Class: 10th

Subject: Physics

Unit 10: SIMPLE HARMONIC MOTION AND WAVES

Exercise MCQs:

1. Which of the following is an example of simple harmonic motion?

(a) the motion of simple pendulum ✅

(b) the motion of ceiling fan

(c) the spinning of the Earth on its axis

(d) a bouncing ball on a floor

2. If the mass of the bob of a pendulum is increased by a factor of 3, the period of the pendulum's motion will

(a) be increased by a factor of 2

(b) remain the same ✅

(c) be decreased by a factor of 2

(d) be decreased by a factor of 4

3. Which of the following devices can be used to produce both transverse and longitudinal waves?

(a) a string

(b) a ripple tank

(c) a helical spring (slinky) ✅

(d) a tuning fork

4. Waves transfer

(a) energy ✅

(b) frequency

(c) wavelength

(d) velocity

5. Which of the following is a method of energy transfer?

(a) conduction

(b) radiation

(c) wave motion

(**d**) all of these ✅

6. In a vacuum, all electromagnetic waves have the same

(**a**) speed ✅

(b) frequency

(c) amplitude

(d) wavelength

7. A large ripple tank with a vibrator working at a frequency of 30 Hz produces complete waves in a distance of 50 cm. The velocity of the wave is

(a) 53 cm s^{-1}

(**b**) 60 cm s^{-1} ✅

(c) 750 cm s^{-1}

(d) 1500 cm s^{-1}

(Velocity = frequency × wavelength ⇒ v = 30 Hz × 2 cm = 60 cm/s)

8. Which of the following characteristics of a wave is independent of the others?

(a) speed

(b) frequency

(c) amplitude ✅

(d) wavelength

9. The relation between v, f, and λ of a wave is:

(a) $vf = \lambda$

(b) $f\lambda = v$ ✅

(c) $v\lambda = f$

(d) $v = \lambda/f$

Important MCQs:

1. What is the direction of acceleration in Simple Harmonic Motion (SHM)?

(a) Away from the mean position

(b) Towards the mean position ✅

(c) Perpendicular to displacement

(d) Opposite to motion

2. Which of the following is an example of SHM?

(a) A freely falling ball

(b) A rotating fan

(c) A mass attached to a spring ✅

(d) A moving car

3. What is the time taken by a simple pendulum to complete one cycle called?

(a) Amplitude

(b) Frequency

(c) Time period ✅

(d) Wavelength

4. The time period of a simple pendulum depends on:

(a) Amplitude only

(b) Mass of the bob

(c) Length of the pendulum ✅

(d) Density of air

5. What is the reciprocal of time period?

(a) Amplitude

(b) Frequency ✅

(c) Velocity

(d) Displacement

6. What is the maximum displacement from the mean position in SHM called?

(a) Frequency

(b) Wavelength

(c) Amplitude ✅

(d) Cycle

7. Which type of waves require a medium for propagation?

(a) X-rays

(b) Radio waves

(c) Mechanical waves ✅

(d) Electromagnetic waves

8. In which waves do particles vibrate perpendicular to the direction of wave propagation?

(a) Compressional waves

(b) Transverse waves ✅

(c) Longitudinal waves

(d) Sound waves

9. What happens to frequency of a wave when it passes from one medium to another?

(a) It increases

(b) It decreases

(c) It remains the same ✅

(d) It becomes zero

10. What is diffraction of waves?

(a) Bouncing of waves from a surface

(b) Change in direction of waves

(c) Bending of waves around edges ✅

(d) Transfer of particles with energy

11. Which of the following is an example of simple harmonic motion (SHM)?

(a) Car moving on a straight road

(b) A fan rotating

(c) Mass-spring system on a frictionless surface ✅

(d) Object falling freely

12. Hooke's Law is mathematically written as:

(a) F = kx

(b) F = ma

(c) F = −kx ✅

(d) F = mgh

13. The spring constant k is defined as:

(a) k = Fx

(b) k = m/a

(c) k = −F/x ✅

(d) k = 1/Fx

14. In SHM, the restoring force always acts:

(a) Away from mean position

(b) Towards the mean position ✅

(c) At 90° to the displacement

(d) Along the velocity

15. The unit of spring constant k in SI system is:

(a) N

(b) m/s^2

(c) N/m ✅

(d) kg·m/s

16. What is the time period of a mass-spring system?

(a) $T = 2\pi\sqrt{(l/g)}$

(b) $T = 2\pi\sqrt{(m/k)}$ ✅

(c) $T = \sqrt{(k/m)}$

(d) $T = 1/f$

17. In a mass-spring system, when is the velocity maximum?

(a) At extreme position

(b) At mean position ✅

(c) When force is maximum

(d) When displacement is zero

18. In SHM, the acceleration is maximum:

(**a**) At extreme positions ✅

(b) At mean position

(c) Always zero

(d) At midpoint between mean and extreme

19. One complete to and fro motion is called:

(a) Frequency

(b) Oscillation

(**c**) One vibration ✅

(d) Period

20. The formula for time period of a simple pendulum is:

(**a**) $T = 2\pi\sqrt{(l/g)}$ ✅

(b) $T = 2\pi\sqrt{(m/k)}$

(c) $T = l/g$

(d) $T = \sqrt{(g/l)}$

21. Frequency is defined as:

(a) Time for one cycle

(**b**) Number of cycles per second ✅

(c) Maximum displacement

(d) Rate of change of amplitude

22. The unit of frequency is:

(a) m/s

(b) J

(**c**) Hz ✅

(d) N/m

23. Amplitude in SHM is:

(**a**) Maximum displacement from mean position ✅

(b) Speed at extreme position

(c) Acceleration at mean position

(d) Time for one vibration

24. At mean position in SHM, the acceleration of the body is:

(a) Maximum

(**b**) Zero ✅

(c) Constant

(d) Same as force

25. In simple pendulum, the restoring force is:

(a) mg cos(θ)

(**b**) mg sin(θ) ✅

(c) Tension in the string

(d) Weight of the bob

26. In real systems, oscillations do not continue indefinitely due to:

(a) Restoring force

(b) Constant speed

(c) Gravitational pull

(**d**) Friction or resistance ✅

27. Damped oscillations are those in which:

(a) Amplitude increases with time

(b) Energy remains constant

(c) Amplitude remains the same

(**d**) Amplitude gradually decreases with time ✅

28. In a car, which device is used to damp

oscillations caused by road bumps?

(a) Brakes

(b) Accelerator

(c) Gearbox

(**d**) Shock absorber ✅

29. What is transferred through waves?

(a) Mass only

(b) Particles only

(c) Matter and energy

(**d**) Energy and information ✅

30. In the pencil-in-water activity, why does the cork move up and down?

(a) Cork follows the wave

(b) Cork is carried forward

(c) Cork rotates with the wave

(**d**) Cork vibrates about mean position due to wave ✅

31. Which of the following is not a mechanical

wave?

