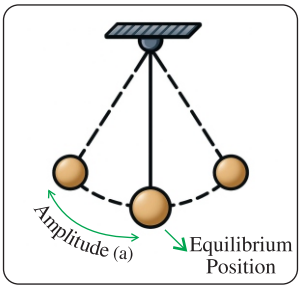
SOUND WAVES

CHAPTER-1

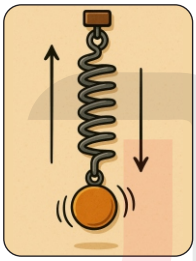
Oscillation

Oscillation is a periodic motion in which an object moves to and fro at regular intervals of time about its equilibrium position.



Examples:

Motion of the pendulum of a clock

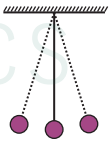


Spring moving up and down

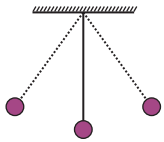
Motion of a child on a swing

Tuning fork vibrations

- The maximum displacement to one side from its equilibrium position is amplitude (a)
- SI unit of amplitude : metre (m)



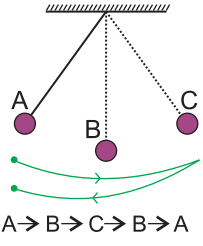
Low amplitude

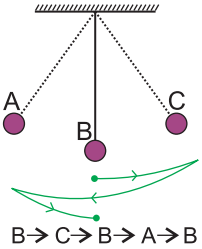


High amplitude

One oscillation of a pendulum ??

- An oscillation is completed when the body moves from its starting position, goes to one extreme, and then returns to its initial position in the same direction from where it started.



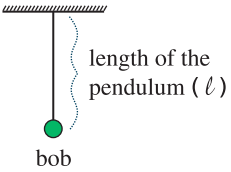


Examples of one oscillation

Period (T)	Frequency (f)
The time taken for one oscillation is called period. SI unit of period: second (s)	The number of oscillations in one second is called frequency. SI unit of frequency : Hertz (Hz) Bigger units of frequency 1 KHz = 1000Hz = 10^3 Hz 1 MHz = 1000000 Hz = 10^6 Hz

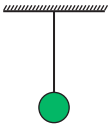
Simple Pendulum

A simple pendulum is a weight (bob)hanging on a string that swings back and forth when you push it



Relation between Length and frequency of a pendulum

- As the length of a pendulum increases, its frequency decreases and its time period increases.
- As the length of a pendulum decreases , its frequency increases and its time period decreases.

Pendulum with shorter length	Pendulum with longer length
	
Higher frequency Lower period	Lower frequency Higher period

Conclusion

- A shorter pendulum completes one oscillation in less time.
- A longer pendulum requires more time to complete one oscillation .

To find period (T)	To find frequency (f)
$T = \frac{\text{Time}}{\text{Number of oscillations}} = \frac{t}{n}$	$f = \frac{\text{Number of oscillations}}{\text{Time}} = \frac{n}{t}$
$T = \frac{1}{f}$	$f = \frac{1}{T}$

- As the period increases, frequency decreases.
- As the period decreases , frequency increases.

The time period and frequency are inversely proportional.

Q. If a pendulum takes 1 minute to complete 30 oscillations, how long does it take to complete one oscillation?

A. n = 30

t = 1 minute = 60s

Time to take one oscillation (T) = $\frac{t}{n} = \frac{60}{30} = 2s$

Q. Find the number of oscillations the same pendulum completes in one second ?

A. Number of oscillations in 1 second (f) = $\frac{n}{t} = \frac{30}{60} = 0.5$

Q. The frequency of a simple pendulum is 1 Hz. What is its period?

A. f = 1Hz

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

Q. If a pendulum takes 0.5 s to complete one oscillation, what is its frequency?

A. t = 0.5s

n = 1

$f = \frac{n}{t} = \frac{1}{0.5} = 2Hz$

Natural Frequency

When an object vibrates freely, it vibrates at its own frequency. This is the natural frequency of that object

Factors influencing natural frequency

- Length of the object
- Size of the object
- Nature of the material
- Elasticity

Q. If the tuning forks shown in the picture are excited in the same way, will the sounds produced be the same or different? Why?

