Unit - 10

General Wave Properties

Students Learning Outcomes (SLOs)

After learning this unit students should be able to

- Describe wave motion as illustrated by vibrations in rope, slinky spring, experiments with water waves
- Identify transverse and longitudinal waves in mechanical media, slinky springs
- Describe that waves are means of energy transfer without transfer of matter
- Distinguish between mechanical and electromagnetic waves
- Describe properties of waves such as reflection, refraction, and diffraction with the help of ripple tank
- Define the terms speed (v), frequency (f), wavelength (λ), time-period (T), amplitude, crest, trough, cycle, wavefront, compression, and rarefaction
- Solve problems by applying the relation $f = 1/T$ and $v = f\lambda$
- State the conditions necessary for an object to oscillate with SHM
- Explain SHM with simple pendulum, ball, and bowl examples
- Draw forces acting on a displaced pendulum
- Solve problems by using the formula $T = 2\pi \sqrt{l/g}$ for a simple pendulum
- Understand that damping progressively reduces the amplitude of oscillation

When the calm water surface is disturbed by a stone dropping into it, circular water ripples spread out from the point where the stone hits the water. The continuous disturbance of the water surface by the blasts of the wind caused by a helicopter hovering above creates water waves that move outwards. The disturbance on the water surface moves outwards, carrying energy, and no water, because after the waves pass, the water remains where it was before the wave was produced

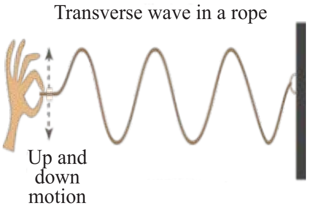


Fig: 10.1 Up and down movements produce a wave

Fig: 10.2 slinky spring

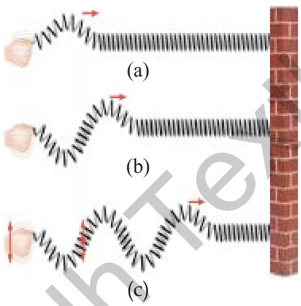


Fig: 10.3
An upward pulse moves to the right, followed by *(b)* A downward pulse. *(c)* When the end of the Slinky is moved up and down continuously, a transverse wave is produced

We experience the impacts of waves every day in our daily life. Every sound we listen to depends on sound waves. Every sight we see depends on light waves. A little wave can travel across the water in a glass, and a very large tide can travel over the sea. Sound waves, light waves, and water waves appear very different. So, what similarities do all these different forms of waves have? What, exactly, is a wave? What are the characteristics of a wave? We will study it all in detail in this unit.

10.1 Waves and nature of waves

A method transport energy from one point to another point without transfer of matter is called wave.

Formation of waves

Disturbance of medium cause of formation of wave like, we can produce waves by using a rope, slinky spring, and water waves in ripple tanks. Let us discuss them in detail.

Wave Motion by using a Rope

We can produce waves on a rope by attaching one end to a wall and continuously moving the other end up and down, as shown in figure 10.1. These up-and-down movements produce oscillations or vibrations. We can observe that the generated rope waves travel towards the wall, whereas the rope itself moves only up and down. The rope is the medium through which the waves travel or propagate.

Waves in a Slinky Spring

A slinky spring is a pre-compressed helical or coiled spring as shown in fig 10.2.

We can perform several experiments with a slinky in the laboratory to understand the phenomenon of different types of wave motion.

Attach one end of the spring with a wall. Now moving the free end of the slinky horizontally left and right continuously on the table will be able to see the coils of the spring moving left and right, whereas humps travel to the other end. (10.3) (a,b,c).

Now moving the free end of the attached wall slinky spring continuously back and forth as horizontally shown in fig 10.4. You can observe the individual coils moving forwards and backwards. Where the coils are compressed, are seen traveling from the fixed end to the other end.

In both of the above experiments, the slinky spring is said to be the medium through which the waves travel or propagate.

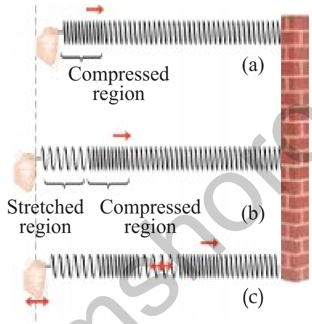


Fig: 10.4 (*a*) A compressed region moves to the right, followed by (*b*) a stretched region. (*c*) When the end of the Slinky is moved back and forth continuously, a longitudinal wave is produced.

Water wave in (Ripple Tank)

A **ripple tank** is a shallow glass tank of water used to demonstrate the basic properties of waves.

It is a particular type of wave tank. The ripple tank is usually illuminated from above so that the light shines through the water to visualize the wave being produced.

In the laboratory, we can produce water waves with the ripple tank. In the ripple tank, a small vibrator moves up and down the water surface, resulting in the water particles at the surface that are in contact with the dipper being made to move up and down. This up and down motion soon spread to other parts of the water surface in the tank in the form of ripples; fig.10.5. Here the water is the medium through which the ripples travel or propagate.