(a) Water wave

(b) Sound wave

(**c**) Light wave ✅

(d) Wave on string

32. Mechanical waves require a _____ for their propagation.

(a) Magnetic field

(b) Source of light

(c) Vacuum

(**d**) Medium ✅

33. Electromagnetic waves consist of:

(a) Only electric field

(b) Only magnetic field

(**c**) Electric and magnetic fields oscillating perpendicular to each other ✅

(d) Vibrating particles in a medium

34. In longitudinal waves, the particles of the

medium:

(a) Vibrate up and down

(b) Vibrate perpendicular to wave direction

(**c**) Vibrate along the direction of wave ✅

(d) Do not vibrate

35. The regions in longitudinal waves where particles are closely packed are called:

(a) Troughs

(b) Rarefactions

(**c**) Compressions ✅

(d) Crests

36. In transverse waves, the direction of particle vibration is:

(a) Same as wave direction

(b) Circular

(c) Opposite to wave direction

(**d**) Perpendicular to wave direction ✅

37. The highest point of a transverse wave is

called:

(a) Compression

(b) Trough

(c) Crest ✅

(d) Peak force

38. Which one is an example of a longitudinal wave?

(a) Light wave

(b) Water wave

(c) Sound wave ✅

(d) Heat wave

39. Which of the following is not a transverse wave?

(a) Water wave

(b) Light wave

(c) Sound wave ✅

(d) Wave on string

40. Energy in a wave is directly dependent on:

(a) Frequency only

(b) Wavelength only

(c) Amplitude ✅

(d) Speed only

41. What does the wave transfer from one point to another?

(a) Matter

(b) Energy ✅

(c) Mass

(d) Volume

42. What is the correct formula to find the speed of a wave?

(a) $v = f + \lambda$

(b) $v = f / \lambda$

(c) $v = f \times \lambda$ ✅

(d) $v = \lambda / f$

43. A wave on a slinky has a frequency of 4 Hz and a wavelength of 0.4 m. Its speed is:

(a) 1.0 m/s

(b) 1.6 m/s ✅

(c) 2.4 m/s

(d) 0.4 m/s

44. What is the main purpose of a ripple tank?

(a) To produce sound waves

(b) To reflect light

(c) To produce and study water waves ✅

(d) To measure temperature

45. Which device is used in a ripple tank to generate water waves?

(a) Iron rod

(b) Electric bulb

(c) Vibrator ✅

(d) Paddle wheel

46. What happens to the wavelength of water waves when they enter shallow water?

(a) It increases

(b) It remains constant

(c) It becomes infinite

(**d**) It decreases ✅

47. What is the law of reflection for water waves?

(a) Angle of incidence is greater than angle of reflection

(**b**) Angle of incidence equals angle of reflection ✅

(c) Angle of incidence is less than angle of reflection

(d) Angle of reflection is always 90°

48. What is diffraction of waves?

(a) Bouncing back of waves from a surface

(b) Change in direction when entering a new medium

(**c**) Spreading of waves around corners or obstacles ✅

(d) Absorption of wave energy by a medium

Important Short Questions:

1. What is Simple Harmonic Motion (SHM)?

Answer:

SHM is a to and fro oscillatory motion in which acceleration is directly proportional to displacement from the mean position and directed towards it.

2. Give two examples of Simple Harmonic Motion.

Answer:

Examples include:

- Motion of a mass attached to a spring
- Motion of a simple pendulum
- A ball oscillating in a bowl

3. On which factors does the time period of a simple pendulum depend?

Answer:

The time period depends on the length of the pendulum and is independent of its mass and amplitude.

4. What is meant by frequency of vibration?

Answer:

Frequency is the number of cycles completed by a vibrating body in one second. It is the reciprocal of time period:

f = 1 / T

5. Define amplitude.

Answer:

Amplitude is the maximum displacement of a body from its mean position during SHM.

6. What is a wave?

Answer:

A wave is a phenomenon of transferring energy from one place to another without the transfer of matter.

7. Differentiate between mechanical and electromagnetic waves.

Answer:

- **Mechanical** waves need a medium for propagation.
- **Electromagnetic** waves do not require any medium.

8. Define transverse waves with example.

Answer:

In transverse waves, particles vibrate perpendicular to the direction of wave propagation.

Example: Light waves, water waves.

9. What are compressional or longitudinal waves?

Answer:

These are mechanical waves in which particles vibrate along the direction of wave propagation.

Example: Sound waves

10. What is the relationship between speed, frequency, and wavelength of a wave?

Answer:

The speed of a wave is given by the formula:

$v = f \times \lambda$

where f is frequency and λ is wavelength.

11. What is meant by Simple Harmonic Motion (SHM)?

Answer:

SHM is a type of periodic motion in which the restoring force is directly proportional to the displacement and always acts towards the mean position.

12. Write the formula for restoring force in a spring.

Answer:

Restoring force is given by $F = -k \times x$, where k is spring constant and x is displacement.

13. What does the negative sign in the formula $F = -k \times x$ indicate?

Answer:

It indicates that the force is always directed opposite to the displacement (towards the mean position).

14. What is spring constant.

Answer:

It is a measure of the stiffness of a spring and is defined by the formula $k = -F / x$.

15. Define restoring force.

Answer:

Restoring force is the force that brings the object back towards its mean position in oscillatory motion.

16. What is the formula for time period of a mass-spring system in SHM?

Answer:

➡ $T = 2\pi \sqrt{m / k}$

17. What type of motion is shown by a ball in a bowl?

Answer:

The to and fro motion of the ball in a bowl is Simple Harmonic Motion (SHM).

18. How does a simple pendulum show SHM?

Answer:

A simple pendulum shows SHM as the restoring force $mg\sin(\theta)$ acts towards the mean position, and acceleration is proportional to displacement.

19. What is the time period of a simple pendulum?

Answer:

➡ $T = 2\pi \sqrt{l / g}$

20. Define vibration, amplitude, time period, and frequency.

Answer:

- **Vibration**: One complete to and fro motion.
- **Amplitude**: Maximum displacement from mean position.
- **Time Period (T):** Time taken for one vibration.
- **Frequency (f):** Number of vibrations per second; $f = 1/T$

21. What are damped oscillations?

Answer:

Oscillations in which the amplitude gradually decreases due to the presence of a resistive force like friction are called damped oscillations.

22. What causes damping in real systems?

Answer:

Friction or resistance causes damping, which reduces the mechanical energy of the system over time.

23. What happens to the amplitude in damped oscillations?

Answer:

The amplitude gradually decreases with time due to loss of energy.