A. The sounds will be different.
Reason: The natural frequencies of the tuning forks shown in the picture are different.

Forced Vibration

Forced Vibration Forced vibration is the vibration of an object caused by an external vibrating object.

Examples

When a tuning fork is excited and its stem is placed on a table, the table also vibrates

When the phone in our hand vibrates, we feel the vibration in our hands.

When lightning happens, the windows in the buildings vibrate and make sound.

- The object that undergoes vibration, the object being vibrated will vibrate at the same frequency as the object that causes it to vibrate

Q. When the stem of the excited tuning fork is pressed on the table, the sound becomes louder. why ?

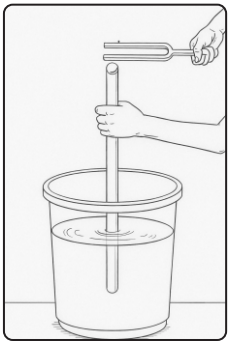
A. The table vibrates because of forced vibration. Since the table has a larger surface area, it makes the sound louder.

Resonance

- If the natural frequency of the forcing object and that of the forced object are equal, the objects are said to be in resonance.
- Objects that undergoing resonance will vibrate with maximum amplitude.

Resonance: frequency of forcing object = frequency of forced object

Resonance Column Experiment



- Take a beaker with water and place a PVC pipe in it, as shown in the image. Excite a tuning fork and hold it at the top of the pipe.

Observations :

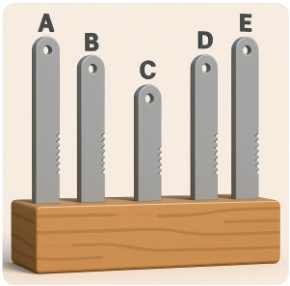
Due to the vibration of the tuning fork, the air column inside the pipe also starts vibrating, causing resonance. This results in sound coming from the pipe.

- Repeat the experiment by raising and lowering the pipe, which changes the length of the air column inside. At a particular length, the sound becomes louder. Why ??

Reason :

At this particular point, the frequency of the tuning fork and the frequency of the air column inside the pipe become equal. This means that both the tuning fork and the air column are in resonance, causing the air to vibrate with greater amplitude, which produces a louder sound.

Q. Five hacksaw blades are fixed between wooden blocks as shown in the picture. The lengths of blades A and D are the same. Similarly, the lengths of B and E are the same.



a) When blade C is tapped with a finger, all other blades (A, B, D, and E) also start vibrating. What is this phenomenon called?

b) In this case, will the vibrating frequency of the other blades be equal to the frequency of blade C ?

c) Why does blade D vibrate with greater amplitude when blade A is excited?

d) If we want blade B to vibrate with the greatest amplitude, which blade should be excited, and why?

ANSWERS

a) Forced vibration

b) Yes

c) Blade A and blade D are equal in length, so they have the same natural frequency. when A is excited, resonance happens in D, causing it to vibrate greater amplitude

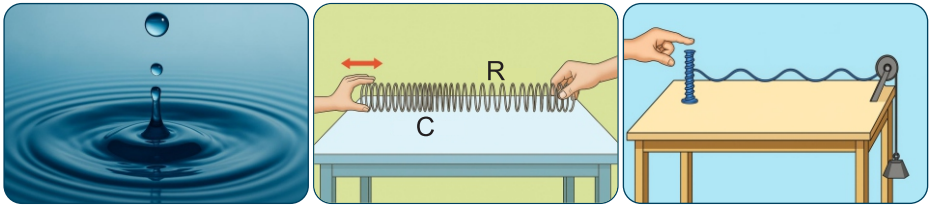
d) We should excite blade E, because blade B and E are of the same length.. they have the same frequency, so resonance will occur, and blade B will vibrate with the greater amplitude.

Applications of forced vibration and resonance

MRI scanning | Radio tuning | In musical instruments like guitar, violin, veena, harmonium, trumpets, nagaswaram, mridangam etc | In stethoscope | megaphones | horns

Wave Motion

The continuous transfer of energy from one part to another through oscillation is called wave motion



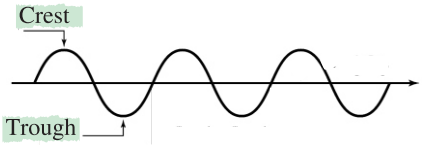
Examples :

Radio Waves | Seismic Waves | Light Waves | Sound Waves
Ripples on the surface of water | Microwaves | Infrared etc...

