

REVIEW QUESTIONS

10.1 What is simple Harmonic Motion? What are the necessary condition for a body to execute simple harmonic motion?

Ans:

Simple Harmonic Motion (S.H.M):

Simple Harmonic motion (S.H.M) is a to and fro oscillatory motion in which acceleration of the body is directly proportional to the displacement of the body from the mean position and it is always directed towards mean position.

Mathematically

$$a \propto -x$$

Basic Conditions to Execute S.H.M:

Basic conditions to execute simple harmonic motion as under.

- (i) A system executing simple harmonic motion always vibrates about a fixed position.
- (ii) Its acceleration is always directed towards mean position.
- (iii) Magnitude of acceleration is directly proportional to displacement from the mean position.

10.2 Think of several examples in everyday life of motion that are simple harmonic.

Ans: Example of Simple Harmonic Motion (SHM)

- (i) Motion of a body attached to one end of spring.
- (ii) Motion of bob of simple pendulum.
- (iii) Motion of ball in bowl system.
- (iv) Motion of the prong of the tuning Fork.

10.3 What are damped oscillations? How damping progressively reduces the amplitude of oscillation?

Ans: Damped Oscillations

"Any oscillation in which the amplitude of the motion decreases with the time is called damped oscillation".

Damping reduces the amplitude:

Practically in all system the force of friction and resistance retards the motion, so the system do not oscillate for long period of time. The friction reduces the mechanical energy of the system as time passes. Due to the reason damping progressively reduces the amplitude of the motion.

10.4 How can you define term wave? Elaborate difference between mechanical and electromagnetic waves.

Ans: Wave:

A wave is disturbance in the medium which causes the particles of medium to under go vibratory motion about their mean positions in equal intervals of time.

Examples: Water waves, Waves produced in the strings and springs.

Mechanical Wave

Waves which require a medium for their propagation are called mechanical waves.

Examples:

- Radio Waves
- Television Waves
- X-rays

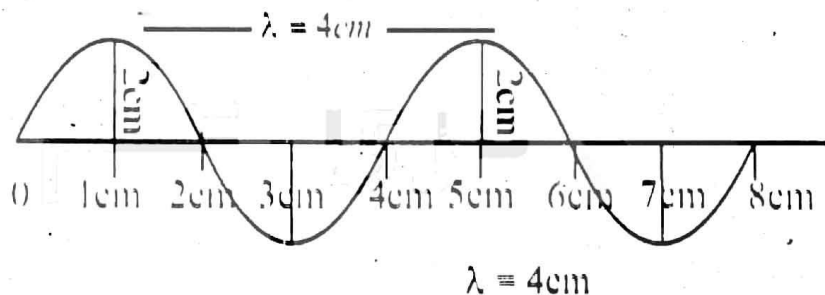
10.5 Distinguish between longitudinal and transverse waves with suitable examples.

Ans:

Longitudinal Waves:	Transverse Waves:
- In longitudinal waves the particles of medium move back and forth along the direction of the propagation of wave. - Longitudinal wave is made up of compression and rarefaction	- In transverse waves particles of medium vibrate perpendicular to the motion of wave. - Transverse wave is made up of crest and trough
Example: - Sound wave - Earth quake - Vibration in gas	Example - Light wave - Water waves

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

Ans:



10.7 Derive a relationship between speed, frequency and wavelength of a wave. Write a formula relating speed of a wave to its time period and wavelength.

Ans: See Q. No. 9

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

Ans: See Q. 8

10.9 Explain the following properties of waves with reference to ripple tank experiment.
a. Reflection b. Refraction c. Diffraction

Ans: See Q. 10

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

Ans. No, wavelength does not increase with increase of frequency of waves because frequency depends upon the source which produces waves per second. But the wavelength of the wave depends on the magnitude of vibrating particles.

Relationship of frequency (f) and wavelength (λ)

Generally, frequency (f) and wavelength (λ) are inversely related to each other by the following equation.

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

Hence from this equation we conclude that when frequency (f) of waves increases then their wavelength (λ) decreases.

CONCEPTUAL QUESTIONS

- 10.1** If the length of the simple pendulum is doubled what will be change in its time period?

When the length of simple pendulum is increased its time period increases as we know that

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

According to given condition

If $L = 2\ell$

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

$$= \sqrt{2} \left(2\pi \sqrt{\frac{\ell}{g}} \right)$$

$$T' = \sqrt{2}T$$

Thus time period become $T' = \sqrt{2}T$

- 10.2** A ball is dropped from certain height onto the floor and keeps bouncing. Is the motion of the ball is simple harmonic motion.

No the motion of the bouncing ball is not the example of SHM. Because it does not fit the definition of SHM which is as follows:

SHM occurs when the net force is proportional to the displacement from the mean position and is always directed towards the mean position.

- 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! Why?

As
$$T = 2\pi \sqrt{\frac{\ell}{g}}$$

Above formula clearly shows that the time period of the simple pendulum is independent of mass therefore, when a student performed two experiments with the simple pendulum by using two bobs of different mass by keeping other parameters constant. Then time period of simple pendulum remains same.

- 10.4** What types of waves do not require any material medium for their propagation?

Electromagnetic waves do not require any material medium for their propagation. They are caused due to varying electric and magnetic fields.

Example:

1. Radio waves 2. Light 3. X – Rays etc

- 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?

As we know that

$$V = f\lambda$$

In ripple tank frequency of waves is constant because it is equal to the frequency of vibrator. Hence wave speed is directly proportional to wave length. With increase of wavelength speed will also be increased similarly with decrease in wave length wave speed also decreases. As the water wave enters into the shallow region from deep region its wavelength (λ) decreases, due to this speed of wave also decreases.

INFORMATION BASED QUESTIONS AND THEIR ANSWERS

QUICK QUIZ (PAGE 4)

Q.1 What is the displacement of an object in SHM when the kinetic and potential energies are equal?

Ans. Kinetic energy and potential energy are equal at mid point between mean position and extreme position

Check your understanding (Page 5)

Q.2 Tell whether or not these motions are examples of simple harmonic motion:

- (a) Up and down motion of a leaf in water pond.
- (b) Motion of a ceiling fan.
- (c) Motion of hands of clock.
- (d) Motion of a plucked string fixed at both its ends.
- (e) Movement of honey bee.

Ans. Among all these motions, only example of SHM is the up and down motion of a leaf in water pond about a fixed position.

QUICK QUIZ (PAGE 8)

Q.3 Do mechanical waves pass through vacuum, that is, empty space?

Ans. Mechanical waves require some material medium for their propagation, and hence they cannot pass through empty space i. e. vacuum.

Activity (page 14)

Q.4 What do the dark and bright fringes on the screen of ripple tank represent?

Ans. The dark and bright fringes on the screen of ripple tank represent troughs and crests respectively.

Activity (page 14)

Q.5 What happens to the angle of refraction when water waves pass from deep to shallow part of water?

Ans. When water waves travel from deep to shallow water, angle of refraction decreases. It is due to the decrease in the speed of water waves in the shallow water.

Q.6 DO The magnitude of angle of incidence and angle of refraction equal?

Ans. Angle of incidence and angle of refraction are not equal due to different depth of water in shallow and deep parts.

EXERCISE MULTIPLE CHOICE QUESTIONS FROM TEXT BOOK

- (1) Which of the following is an example of simple harmonic motion?
☒ (a) Motion of a simple pendulum (b) The motion of ceiling fan
 (c) The spinning of the Earth on its axis (d) A bouncing ball on 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 a 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 25 complete waves in a distance of 50 cm. The velocity of the wave is
 (a) 53 cm^{-1} ☒ (b) 60 cms^{-1} (c) 750 cms^{-1} (d) 1500 cms^{-1}
- (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) $v = \frac{\lambda}{f}$

ANSWER KEY

1	2	3	4	5	6	7	8	9
a	b	c	a	d	a	b	c	b

SHORT QUESTIONS

10.1 Simple Harmonic Motion (SHM)

(1) What is meant by oscillation?