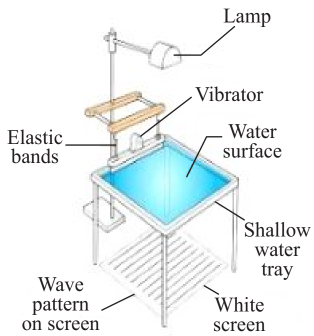


Fig: 10.5. Schematic diagram of a ripple tank

Types of Wave Motion

The direction in which the displacement takes place within a wave motion affects the properties of the wave. These wave types can be illustrated using a slinky, long flexible steel coil or spring, which rests on a smooth table during use. Wave energy can be transmitted, for example, by a slinky, and for illustrations, each of the coil turns can represent a particle of the medium through which a wave is traveling.

Transverse Wave

The slinky illustrates the transverse wave in Fig. 10.5. Move the free end of the slinky up and down repeatedly. These up and down movements of the coils produce oscillations. Have you noticed that when coils move up and down, the direction of the wave motion is

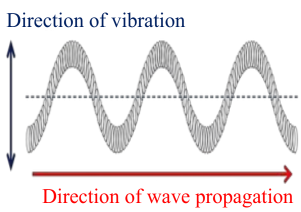


Fig: 10.6. A transverse wave in a slinky

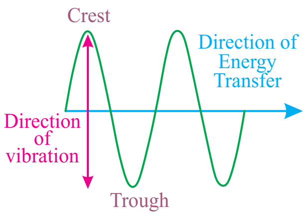


Fig: 10.7
Transverse wave

Weblinks

Encourage students to visit the below link for longitudinal waves and transverse waves. https://www.sciencelearn.org.nz/resources/2681-waves-and-energy-energy-transfer

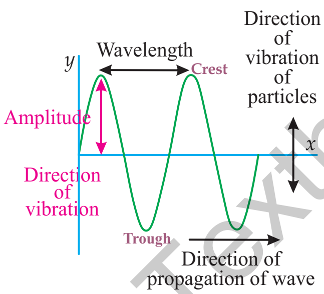


Fig: 10.8.
The transverse wave is represented by Amplitude, Crest, Trough, and wavelength spreading

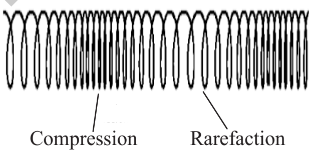


Fig: 10.9 Longitudinal Wave in a Slinky

perpendicular to the direction of oscillation? We call this type of wave is a transverse wave; Fig. 10.7.

In the light of the above experiment, transverse waves can be defined as

Transverse waves are waves that travel in a direction perpendicular to the direction of wave motion".

Transverse wave motion can also be observed on the surface of the water in a pond or a ripple tank, vibrations in a guitar string. Another essential type of transverse wave is electromagnetic waves, e.g., light waves, microwaves, radio waves.

Amplitude is the maximum displacement moved by a point on a vibrating body from the rest or mean position.

It is the height of a crest or depth of a trough measured from the rest position as shown in fig 10.8. Its SI unit is meter (m).

Crest is a point on a surface wave where the displacement of the medium is at a maximum. OR

The positive/upper part of wave is called crest.

Trough is a point on a surface wave where the displacement of the medium is at a maximum.

Longitudinal Wave

The slinky illustrates the longitudinal wave in Fig. 10.8. Move the free end of the slinky forward and backward (i.e. push and pull) to expand and compress the slinky repeatedly. These forwards and backwards movements of the coils produce oscillations. Have you noticed that when coils move forwards and backwards, the direction of the wave motion is parallel to the direction of oscillation? We call this type of wave is a longitudinal wave.

Longitudinal waves can be defined as

"Longitudinal waves are waves that travel in a direction parallel to the direction of wave motion".

Another common example of a longitudinal wave is sound waves.

Compression, in the longitudinal waves this is a region where turns of the coil or particles are closer together than average.

Rarefaction, in the longitudinal waves this is a region where turns of the coil or particles are further apart than average.

Waves are means of energy transfer without transfer of matter

The wave is a disturbance in a medium that transfers energy from one place to another

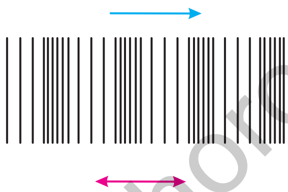
Waves transfer energy over a distance. Can waves move matter the entire distance? For example, a tide can travel many kilometers. The water moves up and down- a disturbance that travels in a wave, transferring energy, not matter.

Mechanical and electromagnetic waves

Difference between these waves on the basis of medium.

Mechanical waves	Electromagnetic waves
Mechanical waves are such waves that need a medium for propagation.	Electromagnetic waves are such waves that do not need a medium for propagation.
Mechanical waves are produced by vibratory motion in the respective medium.	Electromagnetic waves are produced by a changing of electric and magnetic fields.
Sound waves, water waves, and seismic waves are some examples of mechanical waves.	Radio waves, microwaves, light waves, U.V waves and infrared waves are some examples of electromagnetic waves.
Mechanical waves consist of transverse as well as longitudinal waves.	Electromagnetic waves are only comprised of a transverse wave in nature.
Mechanical waves cannot travel through the vacuum.	Electromagnetic waves travel through the vacuum at the speed of 3×10^8 m/s.
All mechanical waves travel through their media at different speeds depending upon the physical properties of the respective medium.	All electromagnetic waves can travel through transparent media at different speeds depending upon the refractive index of the respective medium.

