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.

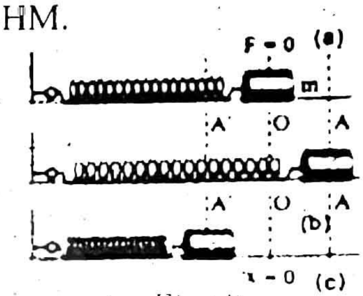


Fig (i)

Hook's Law

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

$$F = -kx \quad \text{.........(i)}$$

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.

$$F_r = -kx \quad \text{\_\_\_\_\_\_\_\_\_\_ (ii)}$$

According to Newton's 2^{nd} Law of Motion

$$F_r = ma$$

Putting the value of Fr into eq (ii)

$$ma = -kx$$

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

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

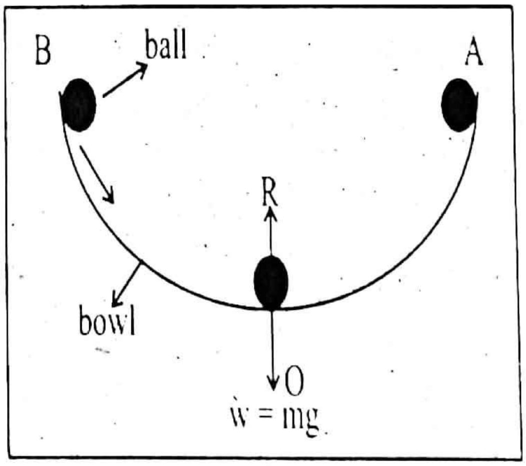
The motion of a ball placed in a bowl is another example of simple harmonic motion.

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

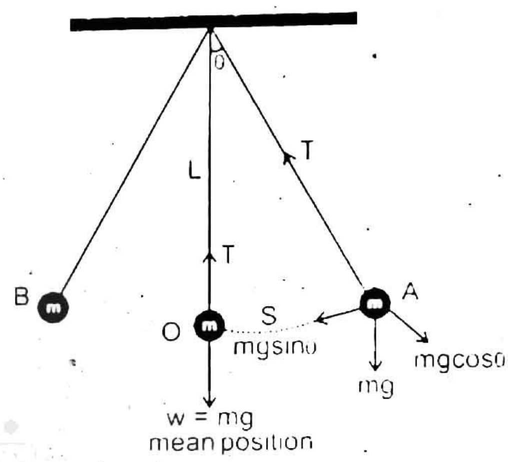
Definition

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 cosθ.

The component of the weight mg sin θ 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 sinθ 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):

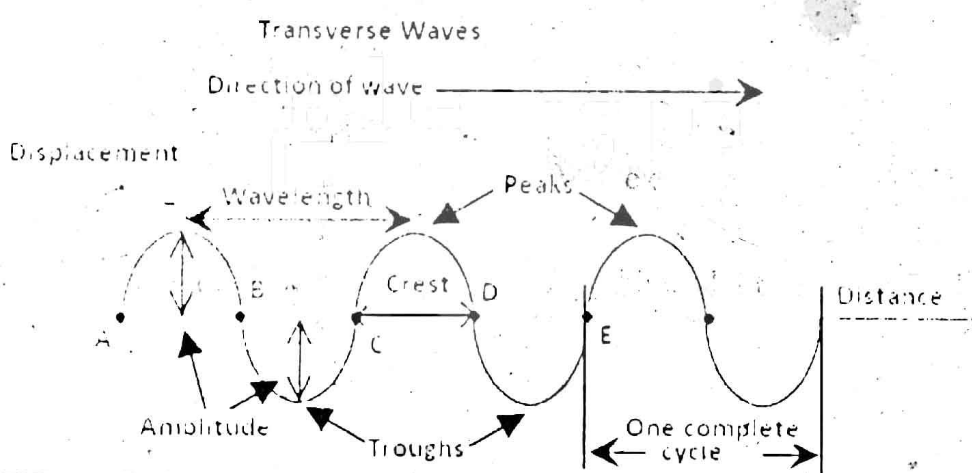
The number of vibrations per cycle of a vibrating body in one second is called its frequency. It is reciprocal of time period i.e $f = 1/T$

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:

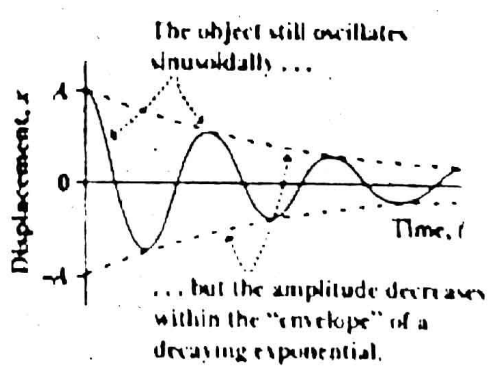
Definition:

"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.

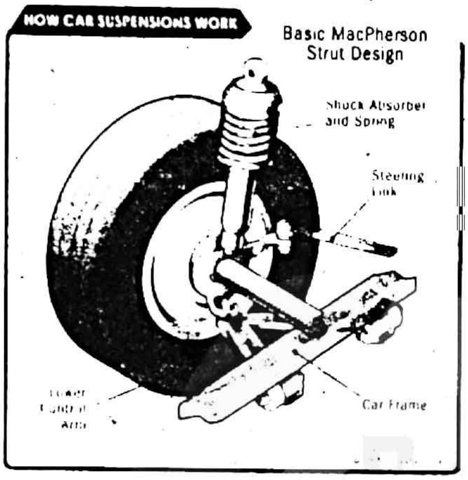
The friction reduces the mechanical energy of the system as time passes, and the motion is said to be damped. This damping progressively reduces the amplitude of the motion as shown in fig.