Ans: When a body moves back and forth or to and fro about its mean position, is called vibration or oscillation.

Example:

Motion of the Simple Pendulum.

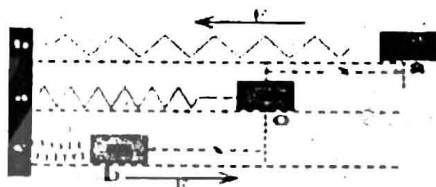
(2) Define Simple Harmonic Motion.

Ans: Simple Harmonic Motion

"The acceleration of a body executing SHM is directly proportional to the displacement of the body from the mean position and is always directed towards the mean position".

Mathematically

$$a \propto -x$$



Where a is acceleration. It is always directed towards the mean position and x is displacement from mean position.

(3) Define Hooke's Law. Give its expression.

Ans: According to Hooke's law the exerted force is directly proportional to change in length.

$$F \propto x$$

(4) How does stiffness of the spring affect the value of k ?

Ans: The value of k is a measure of the stiffness of the spring.

Stiff springs have large k values, and soft springs have small k values.

(5) What is the function of restoring force during oscillatory motion?

Ans: A restoring force always pushes or pulls the object performing oscillatory motion towards the mean position.

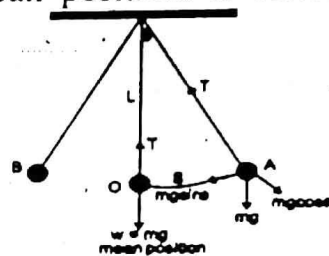
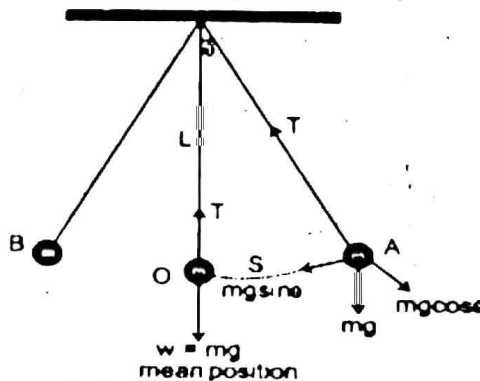
$$F_r = -kx$$

(6) Which type of forces are acting on a displaced pendulum?

OR

Which component of force act as restoring force during the oscillation of simple pendulum.

Ans: The restoring force that causes the pendulum to undergo simple harmonic motion is the component of gravitational force $mg \sin \theta$ tangent to the path of motion.



- (7) Define Time Period and Write down formulas of Time Period for mass attached to a spring and for simple Pendulum

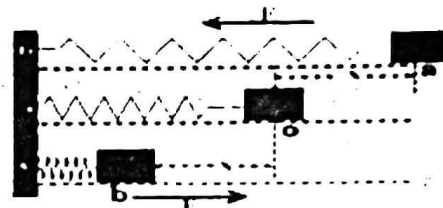
Ans:

Time Period (T):

"Time required to complete one vibration is called time period. It is denoted by T."

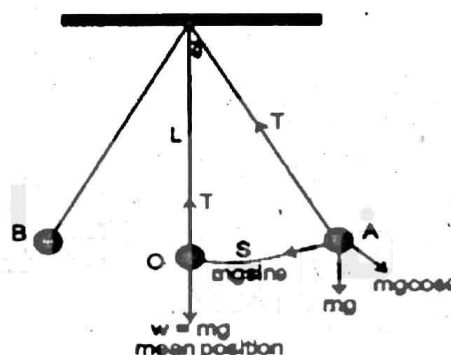
- The time period T of the simple harmonic motion of a mass m attached to a spring is given by the following equation:

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



- Formula for the time period of simple pendulum

$$T = 2\pi \sqrt{\frac{L}{g}} \dots\dots(10.2)$$



- (8) Define following terms which characterize simple harmonic motion.

- | | | |
|-----------------|------------------|------------------|
| (i) Vibration | (ii) Time period | |
| (iii) Frequency | (iv) Amplitude | (v) Displacement |

Ans:

- (i) **Vibration:**

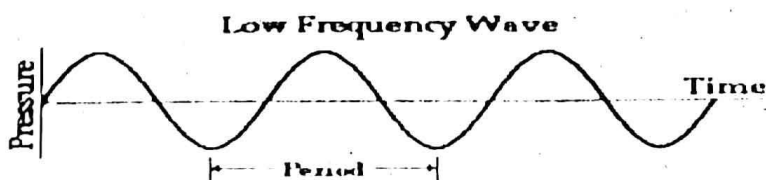
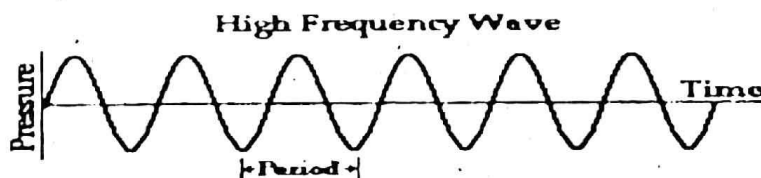
One complete round trip of a vibrating body about its mean position is called one vibration.

- (ii) **Time period (T):**

The time taken by a vibrating body to complete one vibration is called time period

- (iii) **Frequency (f):**

The number of vibrations per cycle of a vibrating body in one second is called its frequency. It is reciprocal of time period i.e $f = 1/T$

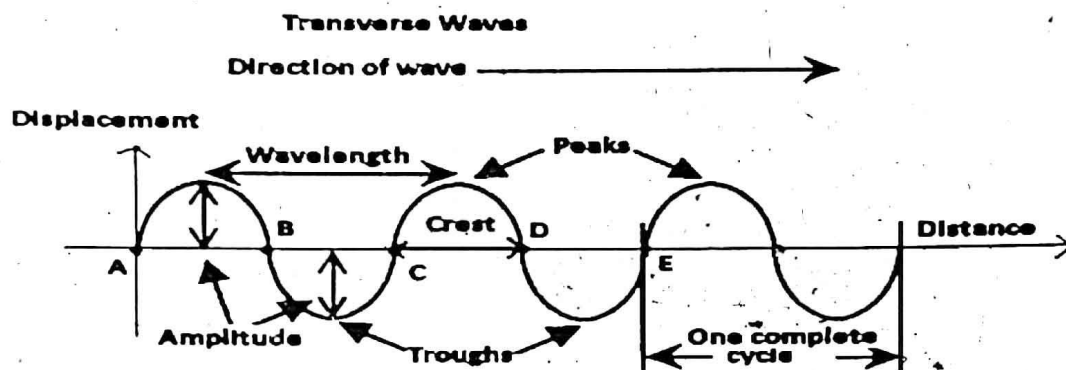


(iv) **Amplitude (A):**

The displacement of a vibrating body on either side from its mean position to extreme position is called its amplitude.

(v) **Displacement (D)**

Distance covered by the vibrating body at any instant during the vibration from mean position.



(9) **Write down important features of Simple Harmonic Motion**

Ans: Important features of SHM are summarized as:

- A body executing SHM always vibrates about a fixed position.
- Its acceleration is always directed towards the mean position.
- The magnitude of acceleration is always directly proportional to its displacement from the mean position i.e. acceleration will be zero at the mean position while it will be maximum at the extreme positions.
- Its velocity is maximum at the mean position and zero on the extreme positions.