Direction of wave propagation



Direction of particle motion

Fig: 10.10 Longitudinal Wave

Do You Know!

We can produce plane waves by using a straight dipper in a ripple tank. These waves can be seen as bright and dark lines on a screen below the tank. These bright and dark lines represent the crests and troughs of the plane waves respectively

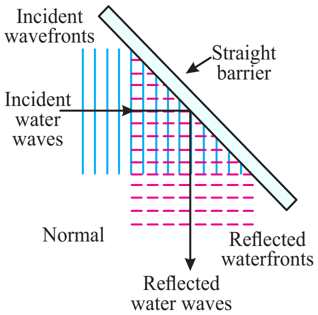


Fig: 10.11
Reflection of the water waves

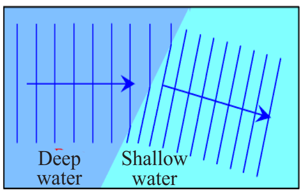


Fig: 10.12
when a barrier is placed to decrease the depth of water in a ripple tank

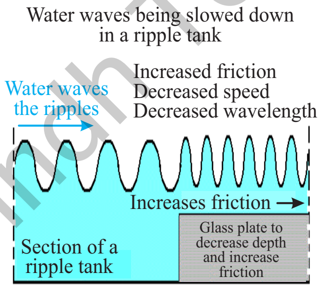


Fig: 10.13
Change in the direction of wave front and decrease in wavelength

SELF ASSESSMENT QUESTIONS:

Q1: Distinguish between transverse and longitudinal waves.

Q2: Wave motion transfers energy without moving matter. Justify this statement with an example.

Q3: What is the main difference between mechanical waves and electromagnetic waves?

10.2 Properties of Waves

The depth at which the dipper is placed affects the amplitude of the waves, while the frequency of vibration of the dipper corresponds to the frequency of water waves produced.

Let us demonstrate some wave properties such as reflection, refraction, and diffraction concerning the ripple tank.

Reflection of the waves

Figure 10.11 shows how one can demonstrate the reflection of the waves? When a vertical straight surface is placed in the path of the incoming waves. The incident waves are reflected from the surface at the same angle. It can be seen that the reflected waves obey **the law of reflection,** Example, the angle of the incident wave along the normal will be equal to the angle of the reflected wave. Hence we define the reflection of waves as:

Bouncing back of waves into same medium by striking other medium surface is called reflection.

Refraction of waves

Figure 10.12 shows how refraction of the waves can be demonstrated. When a flat piece of a block is immersed in the ripple tank, water depth becomes shallow. You will find that the wavelength of the plane waves shortens and changes direction; Fig. 10.13 as they move from the boundary between two media, deep to shallow water. However, the frequency of water waves stays the same in both waves because it is the same as the frequency of the vibrator. This result shows that the speed of a wave in water depends on water depth. Waves travel faster in deep water than in shallow water. This effect is called refraction. Hence we can define the refraction of the waves as:

When a wave enters from a region of deep water to a region of shallow water at an angle, the wave will change its direction.

Diffraction of waves

Figure 10.14 shows when an obstruction or a straight surface with a gap in the ripple tank is placed in the path of the incoming water waves, they strike it, the waves will bend around the sides of an obstruction or spread out as they pass through a gap. This phenomenon is called diffraction.

Diffraction is only significant if the size of the gap is about the same as the wavelength of the incident wave, narrow the gap whose width is equal to the wavelength of the incoming ripples, the ripples that pass through the gap are almost circular and seem to originate from a point source situated in the gap. Wider gaps produce less diffraction. Hence we define the diffraction of waves as.

The spreading of the waves near an obstacle is called diffraction.

Fig: 10.14. Diffraction of waves near an obstacle (a) Wider the gap, less spreading (b) narrow the gap, more spreading

Waves Characteristics

The following are some terms used to describe wave motion.

Time-Period (T),is the time taken for any one point on the wave to complete one oscillation.

The SI unit of the period is second (s).

Frequency (f),is the number of complete waves produced by a source per unit of time.

Thus,

Frequency = Number of complete waves produced/ time taken

If the number of waves produced= is 1

And time is taken =T Then $f=1/T$

In general,

Frequency is also defined as the reciprocal of the period.

The SI unit of frequency is the hertz (Hz).

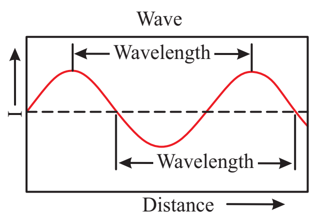


Fig: 10.15 (a)

Wavelength (λ), is the linear distance between two successive crests or troughs in a transverse wave and two

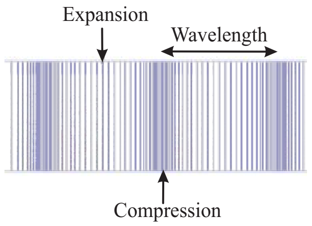


Fig: 10.15 (b)
Wavelength (λ)

successive compressions and rarefactions in a longitudinal wave. Its SI unit is meter (m).

