Class 9th

SOUND

“ Prashant Bhaiya ”

Topics to be Covered

- Sound
- Transverse and Londitudinal Waves
- Sound as longitudinal wave
- Reflection of sound wave
- Echo
- Reverberation
- SONAR system
- Characteristics of a wave
- Characteristics of sound
- Human Ear

Sound

- **Sound is a form of energy which creates a sensation of hearing when it reaches the ear.**

- *Law of conservation of energy is also applicable to sound.*

Sound is produced by vibrating objects.
For example: Striking a tuning fork, Vibrating vocal cords (human voice)

Vibration : is a rapid back-and-forth motion of an object.




How Sound is Produced?

- The substance through which sound travels is called a **medium**. A medium can be a solid, liquid, or gas.

Process of Sound Propagation:

When an object vibrates, it causes the air particles around it to vibrate in the same way, displacing them from their stable positions.

→

These vibrating air particles exert a force on neighboring particles, causing them to also vibrate and move from their rest positions.

→

This chain reaction continues throughout the medium, transferring the disturbance until it reaches our ears.

Note: It is the disturbance caused by the vibrations that travels through the medium, not the particles themselves.

Sound travels in the form of wave

Sound as a Wave:

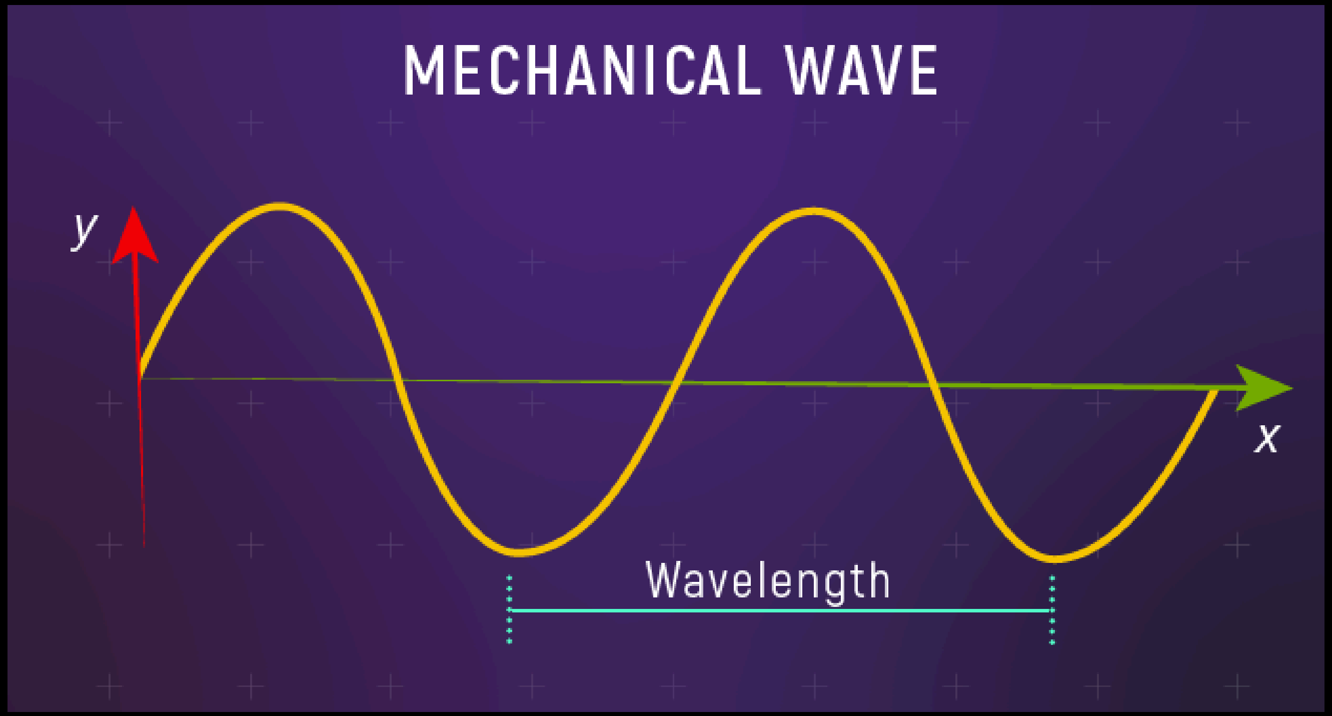
- A wave is a disturbance that travels through a medium, carrying energy.
- Sound travels in the form of mechanical waves, which require a medium to propagate.