(10) **Define time period and frequency in case of vibratory motion.**

Ans:

	Time Period	Frequency
Vibratory Motion	The time required to complete one vibration is known as time period.	The number of vibrations completed in one second is known as frequency
Waves	The time required to pass one wave from a certain point is called time period $T = \frac{1}{f}$	The number of waves passing through a certain point in one second is known as frequency. $f = \frac{1}{T}$

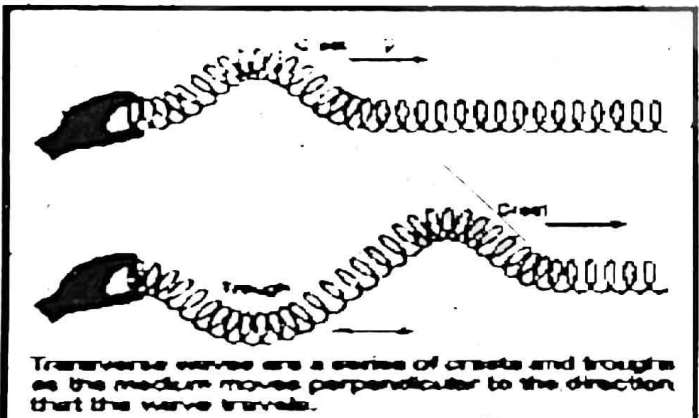
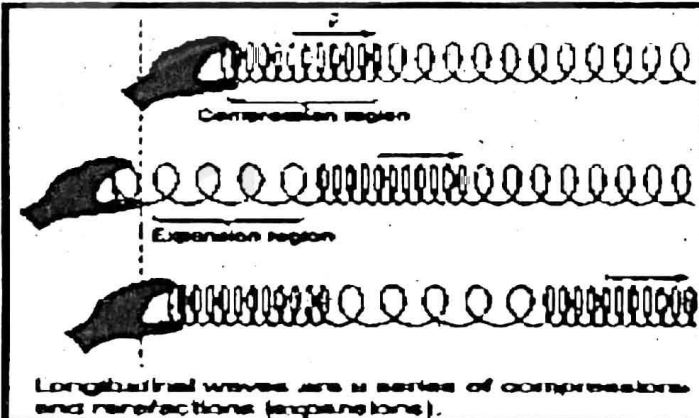
(11) Differentiate between mechanical waves and electromagnetic waves.

Ans:

Mechanical Waves	Electromagnetic Waves
The waves which require a material medium for their propagation are known as mechanical waves.	The waves which can propagate with or without material medium are known as electromagnetic waves.
Examples • Sound waves • Waves produced on a rope • Water waves	Examples • X-rays • Radio waves • Heat and light waves

(12) Differentiate between transverse waves and compressional or longitudinal waves.

Ans:

Transverse Waves	Compressional or Longitudinal Waves
The waves in which the direction of vibratory motion of particles of medium is perpendicular to the direction of propagation of waves are called transverse waves.	The waves in which the direction of vibratory motion of particles of medium is parallel to the direction of propagation of waves are called compressional or longitudinal waves.
Examples • Waves produced in a rope • Water waves	Example • Sound waves
	

(13) Write down the relationship between frequency and time period

Ans: Frequency is a reciprocal of time period (They have inverse relationship)

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

(14) If we double the length of the pendulum then what will be the time period?

Ans: As we know that

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

Now l becomes $2l$

So

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

$$= \sqrt{2} \left(2\pi \sqrt{\frac{l}{g}} \right)$$

$$T' = \sqrt{2} T$$

Hence Time period is $\sqrt{2}$ times of time period

- (15) Find the time period and frequency of a simple pendulum 1.0 m long at a location where $g = 10.0 \text{ ms}^{-2}$

Ans:

Given Data

$$L = 1.0 \text{ m},$$

$$g = 10.0 \text{ ms}^{-2}.$$

Required

Time period of simple pendulum $T = ?$

Frequency of Simple pendulum $f = ?$

Formula

Time Period of Simple Pendulum

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

By putting the values

$$T = 2\pi \sqrt{\frac{1.0 \text{ m}}{10.0 \text{ ms}^{-2}}}$$

$$T = 1.99 \text{ s}.$$

Frequency of simple pendulum

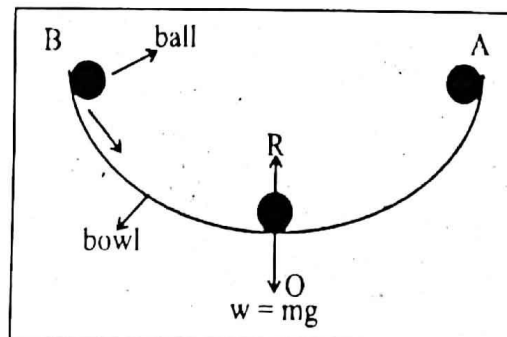
$$f = \frac{1}{T}$$

$$f = \frac{1}{1.99}$$

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

- (16) When the ball is at the center of the bowl what will be the net force?

Ans: When the ball is at the center of the bowl the net force acting on the ball is zero because at this position weight of the ball acts downward and is equal to the upward normal force of the surface of the bowl.



(17) What is the displacement of an object in a simple harmonic motion when kinetic and potential energy are equal?

Ans: Kinetic energy and potential energy are equal when the body is at the middle of mean and extreme position.

(18) If we replace iron bob of simple pendulum with the wooden bob what will be the affect of time period of simple pendulum?

Ans: The time period of simple pendulum would remain same because period of a pendulum is independent of mass and amplitude.

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

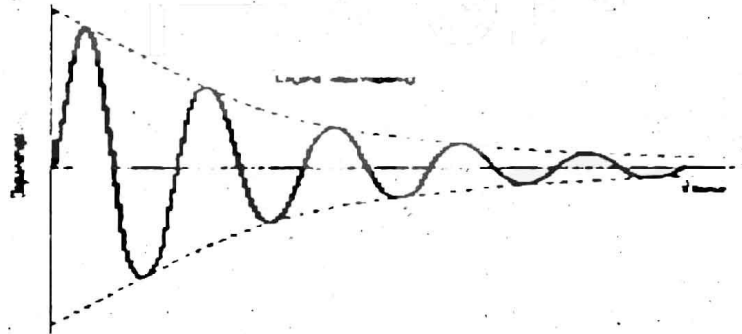
10.2 & 10.3 Damped Oscillations and Wave Motion

(19) What is meant by damped oscillation?

Ans: The oscillations of a system in the presence of some resistive force are damped oscillations.

(20) How does the mechanical energy of system reduce?

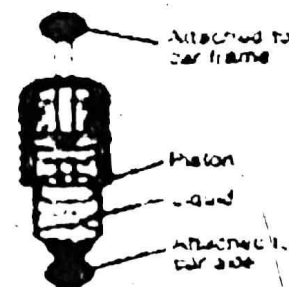
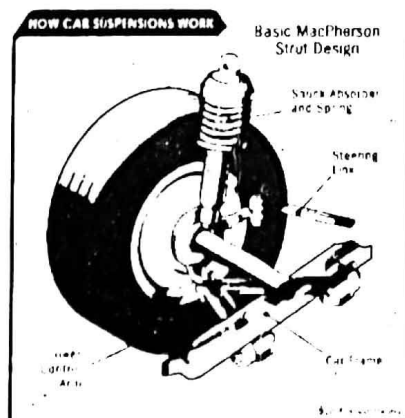
Ans: The friction reduces the mechanical energy of the system as time passes, and the motion is said to be damped, this damping progressively reduces the amplitude of the motion.



(21) Explain function of the shock absorber (application of the damped oscillation)

Ans: Shock absorbers

Shock absorbers are one practical application of damped motion. A shock absorber consists of a piston moving through a liquid such as oil. The upper part of the shock absorber is firmly attached to the body of the car. When the car travels over a bump on the road, the car may vibrate violently. The shock absorbers damp these vibrations and convert their energy into heat energy of the oil.