24. Give one practical example of damped motion.

Answer:

Shock absorbers in automobiles are a practical example of damped motion.

25. How does a shock absorber work?

Answer:

It uses a piston moving through oil to absorb vibrations and convert their energy into heat, reducing oscillations.

26. What is a wave?

Answer:

A wave is a disturbance in a medium that causes particles to vibrate about their mean position at regular intervals.

27. What are mechanical waves?

Answer:

Waves that require a medium for propagation, such as sound or water waves, are called mechanical waves.

28. What are electromagnetic waves?

Answer:

Waves that do not require a medium and consist of oscillating electric and magnetic fields, like light or radio waves, are called electromagnetic waves.

29. Do mechanical waves travel in a vacuum?

Answer:

No, mechanical waves cannot travel in a vacuum; they need a medium to propagate.

30. What is the direction of vibration in a rope wave activity?

Answer:

The vibration of a point on the rope is perpendicular to the direction of wave motion.

31. What are mechanical waves?

Answer:

Mechanical waves are waves that require a medium for their propagation.

32. Define longitudinal waves.

Answer:

In longitudinal waves, the particles of the medium move back and forth along the direction of wave propagation.

33. What are compressions and rarefactions?

Answer:

Compressions: Regions where particles are close together.

Rarefactions: Regions where particles are spread apart.

34. Define transverse waves.

Answer:

In transverse waves, the particles of the medium move perpendicular to the direction of wave propagation.

35. Give two examples of transverse waves.

Answer:

Water waves

Light waves

36. What is wavelength?

Answer:

Wavelength is the distance between two consecutive compressions or crests (or troughs) in a wave.

37. How do waves transfer energy?

Answer:

Waves transfer energy by disturbing particles of the medium, which then pass energy to neighboring particles, without transferring matter.

38. On what factor does the energy of a wave

depend?

Answer:

Energy of a wave depends on its amplitude.

39. What is a ripple tank and what is it used for?

Answer:

A ripple tank is a rectangular glass-bottomed tray used to produce water waves and study their characteristics like reflection, refraction, and diffraction.

40. How are waves produced in a ripple tank?

Answer:

Waves are produced by a vibrating wooden plate attached to an electric motor that touches the surface of the water in the tray, generating straight wavefronts.

41. What is meant by the reflection of waves?

Answer:

Reflection of waves is the bouncing back of waves when they strike a surface or barrier, following the law that the angle of incidence equals the angle of reflection.

42. What is refraction of water waves and when does it occur?

Answer:

Refraction occurs when waves move from deep to shallow water. Their wavelength decreases and direction of propagation changes due to a change in speed.

43. Define diffraction of waves.

Answer:

Diffraction is the bending or spreading of waves around sharp edges or through small openings, especially when the opening is comparable to the wave's wavelength.

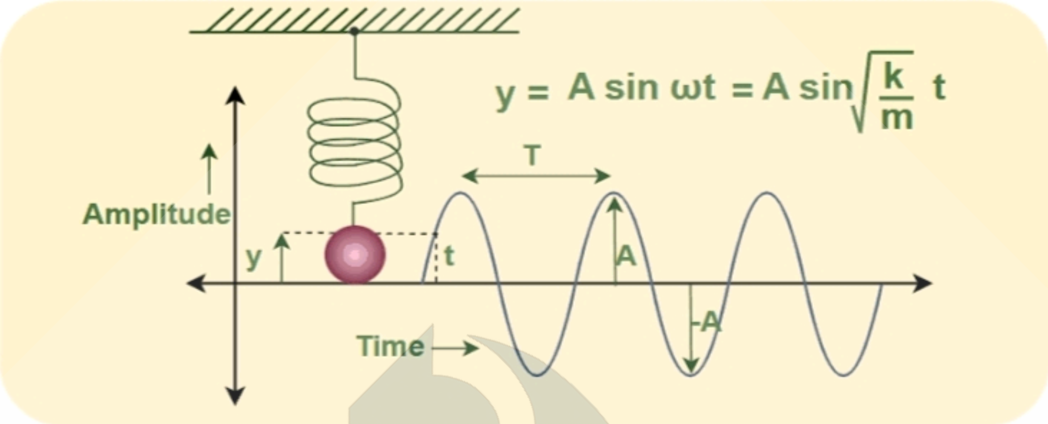
Important Long Questions:

🌟 Q1: Define Simple Harmonic Motion. Explain SHM with examples of:

(i) Mass attached to a spring

(ii) Ball and bowl system

(iii) Simple pendulum



❖ Definition of Simple Harmonic Motion (SHM):

Simple Harmonic Motion is a type of oscillatory motion in which the restoring force acting on the object is directly proportional to its displacement from the mean position, and this force is always directed towards the mean position.

🔁 In simple words:

> When a body oscillates to and fro about a fixed point, and its acceleration is proportional to the displacement but in the opposite direction, the motion is called SHM.

🧪 (i) Mass attached to a spring (Horizontal Spring-Mass System)

➤ Explanation:

A mass is attached to a spring placed on a frictionless horizontal surface.

When the spring is stretched or compressed by a small distance x, it exerts a restoring force.

➤ Hooke's Law:

$$F = -k \cdot x$$

- F = Restoring force
- k = Spring constant
- x = Displacement from mean position
- The **negative sign** shows the force is in the opposite direction of displacement.

➤ Motion:

- When the mass is displaced from equilibrium and released, it starts to move back due to restoring force.

- It gains speed towards the mean position and continues to oscillate back and forth.
- This periodic motion is Simple Harmonic Motion.

⚽ (ii) Ball and Bowl System

➤ **Explanation:**

- A ball is placed at the bottom of a smooth bowl (mean position O).
- When displaced to one side and released, gravity pulls it back towards the center.

➤ **Motion:**

- The ball gains speed as it moves towards the center.
- Due to inertia, it goes to the opposite side and comes to rest.
- It repeats this to-and-fro motion, which is Simple Harmonic Motion.

🕰️(iii) Simple Pendulum

➤ **Structure:**

A small bob of mass is suspended by a light, inextensible string of length .

➤ **Working:**

When the bob is pulled sideways and released, it swings back due to a restoring force (component of weight).

- The force that causes motion is:

$$F = -mg \cdot \sin(\theta)$$

➤ **Result:**

- The pendulum swings back and forth through the mean position.
- The restoring force and acceleration are always directed towards the mean position.

🔍 **Summary:**

All three systems — spring-mass, ball-in-bowl, and simple pendulum — exhibit SHM as they involve:

- A restoring force
- Periodic motion

- Force proportional to displacement

🌟 **Q2: Define and explain the different terms that characterize Simple Harmonic Motion.**

1. Vibration:

One complete to-and-fro movement of a body about its mean position is called one vibration.

