue quantities is called analogue electronics.

Analogue Quantities:

The quantities whose values vary continuously (or) remain constant are called analogue quantities. e.g the temperature of the air in the atmosphere is changing continuously during day and night. The public address sound system is another example of analogue electronic system.

In this sound system, the microphone converts the sound of the speaker in to electrical signals. The sound signal of the speaker is a variable (or) an analogue signal. The electrical signals sent out by the micro phone are also analogue signals. The output of the microphone is fed in to an amplifier, which is also an analogue instrument. The amplifier amplifies its input without changing its shape and operates a loud speaker. In this way is loud sound is produced out of the speaker.

ii) Digital Electronics:

"The branch of electronics which deals with such circuits which provides data in the form of maximum and minimum voltage signals is known as digital electronics".

In this type of data, the change is not continuous and one part of the data is quite different from the other part of the data. The best example is that of computer. Modern telephone system, radar system, medical equipment's and may house hold appliances make use of digital electronics.

ADC and DAC:

The things signals that we perceive by our five senses in our daily life are usually analogue quantities, which cannot be processed by digital circuits. To resolve this difficulty, a circuit has to be designed which can

convert the analogue signals which can convert the analogue signals in to digital signals. This is known as analogue to digital converter i.e. ADC.

When we analogue signals in the form of digital signals then we process it with digital circuit, the output of which is also in digital form. The digital output is converted in to analogue form by a circuit known as digital to analogue converter (DAC). As the output of DAC is an analogue signal, we can easily sense it. The electronic system used at present consists of both analogue and digital type circuits.

Q2. What is meant by thermionic Emission?

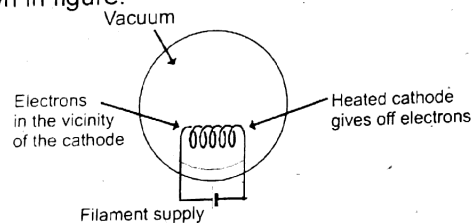
Ans. Thermionic Emission:

"The phenomena of emission of electrons from heated metals are called thermionic emission." OR

"The emission of electrons from certain metals due to heat is known as thermionic emission."

Explanation:

Thermionic emission can be produced by electrically heating a fine tungsten filament. This can be achieved by passing a current through the filament as shown in figure.



Thermionic Emission by filament

Thermionic emission has provided physicists with an important means of producing a continuous supply of electrons. In metals the valance electrons are free to move like the atoms and molecules of gas which are free to move in container. These electrons can move freely through the metal and performs random motion. Such electrons are known as free electrons. Now if we supply heat to the metal, then the valance electrons absorbs the supplied heat energy and they become able to overcome the attractive forces of atomic nuclei. In this way the electrons can escape from the surface of the metal. Such emission of electrons due to heat is known as thermionic emission.

Q3. Describe the construction and working of electron gun?

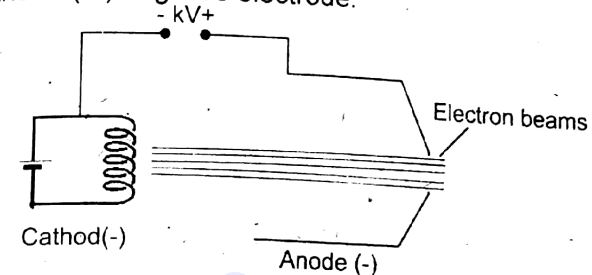
Ans. Electron Gun:

A device which is used to study the properties of electron beam is called electron gun.

Explanation:

Electron gun consists of a glass tube in which the tungsten filament (cathode) and cylindrical anode are sealed at low pressure. The electrons

are produced by thermionic emission from tungsten filament heated by a 6V supply. The electrons will be accelerated to a high speed and they shoot straight through the hole of the anode in a fine beam of electrons. This electron beam is also called as cathode rays as they are produced from the cathode (or) negative electrode.

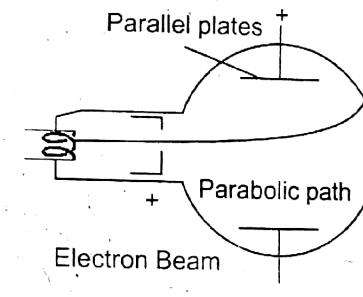


Electron Gun

The effect of electric field and magnetic field upon the beam of these free electrons is as follows.

a) Effect of electric field on Beam of electrons:-

When an electron beam passes between two plates, electron beam deflect toward the positive plate as shown in figure.

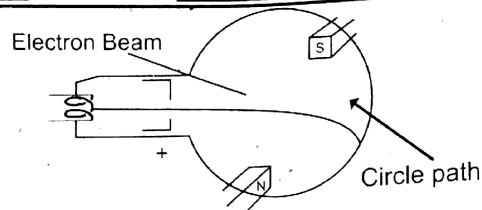


Deflection by Electric Field

This observation shows that the charge on electron beam is negative. Therefore the electron beam is repelled by negative and attracted by positive plate. It is also found that greater the strength of the electric field greater would be the degree of deflection of the electron beam.

b) Effect of magnetic Field on Electron Beam:-

When the beam of electrons passes in a magnetic field between the opposite poles of a magnet. The electron beam deflect toward the north pole of the magnet as shown in figure.



Deflection by Electric Field

It is found that greater the strength of magnetic field greater would be the degree of deflection electron beam.

Q 4. Explain the construction, working principle Oscilloscope (C.R.O)

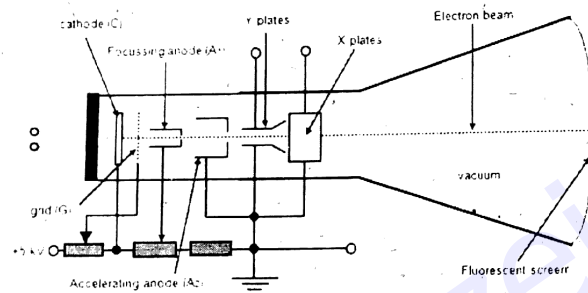
Ans. Cathode Ray Tube (or) cathode ray oscilloscope (C.R.O):

A graph plotting device with the help of which we can see the wave form of an electronic signal is called cathode ray oscilloscope.

Construction and working

The cathode ray oscilloscope consists of the following components.

- The electron gun.
- The deflecting plates.
- A fluorescent screen.



Cathode Ray Tube

i) Electron Gun:

Electron gun provided a beam of electrons. It consists of cathode, anode and grid. The grid is connected to a negative potential. The more negative this potential, the more electrons will be repelled from the grid and few electrons will reach the anode and the screen. The number of electrons reaching the screen determines the screen brightness of the light. Hence the negative potential of the grid can be used as a brightness control. The other feature in the electron gun is the use of the anode. The anode at positive potential accelerates the electrons and the electrons are focused in to a fine beam as they pass through the anode.

ii) The Deflecting system:

Two pairs of plates are fitted in the C.R.O. voltages can be applied to these plates so as to deflect the electron beam. The "Y- plates" will cause deflection in the vertical direction while the "X-plates" will cause the electron beam to be deflected in the horizontal direction if a voltage is applied across them.

iii) The fluorescent screen:

The screen coated with a fluorescent salt, for example, Zinc produce a flash of light.

A cathode ray oscilloscope (C.R.O) is used to see the wave form of a repetitive electronic signal and enable the viewers to see the wave shape of the current signal.

Q5. What are logic gates? Draw symbol and truth table of the following logic gates.

- AND gate
- OR gate
- NOT gate
- NAND gate
- NOR gate.

Ans. Logic Gates:-

"A systematic ordered system that controls the flow of electric current through a circuit is called logic gate." **OR**

"A barrier that is used to control the flow of electric current through a circuit is called logic gate."

To express the working of a logic gate, a logic table of the gate is prepared. This called the truth table. Truth table gives the outcome of every possible switching. A logic table that makes the logic use of binary number i.e. 0 and 1.

Logic "0" stands for OFF and logic "1" stands for ON.

a) AND Gate:

"The logic gate in which the output is "ON", when both the inputs "A" and "B" are "ON" is called AND gate". "OR"

"The gate which implement the AND operation is called AND gate."

Symbol:

The symbol used for AND gate is as follows.

Truth table:

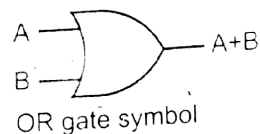
The truth table for AND gate is shown below,

2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

OR Gate:

The logic gate in which the output is ON, when the input A (or) "B" is ON is called OR gate.

The gate which implement the "OR" operation is called "OR" gate.

Symbol:**Truth Table:**

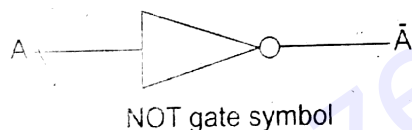
The truth table for "OR" gate is shown below.

2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

NOT Gate:

The logic gate in which the output is "ON" when the input is "OFF" is called NOT gate. "OR"

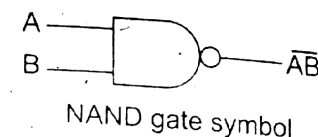
The logic gate which implements NOT operation is called NOT gate.

Symbol:**Truth table:**

NOT gate	
A	A
0	1
1	0

d) NAND- Gate:

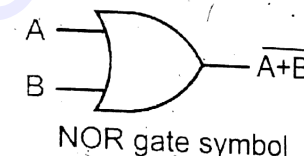
The combination of AND and NOT gate is called NAND gate. The NAND gate has two input A and B one output "C". This gate inverts the output of AND gate. Therefore NAND gate is the inverter of AND gate.

Symbol:**Truth table:**

2 Input NAND gate		
A	B	A.B
0	0	1
0	1	1
1	0	1
1	1	0

e) NOR Gate:

The combination of OR- gate and NOT gate is called NOR gate. "OR" An OR-gate followed by NOT gate is called NOT gate, is called NOR gate.

**Truth table:**

2 Input NOR gate		
A	B	A + B
0	0	1
0	1	0
1	0	0
1	1	0

Q6. Explain the uses of logic gates in

(a) Automatic light bulb switching (b) Textile coloring plant

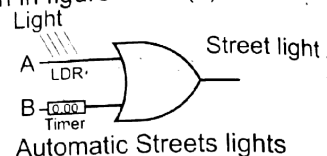
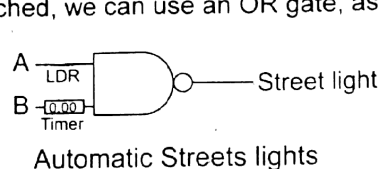
Ans. **Uses of logic gates:**

Equipment and devices could be turned on and off automatically by using logic gates and their combinations.

a) **Automatic light bulb switching:**

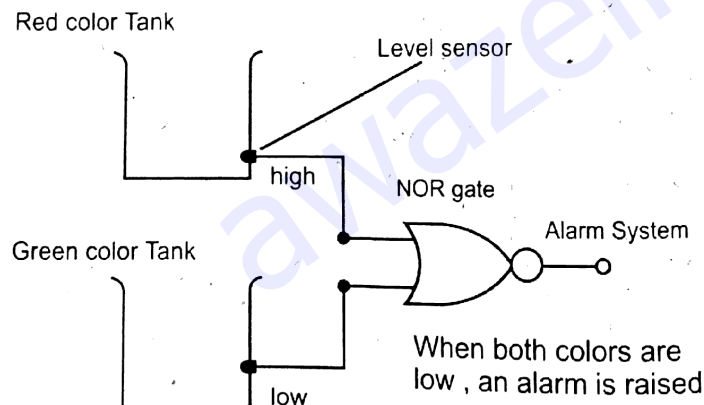
If you desire to automatically switch the street lights on an off, after appropriate time and light level, you can use an AND gate. During day when light shines on light Dependent resistor (LDR), the resistance is high and current in the wire is low (0). In the evening when light fades out, the

resistance of LDR decreases and it starts conducting and turns to high (1). But the light will not glow until the timer time is not reached after which it would also turn high (1) when both the terminals are high the street light will turn up. The schematic representation is shown in the figure 16.16(a). On the other hand if we want to turn the light is low or timer time is reached, we can use an OR gate, as shown in figure 16.18(b).



b) Textile coloring plant:

A textile coloring plant uses two tanks to store red color and green color. Each tank has a sensor that detects when the color level drops to 25% of full. The sensors produce a high level of 5 V when the tanks are more than one-quarter full. When the volume of color in a tank drops to one quarter full or less, the sensor puts out a low level of 0V. Manufacturer requires that an alarm is raised when both tanks are more than one-quarter empty. A NOR gate with its two inputs connected to the tank level sensors and its output connected to the indicator alarm system is shown in figure 16.17. Such that if red color tank is above one-quarter full, the signal is low (0V), even if one tank reduces to less than 25% of full. As soon as both sensor outputs are low (0V), indicating that both tanks are less than one-quarter full, the NOR gate output is (5V) are alarm is raised. Here NAND gate circuitry can be used to indicate by a green light that both tanks are full.