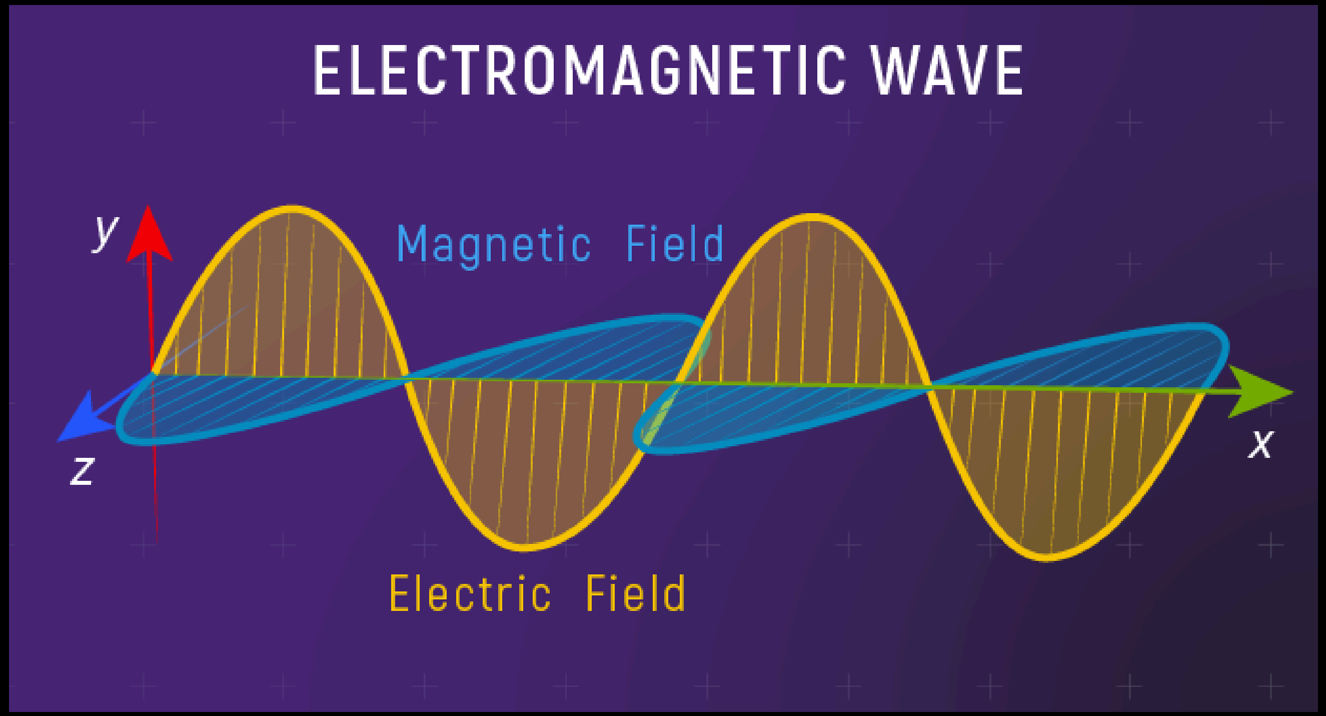
This mechanism allows sound to move efficiently through solids, liquids, and gases, enabling us to hear vibrations from various sources.

WAVES

- Electromagnetic Waves
- Mechanical Waves
  - Transverse Wave
  - Longitudinal Wave

Mechanical Waves	Electromagnetic Waves
Waves that require a medium to propagate.	Waves that do not require a medium to propagate.
Example: Sound waves	Example: Light waves
Cannot travel through a vacuum.	Can travel through a vacuum.