Waves can be classified into two types

Electro magnetic waves	Mechanical waves
Waves that do not require a medium for transmission Examples: Radio Waves, Microwaves, Infrared Waves, Visible Light, Ultraviolet Waves, X-rays, Gamma Rays	Waves that require a medium for transmission Examples: Sound Waves, Seismic Waves, Waves on a String etc...

Mechanical waves are classified into TWO

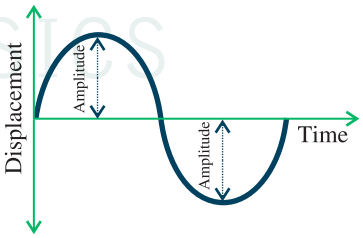
Longitudinal Waves	Transverse waves
Particles in the medium vibrate parallel to the direction of wave propagation	Particles in the medium vibrate perpendicular to the direction of wave propagation
	
Compressions (C) and Rarefactions (R) are formed	Crests and troughs are formed
Pressure variations occur in the medium	No pressure variations occur in the medium
Example : Sound waves, Pressure waves in a slinky.	Example : Light waves, Electromagnetic waves, Ripples on the surface of water.

Characteristics of Waves

1) Amplitude (a)

Maximum displacement of particles from the equilibrium position

- SI unit: metre (m)



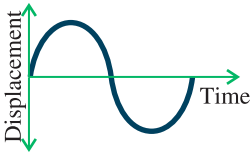
2) Period (T)

Time taken by the particle in the medium to complete one vibration (cycle)

$$T = \frac{1}{f} \qquad T = \frac{\text{Time}}{\text{Number of vibrations}}$$

- SI unit : second (s)

ONE Cycle..?



A cycle is one complete oscillation of a particle in wave motion.

1 Cycle = 1 Crest + 1 Trough

3) Frequency (f)

Number of cycles that passthrough a point in one second

- SI unit : Hertz (Hz)

$$f = \frac{1}{T} \qquad f = \frac{\text{Number of vibrations}}{\text{Time}}$$

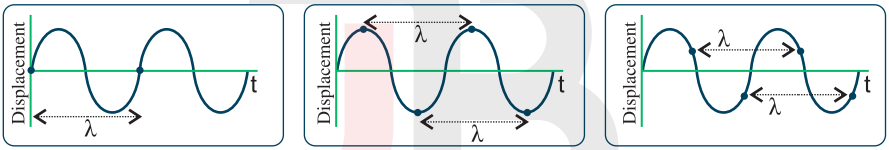
4) Wave Length (λ)

Wavelength is the distance between two consecutive particles which are in the same phase of vibration

- SI unit: metre (m)

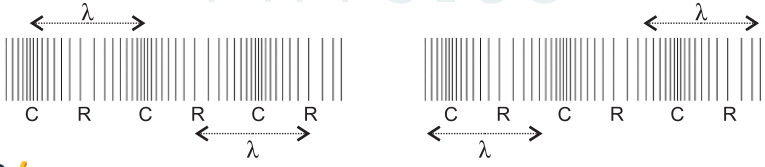
Wave length - in Transverse waves

- The distance between two consecutive crests or two consecutive troughs

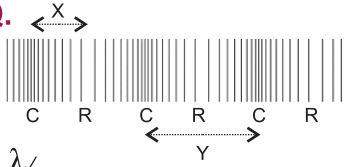


Wave length in Longitudinal waves

- The distance between two consecutive Compressions (C) or two consecutive Rarefactions (R)



Q.



a) What does the distance 'x' in the picture indicate ?
$(\lambda, \lambda/2, \lambda/4, 2\lambda)$

b) What does the distance 'y' in the picture indicate?
$(\lambda, \lambda/2, \lambda/4, 2\lambda)$

A. (a) $\lambda/2$

(b) λ

5) Speed of Wave (v)

It is the distance traveled by the wave in one second

$$\text{Speed of wave (v)} = \frac{\text{Total distance traveled}}{\text{Time}}$$

- SI unit : m/s

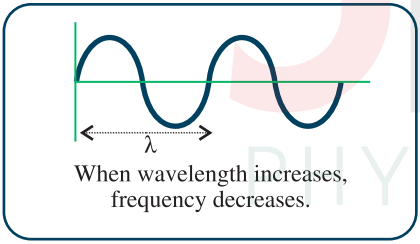
Q. If a wave travels 700 m in 2 s, what is the speed of the wave?