EXERCISE

1. Choose the correct answer for each of the following;

- i. Cathode rays are beam of
 - a. Protons
 - b. electrons
 - c. ions
 - d. neutrons
- ii. If electric field is applied parallel to the direction of electron beam, the electrons will,
 - a. Speed up
 - b. slow down
 - c. deflect
 - d. not change its state
- iii. If magnetic field is applied parallel to the direction of electron beam the electron will
 - a. Speed up
 - b. slow down
 - c. deflect
 - d. not change its state
- iv. The electronic circuit that gives high (1) output when all its input are high (1) is called _____ gate.
 - a. AND
 - b. OR
 - c. NAND
 - d. NOR
- v. The electronic circuit that give high (1) output when one or more of its input are high (1) is called _____ gate.
 - a. AND
 - b. OR
 - c. NAND
 - d. NOR
- vi. The electronic circuit that gives low (0) output when one or more of its input are high (1) is called _____ gate.
 - a. AND
 - b. OR
 - c. NAND
 - d. NOR
- vii. The Boolean equation for OR gate is
 - a. $X=AB$
 - b. $X=A+B$
 - c. $X=\overline{AB}$
 - d. $x=\overline{A+B}$
- viii. The Boolean equation for NAND gate is
 - a. $X=AB$
 - b. $X=A+B$
 - c. $X=\overline{AB}$
 - d. $x=\overline{A+B}$

Conceptual Questions

Q 1. What are free electrons?

Ans. Free Electrons:

Any electron that is not attached to an ion, atom (or) molecule and is free to move under the influence of an applied electric (or) magnetic field is called free electron.

Explanation:

A free electron is an electron that is not attached to an atom in a structure. Free electrons make the substance conductive. Valance electrons are loosely attached to the nucleus of an atom. When external energy in the form of heat (or) light is supplied to the valance electrons then they get pulled to the valance electrons then they get pulled away from the parent atom and become free.

The attractive force of nucleus does not act on the free electrons. Materials with enormous number of free electrons conduct electricity e.g. metals which contain a large number of free electrons.

Q2. What is the function of accelerating anode in electron gun?

Ans. Function of Accelerating Anode in electron Gun:

The main function of accelerating anode in electron gun is to accelerate electrons towards the florescent screen.

Explanation:

An electron gun produces a narrow electron beam with a specific K.E. In electrons are then directed toward the screen at a high speed with the help of an accelerating anode to avoid any loss of electrons in the way. The electrons hitting the screen produce fluorescence for creating images on it.

Q3. If the electron beam in a television tube is striking just one point on the screen at a time, how can we get a full picture? Explain.

Ans. The electron beam is scanned on the whole screen in saw tooth shape that is why we get a full picture.

Explanation:

The electron beam is controlled by electromagnets inside the tube. This beam moves back and forth across the screen line by line painting a picture on the screen. The electron beam moves so quickly that we don't see it building up the picture. It produces a bright spot on the screen where it hit the screen. The screen is coated with "Zns" which produces light when electron hit it.

The electron beam is scanned across the screen in a pattern of horizontal lines called a "raster". Controlling the intensity of the beam at

particular point allows a picture to form. Colour televisions use three electrons guns and three types of screen coating that glow red, blue and green, combining these in various proportions to produce any colour.

Q4. Why image is distorted when a magnet is brought close to old television screen (or) monitors with cathode ray tube (CRT) inside?

Ans. Effect of magnet on Image of old T.V screen (or) monitors with C.R.T:

When a magnet is brought close to an old television (T.V) screens (or) monitors with cathode ray-tube (C.R.T) inside, it deflects the beam of electrons and distorts the image.

Explanation:

Electrons are negatively charged particles which are affected by magnetic field of the magnet. Magnetic field diverts the electrons away from where they should go and so the wrong phosphor spots give a distorted image. Thus you should be very careful with magnets near screens having cathode Ray tube (CRT) inside.

Q5. Assuming that cathode rays are a beam of charged particles, how could you demonstrate that these particles are negatively charged? Explain.

Ans. Demonstration of cathode Rays as negatively charged particles:

We can easily demonstrate that cathode rays are negatively charged particles by passing those rays through an electric and magnetic field.

Explanation:

When cathode rays are passed through an electric field, they are attracted by positive plate which shows the negative nature of cathode rays. When cathode rays are passed through a magnetic field, they are deflected by magnetic field which again shows the negative nature of cathode rays.

Conclusion:

Hence, cathode rays as negatively charged particles can be easily demonstrated by passing these rays through electric and magnetic field.

Q6. If there are four inputs in any logic gate, how many combinations are possible?

Ans. Logic Gate with four inputs:

If there are four inputs in any logic gate, there will be sixteen possible combinations.

Explanation:

Adding more input terminals to a logic gate increases the number of state possibilities. A single input gate such as inverter, there will be two

possible input states. Similarly a two input gate has four possibilities and so on. The numbers of possible input states are given by formula;

No of possible input states possible (combinations) = 2^n

Where n = No. Of inputs

For four inputs i.e. $n=4$

Possible combinations = $2^4 = 16$

Conclusion:

Hence; there will be sixteen (16) possible combinations; if there are four (4) inputs in any logic gate.

Q 7. What conditions produce a high (1) output for an AND gate and NOR gate?

Ans. Conditions to produce A high (1) out put for An AND Gate and NOR Gate:

To produce a high (1) output, the condition for AND gate is that both the inputs must be high (1) and the condition for NOR-gate is that both the inputs must be low (0) to produce high output.

Explanation:

The truth tables for AND and NOR gates are as follows.

Truth table for AND Gate:

Input(1)	Input(2)	Output
A	B	$C=AB$
0	0	0
0	1	0
1	0	0
1	1	1

Truth table for NOR Gate:

Input(1)	Input(2)	Output
A	B	$C=A+B$
0	0	$\bar{0}=1$
0	1	$\bar{1}=0$
1	0	$\bar{1}=0$
1	1	$\bar{1}=0$

From both the truth tables it is clear that to produce high(1) output, the condition for AND gate is that both the input must be high and the condition for NOR gate is that both the inputs must be low (0) to produce high(1) output.

Q 8. What are algebraic Boolean expressions to represent the output of AND, OR, NOT, NAND, and NOR gates?

Ans. Boolean Expression For AND Gate:

The Boolean expression for AND gate is given by;

$$\text{Output} = (1^{\text{st}} \text{ input}) \cdot (2^{\text{nd}} \text{ input})$$

$$C = A \cdot B$$

$$C = AB$$

Which is read as "C" equals "A" and "B".

Boolean expression For OR Gate:

The Boolean expression for an OR-gate is given by;

$$\text{Output} = (1^{\text{st}} \text{ input}) + (2^{\text{nd}} \text{ input})$$

$$C = A + B$$

Which is read as "A" or "B"

Boolean expression for NOT Gate:

The Boolean expression for NOT gate is given by;

$$\text{Output} = \text{Input}$$

$$B = \bar{A}$$

Which is read as "X" equals not "A"

Boolean expression For NAND Gate:

The Boolean expression for NAND is given by;

$$\text{Output} = (1^{\text{st}} \text{ input}) \cdot (2^{\text{nd}} \text{ input})$$

$$C = \overline{A \cdot B}$$

$$\text{Or } C = \overline{AB}$$

Which is read as "X" equals not A and B.

Boolean expression For NOR Gate:

The Boolean expression for NOR gate is given by;

$$\text{Output} = (1^{\text{st}} \text{ input}) + (2^{\text{nd}} \text{ input})$$

$$C = \overline{A + B}$$

Which is read as "X" equals not A or B"

Chapter No.17

Information and Communication Technology

Major Concepts

- ICT
- CBIS
- Flow of information's
- Transmission of electrical signal through wires.
- Transmission of radio waves through space
- Fax machine, cell phone and photo phone
- Transmission of light signal through optical fibres
- Computer
- Information storage devices
- Application of computer



Comprehensive Question

Q1. What is Information and communication technology (ICT)? Explain briefly its components?

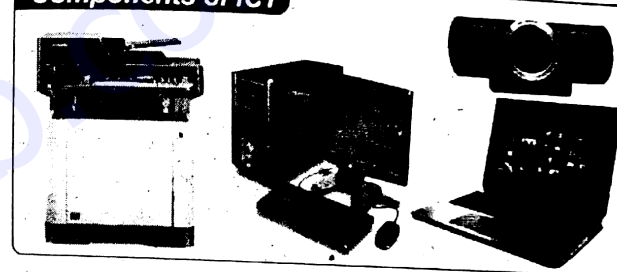
Ans. Information technology:

"The technology by means of which information can be handled, processed, transmitted and recorded by applying modern science is called information technology". "OR"

"The scientific method of storing, protecting, processing, transmitting, receiving and retrieving information is called information technology (I.T)"

Due to I.T the various learning resources can be accessed instantly, by students as well as by teachers at their convenience. Presently the world has become a small well informed and well-connected village which is called a global village.

Components of ICT

**Communicating information "OR" Telecommunication:**

"The method that is used to communicate information to far off places instantly is called telecommunication.

Various devices used for telecommunication are telephone, fax machine, cell phone, television and computer.

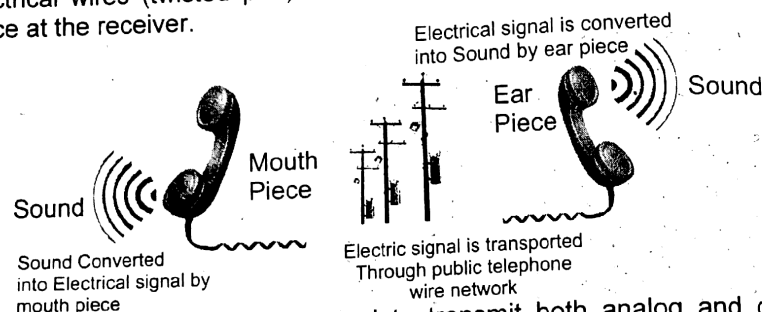
Q 2. Explain the flow of information. Describe how information is transmitted as electric signal through wires, light signals through optic fibers and radio waves through air/vacuum?

Ans. Flow of information is a particular view that focuses on the path and means followed by information entities in telephone, information path is wires in which the information flows by mean of electrical signals. In radio, television and cell phone, information path is either air, vacuum, and /or seawater in which the information travels in the form of electromagnetic waves or through optical fibres through which information travels in the form of light.

Transmission of electrical signal through wire:

Data or information can be transmitted and received over a wire-based communication technology. The information is converted to electrical signals at the transmitter, which is sent through wires (twisted pair, coaxial cable etc.) and information is converted back to original form at receiver's end. Examples include telephone networks, cable television and internet access.

For example in figure 17.2, a simple telephone model sound is converted into electrical signals through mouth piece and sent through electrical wires (twisted pair) and converted back to sound through ear piece at the receiver.



Electrical wire may be used to transmit both analog and digital transmission. For analog signals, amplifiers are required about every few kilometers and for digital transmission (using either analog or digital signals), repeaters are required every kilometer, depending upon the type of wire used.

Transmission of electrical signal through optical fibers:

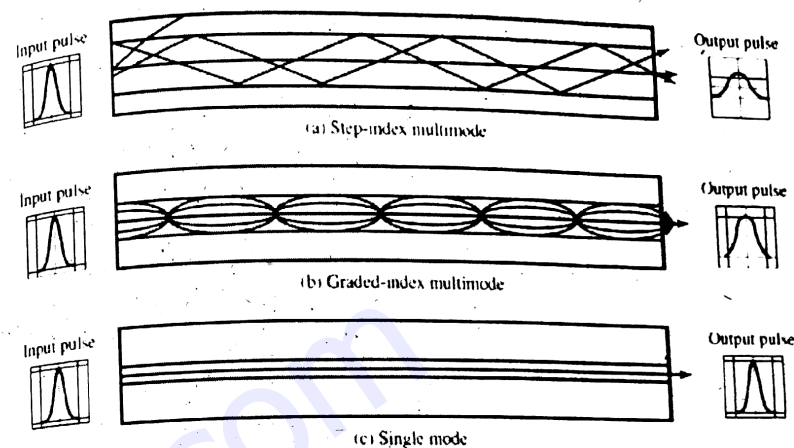
An optical fiber transmits a signal encoded beam of light by means of total internal reflection. Total internal reflection can occur in any transparent medium that has a higher index of reflection than the surrounding medium.

The information is converted into electrical voltage signals; this varying voltage is used to produce light. Two different types of light source are used in fiber optic systems. The light emitting diode (LED) and the injection laser diode (ILD). Both are semi-conductor devices that emit a beam of light when a voltage is applied. The LED is less costly, operates over a greater temperature range and has a longer operational life. The ILD, which operates on the laser principle, is more efficient and can sustain greater data rates. Figure 17.3 shows the principle of optical fiber transmission.