🔁 **Example**: When a pendulum moves from point A ⇒ O ⇒ B ⇒ O ⇒ A, it completes one vibration.

2. Time Period (T):

> The time taken to complete one full vibration is called the Time Period.

🕰️It is represented by the symbol T.

🧮 Unit: Second (s)

For mass-spring system:

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

- For **simple pendulum**:

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

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3. Frequency (f):

The number of vibrations per second is called the Frequency.

🔁 It tells how fast the oscillations occur.

🧮 **Formula:**

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

🧮 Unit: Hertz (Hz)

👉 1 Hz = 1 vibration per second

4. Amplitude (A):

- The maximum displacement of the vibrating body from the mean position is called its Amplitude.
- 📏 It shows how far the object moves from the center.

🧮 **Unit:** Meter (m)

🔍 **Summary:**

These terms (vibration, time period, frequency, amplitude) are essential to describe and understand the behavior of objects undergoing simple harmonic motion. Each plays a key role in analyzing SHM in real-world systems.

🌟 **Q3: Explain how the motion of a mass-spring system is an example of SHM.**

🔹 **Include derivation using Hooke's Law.**

❖ **Definition of SHM:**

- Simple Harmonic Motion (SHM) is a type of periodic motion in which:
- The restoring force is directly proportional to the displacement of the body from the mean (equilibrium) position, and
- It always acts towards the mean position.

⚙ Mass-Spring System and SHM:

When a mass is attached to a spring and displaced from its equilibrium position, the spring exerts a restoring force on the mass that tries to bring it back to its mean position.

📗 Hooke's Law:

> Hooke's Law states that:
> **F = −k × x**

Where:

- **F** is the restoring force
- **k** is the spring constant
- **x** is the displacement from equilibrium
- The **negative sign** shows that the force is always directed opposite to the displacement (towards mean position).

🧮 Derivation (Using Newton's Second Law + Hooke's Law):

- Let the mass of the body = m
- Restoring force (by Hooke's Law) = F = −k × x

Using Newton's Second Law:

F = m × a

where a is the acceleration of the mass.

So, equating both forces:

$$m \cdot a = -k \cdot x$$

Since acceleration **a** is the second derivative of displacement:

$$m \cdot \frac{d^2x}{dt^2} = -k \cdot$$

Rearranging:

$$\frac{d^2x}{dt^2} + \frac{k}{m}x =$$

This is the standard differential equation of Simple Harmonic Motion.

🔍 Summary:

The motion of the mass-spring system satisfies the basic condition of SHM:

- The acceleration is proportional to displacement and directed towards the mean position.
- Therefore, the mass-spring system executes Simple Harmonic Motion.

⏱ Time Period of Mass-Spring System:

The time period (T) is given by the formula:

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

Where:

- **T** = Time period
- **m** = Mass
- **k** = Spring constant

🌟 **Q4: Define and explain longitudinal and transverse waves with examples and diagrams.**

❖ **Definition:**

- Mechanical waves are the waves that require a material medium (like air, water, or solids) to travel through.
- These waves are created when a source of energy causes a disturbance in the medium, resulting in the transfer of energy from one point to another without the net movement of particles.

📏 1. Longitudinal Waves

❖ Definition:

A longitudinal wave is a type of wave in which the particles of the medium vibrate back and forth in the same direction as the wave is moving.

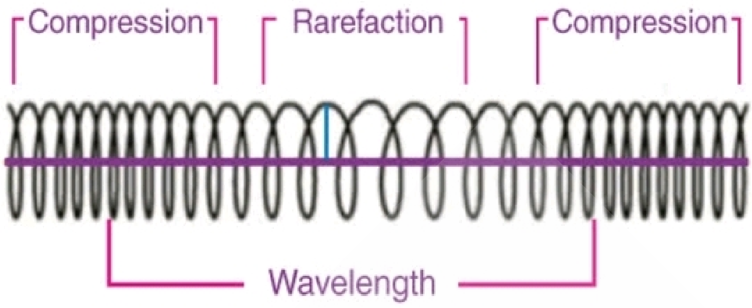
🔧 How to produce it (Slinky Activity):

- Fix one end of a slinky to a rigid support.
- Push and pull the free end along its length.
- A series of compressions and rarefactions will move along the slinky.

💬 Key Terms:

- **Compression**: Region where particles are close together.
- **Rarefaction**: Region where particles are spread apart.
- **Wavelength**: Distance between two consecutive compressions or rarefactions.

📊 Diagram of Longitudinal Wave:



🔊 **Examples:**

- Sound waves in air
- Seismic P-waves (earthquake waves)
- Waves in a spring or slinky

🌊 2. Transverse Waves

❖ **Definition:**

A transverse wave is a wave in which the particles of the medium vibrate perpendicular to the direction of wave propagation.

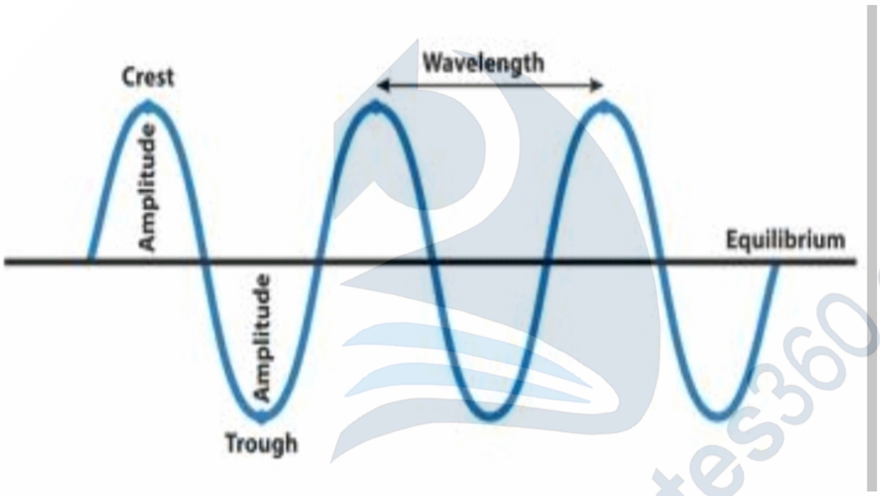
🔧 **How to produce it (Slinky Activity):**

- Fix one end of a slinky.
- Move the other end up and down quickly.
- Crests and troughs will be formed and travel along the slinky.

💬 **Key Terms:**

- **Crest**: The highest point of the wave.
- **Trough**: The lowest point of the wave.
- **Wavelength**: Distance between two crests or two troughs.

📊 **Diagram of Transverse Wave:**



🔊 **Examples:**

- Water waves
- Light waves (though not mechanical)
- Seismic S-waves

🔍 **Summary:**

- **Longitudinal** and transverse waves differ in the direction of particle motion relative to the wave.