Wave speed (v), is the speed at which a wave travels. It is defined as the distance traveled by a given point on the wave, such as a crest in a given interval of time.

Speed = Distance traveled/time taken or

Let us consider for a wave,

Distance travelled=λ and time is taken =T, then

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

Hence $S = \lambda$

so $t = T$

$$v = \frac{\lambda}{T} \rightarrow \text{(i)} \quad \therefore \quad \frac{1}{T} = f$$

$$v = f\lambda$$

$$S = v \times t$$

$$\lambda = v \times T \rightarrow \text{(ii)}$$

The speed of wave can also be written as $V = f\lambda$

In the SI system, the wave speed is measured in m/s.

The Wavefront is an imaginary line on a wave that joins all points that are in the same phase.

A wavefront is usually drawn by joining all wave crests. There are two types of the wavefront, depending on how the waves are produced, which are concentric circles; figure 10.16. (a) and plane straight lines; figure 10.16. (b).

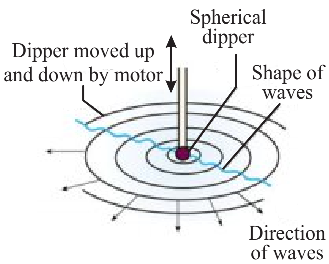


Fig: 10.16 (a)
concentric circles

Figure 10.16 (a). In a ripple tank, a dipper can produce circular waves. These waves have a circular wavefront.

Figure 10.16 (b). In a ripple tank, a plane dipper can produce plane waves. These waves have a plane wavefront.

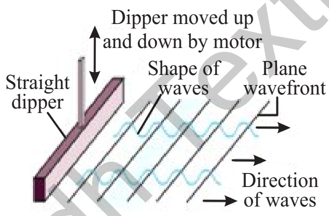


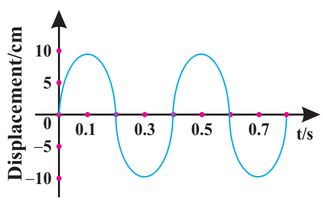
Fig: 10.16 (b)
Straight Line

Worked Example 1

The given figure shows the displacement vs the time of a wave traveling to the right with a speed of 4 m/s.

(a) What is the time period and frequency of the wave?

(b) Calculate the wavelength of the wave?



Solution:

Step 1: Write down the known quantities and quantities to be found.

(a) $v = 4\ ms^{-1}$

i. T =?,

ii. f=?

(b) λ =?

Step 2: Write down the formula and rearrange if necessary.

(a) (i) T, use graph, and

(ii) $f = 1/T$

(b) $v = f \times \lambda$

Step 3: Put the values and calculate

a. (i) From the graph

T = 0.4 s

(ii) f = 1/(0.4s)

= 2.5 Hz

b. $\lambda = 4(ms^{-1})/(2.5Hz)$

Result: = 1.6 m.

Weblinks

Encourage students to visit below link for displacement time graphs

https://www.youtube.com/watch?v=TG2Y2MDx-zE&ab_channel=FuseSchool-GlobalEducation

Worked Example 2

A fisherman notices that his boat is moving up and down regularly due to waves on the surface of the water. It takes 4.0 s for the boat to travel from the highest to the lowest point, a total distance of 3.0 m. The fisherman sees that the wave crests are spaced 8.0 m apart.

(a) What is the period, frequency, amplitude, and wavelength of the waves?

(b) How fast are the waves moving?

Solution:

Step 1: Write down the known quantities and quantities to be found.

Moving from the highest point to the lowest point

Time taken=is 4.0 s

Distance = 3.0m

Distance between the crests = 8.0 m

(a)

i. T=?

ii. f=?

iii. A=?

iv. λ=?

Weblinks

Encourage students to visit below link for period, frequency and amplitude

https://www.youtube.com/watch?v=TG2Y2MDx-zE&ab_channel=FuseSchool-GlobalEducation

(b) v=?

Step 2: Write down the formula and rearrange if necessary.

a.

i. T is the time taken to move from the highest point to the lowest point and from the lowest point to the highest point.

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

iii. A is the one-half of displacement from the highest point to the lowest point

iv. λ is the distance between the two consecutive crests

b. $v = f \times \lambda$

Step 3: Put the values and calculate

a.

i. $T = 2(4.0s)$
$= 8.0s$

ii. $f = \frac{1}{80s}$
$= 0.125$ Hz.

iii. $A = \frac{1}{2}(3.0m)$
$= 1.5m.$

iv. $\lambda = 8.0$ m.

b. $v = (0.125Hz)(8.0m)$

Result: $= 1.0$ m/s.

Thus, the period, frequency, amplitude, and wavelength of the waves are 8.0s, 0.125Hz, 1.5m, and 8.0m respectively. The wave is moving at the speed of 1.0 m/s.

SELF-ASSESSMENT QUESTIONS:

Q1: How spherical wavefronts are produced in the ripple tank?

Q2: What is the difference between displacement and amplitude of the wave?

Q3: Drive the relation between wave speed and frequency.