(a). Step - index multimode:

Light from a source enters the cylindrical glass or plastic core. Rays at low angles are reflected due to total internal reflection and travel along

the fiber; other rays are absorbed by surrounding material. This form of propagation is called step-index multimode. This type of fiber is best suited for transmission over very short distances.

**(b). Single - mode:**

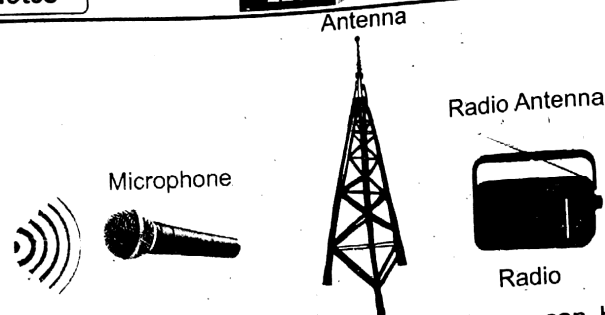
When the fiber core radius is reduced to the order of a wavelength, only a single angle or mode can pass. Single -mode is typically used for long distance applications, including telephone and cable television.

(c). Graded-index multimode:

When the index of refraction at the Centre of the core is made higher and reduced gradually, light in the core curves helically due variation in the index of refraction. The shortened path and higher speed allows light at the periphery to arrive at a receiver at about the same time as the straight rays in the core axis. Graded - index fibers are often used in Local Area Networks (LAN).

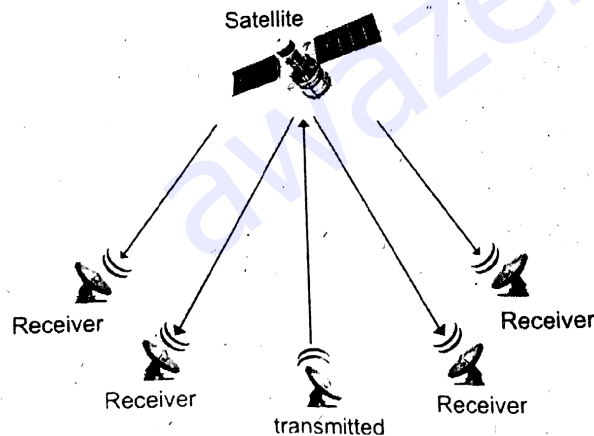
(d). Transmission of radio-waves through air of space:

Electrical signals representing information from a microphone, a TV, camera, or a computer (Transmitters) can be sent from one place to another place using radio wave. For transmission of a signal, radio-frequency electrical energy from the transmitter is converted into electromagnetic energy by the antenna and radiated into the surrounding environment (atmosphere, space, water). For reception of a signal, electromagnetic energy falling on the antenna is converted into radio-frequency electrical energy and fed into the receiver.



In two-way communication, the same antenna can be used for both transmission and reception. An antenna can be defined as an electrical conductor or system of conductors used either for radiating electromagnetic energy or for collecting electromagnetic energy. For example sound waves produced at the radio station as shown in figure are changed into electrical signals through microphone. These electric signals are then fed in to the transmission antenna which superimposes these electric signals on electromagnetic waves and emits them, in form of radio waves. At the receiving end, the receiver selects and amplifies this radio wave signal. The receiver extracts the information and converts it to sound with the help of a speaker.

A Communication satellite is in fact a microwave relay station. It is used to link two or more ground-based microwave transmitter / receives transmissions of one frequency band (uplink), amplifies or repeats the signal, and transmits it on another frequency (downlink). Figure 17.5 depicts in a general way communications between one ground-based transmitter and a number of ground-based receivers.



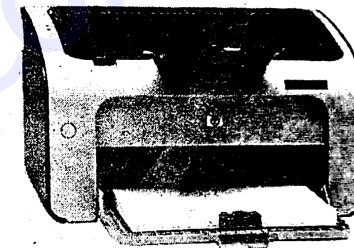
Q 3. Describe function and use of fax machine, cell phone, photo phone and computer.

Ans. **Telecommunication Devices:**

The machines or devices used to carry information to far places are called telecommunication. Fax machine, cell phone, photo phone and computer are few examples of telecommunication devices.

A. Fax machine:

A fax machine is designed to send as well as receive documents so it has a sending part and a receiving part. The sending parts are a bit like a computer scanner that scans only one line of a document at a time, and only in black and white. A fax machine transmits one kind of electric pulse down the phone line to represent black and another to represent white. The phone line transmits this information almost instantly to a fax machine at the other end. It receives the electrical pulses and uses them to control a printer. Takes about a minute or so to transmit a single of writing (or a complex drawing) in very systematic way.



B. Cell phone:

Wireless phones which receive their signals from towers. A cell is typically the area (several miles) around a tower in which a signal can be received. Cell phones provide an incredible array of functions. Depending on the cell-phone model, you can:

- Store contact information
- Make task or to-do lists
- Send text messages
- Keep track of appointments and set reminders
- Use the built-in calculator for simple math
- Get information (news, entertainment, stock quotes) from the internet
- Send or revive e-mail
- Customizable operating systems (oss - software that allows users to interact with the computer system) - enable the user to download apps



like games, GPS, watching TV, utilities, and other tools. Android, a mobile OS developed by Google, is the first completely open source mobiles. Os, meaning that any cell phone manufacturer can use it in their phones for free.

C. Photo phone:

The photo-phone is a telecommunications device that allows transmission of speech (sound) on a beam of light. This means that the light we use will not only provide light but also act as a means of communication. Until the late 1960s, radio and radar communications were more successful than optical communications (OC). OC started to get real attention with the invention of the light amplifications by stimulated emission of radiation (laser) and the laser diode (LD) in the 1960s, followed in the 1970s by the development of low-loss optical fibres (OF) as a medium for transmitting information using light.

D. Computer:

An electronic machine which after analyzing and arranging the given information, presents it in a very short time is called computer. All the works is done by the computer in the light of those instructions which are called program and is saved in its memory.

Parts of a computer:

The important parts of a computer are given below.

i. Input Devices:

In the computer, calculations and instructions are inserted by an input unit as shown in figure.

A key board, mouse, floppy discs and CDs etc. are input devices. Input devices send the received data to CPU so that its arrangement and analysis may be done.



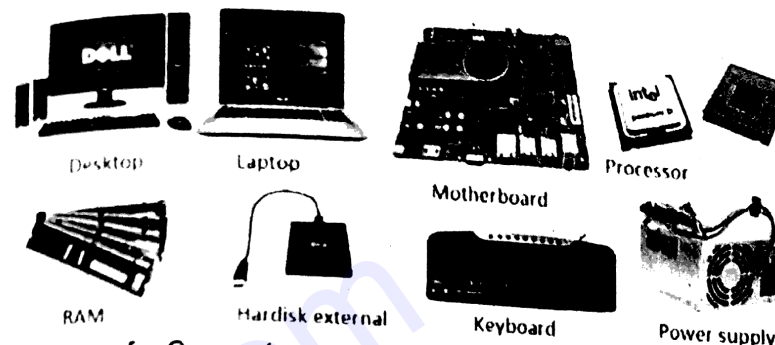
ii. Central processing unit (CPU):

It is a type of a brain of the computer which performs the whole job. This part comprises of a control unit and a memory unit.

iii. Output Devices:

The internal working of the computer is presented on the output unit.

All the processes can be observed on the screen of the monitor while the print out of the result can be taken on a paper with the help of an attached printer. More output can be recorded on a floppy disc (or) CDs (or) flash drives (USB).



Importance of a Computer:

- The computer has made our work easy and fast.
- The computer provides accurate solution of the given information.
- The computer provides us the facility of internet.
- Computer can store office data and records.
- Computer is used for data managing and graphic designing.

Q 4. What is email and internet? List few uses of internet in daily life?

Ans. Email and internet:

The internet is a worldwide system of computer network- a network of networks in which users at any one computer can, if they have permission, get information from any other computer (and sometimes connect directly to users at other computers).

Electronic mail (email or e-mail) is a method of exchanging messages ("mail") between people using electronic devices. Email has practically replaced the postal service for short written transactions. Email operates across computer networks, which today is primarily the internet.

Uses of internet:

Some uses of internet in daily life are as follows,

Communication	- Email - Social media (face book, twitter, Instagram etc.) - Read or write blogs. - Chat -room - Forums - Internet telephone (VoIP)
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Exploring the world	• Exploring through satellite mapping applications (google earth) • Travel sites providing details of places with pictures and videos • Almanacs and encyclopedias
Managing your life	• Online banking (make deposits and withdrawals, order checks) • Online shopping (buying and selling) • Pay utility bills • Investing money. • Keeping a calendar. • Finding a new job
Study and research information	• Find research papers and articles • Find professional services. • Take classes.
Entertaining yourself	• Watch television and movies. • Watching online video (YouTube) • Play games. • Listen to music. • Look for holidays and tickets (sports, concerts etc.)

Q5. What are information storage devices? Describes the use of

Ans. Information Storage Devices:

Information can be stored by virtually any form of energy. Handwriting (paper documents), phonographic recording. Magnetic tape, DNA and RNA and optical discs are all examples of storage media. Electronic data storage requires electrical power to store and retrieve data. Computer data storage is one of the core functions of a general purpose computer. electronic documents can be stored in much less space than paper documents. There are two different types of electronic data storage device:

A. Primary storage devices:

Generally smaller in size, these are designed to hold data temporarily and are internal to the computer. They have the fastest data access speed, and include Ram and cache memory.

B. Secondary storage devices:

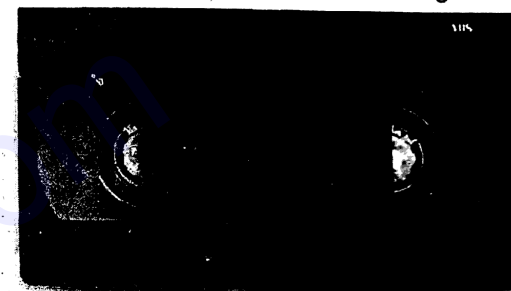
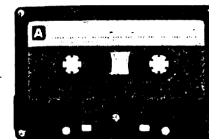
These usually have large storage capacity and the store data permanently. They can be either internal or external to the computer, and

they include the hard disk, optical disk drive and USB storage device. Some secondary storage devices are explained below.

a. Audio and video cassettes:

A magnetic tape, in computer terminology, is a storage medium that allows for data archiving, collection, and backup. At first, the tapes were wound in wheel – like reels but then cassettes and cartridges came along, which offered more protection for the tape inside.

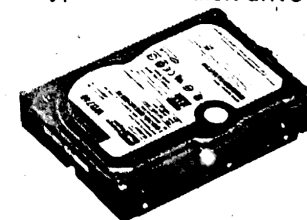
One side of the tape is coated with a magnetic material. Data on the tape is written and read sequentially. Finding a specific record takes time because the machine has to read every record in front of it. Most tapes are used for archival purposes rather than ad –hoc writing / reading.



An audio cassette can store music and sounds. A video cassette on the other hand is magnetic tape used for storing video and usually sounds in addition. Audio and video cassettes are shown in eh figure 17.8. Audio and video cassettes require special devices to be played and recorded.

b. Hard Disk:

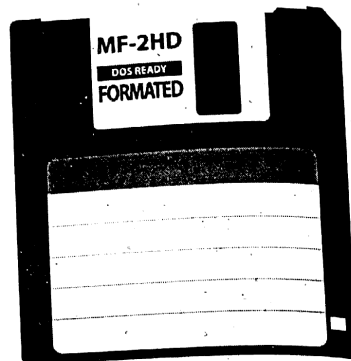
A hard disk drive sometimes abbreviated as hard drive, HD, of HDD) is a device that permanently stores and retrieves data on a computer. A hard drive is a secondary storage device that consists of one or more platters to which data is written using a magnetic head, all inside of an air- sealed casing. A typical hard disk drive is shown in figure 17.9.



c. Floppy:

A floppy disk is a magnetic storage medium for computer system. The floppy disk is composed of a thin, flexible magnetic disk sealed in a

square plastic carrier. In order to read and write data from a floppy disk, a computer system must have a floppy disk drive (FDD). A floppy disk is also referred to simply as a floppy. Since the early days of personal computing, floppy disks were widely used to distribute software, transfer files, and create back-up copies of data. Because hard drives were very expensive, floppy disks were also used to store the operating system of a computer. The picture shown in figure 17.10 is an example of a 3.5 floppy diskette, which was one of the most commonly used floppy diskettes, capable of storing 1.44MB of data.



d. CD and DVD:

A compact DISC (CD) is a portable storage medium that can be used to record, store and play back audio, video and other data in digital form.