- **Both types** are important for transmitting energy in various real-world phenomena.

🌟 **Q5: What are mechanical waves? Explain their types and role in energy transmission.**

❖ **Definition of Mechanical Waves:**

- Mechanical waves are disturbances in a material medium that transfer energy from one point to another without transferring matter.
- They need a medium to propagate (unlike electromagnetic waves which do not).

🔄 Types of Mechanical Waves:

1. Longitudinal Waves:

- **Particle motion**: Parallel to wave direction.
- **Regions**: Compressions and rarefactions.
- **Medium movement**: Back and forth.
- **Examples**: Sound waves, spring waves, P-type seismic waves.

2. Transverse Waves:

- **Particle motion:** Perpendicular to wave direction.
- **Regions**: Crests and troughs.
- **Medium movement**: Up and down.
- **Examples**: Water waves, light waves (partly transverse), S-type seismic waves.

⚡ Waves as Carriers of Energy:

- Mechanical waves transfer energy through the vibration of particles in the medium.
- The energy depends on the amplitude and frequency of the wave:
- Higher amplitude ⇒ More energy
- Higher frequency ⇒ More energy per second
- No permanent displacement of particles; energy travels, not matter.

🌍 Real-Life Significance:

- Sound transmission in air or solids
- Communication systems (e.g., sonar)

- Earthquake detection (seismic waves)
- Water waves used for energy generation
- Medical imaging (ultrasound)

🔍 **Summary:**

Mechanical waves are essential in daily life and science for energy transfer, communication, and observation of natural events. Understanding their types helps us explain many natural phenomena.

🌟 **Q6: What are Damped Oscillations? Explain with diagram and example.**

❖ **Definition:**

Damped oscillations are those vibrations or oscillatory motions in which the amplitude continuously decreases with time due to the presence of friction or resistive forces in the system.

> In other words, damping is the gradual loss of energy in an oscillating system.

🔹 **Role of Friction or Resistance:**

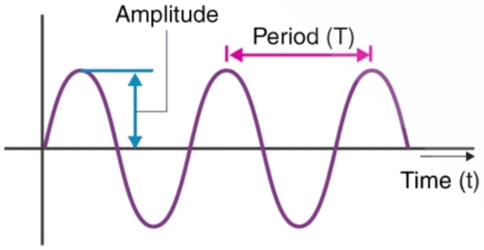
- In an ideal system (no friction), oscillations continue forever.
- But in real systems, air resistance, friction, or any resistive force opposes the motion.
- This resistance reduces mechanical energy, and the object loses amplitude over time.

🔹 **Energy Loss:**

- As oscillations continue, the system's kinetic and potential energy is gradually converted into heat energy due to friction.
- This causes the system to eventually come to rest.

🔹 **Graphical Representation:**

Below is a simple graph showing how amplitude decreases with time in damped oscillations:



🔹 Real-Life Example: Shock Absorbers in Cars

- When a car moves over a bump, it starts vibrating.
- If not controlled, these vibrations make the ride uncomfortable.
- Shock absorbers are used to damp these oscillations.
- They contain oil and pistons.
- When the car vibrates, shock absorbers convert the mechanical energy into heat energy, reducing the amplitude of vibration.
- This helps the car return to its normal position smoothly and quickly.

🔍 **Summary:**

- Damped oscillations are important in engineering, transport, and construction because they:
- Reduce unwanted vibrations
- Increase comfort and safety

- Help control motion in mechanical systems

Exercise Questions:

REVIEW QUESTIONS

🌟 **Q.10.1: What is Simple Harmonic Motion (SHM)? What are the necessary conditions for a body to execute SHM?**

❖ **Definition of SHM:**

Simple Harmonic Motion (SHM) is a type of periodic motion in which:

- A body oscillates back and forth about a mean (equilibrium) position,
- Under a restoring force that is directly proportional to the displacement of the body,
- And this restoring force always acts towards the mean position.

Mathematical Form:

The restoring force F is given by:

$F = -kx$

where:

- F = restoring force
- k = force constant
- x = displacement from mean position

(Negative sign shows force is opposite to displacement)

- **Necessary Conditions for SHM:**

To perform SHM, a system must satisfy these conditions:

1. Restoring Force is Present:

- A force must always act to bring the body back towards the equilibrium position.

2. Proportionality to Displacement:

- The magnitude of restoring force must be directly proportional to the displacement from mean position.

👉 $F \propto -x$

3. Direction Towards Mean Position:

- The force must always be directed opposite to displacement, i.e., towards the center.

4. Frictionless System (Ideal Case):

- For perfect SHM, no energy should be lost due to friction or resistance.

🔍 **Summary:**

Simple Harmonic Motion is a regular, repeating motion with very specific conditions. Systems like pendulums, springs, and vibrating tuning forks are great examples of SHM when ideal conditions are met.

🌟 **Q.10.2: Think of several examples of motion in everyday life that are simple harmonic.**

❖ Everyday Life Examples of SHM:

Here are some common examples of SHM observed around us:

🔸 **1. Mass-Spring System:**

- When a mass is attached to a spring and pulled, it oscillates back and forth.

- The spring provides a restoring force according to Hooke's Law.
- A perfect example of SHM.

2. Simple Pendulum:

- A bob suspended from a string swings back and forth when displaced.
- The restoring force is due to gravity, proportional to the sine of displacement angle.
- For small angles, the motion is almost SHM.

3. Swing (Jhoola):

- A child's swing moves to and fro about a central position.
- The restoring force is provided by gravity.
- It follows SHM when friction is ignored.

4. Tuning Fork:

- When struck, a tuning fork vibrates with SHM.
- Its prongs move in and out from the mean position.

🔸 5. Vibrations in Guitar Strings:

- When a string is plucked, it vibrates in SHM.
- These vibrations produce musical sounds.

🔸 6. Heart Valve Oscillations (Biology-Physics Link):

Artificial valves in heart surgeries sometimes use spring-based SHM to function smoothly.

🔍 Summary:

Simple harmonic motion is very common in our daily lives. From toys to musical instruments, from cars to clocks, SHM plays a vital role in the working of many natural and man-made systems.

🌟 Q.10.3: What are damped oscillations? How does damping progressively reduce the amplitude of oscillation?

❖ Definition of Damped Oscillations:

Damped oscillations are those vibrations or oscillations in which the amplitude decreases gradually over time due to the presence of a resistive force, such as friction or air resistance.

✔ These oscillations lose energy as time passes.

🔹 **Explanation:**

- In ideal conditions (no friction), oscillations continue forever with constant amplitude.
- In real-life systems, friction, air resistance, or internal resistance reduces the mechanical energy of the system.
- This loss of energy reduces the amplitude of vibration progressively with time.