Weblinks

Encourage students to visit below link for Waves Ripple Tank Interference

https://www.youtube.com/watch?v=0c0gvy_OOKc&ab_channel=launchSCIENCE

Weblinks

Encourage students to visit below link for Waves - Frequency, Speed, and Wavelength

https://www.youtube.com/watch?v=4yfXp1jNBn8&ab_channel=JonWhite

10.3 Simple Harmonic Motion (SHM)

Periodic Motion

A motion repeating itself in an equal time interval is referred to as periodic or oscillatory motion.

Simple Harmonic Motion

An object in such a periodic motion oscillates about an equilibrium position due to a restoring force or a restoring torque. Such force or torque will return the system to its equilibrium position. This type of motion is called Simple Harmonic Motion that is defined as:

When an object oscillates about a fixed position (mean position) its acceleration is directly proportional to its displacement from the mean position and is always directed towards the mean position as shown in fig 10.17, its motion is called SHM.

$$a \propto -x$$

$$a = -kx \qquad \text{where k is spring constant}$$

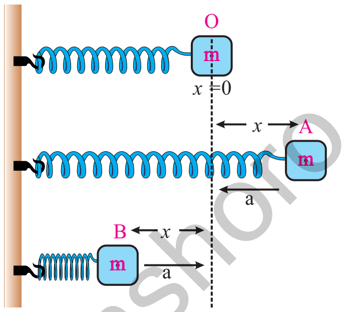


Fig: 10.17
Simple harmonic motion

Many phenomena include electromagnetic waves, alternating current circuits, musical instruments, bridges, and molecular motion that executes the simple harmonic motion.

10.4 Simple pendulum

Forces acting on a displaced pendulum

When the bob of the pendulum is displaced at a small angle 'θ'to an extreme position; Fig. 10.18. The forces that act upon it are as given underneath:

i. Tension 'T' along the direction of the string, and

ii. Weight W= mg, acting vertically downwards.

The weight is further resolved into its components mg sin θ and mg cos θ.

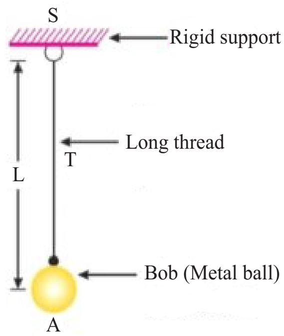


Fig: 10.18. Forces acting on the bob in simple pendulum

Do You Know!

The **restoring force** is a force which acts to bring a body to its equilibrium position.

Motion of a simple pendulum and SHM

Let us think of an experiment to prove that a simple oscillating pendulum executes Simple Harmonic Motion. Old-fashioned clocks, a child's swing, and a fishing sinker are pendulum examples. A pendulum's restoring force is proportional to its displacement for minor displacements under 15 degrees. Simple pendulum has simple harmonic motion.

A simple pendulum consists of a small metallic bob of mass 'm' suspended from a light inextensible string of length 'l' fixed at its upper end.

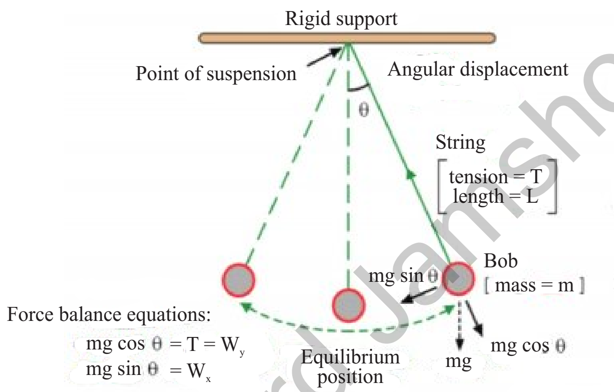


Fig: 10.19. Forces acting on the bob in simple pendulum

Weblinks

Encourage students to visit below link for Simple pendulum stimulation

- https://www.myphysicslab.com/pendulum/pendulum-en.html
- https://phet.colorado.edu/sims/html/pendulum-lab/latest/pendulum-lab_en.html

At the mean position O, a pendulum is in its equilibrium position. If no external force were applied, the bob of a pendulum would naturally settle here as illustrated in fig 10.19.

The curve path s is the distance the bob of a pendulum travels. The weight mg consists of the components mg cosθ along the string and mg sinθ perpendicular to the arc. For each given string, the component mg cos perpendicular to the string is exactly cancelled by the tension in the string. The resulting net force, which is directed back toward the equilibrium point, is tangential to the arc and equals mg sinθ.

Simple pendulum period is affected by length and gravity acceleration. The period is independent of mass and amplitude.

For the simple pendulum executing SHM, we have the following formula for its period;

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

This formula shows that the period 'T' of a simple pendulum depends upon its length 'l' and acceleration due to gravity 'g' over that place. The period of the pendulum is independent of its mass and its amplitude.

Ball and bowl system and SHM

Let us examine that the motion of a ball placed in a bowl executes simple harmonic motion. When the ball is placed at the mean position 'O' as shown in figure 10.20, that is, at the center of the bowl. In this position, the net force acting on the ball is zero. Hence there is no motion.