A DVD (Digital versatile Disc or Digital video Disc) is an optical disc capable of storing up to 4.7 GB of data, more than six times what a CD can hold. CDs and DVDs are used to hold music, data or computer software. They have become the standard medium for distributing large quantities of information in a reliable package. If you have a computer and CD-R drive, you can create your own CDs, including any information you want. A typical 700MB storage CD is shown in figure 17.11



e. Flash Drive:

A flash drive is a small, ultra-portable storage device which, unlike an optical drive or a traditional hard drive, has no moving parts. Flash drives connect to computers and other devices via a built-in USB

(universal serial Bus) Type-A plug, making a flash drive a kind of combination USB device and cable.



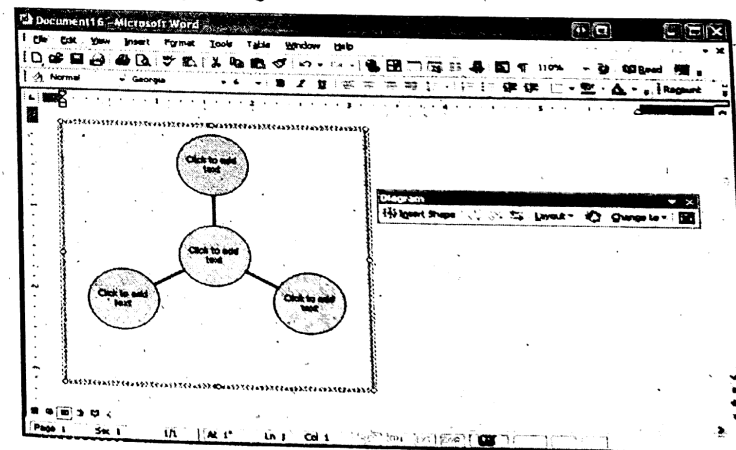
Q 6: What are the functions of word processing?

Ans. Word processing:

Every day we come in to contact with documents, letters, leaflets, books and other printed materials that were prepared using software that enables users to develop and edit-based documents.

Word processing software is used to manipulate a text document, such as a resume or a report. We typically enter text by typing and the software provides tools for copying, deleting and various types of formatting. Some of the functions of word processing software include:

- Creating, editing, saving and printing documents.
- Copying, pasting, moving and deleting text within a document.
- Formatting text, such as font type, bolding, underlining or italicizing.
- Creating and editing tables.
- Inserting elements from other software, such as illustrations or photographs.
- Correcting spelling and grammar.



Word processing software typically also contains features to make it easier for us to perform repetitive tasks. For example, let's say we need to send a letter to all our customers regarding a new policy. The letter is the same for all customers except for the name and address at the top of the letter. Word processing software can take a database of customer information and use it to automatically create a letter for each customer.

Q 7. How information is handled? Describe data management and its monitoring and control?

Ans. Handling information:

Handling information is the ability to use ICT for gathering, organising, storing, retrieving, modifying interpreting and presenting information. It involves categories such as databases, spreadsheets and internet.

A. Data management:

Data management is an administrative process that includes acquiring, validating, storing, protecting, and processing required data to ensure the accessibility, reliability, and timeliness of the data for its users. Designing effective data management solutions consists of three primary activities

- An assessment of supply chain information needs should be conducted, including who needs the information, how it will be used and the potential actions that may be taken in response to the data. Secondly, the platform best suited to supporting data collection should be selected. This may range from paper-based systems to mobile phones to sophisticated software programs.
- Standard operating procedures (SOPs) should be developed, with staff trained on how to adhere to the SOPs. Staff need to be trained on how to use the selected tool(s) and equally importantly on how to analyze and use the selected tool(s) and equally importantly on how analyze and use the results.
- The collected data should be made available in a format that enable decision making. The format will depend on the resources available and the audience but the data should be accessible and easy to use to answer key supply chain performance questions.

B. Monitoring and control:

The monitoring and controlling process oversees all the tasks and metrics necessary to ensure that the approved and authorized project is within scope, on time and on budget so that the project proceeds with minimal risk. This process involves comparing actual performance with planned performance and taking corrective actions to yield the desired outcome when significant differences exist. Monitoring and controlling process is continuously performed throughout the life of a project.

EXERCISE

1. Choose the correct answer for each of the following;

- i. The components of information and communication systems are humans, hardware, software, procedures and _____.
 - a. Computers
 - b. fields
 - c. data/information
 - d. signal
- ii. Electric or electromagnetic representations of data or information is termed as
 - a. Computer
 - b. signal
 - c. transmission
 - d. software
- iii. The phenomenon of total internal reflection is used in transmission of signal through
 - a. Electric wires
 - b. optical fiber
 - c. electromagnetic waves
 - d. radio
- iv. Electrical conductor or system of conductor used either for radiating electromagnetic energy or for collecting electromagnetic energy is
 - a. Antenna
 - b. satellite
 - c. repeater
 - d. signal
- v. Software that allows users to interact with the computer system is
 - a. Hardware
 - b. application
 - c. operating system
 - d. program
- vi. Which of the following information storage device has no moving parts to store and retrieve information
 - a. CD/DVD
 - b. hard drive
 - c. Flash drive
 - d. floppy
- vii. Which of the following information storage device is least used these days
 - a. CD/DVD
 - b. hard drive
 - c. Flash Drive
 - d. Floppy
- viii. Telephone communication is the example of transmission of signals through
 - a. Electric wires
 - b. optical fiber
 - c. electromagnetic waves
 - d. All

Conceptual Questions

Q1. Identify the most reliable means of storing information?

Ans. Most Reliable Means of storing Information:

All the storage devices are important and reliable means of storing information depend upon its function.

Explanation:

All storage devices are used for some purposes. For example CDs and DVDs are used in our daily lives for storage, movies, music and much more. Hard disks are used for storing information. Data can be stored in and removed from hard disks easily. USB flash drives are small, portable storage devices that are most commonly used for transferring data from one computer to another.

Q 2. How information is different from data?

Ans. Difference between Information and Data:

	Data	Information
i	A raw and un-organized fact that needs to be processed is called data.	An organized, processed and structured data is called information
ii	Data are the facts (or) details from which information is derived	Information is processed and interpreted data.
iii	Data collected by the investigator may or may not be useful to him because it is not known what they represent.	Information is valuable and useful to the investigator because it is presented in the given context
iv.	Data is not always specific to the need of the investigator.	Information is always specific to his requirements

Conclusion:

Hence; Data is randomly collected facts and figures which are processed to draw conclusions but when the data is organized it becomes information. Data does not depend on information. However, information cannot exist without data.

Q 3. Why frequency band for uplink and downlink is different in transmission of microwaves through space?

Ans. Frequency Band for uplink and Downlink:

The frequency band for uplink and downlink is different in transmission of microwaves through space. The uplink frequency is greater than downlink frequency because the uplink transmitter is on the earth and need plenty of transmit power to overcome the slightly higher

path loss inherent in higher frequency signals. On the other hand, the downlink transmitter is located on the satellite and less power is needed to transmit data from satellite to earth station.

Conclusion:

Hence; the uplink frequencies and downlink frequencies are different due to different values of power consumption.

Q 4. What does cell in cell phone refer to?

Ans. Meaning of cell in cell phone:

Cell in cell phone refers to the geographical area covered by a cellular telephone transmitter.

Explanation:

The transmitter's span of coverage is called a cell and the transmitter itself is called the cell and the transmitter itself is called the cell site. The cell provided by a cell site ranges the cell provided by a cell site ranges from one mile to twenty miles in diameter, depending on transmission power, several coordinated cell sites are called a cell system. When you sign up with a cellular telephone service provider, you generally are given access to their cell system, which is essentially local when travelling out of the range of this system; the cell system can enable you to be transferred to a neighboring company's cell system without your being aware of it. This is called roaming service. The cell sites in a system connect to a mobile telephone switching office (MTSO), which in turn connects to the standard land line telephone system.

Q 5. Can internet be used for shopping? Given an example

Ans. Use of internet for shopping:

Yes, internet is widely used for on-line shopping in the world.

Explanation:

In online shopping a consumer directly by goods (or) services from a seller using a web browser. Consumer find a product of internet by visiting the website of the retailer. Consumers can buy almost everything of his / her daily use.

Conclusion:

Hence; internet can be used for online shopping in the world.

Q 6. How a flash drive is different from other storage devices?

Ans. Difference between USB and storage Devices:

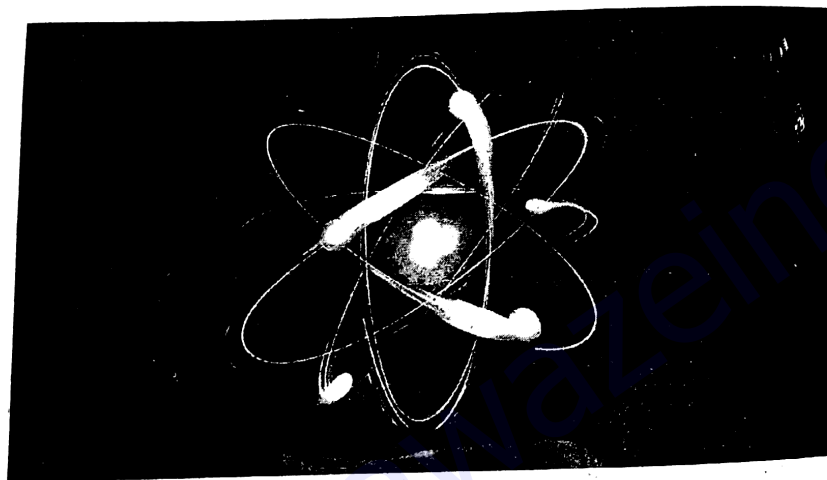
USB (or) flash drive is a data storage device that includes flash memory with an integrated USB interface. IT is removable, re-writable and much smaller while other storage devices are heavy. USB flash drives are often used for storage, data backup and transfer of computer files. A flash drive is often affordable and cost much less than other storage devices. You can store different kinds of files on a USB flash drive and they will remain there unless you delete them.

Chapter No.18

Nuclear Physics

Major Concepts

- Atom and nucleus
- Natural radioactivity
- Background radiations
- Nuclear transmutations
- Nature and properties of radiations
- Half-life and its measurement
- Uses of radioisotopes
- Nuclear fission
- Nuclear fusion
- Hazards of radiation and safety measure
- Solution of problems

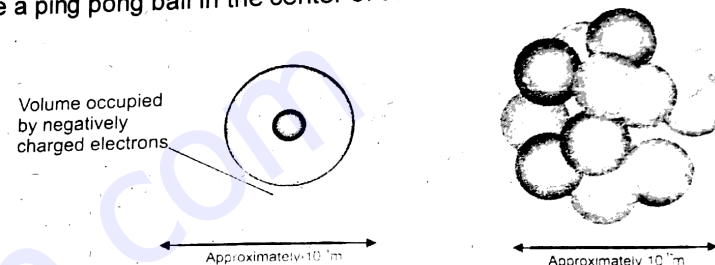


Comprehensive Questions

Q1. What is nucleus? How a nuclide is represented symbolically.

Ans. **Atom and Atomic nucleus:**

All matter is composed of atoms that are in turn composed of a heavier, central, positively charged core called 'nucleus' surrounded by a less massive negatively charged cloud of 'electrons' the nucleus lies at the center of the atom, occupying only 10^{-15} of its volume since the electrical force comes from both the electron and the nucleus as shown in figure. The nucleus is about 10,000 times smaller than atom. The size difference is like a ping pong ball in the center of a 2km circle.



All nuclei are composed of two types of particles; protons and neutrons (called nucleons). The only exception is the ordinary hydrogen nucleus, which is a single proton. In describing the atomic nucleus, we must use the following quantities:

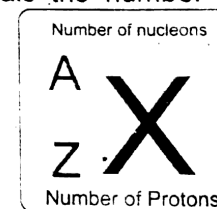
The atomic number Z (sometimes called the charge number), which equals the number of protons in the nucleus.

The nucleon (or mass) number A , which equals the number of nucleons (neutrons plus protons) in the nucleus.

The neutron number N , which equals the number of neutrons in the nucleus ($N=A-Z$).

In representing nuclei, it is convenient to have a system of symbol to show many protons and neutrons are present. The symbol used is ${}_Z^AX$ where " X " represents the chemical symbol for the element, Z represents the number of proton and " A " represent the number of nucleus (i.e number of proton and neutron)

For example ${}_{26}^{56}\text{Fe}$ (iron) has a nucleon number of 56 and an atomic number of 26; It therefore contain 26 proton and $(56 - 26)$ 30 neutrons. The subscript Z is thus some time dropped for example of nitrogen ${}_{7}^{15}\text{N}$ we already known that $Z=7$ form nitrogen is simply write N^{15} , call it as nitrogen fifteen (or may write as nitrogen-15).