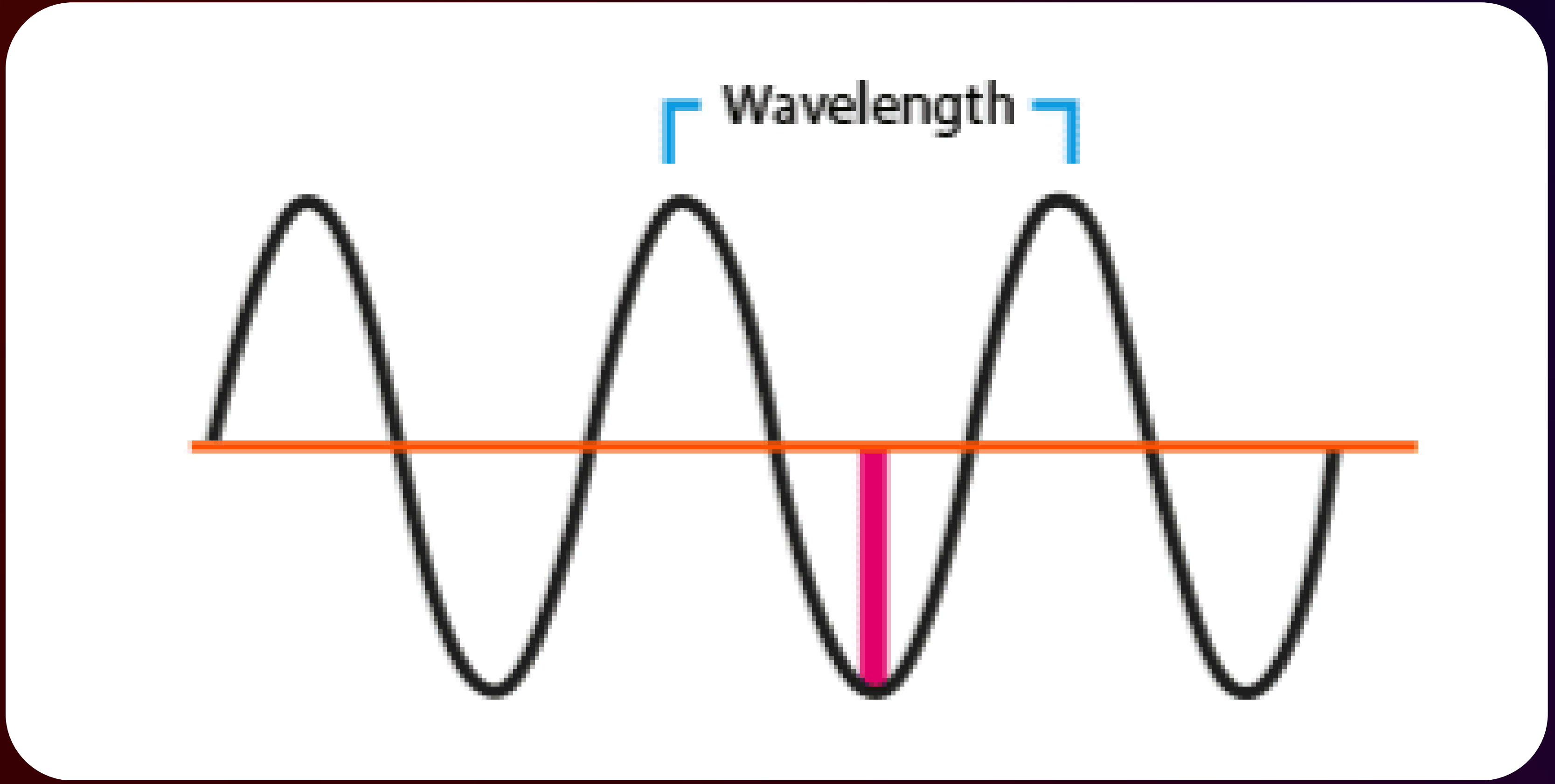


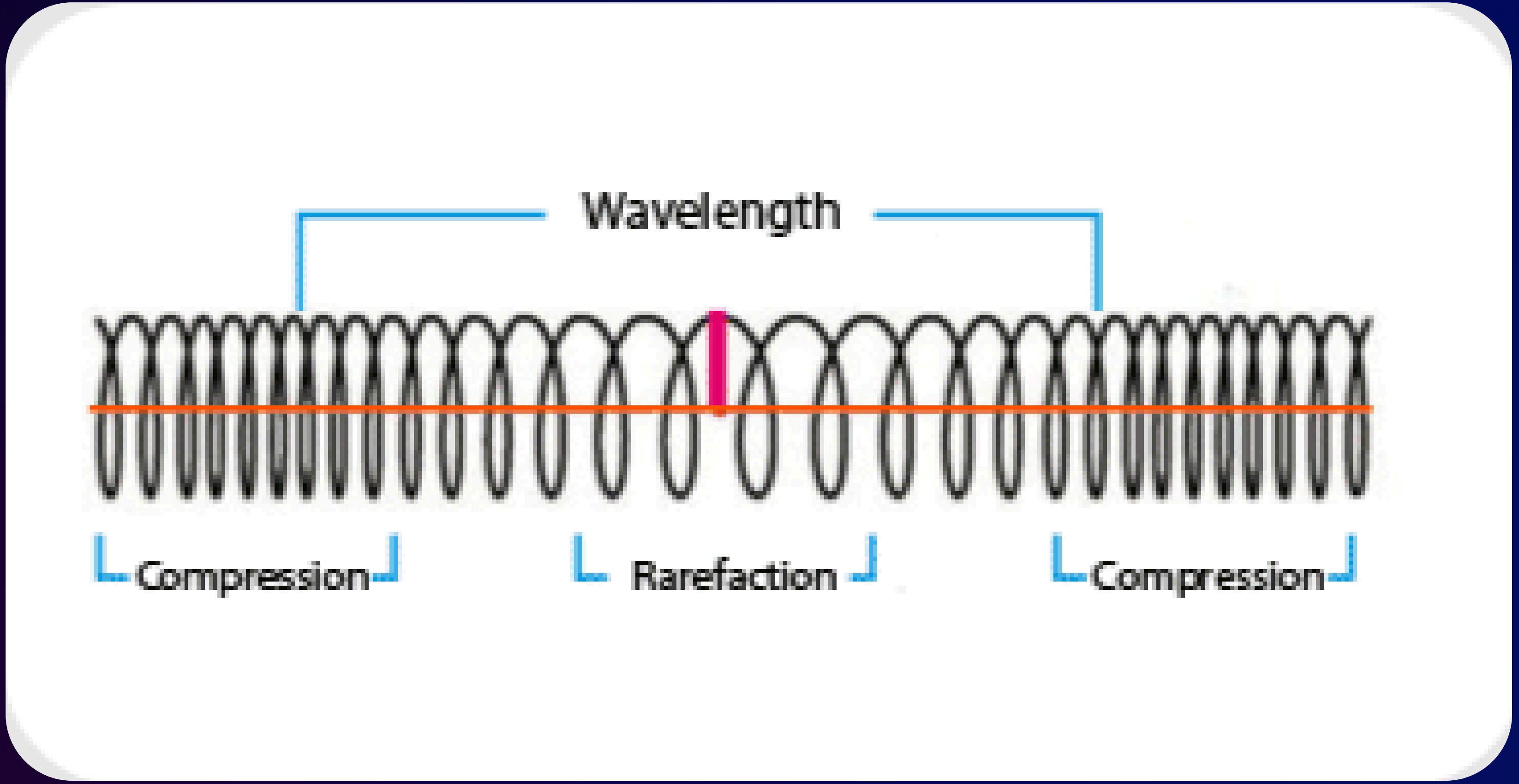
Q. State the difference between transverse and longitudinal waves.