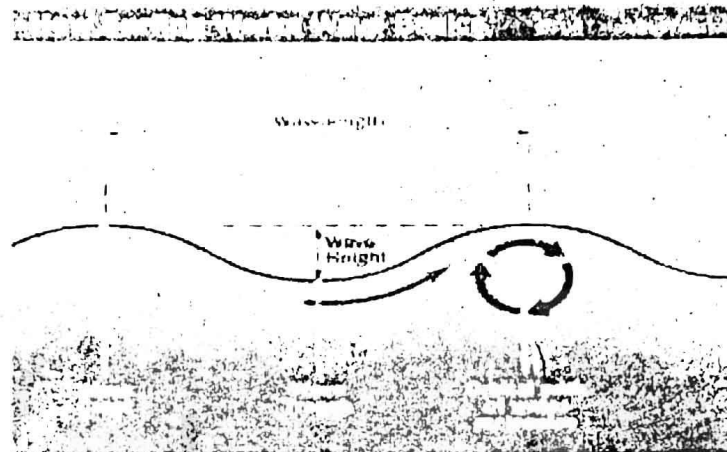
(22) How a wave can be defined? In which categories are these divided?

Ans: Wave

A wave is a disturbance in the medium which causes the particles of the medium to undergo vibratory motion about their mean position in equal intervals of time.

There are two categories of waves.

(i) Mechanical waves (ii) Electromagnetic Waves



(23) Define electromagnetic waves and give its examples.

Ans: Waves which do not require any medium for their propagation are give called electromagnetic waves

Examples:

- Radio waves
- Heat waves
- X-rays etc

(24) Define mechanical waves. Give examples.

Ans: Waves which require any medium for their propagation are called mechanical waves
Examples:

- Water waves
- Sound waves etc

(25) Do the mechanical waves pass through a space?

Ans: No, mechanical waves do not pass through the space because they require medium for their propagation.

10.4 Types of Mechanical Wave

(26) Define longitudinal or compressional waves?

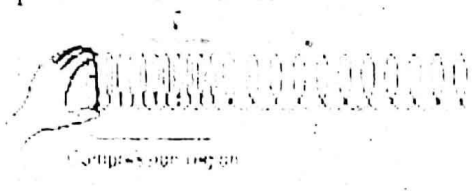
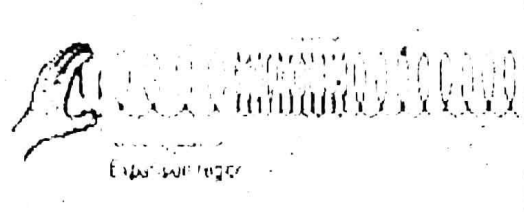
Ans: The waves in which the particles of medium move back and forth along the direction of the propagation of wave are called longitudinal or compressional waves.

Example:

- Sound waves

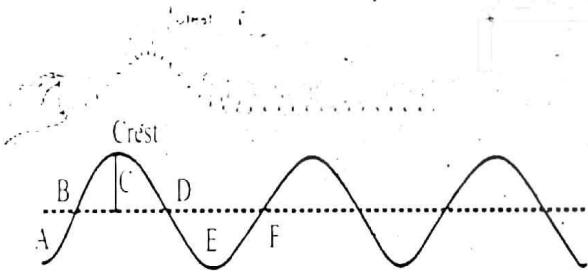
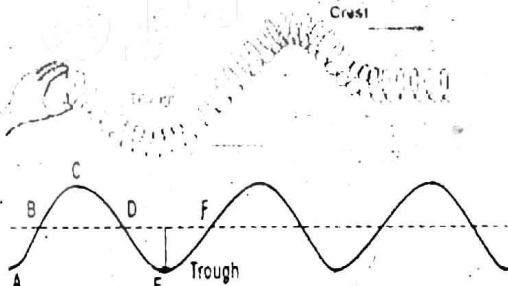
(27) Differentiate between compression and rarefaction?

Ans:

Compression	Rarefaction
The region of a wave where loops of spring are close together is called compression OR The region of a wave where particles of medium are close to each other is called compression of wave.	The region of a wave where the loops of spring are space apart is called rarefaction. OR Region of a wave where the particles of medium are spaced apart is called rarefaction.
	

(28) Differentiate between crest and trough?

Ans:

Crest	Trough
The highest point on the wave is called crest.	The lowest point on the wave is called trough.
	

(29) Define transverse waves?

Ans: Transverse waves

The wave in which the particle of medium moves perpendicular to the direction of propagation of wave.

Example:

- Water waves
- Light waves
- Waves produced on a string and spring

(30) What is wave equation?

Ans: The relation between the velocity, frequency and wavelength of the wave is known as wave equation $v = f\lambda$ (wave equation)

(31) How energy can be transferred from one place to other?

Ans: Energy can be transferred from one place to another through waves.

(32) A wave moves on a slinky with frequency of 4 h z and wavelength of 0.4 m. what is the speed of the wave?

Solution:

Given that:

$$f = 4\text{Hz}, \quad \lambda = 0.4\text{m}$$

Required:

Wave speed $v = ?$

Formula:

$$\begin{aligned}\text{Wave speed } v &= f\lambda \\ &= (4\text{Hz})(0.4\text{m}) \\ v &= 1.6 \text{ ms}^{-1}\end{aligned}$$

(33) Describe Types of Mechanical Waves.

Longitudinal Waves or Compressional Waves

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

Example:

- Sound Waves

Transverse Waves:

"The waves in which motion of particles of the medium is perpendicular to the motion of wave."

Examples:

- Waves on the surface of water and light waves are also transverse waves.

10.5 Ripple tank.

(34) Why bright lines are seen on the screen of the ripple tank?

Ans: The crests of the waves appear as bright lines on the paper because they behave like a convex lens and converge the rays of light falling on them. So, bright lines are seen on the screen of the ripple tank.



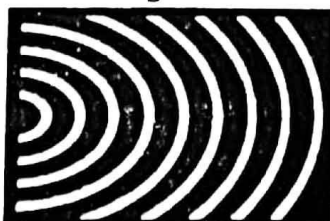
(35) Why dark lines are seen on the screen of the ripple tank?

Ans: The troughs of the waves appear as dark lines on the paper because they behave like a concave lens and diverge the rays of light falling on them. So, dark lines are seen on the screen of ripple tank.



(36) How can we generate circular waves in a ripple tank?

Ans: We can generate circular waves in a ripple tank by attaching a knob on the lower side of vibrating bar. Now it is lowered in such a way that knob touches the water surface. When vibrator is set on, circular waves are produced on the water surface.

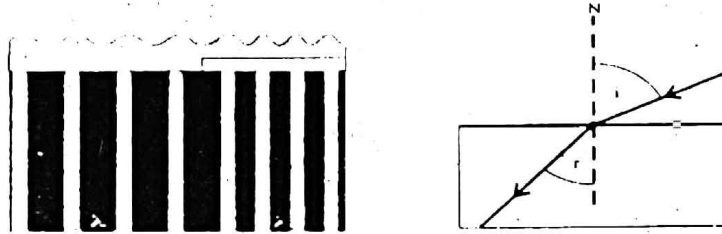


(37) In relation $v = f\lambda$ which two quantities depend upon the properties of the medium and why does third one not?

Ans: In relation $v = f\lambda$, v and λ depend on the properties of the medium while f does not depend on the properties of the medium because f depends upon the frequency of the vibrator.

(38) Why does wavelength decrease in shallow part of water?

Ans: As wavelength changes with the depth of water so there will be a decrease in wavelength of the waves in shallow part of water due to decrease in the speed of the waves.



(39) On what factor refraction of water depends?