The nuclei of all atom of a particular element contain same number of proton (and consequently electrons in a neutral atom) but often contain different number of neutrons. The nuclei of atom which have the same number of proton and neutron are termed as nuclides. Within the nucleus Z positive charge s. to keep these charges from flying apart, the nuclear force must supply an attraction that overcomes their electrical repulsion.

Q2. What is radioactivity? What are α , β , γ rays. Describe their properties.

Ans. History:

In 1896 a French scientist Henry Becquerel discovered the process of radioactivity while performing experiment on the compound of uranium.

Definition:

The disintegration of the nuclei of certain atoms with the emission of alpha, beta and gamma rays is called radioactivity. OR

The phenomena of emission of radioactive rays (alpha, beta and gamma rays) from the nuclei of certain atoms is called radioactivity.

Types:

There are two type of radioactivity.

- Natural radioactivity
- Artificial radioactivity

i. Natural radioactivity:

The spontaneous and uncontrollable disintegration of the nuclei of certain heavy atom having atomic number greater than 82 with the emission of radioactive rays is called natural radioactivity.

ii. Artificial radioactivity:

The radioactivity produce by bombarding subatomic particles in to same element is called artificial radioactivity. OR

The radioactivity produced as a result of bombardment of nucleus of an element by subatomic particle is called artificial radioactivity.

Unit:

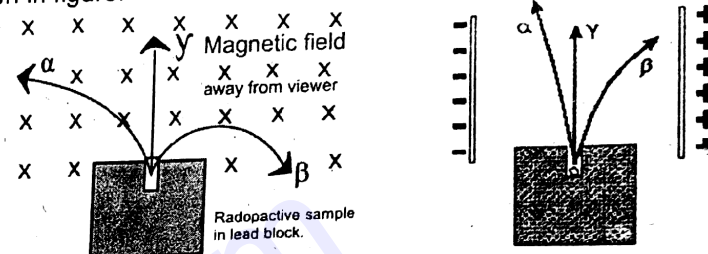
Becquerel (Bq) is the SI unit of radioactivity. One Becquerel is defined as the activity of quantity of radioactive material in which one nucleus decays per second.

A common unit of activity curie (Ci) which is 3.70×10^{10} decay per second i.e $C_i = 3.70 \times 10^{10}$ Bq.

Experiment:

In this experiment a small quantity of radioactive element (uranium) was so placed in the cavity in a lead block that the radiation from uranium come out of the mouth of the cavity. a photographic plate is placed at some distance above the lead block so that the radiation from the uranium fall upon it. The apparatus is placed in vacuum tight chamber, which is

evacuated by a power pull pump. This chamber is then placed between the poles of a strong magnet so that the magnetic field is perpendicular to the plane of the paper and is directed inward. Under the action of magnetic field three separate images are formed on the photographic plate. This show that the radiation coming from uranium are of three types as shown in figure.



The radiation which here deflected toward right are known as β -rays. The radiation which here deflected toward left are known as α -rays, while the radiation which were passes undeflected are known as γ -ray.

Properties of radioactive rays:

a) Alpha rays (α -rays):

- α -rays are deflected by electric and magnetic field,
- α -rays are double positive.
- The α -ray effect the photographic plate.
- α -rays have high ionization power.
- The speed range of α -rays in between 1.4×10^7 m/sec to 1.8×10^7 m/sec.
- α -rays have low penetrating power.
- α -rays produce artificial radioactivity in certain substances.
- α -rays produce burns and sores on human body.

b) Beta rays (β -rays):

- β -rays affect the photographic plate.
- β -rays are negatively charge particles.
- β -rays produce fluorescence in certain substance
- β -Rays the speed of β -rays is in between 2.7×10^7 m/sec to 9×10^7 m/sec
- The ionization power of β -rays is very small.
- The penetrating power of β -rays is very high
- β -rays are deflected by electric and magnetic field.

c) Gama Ray (γ - ray):

- γ - rays are neutral particles.
- γ - rays move with the speed of light.
- The penetrating power of γ - rays is very large compared to β - rays and α - rays
- The ionization power of γ - rays is very low as compared to α - rays and β - Rays
- γ - rays produce feeble fluorescence in Barium platinocynide.
- γ - rays affect the photographic plate.
- γ - rays are electromagnetic waves.

Q3. Discuss the half- life of radioactive elements in detail?**Ans. Half-life of radioactive element:****Definition:**

"The time interval in which half of the atoms in any given sample decay in to daughter element is known as the half-life of that element". OR

"The half-life of an element is that time during which the number of atoms of the radioactive element reduced to one half."

Parent Element:

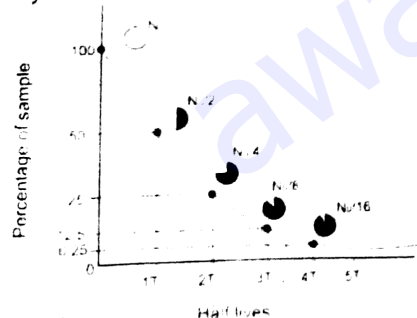
The original radioactive element which continuously emits radiations is called parent element.

Daughter element:

The element which is formed as a result of continuous emission of radiations from an element is called daughter element.

Half life range:

The amount of radioactive isotope in the sample decreases with time as shown in the half-life curve shown in figure. The number of nuclei present at time $t=0$ is $N=N_0$, and the number present at $t=T_{1/2}$ is $N=N_0/2$. The number present at $t=2T_{1/2}$ is $N=N_0/4$, and so on. The value of the half life depends on the nature of the radioactive nucleus. For example, radium has a half-life of 1600 years, because it takes this amount of time for one-half of a given quantity of this isotope to disintegrate.



In another 1600 years, one-half of the remaining radium atoms will have disintegrated, leaving only one-fourth of the original number intact. Let N represent the amount of the original sample remaining after any given time interval Δt , and N_0 represent the original amount in the sample given in the same unit as N . Then

$$\text{After 1 half-life} \quad N = \frac{1}{2} N_0$$

$$\text{After 2 half-life} \quad N = \frac{1}{2} \times \frac{1}{2} N_0 = \left(\frac{1}{2}\right)^2 N_0$$

$$\text{After 3 half-life} \quad N = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} N_0 = \left(\frac{1}{2}\right)^3 N_0$$

$$\text{Generally} \quad N = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \dots N_0 = \left(\frac{1}{2}\right)^n N_0$$

There, the number n , of half-lives is equal to the interval (Δt) divided by the time for one half life $T_{1/2}$.

$$N = \frac{N_0}{2^n}$$

TABLE. For half lives of some common radioisotopes

Radioisotopes	Decay	Half Life
Beryllium-8	α	2.0×10^{-10} s
Polonium	α	1.64×10^{-4} s
Iodine-131	β^-	8.04 d
Cobalt-60	β^-	5.3 y
Radium-226	α	1.62×10^3 y
Carbon-14	β^-	5.73×10^3 y
Uranium-235	α	7.04×10^8 y
Uranium-238	α	4.45×10^9 y

Different materials have different half-lives which ranges from 10^{10} years to a fraction of second. Half-lives of some common radioisotopes are shown in table.

Q4. What are nuclear transmutations? What changes in the composition of nucleus is observed when α , β and γ particles are emitted? Explain by symbolic equation.

Ans. Nuclear Transmutations:

Definition:

"The process through which an unstable nucleus (parent nucleus) transform (or change) in to a more stable nuclide (daughter nucleus) is called nuclear transmutation (Nuclear decay)".

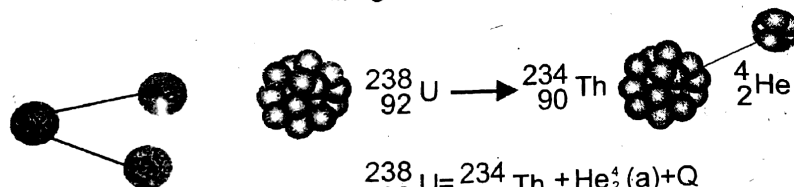
In these nuclear transmutations, the original element is called parent and new formed element is termed as daughter.

Alpha decay:

In alpha decay, the original 'parent' nuclide is converted to a 'daughter' by the emission of an α particles. Balancing the reaction shows that the daughter nuclide has a nucleon number reduced by four and a charge reduced by two. Mathematically,

$${}^A_ZX = {}^{A-4}_{Z-2}Y + {}^4_2\text{He} + Q$$

Where 'Q' is the energy released in the process. Nuclide 'X' changes into nuclide 'Y' with the emission of alpha ' α ' particle and the release of energy 'Q'.



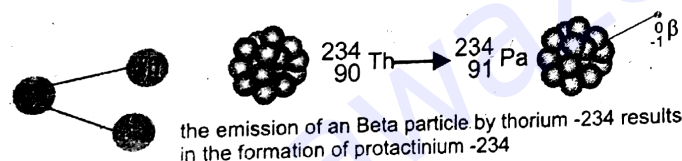
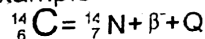
the emission of an alpha particle by uranium -238 results in the formation of thorium -234

Beta decay:

Unlike α -decay, β (or electron) decay of nuclei does not change the number of nucleons. In essence, β -decay changes a neutron into a proton.

$${}^A_ZX = {}^A_{Z+1}Y + \beta + Q$$

Where Q is the energy released in the process. Nuclide 'X' changes in to nuclide 'Y' with the emission of beta " β " particle and released of energy 'Q'. Example



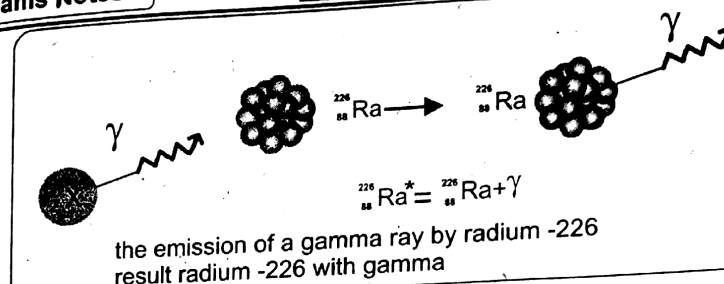
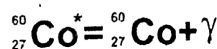
the emission of an Beta particle by thorium -234 results in the formation of protactinium -234

Gamma decay:

In most cases the α or β emission from the nuclei leaves it in excited state such nuclei achieve further stability by emitting gamma rays.

$${}^A_ZX^* = {}^A_ZX + \gamma$$

For example;



Q5. What are radio isotopes? Explain their uses for various applications?

Ans. Definition:

"The isotopes that are unstable and emit radiations are called radioactive isotopes or simply radioisotopes".

Explanation:

Isotopes of elements that occur naturally are somewhat stable. But the isotopes, manufactured in nuclear laboratories by bombarding o subatomic particles, usually have a short life span, mostly due to their unstable nature and radioactivity. Among about 3000 known nuclides, only 257 are stable. The time scale of these decay processes ranges from a small fraction of a microsecond to billions of years.

Carbon 12 6 Protons 6 Neutrons 6 Electrons	Carbon 13 6 Protons 7 Neutrons 6 Electrons	Carbon 14 6 Protons 8 Neutrons 6 Electrons	Carbon 11 6 Protons 5 Neutrons 6 Electrons
(a) Three natural Isotopes of carbon			(b) The most stable artificial isotopes of carbon

The element carbon (figure) as we find it in nature consists 98.89% of ${}^{12}\text{C}$ atoms and only about 1.11% ${}^{13}\text{C}$ atoms. Where ${}^{14}\text{C}$ isotopes of carbon is in trace amounts, with a half- life of 5,700 years. Carbon as a whole has 15 known isotopes from ${}^8\text{C}$ to ${}^{22}\text{C}$, of which the most stable artificial radioisotopes have half- lives under 20 seconds, most less than 200 milliseconds.

Most elements have between two and six stable isotopes (as opposed to unstable or radioactive ones). Twenty elements, including fluorine, sodium, aluminum, phosphorus, and gold consist of only one stable isotope each. Tin, however, has ten-more than any other element.

Uses of radioisotopes:

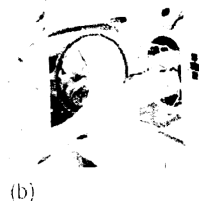
Radioactive isotope behaves in just the same way as the normal isotope chemically, which make it useful in wide variety of applications. Over 2,000 radioisotopes- radioactive isotopes- either exist in nature or have been made artificially by bombarding stable isotopes in particle accelerators. They are useful in so many applications that the word isotope is commonly used to mean radioisotope, as if stable isotopes did not exist. Few of the use of radioisotopes are discussed below.

i. Food preservation:

Food irradiation is a method of treating food in order to make it safer to eat and have a longer shelf life. Even after it has been packaged, gamma rays can penetrate the packing and be used to kill bacteria, mould and insect in food as shown in figure (a). This process prolongs the shelf-life of the food, but sometime changes the taste.

ii. Sterilizing:

Gamma rays are also used to sterilize hospital equipment by radiation, especially the plastic syringes that would be damaged if heated as shown in figure (b).