🔹 Graphical Representation:

The following behavior is observed:

📉 As time increases ′n Amplitude decreases gradually

Eventually, the motion stops completely.

(A graph can be drawn showing decreasing amplitude sinusoidal wave over time)

🔹 **Example: Shock Absorbers in Cars:**

- Shock absorbers are installed in vehicles.
- When a car hits a bump, the suspension system vibrates.
- The shock absorber (filled with oil) converts the vibrational energy into heat energy, damping the oscillations and making the ride smooth.

🔍 **Summary:**

Damped oscillations are present in all real systems due to friction or resistance. The amplitude reduces over time, and the motion eventually stops unless energy is supplied.

🌟 **Q.10.4: Define the term wave. Differentiate between mechanical and electromagnetic waves with examples.**

❖ **Definition of Wave:**

A wave is a disturbance or vibration that transfers energy from one point to another without the actual transfer of matter.

✅ **Example:** Sound, light, water ripples.

🔹 Types of Waves:

Waves are mainly divided into two types:

🔸 1. Mechanical Waves:

❖ Definition:

Waves that require a material medium (solid, liquid, or gas) to travel through are called mechanical waves.

Key Features:

- Cannot travel through vacuum
- Need a medium for propagation
- Produced by mechanical vibrations

Examples:

- Sound waves
- Water waves
- Seismic waves
- Waves on a string

🔸 2. Electromagnetic Waves:

Definition:

Waves that do not require a medium to travel and can move through a vacuum are called electromagnetic (EM) waves.

Key Features:

- Can travel through vacuum and medium
- Produced by vibrating electric and magnetic fields
- Travel at the speed of light in vacuum

Examples:

- Light waves
- Radio waves
- X-rays
- Microwaves
- Gamma rays

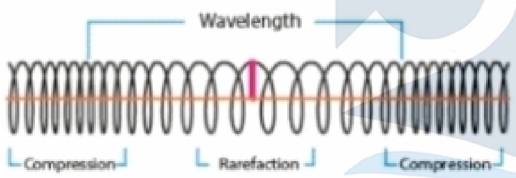
🔍 **Summary:**

- Mechanical waves need a medium and are slower.

- Electromagnetic waves can travel through vacuum and are essential for communication and vision.
- Both play a crucial role in transferring energy in different situations.

🌟 **Q.10.5 Distinguish between longitudinal and transverse waves with suitable examples.**

1. Longitudinal Waves



Particle motion: Back-and-forth (parallel to wave travel).

Wave shape: Successive compressions (crowded particles) and rarefactions (spread-out particles).

Energy flow: Along the same line as particle vibration.

Good examples:

- Sound waves in air.

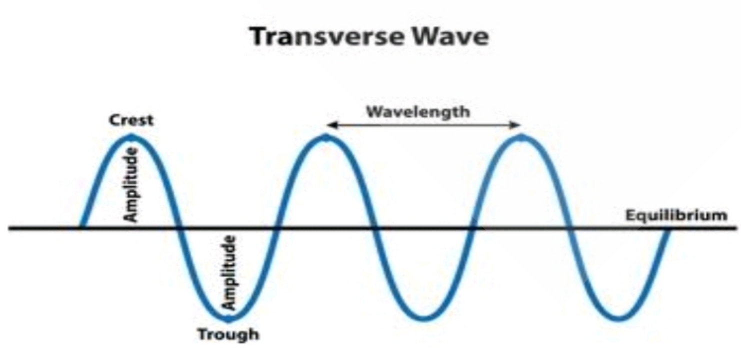
- Push-pull pulses in a slinky.
- Seismic P-waves produced during earthquakes.

2. Transverse Waves

- **Particle motion**: Up-and-down (perpendicular to wave travel).
- **Wave shape**: Alternating crests (highest points) and troughs (lowest points).
- **Energy flow**: Horizontally, while particles move vertically.

Good examples:

- Water surface ripples.
- Vibrations in a stretched rope.
- Light and radio waves (electromagnetic waves behave transversely).



🔑 Key Differences (verbal summary)

1. **Direction of particle motion**: parallel vs. perpendicular to propagation.

2. **Wave elements**: compressions/rarefactions vs. crests/troughs.

3. **Typical media**: longitudinal waves travel easily in all media; transverse waves need solids or surfaces (except EM waves, which need no medium).

🌟 Q.10.6: Draw a transverse wave with an amplitude of 2 cm and a wavelength of 4 cm. Label a crest and a trough on the wave.

🔹 **What is a Transverse Wave?**

A transverse wave is a type of wave in which the particles of the medium vibrate perpendicular to the direction of wave propagation.

❖ **Definitions:**

Amplitude (A):

The maximum displacement of a wave from its rest (mean) position.

In this case:

$$A = 2\,\mathrm{cm}$$

- **Wavelength (λ):**
  The **distance between two consecutive crests or troughs**.
  In this case:

$$\hat{I}» = 4\,\mathrm{cm}$$

- **Crest:**
  The **highest point** on a **transverse** wave.

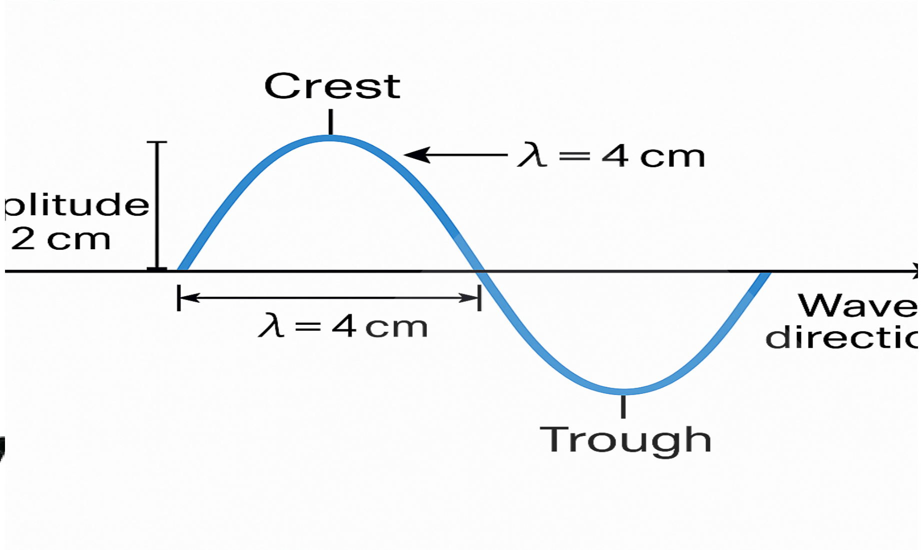
- **Trough:**
  The **lowest point** on **a transverse** wave.