Ans: Refraction of water waves depends upon the depth of water waves because speed of water waves depends upon the depth of water. Its speed is reduced when it enters in shallow water. So when water waves enter from deep water to shallow water their wavelength changes but frequency remains the same and refraction of water waves takes place.

(40) What is the effect of diffraction on water waves?

Ans: If we place two obstacles in a line of straight water waves in such a way that separation between them is equal to wavelength of water waves. After passing through the slits between two obstacles, straight water waves are changed into circular waves. But diffraction of waves can only be observed clearly if the size of the slit is nearly equal to wavelength of the wave.

(41) How diffraction is useful in daily life?

Ans: Due to diffraction of radio waves, transmission can be heard in such areas where the waves cannot reach directly.

(42) How do ocean waves cause destruction?

Ans: Sometime, the ocean waves cause the destruction of ships and coastal areas because in case of any disturbance in the ocean, energy is carried by the waves and they travel towards coastal area and causes destruction.



LONG QUESTIONS

10.1 Simple Harmonic Motion (S.H.M)

Q.1 Define simple harmonic motion. Explain it

- i. When mass attached to a spring
- ii. For ball and bowl system
- iii. For simple pendulum

Simple Harmonic Motion

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

When an object oscillates about either side of a fixed position (mean position) such that its acceleration is directly proportional to its displacement from the mean position and is always directed towards the mean position, its motion is called SHM.

(i) Motion of mass attached to a spring

One of the simplest types of oscillatory motion is that of horizontal mass-spring system as shown in fig if the spring is stretched or compressed through a small displacement x from its mean position, it exerts a force F on the mass.

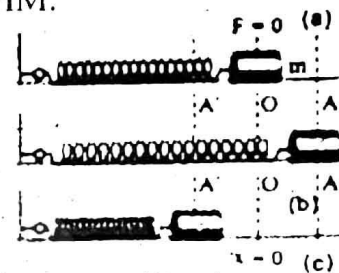


Fig (i)

Hook's Law

According to Hooke's law this force is directly proportional to the change in length x of the spring i.e.,

$$F = -kx \dots \dots \dots (i)$$

Where x is the displacement of the mass from its mean position O , and k is a constant called the spring constant defined as

Spring Constant

The ratio of exerted force to the change in length is called spring constant

$$K = \frac{F}{x}$$

The value of k is a measure of the stiffness of the spring. Stiff springs have large k values, and soft springs have small k values. It is measured in Nm^{-1} .

Restoring Force :

A restoring force always pushes or pulls the object performing oscillatory motion towards the mean position.

$$F_r = -F$$

The **negative sign** in eq. (i) means that the force exerted by the spring is always directed opposite to the displacement of the mass. Because the spring force always acts toward the mean position, it is sometimes called a restoring force.

$$F_r = -k x \dots \dots \dots (ii)$$

According to Newton's 2nd Law of Motion

$$F_r = ma$$

Putting the value of F_r into eq (ii)

$$ma = -kx$$

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

Where $\frac{k}{m} = \text{constant}$ $a = -\text{constant } x$

$$a \propto -x$$

This is mathematical form of simple harmonic motion

Direction of acceleration

Initially the mass m is at rest at mean position O and the resultant force on the mass is zero (fig. 1-a).

From extreme to mean position

As the mass m moves towards the point O from A , its displacement goes on decreasing. Resultantly, the acceleration of the body also decreases. On reaching the point O , x becomes zero and so acceleration ' a ' of the mass m also reduces to zero. But it may be noted that its velocity is maximum at this point.

From mean to extreme position

Due to inertia, the mass m does not stop at the point O but continues its motion towards left till it reaches the point A' . During this motion, the spring is now compressed. Now the restoring force and the acceleration due to it are opposite to the motion of the mass m . This means that the velocity of the mass m starts decreasing as it passes the point O and finally becomes zero as it reaches the point A' .

From extreme to mean Position

After coming to rest at the point A' , the body again returns to the point O under the action of the restoring force. This process continues and the body of mass m keeps on vibrating between the point A and A' .

Conclusion

The above motion of a mass attached to a spring is known as "Simple Harmonic Motion

(ii) Ball and bowl system

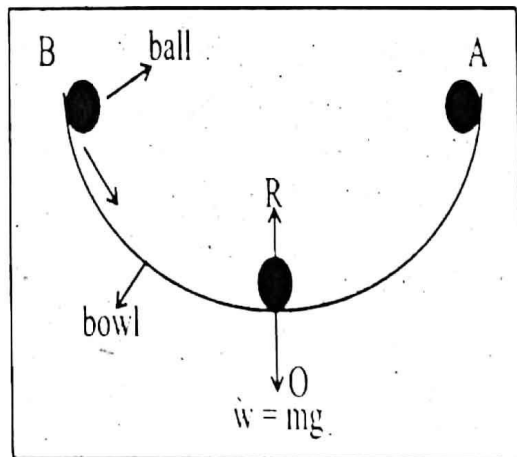
The motion of a ball placed in a bowl is another example of simple harmonic motion.

When ball is at rest (At mean position O):

When the ball is at the mean position O , that is, at the centre of the bowl, net force acting on the ball is zero. In this position weight of the ball acts downward and is equal to the upward normal force of the surface of the bowl. Hence there is no motion.

Observation of motion of ball between extreme positions A and B :

Now if we bring the ball to position A and then release it, the ball will start moving towards the mean position O due to the restoring force caused by its weight. At position O the ball gets maximum speed and due to inertia it moves towards the extreme position (b) while going towards the position B , the speed of the ball decreases due to the restoring force which acts towards the mean position. At the position B , the ball stops for a while and then again moves towards the mean position O under the action of the restoring force. This to and fro motion of the ball continues about the mean position O till all its energy is lost due to friction.



Conclusion

Thus the to and fro motion of the ball about a mean position placed in a bowl is an example of simple harmonic motion.

(iii) Simple pendulum

Definition

A simple pendulum consists of a single isolated bob suspended from a frictionless support by a light inextensible string.

Motion of the Simple Pendulum is an example of Simple Harmonic Motion

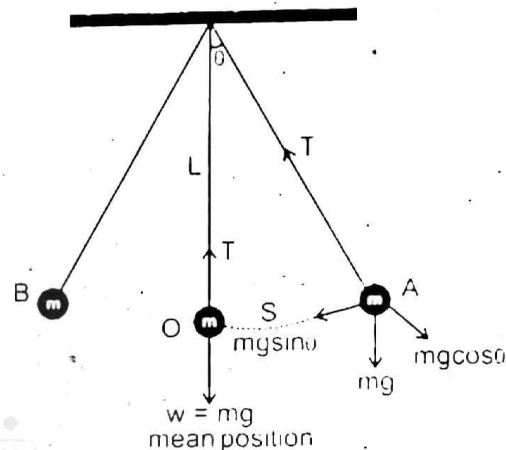
When bob is at rest (at mean position O):

A simple pendulum also exhibits SHM. It consists of a small bob of mass m suspended from light string of length L fixed at its upper end. In the equilibrium position O , the net force on the bob is zero and the bob is stationary.

Observation of motion of bob:

Now if we bring the bob to extreme position A , the net force is not zero as shown in fig. There is no force acting along the string as the tension in the string cancels the component of the weight $mg \cos \theta$.

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 starts moving towards the mean position O . At O the bob has got the maximum velocity and due to inertia it does not stop at O rather it continues to move towards the extreme position B during its motion towards point B , the velocity of the bob decreases due to restoring force. The velocity of the bob becomes zero as it reaches the point B , the restoring force $mg \sin \theta$ still acts towards the mean position O and due to this force the bob again starts moving towards the mean position O . In this way, the bob continues its to and fro motion about the mean position O .