A. $\text{Speed of wave (v)} = \frac{\text{Total distance traveled}}{\text{Time}} = \frac{700}{2} = 350 \text{ m/s}$

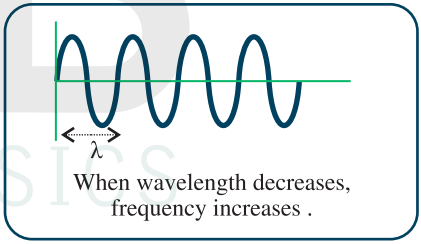
Relation between frequency and wavelength

- When the speed is constant, frequency of the wave is inversely proportional to the wavelength.

$$f \propto \frac{1}{\lambda}$$



When wavelength increases, frequency decreases.

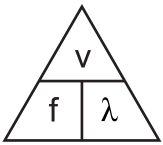


When wavelength decreases, frequency increases .

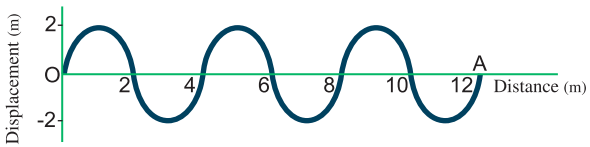
The relation between the speed of wave (v), frequency (f) and wavelength (λ)

Speed of wave = frequency x wavelength

$$v = f\lambda \qquad f = \frac{v}{\lambda} \qquad \lambda = \frac{v}{f}$$



Q.



a) How many crests and troughs are in the figure?
b) What is the wavelength?
c) What is the amplitude?
d) If the wave takes 6 seconds to reach A from O, what is the frequency?
e) What is the speed of the wave?

A. a) Crest : 3, Trough : 3
b) 4m
c) 2m
d) $f = \frac{\text{No of vibrations}}{\text{Time}} = \frac{3}{6} = 0.5\text{Hz}$
e) $v = f\lambda$
$v = 0.5 \times 4 = 2\text{m/s}$

Q. If the frequency of a longitudinal wave travelling at a speed of 350 m/s in the air is 35Hz
a) What is the distance between two consecutive compressions of this wave?
b) What about the distance between two consecutive rarefactions?

A. a) $f = 35\text{Hz}$, $v = 350\text{ m/s}$

$$\lambda = \frac{v}{f} = \frac{350}{35} = 10\text{m}$$

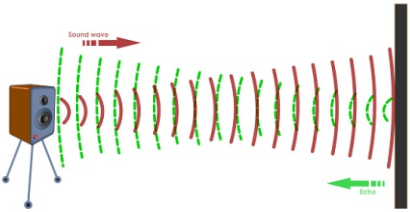
b) 10m

Q. A sound wave with a frequency of 175 Hz has a wavelength of 2 m. Calculate the speed of sound.

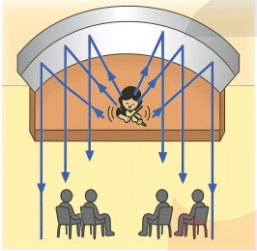
A. $f = 175\text{Hz}$, $\lambda = 2\text{m}$
$v = f\lambda = 175 \times 2 = 350\text{ m/s}$

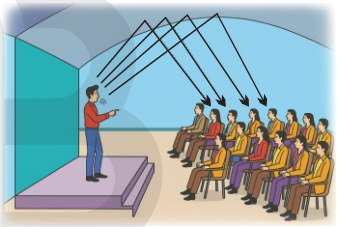
Reflection of sound

- It is the bouncing back of sound waves when they hit a surface or object.
- Sound is reflected more on a smooth surface (Loudness will be more)
- Sound is reflected less on a rough surface. (Loudness will be less)



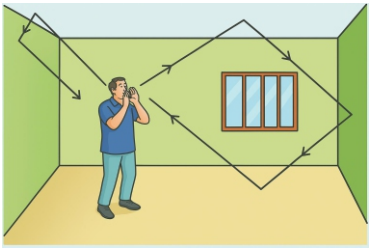
Reflection of sound is utilised in..