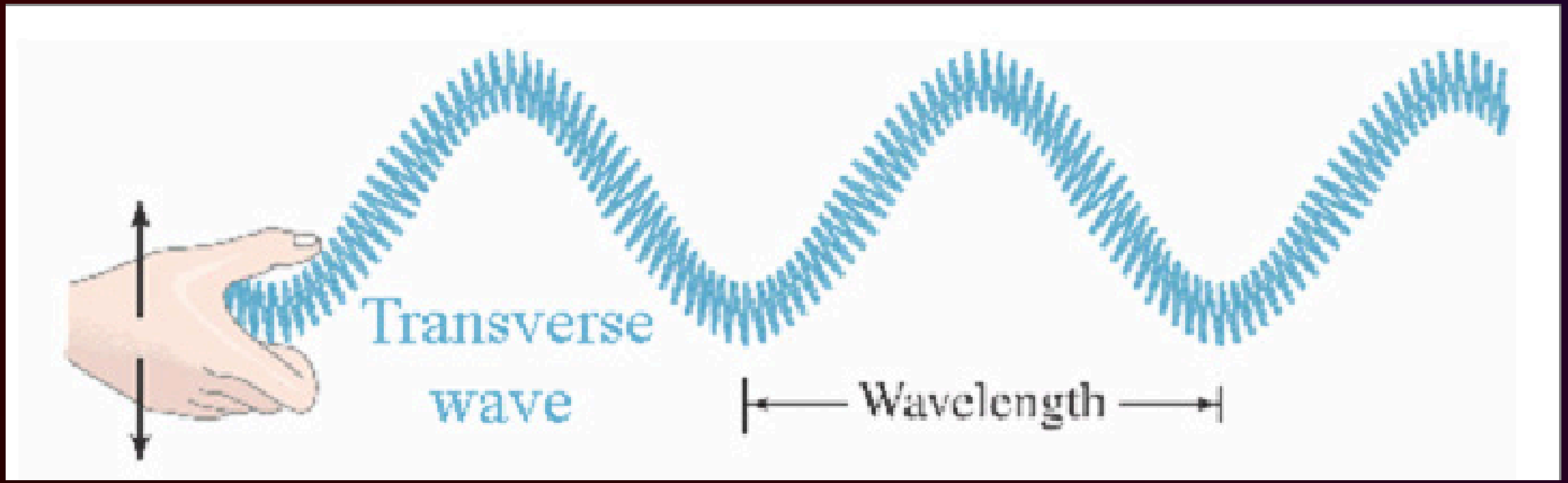
Transverse Waves	Longitudinal Waves
Particles oscillate perpendicular to the direction of wave propagation.	Particles oscillate parallel to the direction of wave propagation.
Has crests (high points) and troughs (low points).	Has compressions (high-pressure regions) and rarefactions (low-pressure regions).
Examples: Light waves, water waves, and waves on a string.	Examples: Sound waves, waves in a slinky, and seismic P-waves.
Can travel without a medium (e.g., light in space).	Always requires a medium (e.g., air, water, or solid).
Do not require material medium particles to vibrate.	Mechanical in nature; requires vibration of medium particles.
Can be demonstrated using a rope.	Can be demonstrated using a stretched slinky.