Conclusion

It is clear from the above discussion that the speed of the bob increases while moving from point A to O due to the restoring force which acts towards O . Similarly, when the bob moves from O to B , its speed decreases due to restoring force which again acts towards O . It follows that the acceleration of the bob is always directed towards the mean position O . Hence the motion of a simple pendulum is SHM.

Q. 2 Define Time Period and Write down formulas of Time Period for mass attached to a spring and for simple Pendulum

Time Period (T):

Time required to complete one vibration is called time period. It is denoted by T

- The time period T of the simple harmonic motion of a mass m attached to a spring is given by the following equation:

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

- Formula for the time period of simple pendulum

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

Q. 3 Define different terms which characterizes simple harmonic motion?

Vibration:

One complete round trip of a vibrating body about its mean position is called one vibration.

Time period (T):

The time taken by a vibrating body to complete one vibration is called time period (T)

Frequency (F):

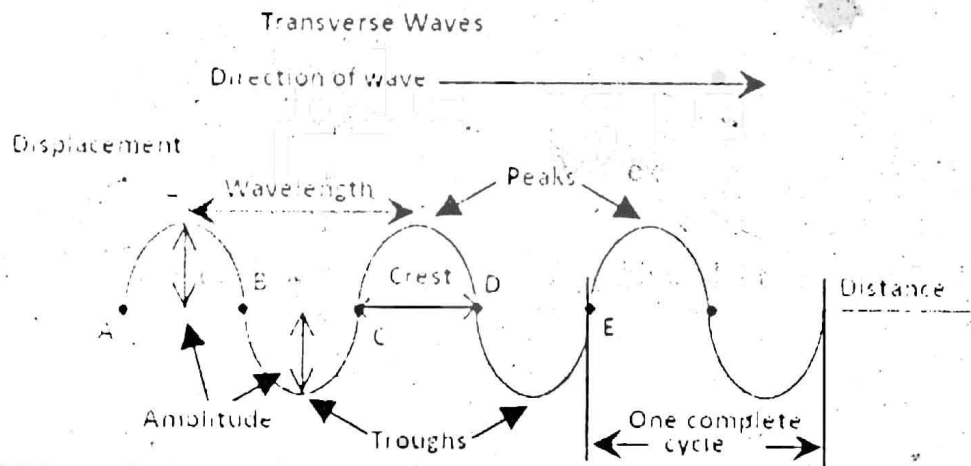
The number of vibrations per cycle of a vibrating body in one second is called its frequency. It is reciprocal of time period i.e $f = 1/T$

Amplitude (A):

The displacement of a vibrating body on either side from its mean position to extreme position is called its amplitude.

Displacement (D)

Distance covered by the vibrating body at any instant during the vibration from mean position.



10.2 Damped oscillations:

Q. 4 What are damped oscillations? How damping progressively reduces the amplitude of oscillation? Describe its one application.

Damped Oscillation:

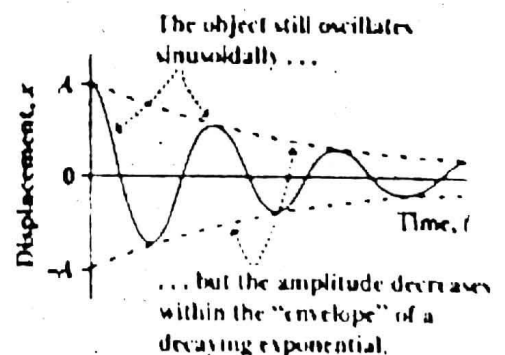
Definition:

"The oscillations of a system in the presence of some resistive force are damped oscillations."

Damping progressively reduces the amplitude of oscillation

Vibratory motion of ideal systems in the absence of any friction or resistance continues indefinitely under the action of a restoring force. Practically, in all systems the force of friction retards the motion, so the system do not oscillate indefinitely.

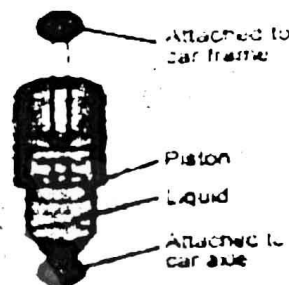
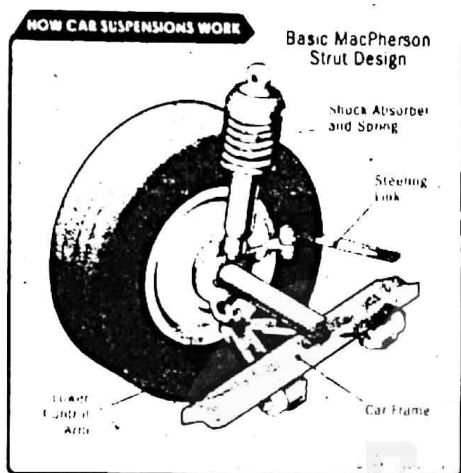
The friction reduces the mechanical energy of the system as time passes, and the motion is said to be damped. This damping progressively reduces the amplitude of the motion as shown in fig.



Application

Shock absorbers

In automobiles shock absorbers are one practical application of damped motion. A shock absorber consists of a piston moving through a liquid such as oil as shown in fig. the upper part of the shock absorber is firmly attached to the body of the car. When the car travels over a bump on the road, the car may vibrate violently. The shock absorbers damp these vibrations and convert their energy into heat energy of the oil.



10.3 Wave motion:

Q. 5 What is wave? Explain wave motion with the help of experiments.

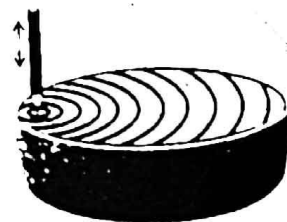
Ans: Wave

"A wave is a disturbance in the medium which cause the particles of the medium to undergo vibratory motion about their mean position in equal intervals of time."

Experiment 1:

Dip one end of a pencil at the edge of a tub containing water; rapidly move the pencil up and down vertically, the ripples emerges outwards on the surface of water.

When we place some small pieces of the cardboard or cork equally spaced, in the direction of the waves, and observe the movement of the pieces as the waves pass. It is observed that every piece of cardboard move up and down about its mean position.



Wave produced by a dipping a pencil in a water tub.

They are not displaced forward from their original position along with the water waves. The motion of these pieces about their mean positions is known as vibratory motion. If we examine the vibratory motion of all the pieces, it can be observed that they do not vibrate together but they have consecutive vibratory motion.

Conclusion

In this experiment, the vibratory motion of the pencil produces a disturbance in the constituent molecules of the water, due to which they start exhibiting vibratory motion about their mean position. Thus this disturbance is transferred along with the wave, and a visible water wave can be observed.

Q. 6 What is wave? Describe its different types.

Wave

"A wave is a disturbance in the medium which causes the particles of the medium to undergo vibratory motion about their mean position in equal intervals of time."

Types of Waves

1. Mechanical waves.
2. Electromagnetic waves

Mechanical waves:

Waves which require any medium for their propagation are called mechanical waves.

Examples:

- Water waves,
- Sound waves
- Waves produced on the strings and springs.

Electromagnetic waves:

Definition:

Waves which do not require any medium for their propagation are called electromagnetic waves.

Examples:

- Radio waves,
- Television waves,
- X-rays, heat and light waves

10.4 Types of Mechanical Waves

Q. 7 Distinguish between longitudinal and transverse waves with suitable examples.

Ans. Longitudinal waves:

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

Explanation:

Sound waves also travel from one place to another in longitudinal pattern. Longitudinal waves are also called compressional waves. These waves travel in the form of compressions and rarefactions.

How longitudinal waves are produced:

Longitudinal waves can be produced on a spring placed on a smooth floor. Fix one end of the spring (slinky) with a rigid support and hold another end into your hand. Now give it a regular push and pull quickly in the direction of its length as shown in fig.