**iii. Agriculture:**

If a plant is given fertilizer tagged with radioactive carbon then the plant releases "beta radiation" and thus by measuring radioactive in different part of the plant, the uptake of the fertilizer by plant can be determined.

This technique can help in elaborating the complex process of photosynthesis as well. Higher yield varieties of seed have also been developed after mutation through radiation.



Figure: Radioisotopes in agricultural

iv. Medical uses:

Radio pharmaceutical – drugs that contain radioactive material – are imported in diagnosis and treatment of many disease. They can be injected into the body, inhaled, or taken orally as medicines or to enable imaging of internal organ and bodily processes. Ionizing radiation has two very different uses in medicine – for the diagnosis and therapy.

a. Medical diagnostic:

Every organ in our body acts differently from a chemical point of view. Doctors and chemist have identified a number of chemical which are absorbed by specific organs. The thyroid, for example, takes of iodine; the brain consumes quantities of glucose, and so on. With this knowledge, radio-pharmacists are able to attract various radioisotopes to biologically active substances. Image are then obtained via gamma camera or a PET scan in nuclear diagnostic which enable to accurately detect disease progression and staging in vital organs.

A radioisotopes used for diagnostic must emit gamma rays of sufficient energy to escape from the body and it must have a half –life short enough for it to decay away soon after imaging is completed.

b. Radiation therapy:

High energy radiation can be used to destroy selected tissues, such as cancerous tumor. Cobalt 60 which emits β particle and high energy gamma rays can be used to treat various cancers. Some radioisotopes are made absorb by selected organ and radiation is concentrated on the infected tissue. For example cancerous thyroid can be treated with iodine-131.

Q6. How is carbon -14 used to determine the age of wood, bones and other artifacts?

Ans. Radioactive dating:

Archeologist and geologist use radioactive dating to estimate the age of ancient objects. One common used procedure carbon-14 which has a half –life of 5730 years. as long as the creature is alive, it will continue to absorb and collect carbon-14. Once the creature dies, no further carbon -14 will be ingested, and the proportion of carbon-14 is very small. Nevertheless the amount is the measurable. the measurement of the activity present can therefore be used to estimate the age of the specimen. Carbon-14 dating can be used for biological tissue as old as 50 or 60 thousand year, but is most accurate for younger samples, since the abundance ^{14}C nuclei in them are greater. Very old biological material contains no ^{14}C at all. Material with relatively longer half-life can be used to determine the age of geological formation. Uranium -238, for example, with a half-life of 4.53×10^9 year can be used to date even the oldest deposits on earth.

Q7. Discuss nuclear fission and fusion in detail?

Ans. Nuclear fission:

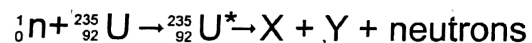
Definition:

The splitting of the heavy nucleus in the fragment with the emission of energy when bombarded by a slow neutron is called nuclear fission. **OR** The process of splitting of nuclei into intermediate size nuclei is called nuclear fission. The fission processes often produce free neutron and gamma rays, and release a large amount of energy.

Discovery:

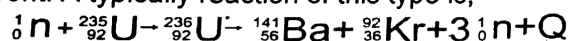
Nuclear fission was discovered in December 17, 1938 by Otto Hahn and his assistant Fritz Strassman, and explained theoretically in January 1939 by Lise Meitner and her nephew Otto Robert Frisch.

They found that a uranium nucleus, after absorbing a low energy neutron (thermal neutron), splits into two fragments of intermediate size. The splitting of a massive nucleus into two less fragments was termed a nuclear fission. It can be represented by the following nuclear reaction.

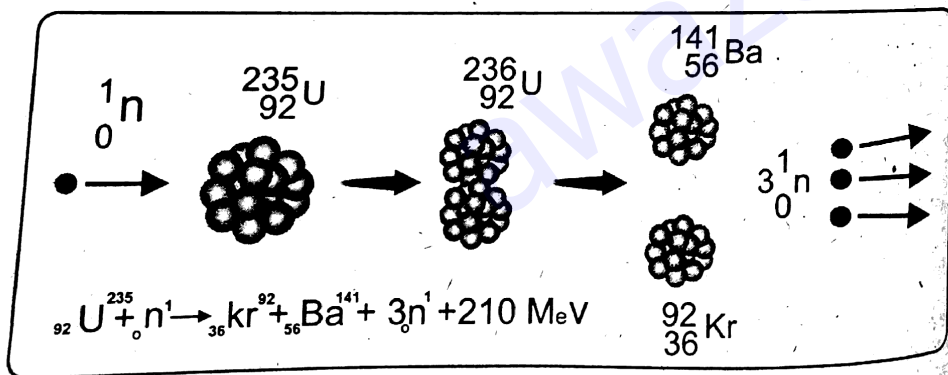


Where ${}_{92}^{236}\text{U}^*$ is an intermediate excited state that lasts for only about 10^{-12} s before splitting into X and Y. The resulting nuclei X and Y are called fission fragments. Many combinations of X and Y are possible in the above nuclear reaction.

Figure shows that the actual mass distribution of fragments in the fission of ${}_{92}^{235}\text{U}$. The process results in the production of several neutrons, typically two or three. On the average, about 2.5 neutrons are released per event. A typical reaction of this type is,



Where Q is the nuclear reaction energy



In the uranium nucleus the nucleons are bound with an average energy of about 7.6 MeV per nucleon. In the fission product nuclei, the medium binding energy per nucleon amounts to approx. 8.5 MeV. This difference in binding energy of 0.9 MeV per nucleon is released in the nuclear fission. Since the uranium nucleus has 235 nucleons, a quantity of about 210 MeV is released per fission. It is made up of the following partial amounts.

❖ K.E of fission products 175 MeV.

❖ K.E of fission neutrons 5 MeV.

❖ Energy of γ -radiation occurring during the fission 7 MeV.

❖ Energy of " β " and " γ " radiation during the decay of the radioactive fission products 13 MeV.

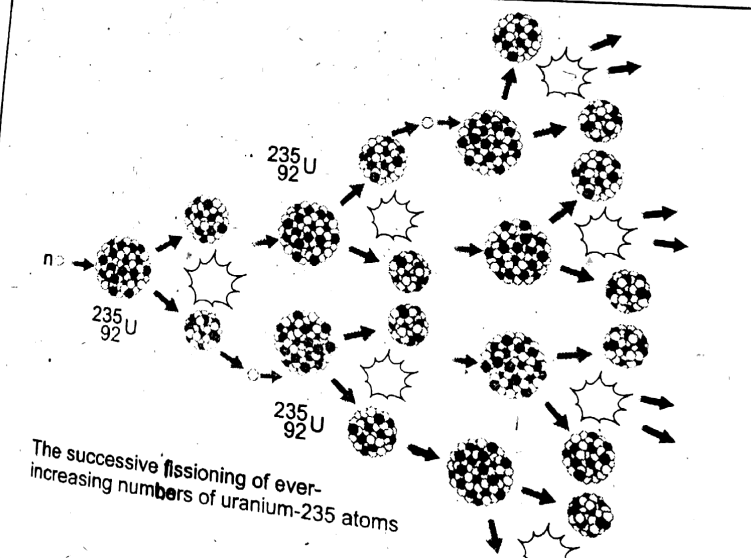
❖ Energy of the neutrinos 10 MeV.

It is found that 1kg of uranium delivers as much energy as 3000 tons of coal.

Fission Chain reaction:

When one nuclear reaction causes an average of one or more nuclear reactions, thus a self-propagating series of these reactions is achieved and is called chain reaction.

The fact that fission reactions of uranium-235 give off more than one neutron on average has significant implications. As the fission of uranium-235 is initiated by the absorption of a neutron. So the neutrons given off by one fission reaction may cause additional fission reactions in other nuclei. If each of the neutrons, followed by more fissions, and so forth. As long as the average number of neutrons available to produce new



fission, is greater than 1 per reactions, the number of fissions grows with time as shown in figure. If we have such an event in uncontrolled way, it may produce huge amount of energy in very short time. In explosion of atomic bomb we produce such an uncontrolled fission chain reaction. The nuclear reactors on the other hand release the energy from nuclear fission in a controlled manner.

Nuclear fusion:

"The process in which small nuclei diffuse to form a heavy nucleus is called nuclear fusion." OR

"The nuclear process in which two light nuclei ($A < 30$) fuse together to form a heavy nucleus is called nuclear fusion." OR

"When two light nuclei combine to form a heavy nucleus, the process is called nuclear fusion.

Discovery:

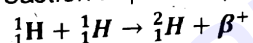
In 1920, Mark Edington gave the idea about the energy released from the sun and other stars. He told that in sun and other stars, the protons are converted into Helium nucleus. This idea was confirmed.

Explanation:

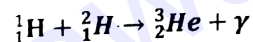
When two nuclei form a large nucleus, the mass of larger nucleus is less than the mass of nuclei that formed it. This loss in mass appears in the form of energy. A self-sustaining fusion reaction is also possible but the energy required is possible only in the environments of stars including sun. One such cycle is;

A. proton – proton cycle:

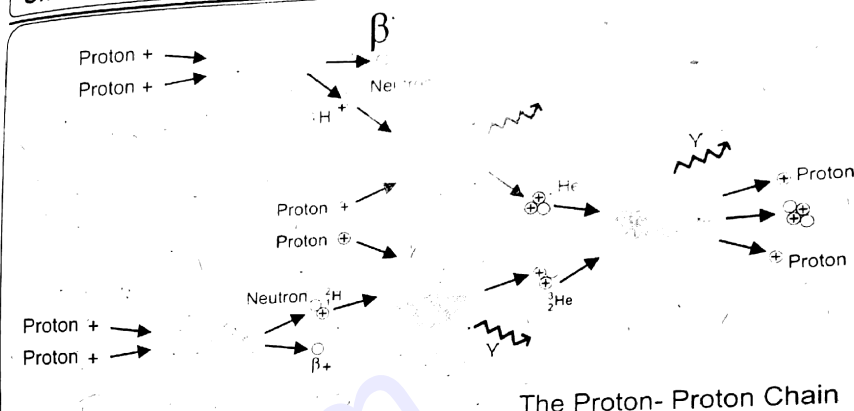
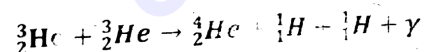
In this process the direct collision of protons results in the formation of heavier nuclei whose collision in turn produces helium nuclei as shown in figure 18.15. The initial reaction in proton- proton cycle is,



A deuteron produced in the above reaction may combine with other proton as,



Finally two such reactions can combine to form helium-4 with the release of two protons as,



The total energy released in this process is 24.7 Mev which is the difference between the masses of 4-Protons and mass of alpha particle plus two positrons.

Q8. What are back ground radiations? What are of major sources?

Ans. Background radiation:

Definition:

All living creatures, from the beginning of time, have been and are still being exposed to radiation. When a radiation detector is used it will record these radiations called natural back ground radiation. It comes from three sources:

Major sources of background radiations:

The earth and all living things on it, are constantly bombarded by radiations from space. The dose from cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field.

Terrestrial radiation:

Radioactive material is also found throughout nature. It is in the soil, water and vegetation. Low levels of uranium, thorium, and their decay products are found everywhere. The dose from terrestrial sources also varies in different parts of the world.

Internal radiation:

All people also have radioactive potassium -40, carbon-14, lead -210, and other isotopes inside their bodies from birth.

Q 9. What are radiation hazards? How can we safeguard ourselves from radiation?

Ans. Radiation Hazards:

Nuclear radiation is potentially harmful to human because the ionization it produces can significantly alter the structure of molecules within a living cell. The alteration significantly can lead to the death of the cell and even of the organism itself. The amount of biological damage produced by ionizing radiation is different for different kind of radiation.

Everyone is continually exposed to back ground radiation from natural sources, such as cosmic rays (high-energy particles that come from outside the solar system), radioactive material in the environment, radioactive nuclei (primarily carbon and potassium $^{40}_{19}K$) within our bodies, and radon.

The effect of radiation on human can be grouped into two categories, according to the time span between initial exposure and the appearance of physiological symptom: (1) short-term or acute effect that appear within a matter of minute, days or week and (2) long term or latent effect that appear year, decades, or even generation later.

The radiation from the material can damage the cells of the person directly. This is damage by irradiation. Some of the radioactive material can be swallowed or breathed in while inside the body, the radiation it emits can produce damage. This is damage by contamination.

Radiation Sickness:

Radiation sickness is the general term applied to the acute effect of radiation. Depending on the severity of the dose, a person with radiation sickness can exhibit nausea, vomiting, fever, diarrhea and loss of hair. Ultimately, death can occur. The severity of radiation sickness is related to the dose received, and in the following discussion, the biologically equivalent doses quoted are whole-body single doses.