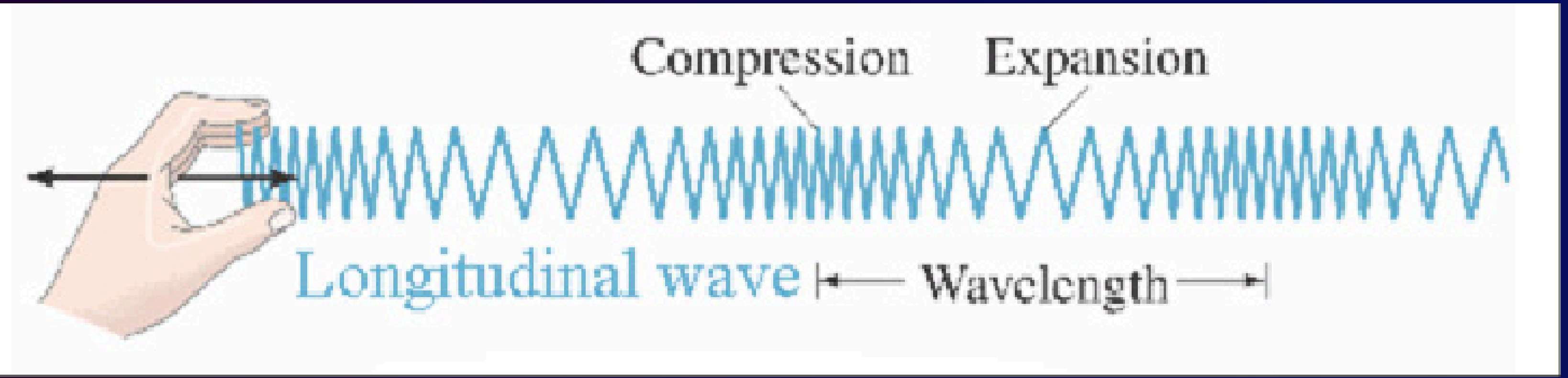
TRANSVERSE WAVES

LONGITUDINAL WAVES









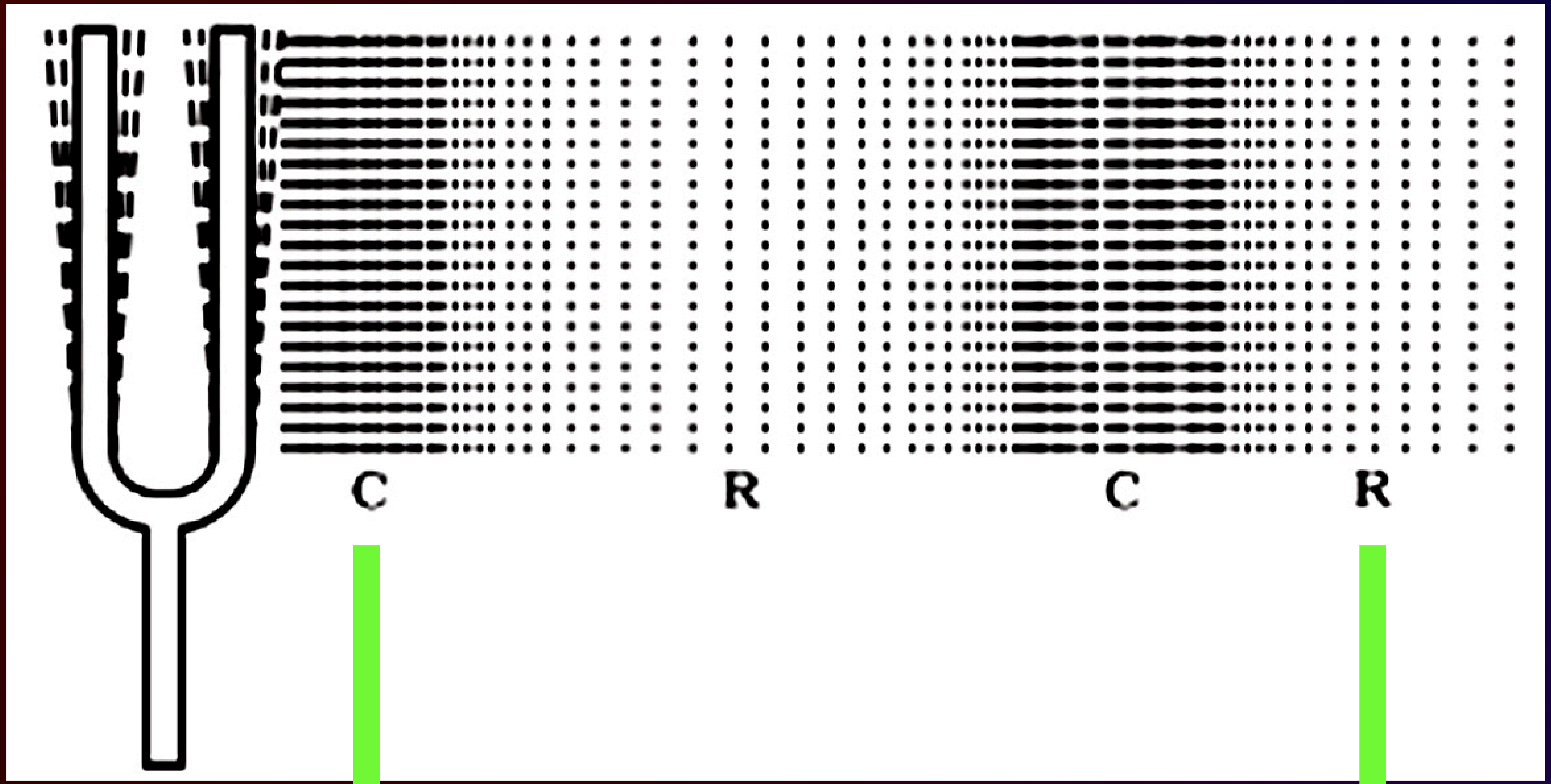
Feature	Compression	Rarefaction
Definition	Region where particles are closely packed, resulting in high pressure.	Region where particles are spread apart, resulting in low pressure.
Pressure	High pressure	Low pressure
Density	High density	Low density
Particle Arrangement	Particles are tightly packed together.	Particles are spread apart.
Motion of Particles	Particles move towards each other.	Particles move away from each other.
Occurs When	The vibrating object moves forward, pushing particles together.	The vibrating object moves backward, pulling particles apart.
Wave Type	Forms the part of the wave where energy is compressed.	Forms the part of the wave where energy is spread out.
Example	When a tuning fork vibrates and compresses air in front of it.	When the fork moves backward, creating a region with less air pressure.