Trough:

The lowest point on a transverse wave.

✏️ Key Features to Label in the Diagram:

- Label the amplitude as 2 cm from the baseline to the crest or trough.
- Mark a crest at the top of the wave.
- Mark a trough at the bottom of the wave.
- Mark the wavelength (λ = 4 cm) between two crests or two troughs.



🔍 **Summary:**

- This question tests your understanding of wave structure, and how to correctly represent wavelength and amplitude on a diagram. It is important to remember:
- Crests and troughs show the oscillation.
- Wavelength shows the spacing between similar points.
- Amplitude shows how far the particles move from the rest position.

🌟 **Q.10.7: Derive a relationship between velocity, frequency, and wavelength of a wave. Also write a formula relating velocity of a wave to its time** period and wavelength.

- **Definition and Explanation:**

A wave transfers energy from one point to another without the transfer of matter. As a wave moves, the disturbance travels, but particles of the medium only oscillate about their mean positions.

Let's derive a relationship between:

- **Velocity (v)**: How fast the wave travels.
- **Frequency (f)**: How many wave cycles pass a point per second.
- **Wavelength (λ)**: The distance between two crests or two troughs (or compressions in longitudinal waves).

🧮 Derivation of Formula: $v = f \times \lambda$

Suppose a wave travels a distance equal to one wavelength (λ) in one time period (T). So:

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}} = \frac{\hat{I}»}{T}$$

But frequency **f = 1** / T, so:

$$\Rightarrow v = \frac{\hat{I}»}{T} = f\,\tilde{A}▯\hat{I}»$$

✅ Final Formula:

$$\boxed{v = f\,\tilde{A}▯\hat{I}»}$$

Where:

- v = wave speed (m/s)
- f = frequency (Hz)
- $\hat{I}»$ = wavelength (m)

✳ Alternate Form Using Time Period

Since , we can also write:

Since $f = \frac{1}{T}$, we can also write:

$$\boxed{v = \frac{\hat{I}»}{T}}$$

💡 Example

If a wave has frequency 50 Hz and wavelength 2 meters:

$$v = f\tilde{A}\text{ı}\hat{I}» = 50\tilde{A}\text{ı}2 = 100\ \mathrm{m/s}$$

🌟 Q.10.8: Waves are the means of energy transfer without transfer of matter. Justify this statement with the help of a simple experiment.

❖ Definition:

Waves can transfer energy without transporting the particles of the medium from one place to another. This is a key property of both mechanical and electromagnetic waves.

🔹 Simple Experiment: The Ripple Tank or Float on Water

🧪 Setup

- Fill a tray or tub with water.
- Place a small floating object (like a cork or leaf) on the water surface.
- Create ripples on the surface by gently tapping one side of the tray.

🔎 **Observation**

- Ripples (waves) travel across the surface.
- But the floating cork only bobs up and down in place—it does not travel with the wave.

🔍 **Summary:**

This shows that:

- Energy is transferred from the point where the wave started to other points.
- No mass (matter) is transferred with the wave.
- Only the disturbance moves; particles oscillate about their positions.

✅ **Final Justification Statement**

> This experiment proves that waves act as carriers of energy, not matter. The medium (like water or air) provides a path for the wave, but its particles only vibrate—they do not move along with the wave.

🌟 **Q.10.9: Explain the following properties of waves with reference to the ripple tank experiment:**

🔷 **a. Reflection of Waves**

📘 Explanation:

Reflection is the bouncing back of waves when they hit a barrier or obstacle.

🔹 **Ripple Tank Experiment:**

- When water waves produced in the ripple tank hit a straight barrier (like a metal strip), they bounce back in the opposite direction.
- The angle of incidence is equal to the angle of reflection.

🔍 Summary:

Reflection of waves follows the same laws as the reflection of light. The direction and pattern of the wave change, but its speed and frequency remain the same.

🔷 b. Refraction of Waves

📘 Explanation:

Refraction is the change in direction and speed of waves when they move from one medium to another.

🔹 **Ripple Tank Experiment:**

- Place a glass sheet under part of the ripple tank to create two regions with different depths.

As waves move from deep water to shallow water:

- Their speed decreases
- Their wavelength shortens
- The wavefront bends at the boundary

🔍 **Summary:**

This bending and change in speed shows refraction. It occurs because the wave moves through mediums of different densities or depths.

🔷 c. Diffraction of Waves

📘 **Explanation:**

Diffraction is the spreading of waves when they pass through a small gap or around an obstacle.

🔹 **Ripple Tank Experiment:**

- Place two barriers close together to form a narrow gap in the ripple tank.

- When straight water waves pass through this gap, they spread out in circular patterns.

🔍 **Summary:**

The amount of diffraction increases when the size of the gap is comparable to the wavelength. This proves that waves can bend around corners and obstacles.

🌟 **Q.10.10: Does increasing the frequency of a wave also increase its wavelength? If not, how are these quantities related?**

❖ **Answer:**

No, increasing the frequency of a wave does not increase its wavelength. In fact, frequency and wavelength are inversely related to each other.

🔷 ✅ **Relationship:**

$$v = f\tilde{A}\text{▯}\hat{I}»$$

Where:

- v = velocity of the wave (m/s)
- f = frequency (Hz)
- $\hat{I}»$ = wavelength (m)

Explanation:

- If the **velocity (v)** of the wave is constant (as in the same medium), then:

$$\boxed{\hat{I}\text{»} = \frac{v}{f}}$$

- If frequency increases, wavelength decreases
- If frequency decreases, wavelength increases

Summary:

Frequency and wavelength are inversely proportional to each other for a wave moving in the same medium. Increasing one will decrease the other.

Example:

If a wave in air has a speed of 340 m/s and a frequency of 170 Hz:

$$\hat{I}\text{»} = \frac{340}{170} = 2\ \text{m}$$

If the frequency is increased to 340 Hz:

$$\hat{I}\text{»} = \frac{340}{340} = 1\ \text{m}$$

CONCEPTUAL QUESTIONS:

🌟 **Q.10.1: If the length of a simple pendulum is doubled, what will be the change in its time period?**

❖ Definition of Time Period:

The time period (T) of a simple pendulum is the time it takes to complete one full oscillation (to and fro motion). It depends on two main factors:

- Length of the pendulum (L)
- Acceleration due to gravity (g)

🔹 Mathematical Formula:

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

Where:

- T = Time period (in seconds)
- L = Length of pendulum (in meters)
- g = Acceleration due to gravity (9.8 m/s²)

🔍 What Happens If the Length is Doubled?