Long-term or latent effect of radiation may appear as a result of high-level, brief exposure or low level exposure over a long period of time. Some long-level effects are hair loss, eye cataract, and various kind of cancer. In addition, genetic defect cause by mutated genes may be passed on from one generation to the next.

Safety measure:

There are general three guidelines for controlling exposure to ionizing radiation: minimizing exposure time, maximizing distance from the radiation source and shielding yourself from the radiation source.

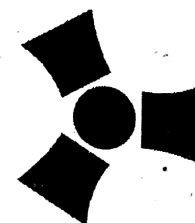
While working in the radiation, Lab coat, Shoes and safety glasses must be worn in the laboratory. Material/equipment which are not required must not be brought in the laboratory or stored inside. An inventory of radioactive sources used in the laboratory must be maintained and updated.

Important symbol:

International symbol (trefoil) of radiation. This sign must be posted where radioactive material are handled or where radiation producing equipment is used. Sign is used as a warning to protect people from being exposed to radioactivity.



International atomic energy agency (IAEA) in 2007 has launched a new symbol for 'ionizing radiation warning – supplement symbol' new symbol is intended to supplement the existing, well recognized, radiation trefoil symbol. The new symbol has been designed to convey the message "danger-stay away" to anyone who sees it, regardless of their age, education or cultural background.

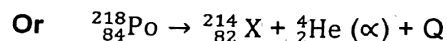
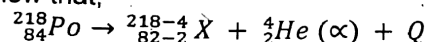


Examples

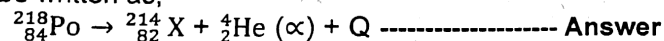
Example 18.1: An unstable polonium-218 ($^{218}_{84}\text{Po}$) atom spontaneously emits an alpha (α) particle and transmutes into an atom of some other element. Show the process, including the new element, in standard nuclear-reaction notation.

Calculation:

We know that;

Conclusion: Hence;

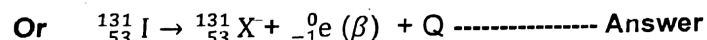
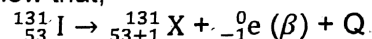
Every element has a unique atomic number. The periodic table shows the new element to be lead (Pb) with $z = 82$. The finalized equation can now be written as,



Example 18.2: The isotope iodine-131 undergoes beta decay. Write the reaction equation, and determine the identity of the daughter nucleus.

Calculation:

We know that;

Conclusion: Hence;

When iodine-131 undergoes β -decay it converts into xenon -131.

Example 18.3: You have a 160.0 μg sample of polonium-218. It decays by alpha emission with a half-life of 3.0 min. How much of the pure sample is left after 9.0 min?

Solution:

Given: Total quantity of pure polonium-218 ' N_0 ' = 160 μg
Half-life of polonium-218 ' $T_{1/2}$ ' = 3.0 min
Total elapsed ' Δt ' = 9 min

Required:

Quantity left ' N ' = ?

Calculation:

We know that; the numbers of half-lives ' n ' past are,

$$n = \frac{\Delta t}{T_{1/2}}$$

Putting value

$$n = \frac{9.0 \text{ min}}{3.0 \text{ min}} = 3$$

Original sample remaining after any given interval is,
 $N = \left(\frac{1}{2}\right)^n N_0$

Putting value

$$N = \left(\frac{1}{2}\right)^3 160 \mu\text{g}$$

$$N = \frac{1}{8} \times 160 \mu\text{g}$$

$$N = 20 \mu\text{g}$$

Conclusion:

The graphical representation confirms that 20 μg of polonium -218 half-life of 3.0 min will be present after 9.0 min.

Example 18.4: Suppose you found frozen dead animal remains in the Himalayas. You took a sample from it and found that carbon-14 (half life ' $T_{1/2}$ ' = 5730 years) activity is reduced 1/8 per gram from original value. How old are the dead animals remain?

Solution:Given:

Quantity left of carbon -14 ' N ' = $\frac{1}{8} N_0$

Half-life of carbon-14 ' $T_{1/2}$ ' = 5730 years

Required:

Total elapsed ' Δt ' = ?

Calculation:

We know that;

$$N = \left(\frac{1}{2}\right)^n N_0 \text{ ----- (1)}$$

Putting value

$$N = \frac{1}{8} N_0$$

$$N = \frac{1}{(2)^3} N_0$$

$$N = \left(\frac{1}{2}\right)^3 N_0 \text{ ----- (2)}$$

Comparing equation 1 and 2 $n = 3$

Thus in three half-lives the quantity left of carbon 14, will be $\frac{1}{8} N_0$ and the number of half-lives ' n ' past is given by relation,

$$n = \frac{\Delta t}{T_{1/2}}$$

$$\Delta t = n T_{1/2}$$

Putting value

$$\Delta t = 3 \times 5730 \text{ years}$$

Therefore,

$$\Delta t = 17,190 \text{ years}$$

Conclusion:

Hence;

The remain of dead animals are 17,190

Answer

Assignments

Assignment 18.1: Find the daughter nucleus when radium -224 undergoes alpha decay.

Solution:

Calculation:

For α -decay for any nuclide is given by,

$${}_Z^AX^A = {}_{Z-2}^{A-4}Y^{A-4} + \alpha + Q \text{ ----- (1)}$$

Replaced ${}_Z^AY^A$ by ${}_{88}^{224}\text{Ra}$ in equation (1), we get,

$${}_{88}^{224}\text{Ra} = {}_{88-2}^{224-4}Y^{224-4} + \alpha + Q$$

$$\text{OR } {}_{88}^{224}\text{Ra} = {}_{86}^{220}Y^{220} + \alpha + Q \text{ ----- (2)}$$

Now the element with ($Z=86$), and ($A=220$) in periodic table is Radon

${}_{88}^{224}\text{Ra}$, replace ${}_{86}^{220}Y^{220}$ by ${}_{86}^{220}\text{Rn}$ in equation (2), we get,

$${}_{88}^{224}\text{Ra} = {}_{86}^{220}\text{Rn} + \alpha + Q \text{ ----- (3)}$$

Conclusion:

So when ${}_{88}^{224}\text{Ra}$ undergoes α -emission, it is converted into ${}_{86}^{220}\text{Rn}$.

Assignment 18.2: An atom of sodium-24 can transmute into an atom of some other element by emitting a beta particle. Represent this reaction in symbols, and identify the daughter element.

Solution:

Calculation:

The general equation for β -decay is given by,

$${}_Z^AX^A = {}_{Z+1}^AY^A + \beta + Q \text{ ----- (1)}$$

replaced ${}_Z^AX^A$ by ${}_{11}^{24}\text{Na}$ in equation (1), we get,

$${}_{11}^{24}\text{Na} = {}_{11+1}^{24}Y^{24} + \beta + Q$$

OR

$${}_{11}^{24}\text{Na} = {}_{12}^{24}Y^{24} + \beta + Q \text{ ----- (2)}$$

Now the element with ($Z=12$) and ($A=24$) in periodic table is magnesium

${}_{12}^{24}\text{Mg}$

So replace ${}_{12}^{24}\text{Y}$ by ${}_{12}^{24}\text{Mg}$ in equation (2), we get,

$${}_{11}^{24}\text{Na} = {}_{12}^{24}\text{Mg} + \beta + Q \text{ ----- (3)}$$

Conclusion:

Thus when ${}_{11}^{24}\text{Na}$ undergo β -emission, it is converted into ${}_{12}^{24}\text{Mg}$.

Assignment 3: lead 210 has a half-life of 22.3 years. How much of the 80 mg of lead will be left after 66.9 years?

Solution:

Given data:

$$\text{Half-life lead} = T_{1/2} = 22.3 \text{ years}$$

$$\text{Total quantity of pure lead} = N_0 = 80 \text{ mg}$$

$$\text{Total elapsed} = \Delta t = 66.9 \text{ years}$$

Required:

Quantity left $= N = ?$

Calculation:

We know that,

$$n = \frac{\Delta t}{T_{1/2}} \text{ ----- (1)}$$

Putting the values in equation (1), we get

$$n = \frac{66.9 \text{ years}}{22.3 \text{ years}}$$

$$\Rightarrow n = 3$$

Now the remaining sample is given by,

$$N = \left(\frac{1}{2}\right)^n N_0 \text{ ----- (2)}$$

Putting the values in equation (2), we get,

$$\frac{1}{8} N_0 = \left(\frac{1}{2}\right)^n N_0$$

$$\Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^n$$

$$\Rightarrow \left(\frac{1}{2}\right)^3 = \left(\frac{1}{2}\right)^n \text{ ----- (3)}$$

Comparing the powers on both sides of equation (3), we get, $n=3$

Now putting the values of 'n' and $T_{1/2}$ in equation (1). We get,

$$\Delta t = 3 \times 22.3 \text{ years}$$

$$\Delta t = 66.9 \text{ years}$$

Shams Notes

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Nuclear Physics

Assignment 4: Suppose the fossil of bone you are examining has $\frac{1}{4}$ of carbon 14 deposits as compared to bone of the living animal per gram. The half-life of ^{14}C is 5730 years, what is the approximate age of the fossil?

Solution:

Given data:

$$\text{Half-life} = T_{1/2} = 5730 \text{ years}$$

$$\text{Quantity left of carbon} = N = \frac{1}{4} N_0$$

Required:

$$\text{Total elapsed} = \Delta t = ?$$

Calculation:

We know that,

$$n = \frac{\Delta t}{T_{1/2}}$$

$$\Rightarrow \Delta t = nT \frac{1}{2}$$

We also know that;

$$N = \left(\frac{1}{2}\right)^n N_0 \quad (2)$$

Put $N = \left(\frac{1}{2}\right)^n N_0$ in equation (2), we get,

$$\frac{1}{4} N_0 = \left(\frac{1}{2}\right)^n N_0$$

$$\Rightarrow \frac{1}{4} = \left(\frac{1}{2}\right)^n$$

$$\left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^n \quad (3)$$

Comparing the power on both sides of equation (3), we get, $2=n \Rightarrow n=2$

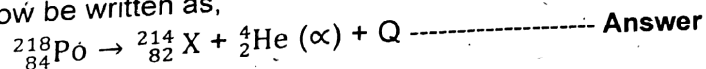
Now putting the values of 'n' and $T_{1/2}$ in equation (1)

$$\Delta t = 2 \times 5730 \text{ years}$$

$$\Rightarrow \Delta t = 11460 \text{ years}$$

Conclusion: Hence,

Every element has a unique atomic number. The periodic table shows the new element to be lead (Pb) with $z=82$. The finalized equation can now be written as,



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Shams Notes

EXERCISE

1. Choose the correct answer for each of the following;

- What is the number of neutrons in the plutonium $^{242}_{92}\text{Pu}$?
a. 92
b. 142
c. 150
d. 242
- Which one or more of the three decay processes (α , β , γ) result in a new element?
a. Only α
b. Only β
c. Only γ
d. α and β
- What type of nuclear decay leaves the number of protons and neutrons unchanged?
a. Alpha decay
b. beta decay
c. gamma decay
d. both A and B
- What type of nuclear decay most often produces the greatest mass and charge loss?
a. Alpha decay
b. beta decay
c. gamma decay
d. both A and B
- $^{214}_{84}\text{Po}$ undergoes α -decay to produce a daughter nucleus that itself undergoes β -decay. which one of the following nuclei is the one that ultimately results
a. $^{211}_{82}\text{Pb}$
b. $^{215}_{80}\text{Hg}$
c. $^{211}_{81}\text{Tl}$
d. $^{212}_{83}\text{Bi}$
- Radium -226 decays by emitting an alpha particle. What is the daughter? What is the daughter nucleus?
a. Rd
b. Rn
c. Bi
d. Pb
- ^{39}Ar is an isotopes with a half -life of 269 yr. it will reduce to half in
a. 134.5min
b. 134.5 years
c. 269 min
d. 269 years
- A sample starts with 1000 radioactive atoms. How many half-lives have elapsed when 750 atoms have decayed?
a. 0.25
b. 1.5
c. 2.0
d. 2.5
- Origin of energy from the sun and stars is
a. Fission
b. fusion
c. carbon dating
d. radioactivity

Conceptual Questions

Q1. The atomic number of one particular isotope is equal to its mass number. Which isotope is it?

Ans. Protium ${}^1_1\text{H}$ (a stable isotope of hydrogen) has same atomic number and mass number, equal to 1.

Explanation:

Hydrogen is the 1st element in periodic table having three isotopes, protium ${}^1_1\text{H}$, deuterium ${}^2_1\text{H}$ and tritium ${}^3_1\text{H}$. Protium has one proton inside the nucleus and no neutron. Therefore, its atomic number as well as mass number is equal to one.

Q 2. Which is more likely to expose, a film kept in a cardboard box, α - particles or β particles? Explain.