A series of disturbances will start moving along the length of the slinky such waves consist of regions called compression, where the loops of the spring are close together, alternating with regions called rarefactions (expansions), where the coils are spaced apart.

Compression and rarefactions:

Compressions are those regions where the particles of the medium are closed together while rarefactions are those regions where particles of the medium are spaced apart. The compression and rarefactions move back and forth along the direction of motion of the wave.

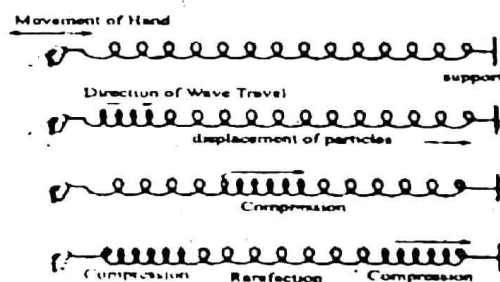


Fig. 10.8: Longitudinal wave on a slinky

Transverse Waves:

In the case of transverse waves the motion of particles of the medium is perpendicular to the direction of wave.

How transverse waves are produced?

Transverse waves can be produced with the help of slinky. Stretch out a slinky along a smooth floor or on a long bench with one end fixed. Grasp one end of slinky and move it up and down quickly as shown in fig.

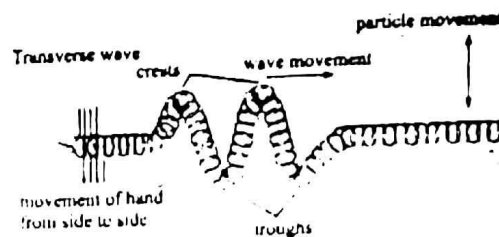


Fig. 10.9 Transverse wave on a slinky

A wave in the form of alternative crests and troughs will start traveling towards fixed end.

Crests and Troughs:

Crests are the highest points while the troughs are the lowest points of the particles of the medium from the mean position. The crests and troughs move perpendicular to the direction of the wave.

Waves as carriers of energy

Q. 8. Waves are means of energy transfer with out transfer of matter. Justify this statement with the help of a simple experiment.

Energy can be transferred from one place to another through waves. For example, when we shake the stretched string up and down, we provide our muscular energy to the string. As a result, a set of waves can be seen traveling along the string. The vibrating force from the hand disturbs the particles of the string and sets them in motion. These particles then transfer their energy to the adjacent particles in the string. Energy is thus transferred from one place of the medium to the other in the form of wave.

Water waves also transfer energy from one place to another as explained below:

Experiment:

Drop a stone into a pond of water. Water waves will be produced on the surface of water and will travel outwards as shown in fig place a cork at some distance from the falling stone. When waves reach the cork, it will move up and down along with the motion of the water particles by getting energy from the wave.



Conclusion:

This experiment shows that water waves like other waves transfer energy from one place to other without transferring matter, i.e. water

Q.9 Derive a relation between speed, frequency and wavelength of a wave. Write its formula relating speed of wave to its time period of wave length.

Wave Equation

The relation between the velocity, frequency and wavelength of the wave is known as wave equation.

Derivation of Formula:

Wave is in fact a disturbance in a medium which travels from one place to another and hence have a specific velocity of traveling. This is called the velocity of wave which is defined by

Velocity = distance/time

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

If time taken by wave in moving from one point to another is equal to the **time period** then the distance covered by the wave will be equal to one **wavelength**,

Hence we can write:

$$v = \frac{\lambda}{T}$$

But time period T is reciprocal of the frequency i.e. $f = \frac{1}{T}$

$$v = f\lambda$$

Note: Above equation is called, the wave equation it is true for all type of waves i.e. longitudinal, transverse etc

10.5 Ripple tank

Q. 10 What is ripple tank? Explain its construction and following properties of waves with the reference of ripple tank experiment.

(i) Reflection (ii) Refraction (iii) Diffraction

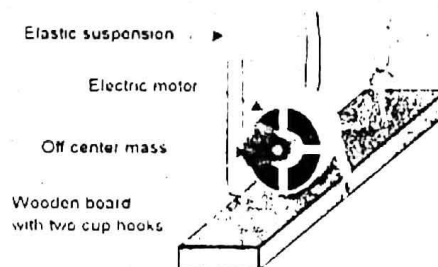
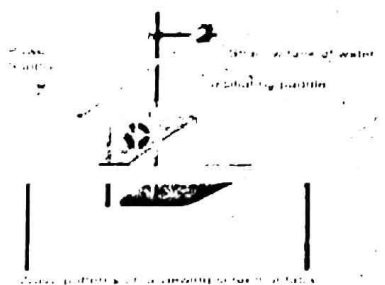
Definition

"Ripple tank is a device to produce water waves and to study their characteristics."

Construction:

This apparatus consists of a rectangular tray having glass bottom and is placed nearly half meter above the surface of a table as shown in fig. waves can be produced on the surface of water present in the tray by means of a vibrator (paddle).

This vibrator is an oscillating electric motor fixed on a wooden plate over the tray such that its lower surface just touches the surface of water. On setting the vibrator on, this wooden plate starts vibrating to generate plane water waves. An electric bulb is hung above the tray to observe the image of water waves on the paper or screen. The crests and troughs of the waves appear as bright and dark lines, respectively, on the screen.



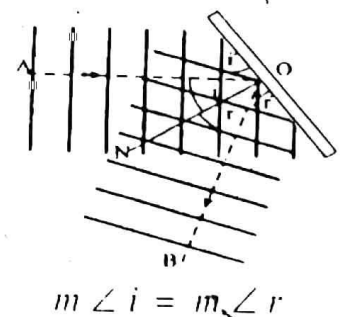
Reflection:

Definition:

"When waves moving in one medium fall on the surface of another medium they bounce back into the first medium such that the angle of incidence is equal to the angle of reflection. This phenomenon is called reflection of waves."

Explanation:

Place a barrier in the ripple tank. The water waves will reflect from the barrier which is placed at an angle to the wave front, the reflected waves can be seen to obey law of reflection i.e. the angle of the incident wave along the normal will be equal to the angle of the reflected wave as shown in fig.



Definition:

Explanation:

boundary between deep and shallow water

straight wave generator

shallow water (wave speed)

wave front

deep water (faster speed)

rectangular tank

Fig. 10.14



Fig. 10-15 Retraction of
Water Waves

Diffraction:

Definition:

Explanation:

$\mathcal{H}_1 = \{H \in \mathcal{H} : H \text{ is a } (d-1)\text{-face of } \Delta\}$
 $\mathcal{H}_2 = \{H \in \mathcal{H} : H \text{ is a } (d-2)\text{-face of } \Delta\}$



Fig. 10.17. Reflection of water waves (the scale is large).

Condition for the Diffraction:

Diffraction of waves can only be observed clearly if the size of the obstacle is comparable with the wavelength of the wave.

NUMERICAL PROBLEMS

10.1 The time period of a simple pendulum is 2s. What will be its length on Earth? What will be its length on the moon if $g_m = g_e / 6$? Where $g_e = 10 \text{ ms}^{-2}$.

Solution:

Given Data:-

Time period of simple pendulum = $t = 2 \text{ sec}$. The gravitation all acceleration on earth as well as on moon should be included in given data.

Required:-

- (i) Length of pendulum on earth = $l_e = ?$
- (ii) Length of pendulum on moon = $l_m = ?$

Formula:-

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

Solution:-

(i) **For Earth**

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

By taking square on both sides, we have

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

or

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

By putting the values, we have

$$l_e = \frac{(2)^2 \times 10}{4 \times (3.14)^2}$$

$$l_e = \frac{4 \times 10}{4 \times 9.86}$$

$$l_e = 1.02 \text{ m}$$

(ii) **For Moon**

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

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

By putting the values, we have

$$l_m = \frac{(2)^2 \times 1.6}{4 \times (3.14)^2} = \frac{6.44}{39.44}$$

$$l_m = 0.17 \text{ m}$$

Result:-

Length of pendulum on earth = $l_e = 1.02 \text{ m}$

Length of pendulum on moon = $l_m = 0.17 \text{ m}$

10.2 A pendulum of length 0.99 m is taken to the moon by an astronaut. The period of the pendulum is 4.9s. What is the value of g on the surface of the moon?