Now, what if we displace the ball to an extreme position 'A' and then release it? The ball starts moving towards the mean position 'O' due to the restoring force caused by its weight component. At position 'O' the ball gets maximum speed and due to inertia, it moves towards opposite extreme position 'B' with the restoring force that acts towards the mean position, the speed of the ball starts to decrease. The ball stops for a while at 'B' and then again moves towards the mean position 'O'. This ball's to and fro motion continues about the mean position 'O'. This result shows that the acceleration of the ball is directed towards 'O'. Hence, the ball's to and fro motion about a mean position placed in a bowl is also an example of simple harmonic motion.

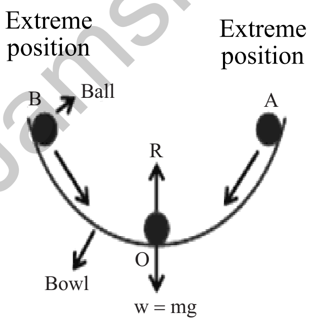


Fig: 10.20.
The motion of a ball in the bowl executing Simple Harmonic Motion

Worked Example 3

Find the period and frequency of a simple pendulum1.0 m long at a location where g = 9.8 m s^{-1}.

Solution:

Step 1: Write down the known quantities and quantities to be found.

L = 1.0 m/s

g = 9.8 m/s^2.

$$\pi \cong \frac{22}{7} \cong 3.141 \text{ and } \pi^2 \cong 9.86$$

i. T = ?

ii. f = ?

Step 2: Write down the formula and rearrange if necessary.

i. $T = 2\pi\sqrt{\frac{l}{g}}$ ii. f= 1/T

Step 3: Put the values and calculate

i. $T = 2 \times 3.14 \times \sqrt{1.0(m)/9.8(m/s)}$

T =2.01 s

ii. $f = 1/2.01\ s$

$= 0.50\ Hz$

Result: The period of the pendulum is 2.01s and its frequency is 0.50 Hz.

Weblinks

Encourage students to visit below link for Pendulum clock invention, oscillation and periodic motion

https://www.youtube.com/watch?v=0c0gvy_OOKc&ab_channel=launchSCIENCE

Worked Example 4

Pendulum clocks with a pendulum measuring out the passing of a second. How long of a pendulum is required to have a period of 1 second? $g = 9.8\ m/s^2$.

Solution:

Step 1: Write down the known quantities and quantities to be found.

$L = ?$

$T = 1.0\ s$

$g = 9.8\ m/s^2$

$\pi \cong \frac{22}{7} \cong 3.141$

Step 2: Write down the formula and rearrange if necessary.

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

Square both the sides

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

Multiply both the sides by g

$$T^2 g = 4\pi^2 L$$

Divide each side by $4\pi^2$

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

Step 3: Put the values and calculate

$$L = \frac{(1s)^2 (9.8m/s^2)}{4\pi^2}$$

$$L = \frac{9.8m}{4\pi^2} \qquad \therefore \qquad \pi \cong \frac{22}{7} \cong 3.141$$

$$L = 0.25m \qquad \therefore \qquad \pi^2 \cong 9.86$$

Result: The length of a pendulum should be 0.25 m.

SELF ASSESSMENT QUESTIONS:

Q1: Calculate the frequency of seconds pendulum?

Q2: Which component of force (weight) is responsible for the oscillatory motion of a simple pendulum?

Q3: At what position acceleration of the simple oscillatory pendulum is maximum, and why?

Q4: The normal reaction of the bowl on the ball is in the upward direction. Why is it not moving in that direction?

Q5: Where is the ball in the bowl system moving fastest, slowest?

10.5. Damped Oscillation

The oscillating system, can not be assumed to have a fixed amplitude unless energy is provided to them. The resistive or damped forces progressively reduce the amplitude of the oscillation.

For example, A knock against a table causes the table to vibrate. This reverberation also fades away often after completing many hundreds of vibrations.

An oscillating system in which friction has an effect is a damped system.

If a simple harmonic motion is subjected to frictional forces, the amplitude of freely oscillating objects progressively decreases. The friction not only affects the amplitude but also slightly reduces the frequency. An oscillation that fades away over time is called damped oscillation; Fig. 10.21, 10.22.

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

SELF ASSESSMENT QUESTIONS:

Q1: What will happen if there is no damping in an oscillating drum skin?