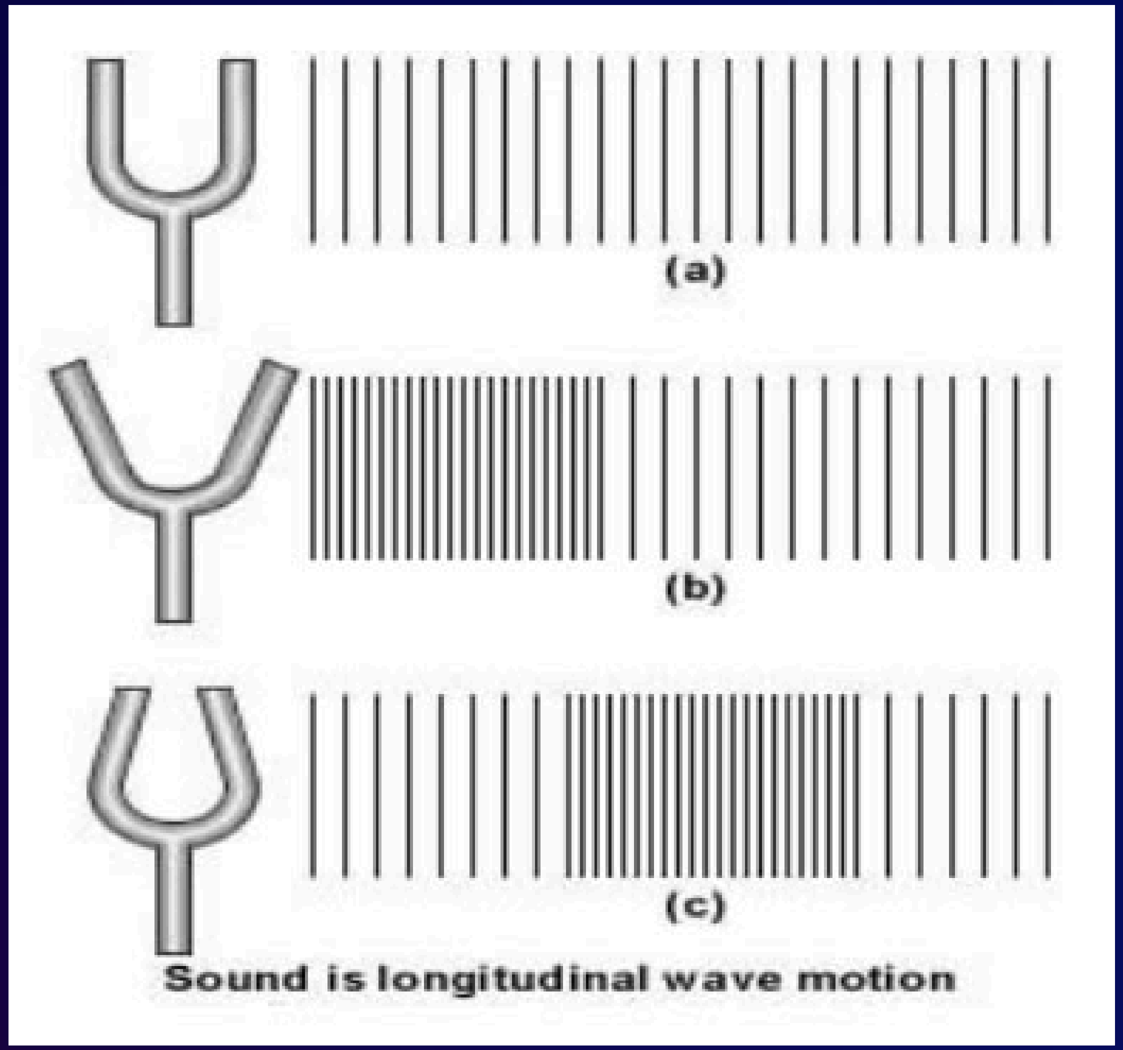
Sound waves as longitudinal waves:

Sound waves are longitudinal waves because the particles of the medium through which they travel vibrate parallel to the direction of wave propagation:

- When a sound is produced, it causes the surrounding particles (like air molecules) to oscillate back and forth along the direction in which the wave is moving.
- This creates regions of **compression** (where particles are close together) and rarefaction (where particles are spread out).
- These compressions and **rarefactions** move through the medium, transferring sound energy.
- Thus, sound waves are longitudinal because the particle motion (vibration) and wave direction are aligned.

Production of Sound waves





Compression

Rarefaction

SOUND NEEDS A MEDIUM TO TRAVEL

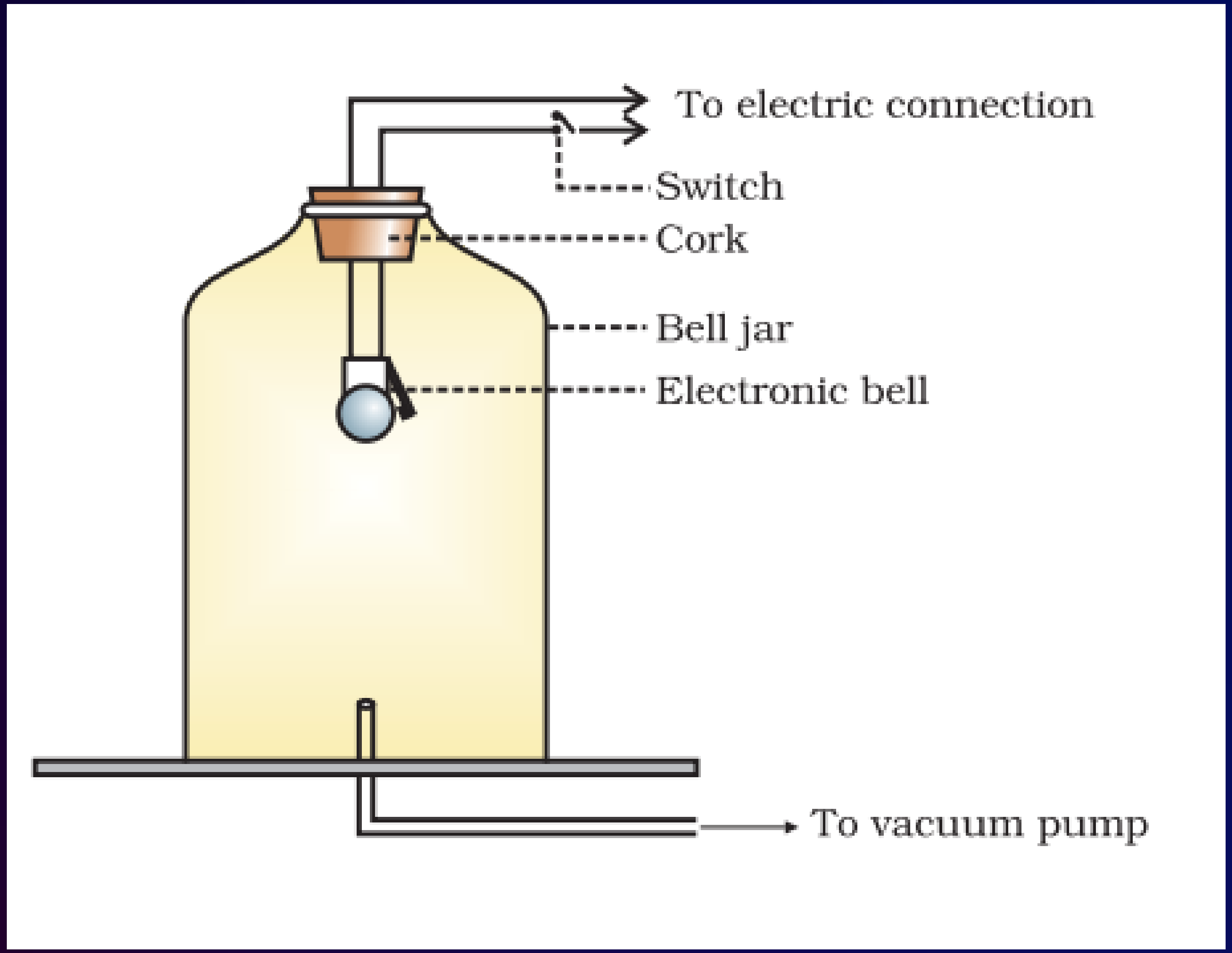
Experiment: Sound and Air Medium

Setup: Electric bell placed inside an airtight glass bell jar connected to a vacuum pump.