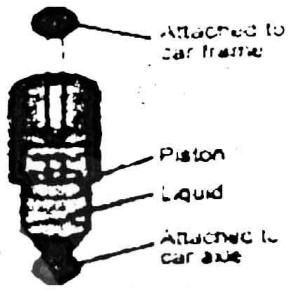


Application

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.

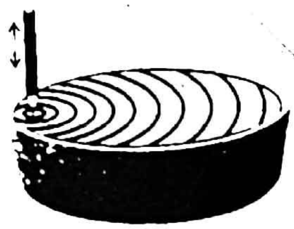
Ans: Wave

"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:

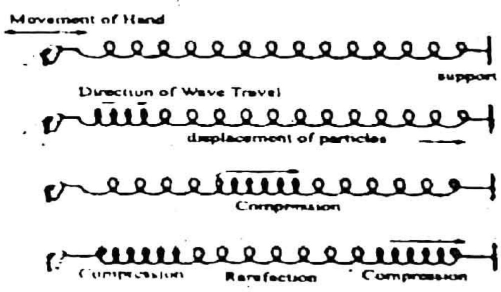


Fig. 10.8: Longitudinal wave on a slinky

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.

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.

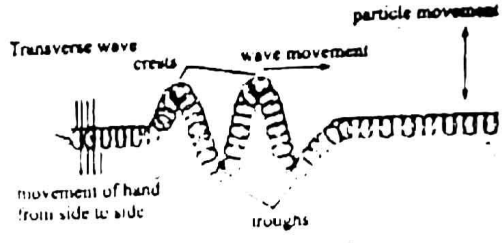


Fig 10.9 Transverse wave on a slinky

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

$$\boxed{v = f\lambda}$$

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

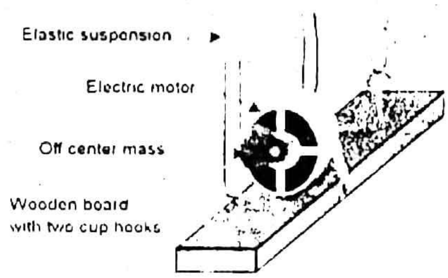
Q. 10 What is ripple tank? Explain its construction and following properties of waves with the reference of ripple tank experiment.
(i) Reflection **(ii) Refraction** **(iii) Diffraction**

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.



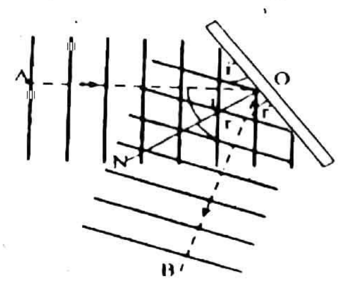
Reflection:

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.



$m\angle i = m\angle r$

Refraction:

Definition:

"When waves from one medium enter in the second medium at some angle their direction of travel may change. This phenomenon is called refraction of waves."

Explanation:

The speed of a wave in water depends on the depth of water. If a block is submerged in the ripple tank, the depth of water in the tank will be shallower over the block than elsewhere. When water waves enter the region of shallow water their wavelength decreases as shown in fig but the frequency of the water waves remains the same in both parts of water because it is equal to the frequency of the vibrator.

Fig 10.14

For the observation of refraction of water waves, we repeat this experiment such that the boundary between the deep and the shallower water is at same angle to the wave front (fig.10.15). Now we will observe that in addition to the change in wavelength the waves change their direction of propagation as well. The direction of propagation is always normal to the wave fronts.

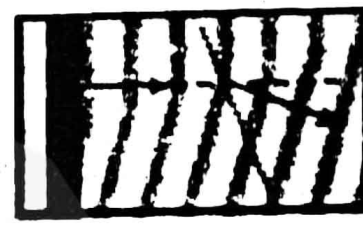


Fig. 10.15 Refraction of water waves

This change of path of water waves while passing from a region of deep water to that of shallower is called refraction.

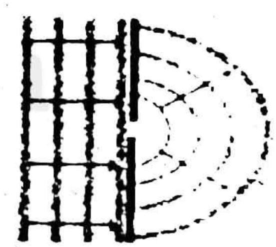
Diffraction:

Definition:

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

Explanation:

We observe the phenomena of diffraction of water waves. Generate plane waves in a ripple tank and place two obstacles in line in such a way that separation between them is equal to the wavelength of water waves. After passing through a small slit between the two obstacles, the waves will spread in every direction and change into almost semicircular pattern as shown in fig (a).



[illegible]

Fig (b) shows the diffraction of waves while passing through a slit with size larger than the wavelength of the wave. Only a small diffraction occurs near the corners of the obstacle.

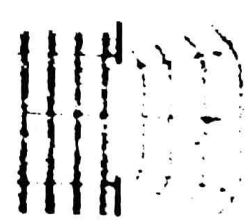


Fig 10.17 [illegible]

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.