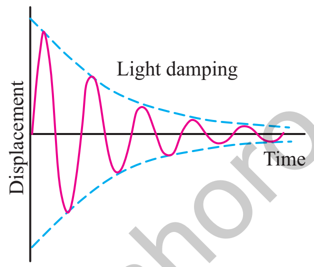


Fig: 10.21.
Variation of amplitude with the time of damping system

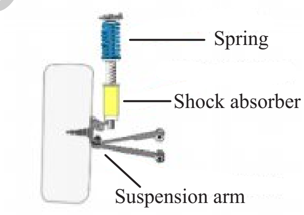


Fig: 10.22.
Shock absorber

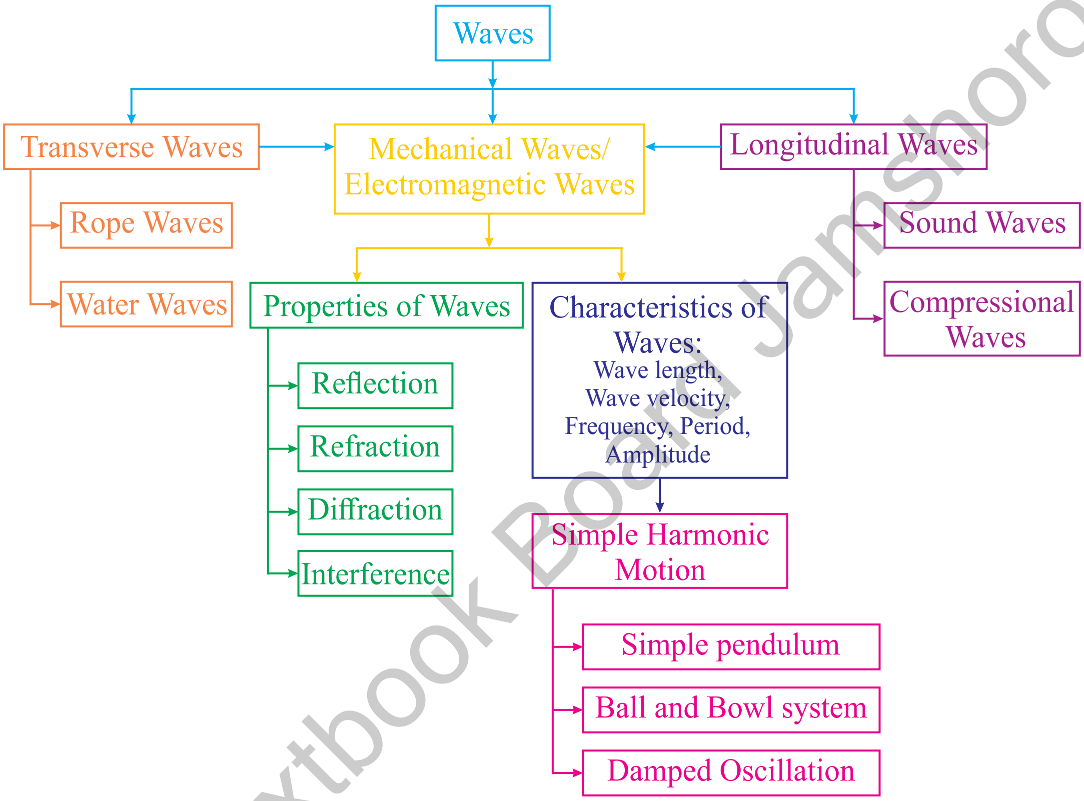
Do You Know!

The practical application of damped motion is shock absorbers in automobiles. A shock absorber consists of a piston that moves through a liquid such as oil. The upper part of the shock absorber is firmly connected to the body of the automobile, when travels over a bump, the automobile may vibrate violently. The shock absorbers dampen these vibrations and convert their mechanical energy into the thermal energy of the oil.

SUMMARY

- Up-and-down movements in the rope produce oscillations or vibrations.
- A slinky is a pre-compressed helical or coiled spring.
- A **ripple tank** is a glass tank of water used to demonstrate the basic properties of waves.
- The particle movement is at right angles to the direction of the wave motion is a transverse wave.
- A transverse wave is comprised of crest and trough.
- The particle movement is in the same direction as the direction of wave motion, a longitudinal wave.
- A longitudinal wave is comprised of compression and rarefaction.
- The wave is a disturbance that transfers energy from one place to another.
- Any substance that a wave can propagate through it is known as a medium.
- Waves that transfer energy through matter are known as mechanical waves.
- All mechanical waves travel through their media at different speeds depending upon the elasticity and inertial properties of the respective medium.
- Waves that transfer energy without the material medium are known as electromagnetic waves.
- Ripple tank experiments demonstrate that water waves can be reflected, refracted, and diffracted.
- When a wave enters from a region of deep water to a shallow, its wavelength and speed decrease.
- The bending of waves around obstacles or sharp edges is called the diffraction of waves.
- When an object oscillates about a fixed position its acceleration is directly proportional to its displacement and is directed towards the mean position, its motion is called SHM.
- A simple pendulum consists of a small metallic bob suspended from a light and inextensible string fixed at its upper end.
- The period of a simple pendulum depends upon its length and acceleration due to gravity over that place.
- An oscillating system in which friction has an effect is a damped system. The amplitude of freely oscillating objects progressively decreases.

CONCEPT MAP



Section (A) Multiple Choice Questions (MCQs)

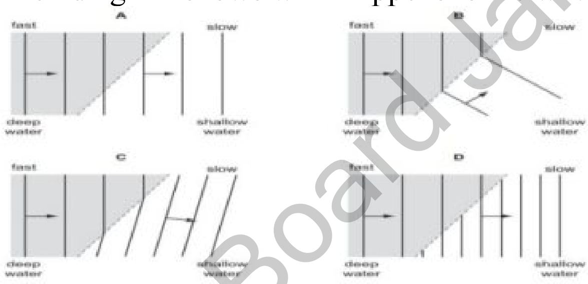
1. A girl throws a small stone into a lake. Waves spread out from where the stone hits the water and travel to the bank of the lake. She notices that ten waves reach the side of the pond in a time of 5.0s. What is the frequency of the waves?

a) 0.50Hz b) 15Hz
c) 2.0Hz d) 50Hz

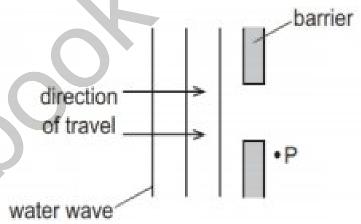
2. Water waves can be used to show reflection, refraction, and diffraction. For each of these, which row shows whether or not the speed of the water waves changes?