Ans. β - particle is more likely to expose a film kept in a cardboard box as α - particle can easily be blocked by a paper and cannot penetrate cardboard.

Explanation:

Penetration power of β - particle is greater than that of α - particles that is why β - particle can easily penetrate through a cardboard. A film kept inside the cardboard will be affected by the β - particle easily.

Q 3. Is it possible for a form of heavy hydrogen to decay by emitting an alpha particle? Explain.

Ans. No, it is not possible for any form of hydrogen to decay by emitting an alpha particle.

Explanation:

Hydrogen is the 1st element in periodic table having three isotopes, protium ${}^1_1\text{H}$ (having only one proton inside nucleus), deuterium ${}^2_1\text{H}$ (having one proton and one neutron inside nucleus) and tritium ${}^3_1\text{H}$ (having one proton and two neutrons inside nucleus). Whereas, an alpha particle is composed of two protons and two neutrons. That is why it is not possible for any isotope (form) of hydrogen to decay by emitting an alpha particle.

Q 4. Different isotopes of a given element have different masses but they have the same chemical properties. Explain why chemical properties are unaffected by a change of isotopes.

Ans. They have similar chemical properties because isotopes of an element have the same number of electrons as an atom of that element.

Explanation:

The electron arrangement is the same and having the same chemical properties. However, they have different numbers of neutrons, which affect the mass number. Mass number determines the physical properties such as boiling / melting / density etc.

Q 5. What fraction of a radioactive sample has decayed after two half-lives have elapsed?

Ans. After two half-lives $\frac{3}{4}$ of a radioactive sample has been decayed.

Explanation:

After 1st half-life, half of the sample will be decayed whereas, half will be left. After 2nd half-life, another half of the half (i.e. $\frac{1}{2}$ of $\frac{1}{2}$) will be decayed (i.e. $\frac{1}{4}$ will be decayed in 2nd half-life and $\frac{1}{4}$ will be decayed in 2nd half-life and $\frac{1}{4}$ will be left in total).

Q 6. Can carbon-14 dating give the age of fossil dinosaur skeleton? Explain.

Ans. yes, carbon -14 dating can give the age of fossil dinosaur skeletons.

Explanation:

All biological organisms contain a given concentration of carbon-14, we can use this information to help solve questions about when the organism died. When an organism dies it has a specific ratio by mass of carbon-14 to carbon-12 incorporated in the cells of its body (the same ratio as in the atmosphere). At the moment of death, no new carbon-14 containing molecules are metabolized; therefore, the ratio is at a maximum. After death, the carbon -14 to carbon-12 ratio begins to decrease because carbon-14 is decaying away at a constant and predictable rate. Remember that the half-life of carbon -14 is 5700 years half as much carbon - 14 remains within the organism.

Q 7. Some food is treated with gamma radiation to kill bacteria. Why is there not a concern that people who eat such food might be consuming food containing gamma radiation?

Ans. There is a common misconception that irradiated food is radioactive. The radiation used to process foods is very different from the radioactive fallout that occurs after, for example, a nuclear accident. In food processing, the radioactive sources permitted do not generate gamma, electrons or x-rays of sufficient high energy to make food radioactive. No radioactive energy remains in the food after treatment. The world health organization (WHO), the American dietetic Association and the scientific committee of the European Union are three internationally recognized bodies that support food irradiation.

Q 8. Radioactive α -emitters are relatively harmless outside the body, but can be dangerous if ingested or inhaled? Explain.

Ans. Alpha particles are the least dangerous in terms of external exposure. Each particle contains a pair of neutrons and a pair of protons. They don't penetrate very deeply into the skin, if at all, in fact, clothing can stop alpha particles. Unfortunately, alpha particle can be inhaled or ingested, usually in the form of radioactive gas. Once ingested, alpha particles can be very dangerous. However, even then they don't typically cause radiation sickness – instead, they lead to lung cancer.

Q 9. If nuclear radiation is harmful. How it can be used for treatment of disease?

Ans: The nuclear radiations are used for the treatment of various diseases. But when these radiations are exposed to human body, they may cause severe burns and other disease. To avoid such harmful effects, there radiation should be used carefully by expert doctors. The radiations should be focused on the germs of affected area and other healthy parts of the body should keep safe and sound from falling of radioactive radiations.

Q1: How many neutrons are contained in a gold nucleus $^{197}_{79}\text{Au}$?

Solution:

Given data:

$$\text{Gold nucleus} = ^{197}_{79}\text{Au}$$

Required:

$$\text{Number of neutrons} = N = ?$$

Calculation:

We know that number of neutrons can be calculated by subtracting "Z" from "A", i.e.,

$$N = A - Z \text{-----(1)}$$

Now for $^{197}_{79}\text{Au}$ we have, $Z=79$, $A=197$
Putting the values of "Z" and "A" in equation (1), we get ,

$$N = 197 - 79$$

$$N = 118 \text{----- Answer}$$

Conclusion:

Number of neutrons contained in the gold nucleus are 118.

Q 2: $^{220}_{86}\text{Rn}$ decays via alpha decay. Identify the daughter nuclide.

Solution:

The general equation for α -decay is given by,

$$^A_Z\text{X} = ^{A-4}_{Z-2}\text{Y} + ^4_2\text{He} + Q \text{-----(1)}$$

Replace ^A_ZX by $^{220}_{86}\text{Rn}$ in equation (1), we get,

$$^{220}_{86}\text{Rn} = ^{220-4}_{86-2}\text{Y} + \alpha + Q$$

$$^{220}_{86}\text{Rn} = ^{216}_{84}\text{Y} + \alpha + Q \text{-----(2)}$$

Now the element with $(Z=84)$ and $(A=216)$ in periodic table is polonium $^{216}_{84}\text{Po}$
so replace $^{216}_{84}\text{Y}$ by $^{216}_{84}\text{Po}$ in equation (ii), we get

$$^{220}_{86}\text{Rn} = ^{216}_{84}\text{Po} + \alpha + Q$$

Conclusion:

Thus $^{220}_{86}\text{Rn}$ undergo α -decay and converted into $^{216}_{84}\text{Po}$

Q 3: Write the nuclear equations for the beta decay of $^{210}_{82}\text{Th}$.

Solution:

Given data:

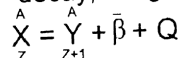


Required:

Nuclear equation=?

Calculation:

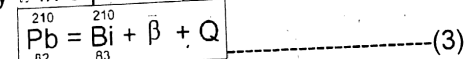
(i) In case of β^- -decay, the general equation is given by,



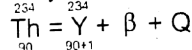
OR

Now the element with (Z=83) and (A=210) in periodic table is bismuth

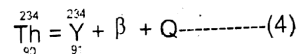
(Bi), So replace ^A_ZY by $^{210}_{83}\text{Bi}$ in equation (ii), we get,



Now replace ^A_ZX by $^{234}_{90}\text{Th}$ in equation (1), we get,

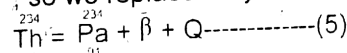


OR



Now the element with (Z=91, A=234) in periodic table, is protactinium

$^{234}_{91}\text{Pa}$, so we replace ^A_ZY by $^{234}_{91}\text{Pa}$ in equation (4), we get



Conclusion:

Thus when $^{234}_{90}\text{Th}$ undergo β^- -decay it is converted into $^{234}_{91}\text{Pa}$.

Q 4. Iodine 131 is an important radioisotopes for medical diagnostic and treatment procedures. The half-life of ^{131}I is 8.02 days. Out of 100g of the sample how much will be left after 24 days?

Solution:

Given data:

Half-life of iodine = $T_{1/2} = 8.02$ days

Total quantity of iodine = $N_0 = 100\text{gm}$

Total elapsed = $\Delta t = 24$ days

Required:

Quantity left = $N = ?$

Calculation:

We know that,

$$N = \left(\frac{1}{2}\right)^n N_0 \quad (1)$$

For finding 'n', we have

$$n = \frac{\Delta t}{T_{1/2}} = \frac{24 \text{ days}}{8.02 \text{ days}}$$

$$\Rightarrow n = 2.99 = 3$$

Now putting the values of 'n' and ' N_0 ' in equation (1), we get,

$$N = \left(\frac{1}{2}\right)^3 \times 100\text{gm} = \frac{1}{8} \times 100\text{gm}$$

$$\Rightarrow N = 12.5 \text{ gm} \quad \text{Answer}$$

Conclusion:

The quantity left is 12.5gm.

Q5: phosphorus-32 is used in plant's sciences for tracking a plant's uptake of fertilizer from the roots to the leaves. The half life of ^{32}P is 15 days. Out of 800 μg of the activity given as fertilizer how much will be left after one month?

Given data:

Half-life of $^{32}\text{P} = T_{1/2}$

Total Quantity of $^{32}\text{P} = N_0 = 800 \mu\text{g}$

Total Time = $\Delta t = 30$ days.

Required:

Quantity Left = $N = ?$

Calculation:

We know that,

$$n = \frac{\Delta t}{T_{1/2}}$$

$$n = \frac{30}{15}$$

$$n = 2$$

Also;

$$N = \left(\frac{1}{2}\right)^n N_0$$

Putting Values

$$N = \left(\frac{1}{2}\right)^2 (800)$$

$$N = \left(\frac{1}{4}\right) (800)$$

$$N = 200 \mu\text{g}$$

Conclusion:

Hence; out of 800 μg of ^{32}P 200 μg will be left after one month.

Q6: ^{12}C to ^{14}C ratio in an animal fossil is found to be one fourth of the ratio in the bone of living animal. The half-life of ^{14}C is 5730 years. how old is the fossil?

Solution:

Given data:

$$\text{Half-life} = T_{1/2} = 5730 \text{ years}$$

$$\text{Quantity left of carbon} = N = \frac{1}{4} N_0$$

Required:

$$\text{Total elapsed } \Delta t = ?$$

Calculation:

$$\text{We know that, } n = \frac{\Delta t}{T_{1/2}}$$

$$\Rightarrow \Delta t = n T_{1/2} \text{-----(1)}$$

We also know that,

$$N = \left(\frac{1}{2}\right)^n N_0 \text{-----(2)}$$

Put $N = \frac{1}{4} N_0$ in equation (2), we get,

$$\frac{1}{4} N_0 = \left(\frac{1}{2}\right)^n N_0$$

$$\Rightarrow \frac{1}{4} = \left(\frac{1}{2}\right)^n$$

$$\Rightarrow \left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^n \text{-----(3)}$$

Comparing the powers on both sides of equation (3), we get,

$$2 = n \quad \text{or} \quad n = 2$$

Now putting the values of 'n' and ' $T_{1/2}$ ' in equation (1), we get,

$$\Delta t = 2 \times 5730$$

$$\Delta t = 11460 \text{ years} \text{----- Answer}$$

Conclusion:

Total elapsed time is 11460 years.

Model Paper Physics(10th)

Total Time: 3:00 Hours

(Fresh/New Course)

Total Marks: 65

Note: There are three sections in this paper

i.e Section A, B & C

Time Allowed: 20 Minutes

"Section -A"

Marks : 15

Instructions:

- Attempt this section on the MCQs Answer Sheet only.
- Use black ball point or marker for shading only one circle for correct option of a question.
- No marks will be awarded for cutting, Erasing, over writing and multiple circles shading.

Q.1. Choose the correct option i.e. A,B,C or D.

- X-rays.....waves.
 - mechanical
 - electromagnetic
 - Sound
 - None of these
- The equation of speed of sound is
 - $v = \frac{f}{\lambda}$
 - $v = f \lambda$
 - $v = \frac{\lambda}{f}$
 - $v = \frac{1}{\lambda}$
- Diffraction is weaker when the gap much than the wave length of the waves.
 - Larger
 - Smaller
 - Different
 - Both a & b
- The diameter of an atom is
 - 10^{-12} cm
 - 10^{-10} cm
 - 10^{-18} cm
 - None of these
- The size of nucleus is about
 - 10^{-18} m
 - 10^{-15} m
 - 10^{-10} m
 - None of these
- A tuning fork and violin string are producing sounds.....
 - Vibration
 - Rotation
 - Tension
 - Compression
- In total internal reflection the value of incident angle is
 - Equal to
 - Less than
 - Greater than
 - None
- The refractive index of water is 1.33, what is the critical angle of water
 - 48.7°
 - 90°
 - 42°
 - 50.1°
- Y-Rays are not affected byfield.
 - Electric
 - Magnetic
 - Electric & Magnetic
 - None of these
- The focal length of a concave mirror is
 - R/2
 - Negative
 - Positive
 - None of these
- The Size of nucleus is about
 - 10^{-18} m
 - 10^{-15} m
 - 10^{-10} m
 - None of these
- Diffraction is weaker when the gap is much larger than theof the waves
 - frequency
 - displacement
 - amplitude
 - wavelength