Solution:

Given data:

Length of pendulum on moon = $l_m = 0.99 \text{ m}$

Time period = 4.9sec

To Find:

Value of g on moon = $g = ?$

Formula:

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

Calculation:

$$4.9 \text{ sec} = 2 \times 3.14 \sqrt{\frac{0.99}{g}}$$

Squaring

$$g = \frac{4 \times (3.14)^2 \times 0.99}{(4.9)^2}$$

$$g = 1.63 \text{ ms}^{-2}$$

Result:

Value of g on moon = $g = 1.6 \text{ ms}^{-2}$

10.3 Find the time periods of a simple pendulum of 1 meter length, placed on Earth and on moon. The value of g on the surface of moon is $1/6^{\text{th}}$ of its value on Earth. When g_e is 10 ms^{-2} .

Solution:

Given data:

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

Value of g on earth = 10 ms^{-2}

Value of g on moon = 1.62 ms^{-2}

To find:

Time period on earth = $T_e = ?$

Time period on moon = $T_m = ?$

Formula:

Calculation:

At Earth:

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

$$T_e = 2(3.14) \sqrt{\frac{1}{10}}$$

$$T_e = (6.28) \sqrt{0.1}$$

$$T_e = (6.28) (0.316)$$

$$T_e = 1.985 \text{ sec.}$$

$$T_e = 2 \text{ sec. Ans}$$

At Moon:

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

$$T_m = 2(3.14) \sqrt{\frac{1}{1.67}}$$

$$T = 2(3.14) \sqrt{0.6172}$$

$$T = 4.9 \text{ sec}$$

Results:

$$\text{Time period on earth} = T_e = 2 \text{ sec}$$

$$\text{Time period on moon} = T_m = 4.9 \text{ sec}$$

10.4 A simple pendulum completes one vibration in two seconds. Calculate its length when $g = 10.0 \text{ ms}^{-2}$.

Solution:

Given data:

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

$$g = 10 \text{ ms}^{-2}$$

To Find:

$$\text{Length of simple pendulum} = L = ?$$

Calculation:

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

Squaring on both sides

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

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

$$l = \frac{(2)^2 \times 10}{4 \times (3.14)^2}$$

$$l = \frac{4 \times 10}{4 \times 9.85}$$

$$l = 1.02 \text{ m}$$

Result:

$$\text{Length of simple pendulum} = l = 1.02 \text{ m}$$

10.5 If 100 waves pass through a point of a medium in 20 seconds, what is the frequency and the time period of the wave? If its wavelength is 6cm, calculate the wave speed.

Solution:

Given data:

$$\text{No. of waves} = 100$$

$$\text{Time} = 20\text{s}$$

$$\text{Wavelength} = \lambda = 6\text{cm} = 0.06\text{ m}$$

Required:

Wave speed = v = ?

Formula:

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

$$f = \frac{100}{20}$$

$$f = 5\text{Hz}$$

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

$$T = \frac{1}{5\text{Hz}}$$

$$T = 0.2\text{ sec}$$

$$V = ?$$

$$V = f\lambda$$

$$V = 5 \times 0.06$$

$$V = 0.3\text{ ms}^{-1}$$

10.6 A wooden bar vibrating into the water surface in a ripple tank has frequency of 12Hz. The resulting wave has a wavelength of 3cm. What is the speed of the wave?

Solution:

Given data:

$$\text{Frequency } f = 12\text{ Hz}$$

$$\text{Wavelength} = \lambda = 3\text{cm} = 0.03\text{ m}$$

Required:

$$\text{Speed of wave} = v = ?$$

Formula:

$$V = \lambda f$$

Calculations:

$$v = (0.03)(12)$$

$$V = 0.36\text{ m/s}$$

Results:

$$\text{Speed of wave is } 0.36\text{ m/s}$$

10.7 A transverse wave produced on a spring has a frequency of 190 Hz and travels along the length of the spring of 90m, in 0.5s.

(a) What is the period of wave?

(b) What is the speed of the wave?

(c) What is the wavelength of the wave?

Solution:

Given data:

Frequency = $f = 190$ Hz

Length = $l = 90$ m

Time = $t = 0.5$ s

Required:

(i) Time period of wave = $T = ?$

(ii) Speed of wave = $V = ?$

(iii) Wavelength of wave = $\lambda = ?$

Calculations:

(i) Time period:

$$T = 1/f$$

$$T = 1/190$$

$$T = 0.005$$

$$T = 0.01 \text{ s}$$

(ii) Speed of wave:

$$V = d/t$$

$$V = 90/0.5$$

$$V = 180 \text{ m/s}$$

(iii) Wavelength:

$$\lambda = v/f$$

$$\lambda = 180/190$$

$$\lambda = 0.95 \text{ m}$$

Results:

Time period is 0.01s; speed of wave is 180 m/s and wavelength of wave is 0.95 m

10.8 Water waves in a shallow dish are 6.0 cm long. At one point, the water moves up and down at a rate of 4.8 oscillations per second.

(a) What is the speed of the water waves?

(b) What is the period of the water waves?

Given data:

Length of wave = $d = 6.0$ cm = 0.06 m

Frequency = $f = 4.8$ Hz

Required:

(i) Speed of waves = ? (ii) period of waves = ?

Calculations:

(i) Time period:

$$T = 1/f$$

$$T = 1/4.8$$

$$T = 0.21 \text{ s}$$

(ii) Speed of waves:

$$V = d/t$$

$$V = 0.06/0.21$$

$$V = 0.29 \text{ m/s}$$

Results:

Time period is 0.21 s and velocity is 0.29 m/s

10.9 At one end of a ripple tank 80 cm across, 5 Hz vibrator produces waves whose wavelength is 40mm. Find the time the waves need to cross the tank.

Solution:

Given data:

$$\text{Length} = l = 80 \text{ cm} = 0.8 \text{ m}$$

$$\text{Frequency} = f = 5 \text{ Hz}$$

$$\text{Wavelength} = \lambda = 40 \text{ mm} = 0.04 \text{ m}$$

Required:

$$\text{Time taken} = t = ?$$

Calculation:

$$\text{As we know that } v = f\lambda$$

$$V = (5)(0.04) = 0.2 \text{ m/s}$$

And

$$v = d/t$$

$$\text{So, } t = d/v$$

$$t = 0.8/0.2$$

$$t = 4 \text{ s}$$

Results:

Time taken is 4s.

10.10 What is the wavelength of the radio waves transmitted by an FM station at 90 MHz? Where $1\text{M} = 10^6$, and speed of radio wave is $3 \times 10^8 \text{ ms}^{-1}$.

Solution:

Given data:

$$\text{Frequency} = f = 90 \text{ MHz} = 9 \times 10^7 \text{ Hz}$$

$$\text{Speed} = v = 3 \times 10^8 \text{ m/s}$$

Required;

$$\text{Wave length} = \lambda = ?$$

Formula:

As we know that

$$v = f\lambda$$

$$\lambda = v/f$$

Putting values:

Calculation:

$$\lambda = \frac{3 \times 10^8}{9 \times 10^7}$$

$$\lambda = \frac{3 \times 10^{8-7}}{9.0}$$

$$\lambda = 3.333 \text{ m}$$

Results:

Wavelength is 3.333m