Let:

- Original length = L
- New length = $2L$

Then the **new time period** (T') becomes:

$$T' = 2\pi\sqrt{\frac{2L}{g}} = 2\pi\sqrt{2} \cdot \sqrt{\frac{L}{g}} = \sqrt{2} \cdot T$$

$$T' \hat{a} 1.41 \cdot T$$

💡 Result:

- If the length of the pendulum is doubled, its time period increases by a factor of √2 (approximately 1.41 times).
- This means the pendulum will take more time to complete each oscillation, so the motion becomes slower.

🔍 Summary:

- When the length of a simple pendulum is doubled, its time period does not double, but increases by the square root of 2.

- This shows that the time period is proportional to the square root of the length of the pendulum.

🌟 **Q.10.2: A ball is dropped from a certain height onto the floor and keeps bouncing. Is the motion of the ball simple harmonic? Explain.**

❖ **Answer:**

🔹 **What is Simple Harmonic Motion (SHM)?**

Simple Harmonic Motion is a repetitive to-and-fro motion in which:

- The restoring force is directly proportional to the displacement.
- The force acts towards the equilibrium position.
- The motion is smooth, continuous, and sinusoidal.

Examples of SHM:

- A mass on a spring
- A simple pendulum (for small angles)

🔍 **Analyzing the Bouncing Ball Motion:**

- When a ball is dropped and it keeps bouncing, here's what happens:
- The motion is repetitive, but not smooth.
- The ball stops momentarily on contact with the ground.
- The height of each bounce decreases due to energy loss (friction, air resistance).
- The direction of motion changes suddenly (upward after hitting the floor).
- The restoring force is not proportional to displacement.

🔹 **Why It Is NOT SHM:**

1. Discontinuity in Motion:

- SHM is a continuous back-and-forth motion.
- Bouncing involves sudden stops and impacts, which breaks continuity.

2. Energy Loss:

- SHM ideally has no loss of mechanical energy.
- In bouncing, energy is lost in each bounce

(converted to heat, sound).

3. Non-Sinusoidal Path:

- SHM follows a sinusoidal (wave-like) path.
- The path of a bouncing ball is parabolic and not symmetric about the equilibrium point.

🔍 **Summary:**

- ❌ The motion of a bouncing ball is not a simple harmonic motion.
- ✔ Although it repeats over time, it lacks the smooth, continuous, sinusoidal characteristics of SHM.
- ✔ It also involves energy loss and non-uniform restoring forces, which violate the conditions of SHM.

🌟 **Q.10.3: A student performed two experiments with a simple pendulum. He/She used two bobs of different masses by keeping other parameters constant. To his/her astonishment, the time period of the pendulum did not change! Explain why.**

❖ **Answer:**

🔹 Concept of Time Period in a Simple Pendulum:

The time period (T) of a simple pendulum is the time it takes to complete one full oscillation.

The time period is given by the formula:

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

Where:

- T = Time period
- L = Length of the pendulum
- g = Acceleration due to gravity
- π = Constant (~3.1416)

🧠 Observation in the Experiment:

- The student changed the mass of the bob.
- All other factors (length, gravity, small angle) were kept constant.

Result: No change in the time period of the pendulum.

Why the Time Period Did Not Change?

➡ The formula for time period of a simple pendulum does not include mass.

➡ It only depends on the length of the pendulum (L) and gravitational acceleration (g).

🔹 **Key Point:**

- The mass of the bob does not affect the time period of a simple pendulum.
- This is a result of the principle of isochronism (Greek: iso = same, chronos = time) which means that:

👉 For small angles, all pendulums of the same length and gravity have the same time period, regardless of mass.

⚖ Why Mass Doesn't Matter:

Both restoring force and inertia increase with mass.

But they cancel each other out in the ratio, so mass has no effect on the period.

🔍 **Summary:**

- The student's observation was correct and in accordance with the laws of physics.

- Changing the mass of the bob does not affect the time period of a simple pendulum.
- The time period only depends on the length of the string and gravity.

🌟 **Q.10.4: What types of waves do not require any material medium for their propagation?**

❖ **Definition of Waves:**

Waves are disturbances that transfer energy from one point to another. Based on the need for a medium, waves are classified as:

- **Mechanical Waves** – Need a material medium (e.g. air, water).
- **Electromagnetic Waves** – Do not need any material medium to travel.

🔹 **Waves That Don't Require Medium:**

Electromagnetic Waves:

➡ Electromagnetic (EM) waves are the waves that can travel through vacuum (empty space) without the need for any material medium.

✅ **Examples of Electromagnetic Waves:**

- Light waves (visible spectrum)
- Radio waves
- Microwaves
- Infrared rays
- Ultraviolet rays
- X-rays
- Gamma rays

🔹 **How Do Electromagnetic Waves Travel?**

- Electromagnetic waves consist of oscillating electric and magnetic fields that propagate perpendicularly to each other and to the direction of wave travel.
- They do not rely on particle vibration like mechanical waves.

🔹 **Real-Life Example:**

☀️ Sunlight reaches the Earth even though outer space is a vacuum. This proves that light (an electromagnetic wave) does not need air or any medium to propagate.

🔍 **Summary:**

- Electromagnetic waves are the type of waves that do not require any material medium for their propagation.
- They can even travel through the vacuum of space, making them essential for radio, satellite, and solar radiation.

🌟 **Q.10.5: Plane waves in the ripple tank undergo refraction when they move from deep to shallow water. What change occurs in the speed of the waves?**

❖ **Answer:**

🔹 **What Is Refraction in Waves?**

- Refraction is the bending or change in direction of waves when they pass from one medium to another due to a change in wave speed.
- In a ripple tank experiment, this can be observed when water waves move from deep

to shallow regions.

🔹 What Happens When Waves Move From Deep to Shallow Water?

- In deep water, waves move faster.
- In shallow water, waves move slower due to increased resistance and interaction with the bottom surface.

📉 Change in Speed:

➡ When waves move from deep to shallow water, their speed decreases.

➡ This causes the wavefronts to bend — this is called refraction.

🔹 Why Does Speed Decrease?

- In shallow water, the depth is less.
- Water particles encounter more friction with the bottom.

So, the wave energy travels more slowly.

🔹 Observation in Ripple Tank:

Waves in deep region are widely spaced and fast.

In shallow region, waves become closer and slow.

🔍 **Summary:**

In a ripple tank, when plane waves move from deep to shallow water, their speed decreases.

This is due to increased resistance in shallow water, and the phenomenon is called refraction of waves.

Note:

This chapter is designed to provide a solid foundation of knowledge, with the goal of deepening understanding and encouraging further exploration of the subject. The content has been carefully selected to support effective learning and inspire students to engage with the topic more deeply.

Author: Muhammad Asghar

Purpose: To contribute to education by offering insightful, valuable content that enhances learning and understanding.

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