Sound boards


Curved ceilings in halls

These help reflect sound from the source and spread it across the hall Multiple Reflection of Sound

Multiple Reflection of sound



Reflected sound waves bounce back again. This is called multiple reflection of sound

Persistence of hearing

- Persistence of Hearing The sound we hear lasts for about 1/10th of a second (0.1 seconds) after it stops. This is called persistence of hearing.
- If another sound reaches the ear at this time, it will seem as if the two sounds are heard together

Echo

- Echo is the sound heard after a while due to the reflection of the initial sound
- To hear an echo, the reflecting surface must be at least 17.5 meters away from the sound source.

Reverberation

- Reverberation is the lingering of sound even after the original sound has stopped.
- It happens due to multiple reflections of sound, and the sound gradually fades away.

Q. Why are the walls of large halls like cinema theaters made rough?

A. To reduce echo and reverberation by absorbing sound.

Q. The echo of fire cracker (kathina) is heard after 1 s by the person who burst it. How far is the reflecting surface from the person hearing the echo?
(speed of sound in air is 350 m/s).

A. Speed of sound in air = 350 m/s

Total distance Traveled by the sound = 2d

$$\text{Speed of sound} = \frac{\text{Total distance traveled}}{\text{Time}}$$

$$350 = \frac{2d}{1}$$

$$350 = 2d$$

$$\frac{350}{2} = d$$

$$d = 175\text{m}$$

The reflecting surface will be 175 m away.

Q. What should be the minimum distance between the source and the reflecting surface to hear the echo in water?
(Consider the speed of sound in water as 1480 m/s)

A. Distance = Speed x Time

$$2d = 1480 \times \frac{1}{10}$$

$$2d = 148$$

d = 74 m

Limit of Audibility

- There are high and low frequency sounds in nature, but humans cannot hear all of them.

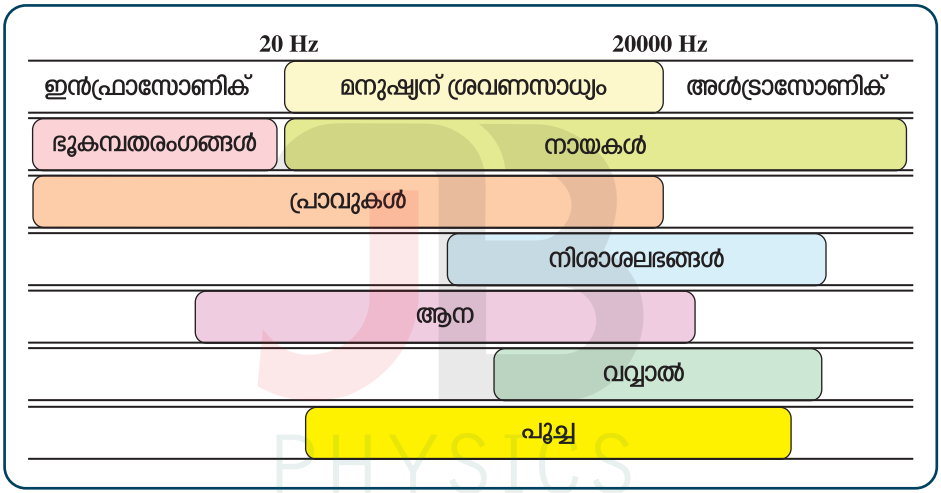
- For a person with normal hearing, the lower limit of audible sound is about **20 Hz, and the upper limit is about 20,000 Hz (20 kHz)**

Human Limit of Audibility:20 Hz – 20,000 Hz (20 kHz)

- **Infrasonic sound** has a frequency below 20 Hz, and **Ultrasonic sound** has a frequency above 20,000 Hz

"Humans cannot hear infrasonic and ultrasonic sounds."

Animals and Their Hearing Frequencies



- Animals like dogs, moths, bats, dolphins, and cats can hear ultrasonic sounds
- Pigeons, elephants, whales, and rhinoceroses can hear infrasonic sounds
- Using ultrasonic sound, bats can travel smoothly and catch prey easily, even in complete darkness

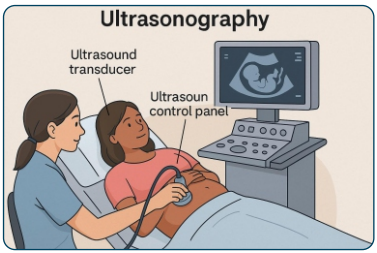
Q. Can humans hear the sound of the Galton whistle used to train dogs?