	Reflection	**Refraction**	**Diffraction**
a)	Yes	yes	Yes
b)	Yes	No	yes
c)	No	yes	no
d)	No	no	no

3. The diagrams show water waves that move more slowly after passing into shallow water. Which diagram shows what happens to the waves?



4. The diagram shows a water wave approaching a barrier with a gap.



The wave reaches point P. What is the name of the effect that causes the wave to reach point P?

a) Diffraction b) Dispersion
c) reflection d) Refraction

5. Water waves pass from deep into the shallow region then refracted. The characteristics of wave which will remains constant is:

a) Direction b) Frequency
c) Speed d) Wavelength.

6. Which is not a characteristic of wave?

a) An amplitude b) Period
c) Mass d) Velocity

7. When an oscillating object is in simple harmonic motion, its maximum speed occurs when the object is at its

a) Highest point. b) Lowest point
c) Equilibrium point d) Extreme point

8. In an oscillating pendulum, the bob accelerates from its extreme position due to
a) Inertia b) Tension in the string
c) Wind d) Gravitational force

9. In the ball and bowl system, the mean position is at
a) The earth b) Floor of the bowl
c) Center of bowl d) Extreme position

10. Oscillations are damped due to the presence of
a) Linear motion b) Restoring force
c) Frictional force d) Mechanical force

Section (B) Structured Questions

1. Define the term transverse wave.
2. Define the term longitudinal wave.
3. **a)** Write a short note on the mechanical wave.
   b) How can you say that mechanical waves are also material waves?
4. Waves are the means of energy transfer without matter. Justify this statement with the help of everyday life examples.
5. **a)** Define the following terms of a wave:
   i) amplitude ii) period
   iii) frequency iv) wavelength
   b) Derive the formula of wave speed, $v = f\lambda$
6. **a)** What is a ripple tank, and explain its working?
   b) Define the wavefront?
7. Reference an experiment to explain the refraction of waves concerning the ripple tank.
8. What is the phenomenon of diffraction?
9. **a)** What is simple harmonic motion?
   b) What are the necessary conditions for a body to execute simple harmonic motion?
10. **a)** With the help of a diagram, explain SHM in the pendulum.
    b) The period of simple pendulum executing the formula gives SHM

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

What will be the effect of the period if there is an increase in its
i) length ii) mass.

11. **a)** With the help of a diagram, explain SHM in the ball and bowl system.

b) Why is the motion of a ball in the bowl executing SHM is maximum at its equilibrium position?

12. **a)** What are damped oscillations?
b) How does damping progressively reduce the amplitude of oscillation?
c) A boy is swinging in the swing. Explain, why its amplitude reduces progressively with time.

Section (C) Numericals

1. What is the wavelength of a radio wave broadcasted by a radio station with a frequency of 1300 kHz?
Where 1K = 10^3, and the speed of the radio-wave is $3\times10^8\,ms^{-1}$. **(230.76m)**
2. The waves moving in the pond have a wavelength of 1.6 m, and a frequency of 0.80 Hz. Calculate the speed of these water waves. **($1.28ms^{-1}$)**
3. If 50 waves pass through a point in the rope in 10 seconds, what are the frequency and the period of the wave? If its wavelength is 8 cm, calculate the wave speed.
Explain the type of wave produced. **(5Hz, 0.2s, $0.4ms^{-1}$)**
4. A slinky has produced a longitudinal wave. The wave travels at a speed of 40 cm/s and the frequency of the wave is 20 Hz. What is the minimum separation between the consecutive compressions? **(0.02m)**
5. Suppose a student is generating waves in a slinky. The student's hand makes one complete forth and back oscillation in 0.40 s. The wavelength in the slinky is 0.60m. For this wave, determine
   a. Period and frequency
   b. Wave speed **(0.40s, 2.5Hz, $1.5ms^{-1}$)**
6. If 80 compressions pass through a point in spring in 20 seconds. Calculate the frequency and the period? If two consecutive compressions are 8 cm apart, calculate the wave speed. **(4Hz, 0.25s, $0.32ms^{-1}$)**
7. Waves on a swimming pool propagate at 0.90 m/s. If you splash the water at one end of the pool, observe the wave go to the opposite end, reflect, and return in 30.0 s. How far away is the other end of the pool? **(0.033Hz, 27.27m)**
8. A simple oscillating pendulum has a length of 80.0 cm. Calculate its
   a. Period
   b. Frequency
   When g = 9.8 m s^{-2} **(1.794s, 0.557Hz)**

•••••••