A. Humans are not able to hear it, because the frequency of the sound produced by a Galton whistle is about 30,000 Hz

Uses of Ultrasonic Waves

1) In physiotherapy
2)To crush small stones in the kidneys
3) Ultra Sonography

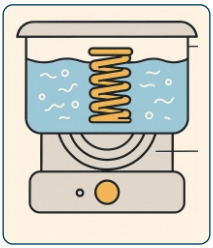
To take images of internal organs such as kidney, liver, gall bladder and uterus.



- **Working:** Ultrasonic waves that travel through body tissues strike and reflect at areas of varying density in the tissues. These waves are converted into electric signals to forman image of the organ

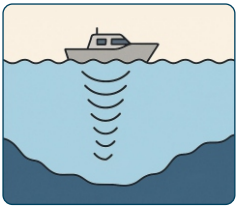
4. Ultrasonic Cleaning

Ultrasonic cleaning For cleaning spiral tubes, irregular machine parts, electronic components etc...



5. SONAR (Sound Navigation and Ranging)

SONAR is used to find the distance to the underwater objects



Q. If an ultrasonic wave emitted by a transmitter, installed on a ship on the surface of the water, strikes a rock at the bottom of the sea and returns after 0.2 s, what is the distance from the ship to the rock? Consider the speed of ultrasonic waves in seawater as 1522 m/s.

A. Distance = Speed x Time

$$2d = 1522 \times 0.2$$

$$d = \frac{1522 \times 0.2}{2} = 152.2\text{m}$$

Seismic Waves and Tsunami

- Seismic waves are vibrations that travel through the Earth's crust due to earthquakes, volcanic eruptions, or explosions.
- The study of seismic waves is called **Seismology**
- earthquake intensity is measured using the **Richter scale**

Tsunami Safety Measures:

- Follow instructions from official tsunami warning centres.
- Move to higher ground immediately after a warning.
- Avoid coastal areas until it is declared safe.
- Participate in community awareness and evacuation drills.

1. Find out the relation between the first pair and complete the other accordingly

   a) Wavelength : metre
      Frequency : .....
   b) Light waves : transverse wave
      Ripples on the surface of water : .....

2. What is the frequency of a wave that produces 50 crests and 50 troughs in 0.5 s?

3. What is the minimum distance required between the sound source and the reflecting surface to hear an echo in air?

4. Which of the following frequency can be heard by humans?

   a) 5Hz, b) 2000Hz, c) 200KHz, d) 50KHz

5. Write whether the following statement is true or false:
   "A shorter pendulum takes less time to complete one oscillation."

6. Match the following

A	B
Sound board	Seismic waves
SONAR	Reverberation
Multiple Reflections	Ultrasonic sound
Tsunami	Reflection
	Echo

7. Classify the following items from the list and write them down

Electromagnetic waves	Mechanical waves

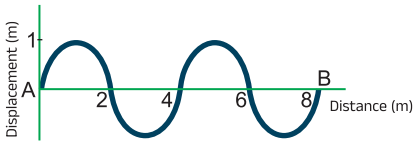
   (1) Radio waves (2) Sound waves (3) Seismic waves (4) Waves on a string

8. Give reasons for the following:
   (a) Ceilings in halls are constructed in an arched shape.
   (b) Windows vibrate when there is thunder.
   (c) The floors and walls of auditoriums are made rough.
   (d) Soldiers are not allowed to march on suspension bridges.

9. a) Which type of wave is produced as a result of an earthquake?
   b) On which scale is the intensity of an earthquake measured?

10. In which of the following situations echo is heard.
    a) Open space having no obstacles.
    b) A smooth reflecting surface at a distance of more than 17.5 m
    c) The reflected sound reaches the listener after 0.1 s

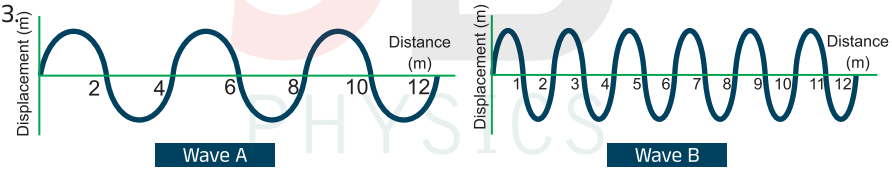
11.



The graphical representation of a sound wave is given below. It takes 4s for the wave to reach B from A.
    a) Find out the amplitude of the wave from the figure.
    b) Find out the frequency of the wave.
    c) How is the frequency of a wave related to the wave length?

12. A sound produced from a SONAR in a ship reached the bottom of a sea and came back in 8s. If the depth of the sea at that place is 6000 m, what is the speed of sound in sea water?

13.



The graphical representation of two waves of same amplitude is given below. Wave "A" needs 1s and "B" needs 4s to travel 12 m along its path.

    a) Find the wavelength of wave A?
    b) What is the speed of Wave B?
    c) Which wave has a higher frequency?
    d) How is frequency and wavelength related when velocity of the wave remains constant?

14. The upper limit of frequency of sound that a bat can hear is 120 kHz. If so, what is the maximum wavelength of sound it can hear? (Consider the speed of sound as 350 m/s.)

15. The distance between two adjacent troughs of a transverse wave is 2 m. Find the frequency if its speed is 20 m/s

16. A tuning fork vibrating at 512 Hz is held near the mouth of a resonance column. A slight increase in sound is heard.
    a) What is the vibration of air inside the resonance column called?
    b) Why does the sound become louder when the pipe inside the column is raised?
    c) What is the frequency of the vibrating air column when the sound is loudest?

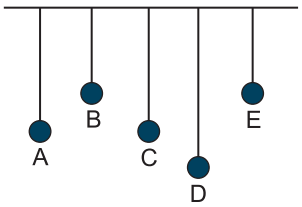
17. 

    a) What type of wave is shown in the figure?
    b) Write two characteristics of this wave.
    c) From the options given in brackets, choose the one that represents the wavelength (C_1R_1, C_1R_2, C_1C_2, C_1C_3)

18. Press the stem of an excited tuning fork of frequency 512 Hz on a table having a natural frequency of 384 Hz
    a) What is the frequency of vibration of the table at this instance?
    b) What is the change in the the loudness of the sound produced? Why?
    c) What phenomenon of sound would you observe if you press a tuning fork of natural frequency 384 Hz on the table? Explain

19. Write any three factors that affect the natural frequency of an object

20. Simple pendulums of different lengths are suspended from a common string as shown in the figure



    a) When only pendulum A is set into oscillation, the other pendulums also begin to oscillate. What is this phenomenon called?
    b) In this case, at what frequency will the other pendulums (B, C, D, and E) oscillate?
    c) When pendulum B is set into oscillation, which pendulum will oscillate at the highest frequency? Explain why.

UNIT TEST - 1 | **SOUND WAVES** | **MAX MARK: 20 TIME : 45 Min**

1. Which of the following shows the correct relationship between wave speed, wavelength, and frequency? (1)

   $v = \frac{f}{\lambda}$, $f = \frac{v}{\lambda}$, $\lambda = vf$, $f = v\lambda$

2. How is frequency and wavelength related when velocity of the wave remains constant? (1)

3. Some statements related to waves are given below. Tabulate them appropriately (2)

   - Particles in the medium vibrate parallel to the direction of wave propagation
   - Crests and troughs are formed
   - Compressions (C) and Rarefactions (R) are formed
   - No pressure variations occur in the medium

Transverse Wave	Longitudinal Wave

4. Find the frequency of a wave if it completes 2560 vibrations in 10s while propagating through a media. (2)

5. a) A person hears the echo of his voice after 4 seconds. Calculate the distance between him and the reflecting surface. (Take the speed of sound in air as 340 m/s.) (2)

   b) What special feature of the human ear makes hearing an echo possible? (1)

6. The speed of sound in air is 340 m/s. If sound waves with a wavelength of 0.01 m travel through the air from a vibrating object and reach your ear, will you be able to hear the sound? Justify your answer (3)

7. Explain an experiment related to resonance (4)

8. A sound signal from a ship on water reaches back to the ship 6 seconds after hitting a rock under the water. (The speed of sound in sea water = 1500m/s)

   a) In which wave form is sound propagated through water? (1)

   b) Which phenomenon of sound caused the return of sound signal to the ship? (1)

   c) Calculate the distance from the water surface to the rock. (2)