Observation:

- Bell rings, and sound is heard when air is present.
- As air is gradually removed using the vacuum pump, the sound becomes fainter.
- When most air is removed, only a very feeble sound is heard.
- If all air is removed (complete vacuum), the sound cannot be heard.

Conclusion: Sound requires a medium (like air) to travel. In a vacuum, sound cannot propagate.

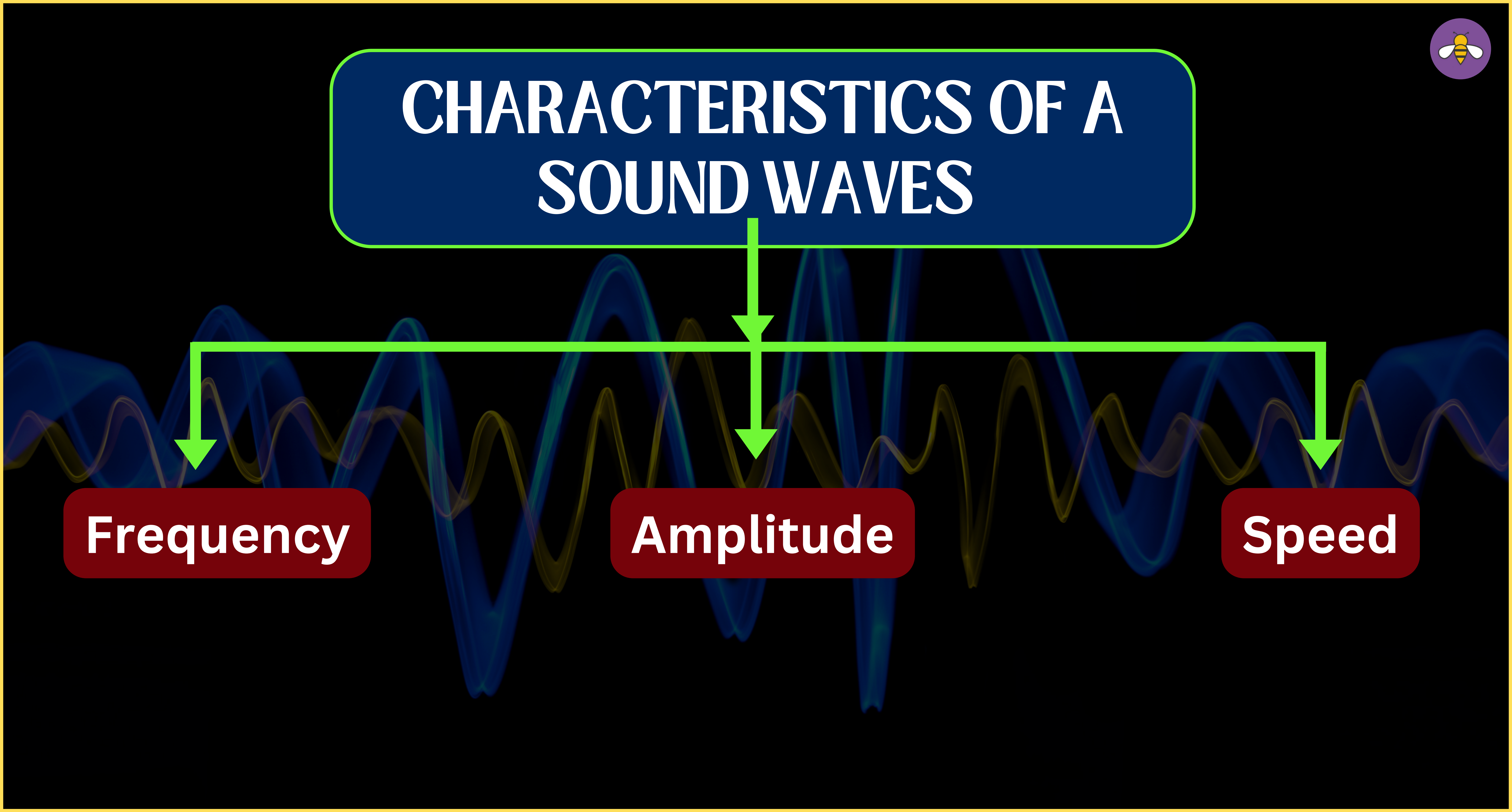


Q. Why are sound waves called mechanical waves?

A. Sound waves are called as mechanical waves because they require a material medium, like air, water or silver, to travel through. They cannot propagate in a vacuum.

Examples of mediums:

- Air: Communication and hearing.
- Water: Marine sound transmission.

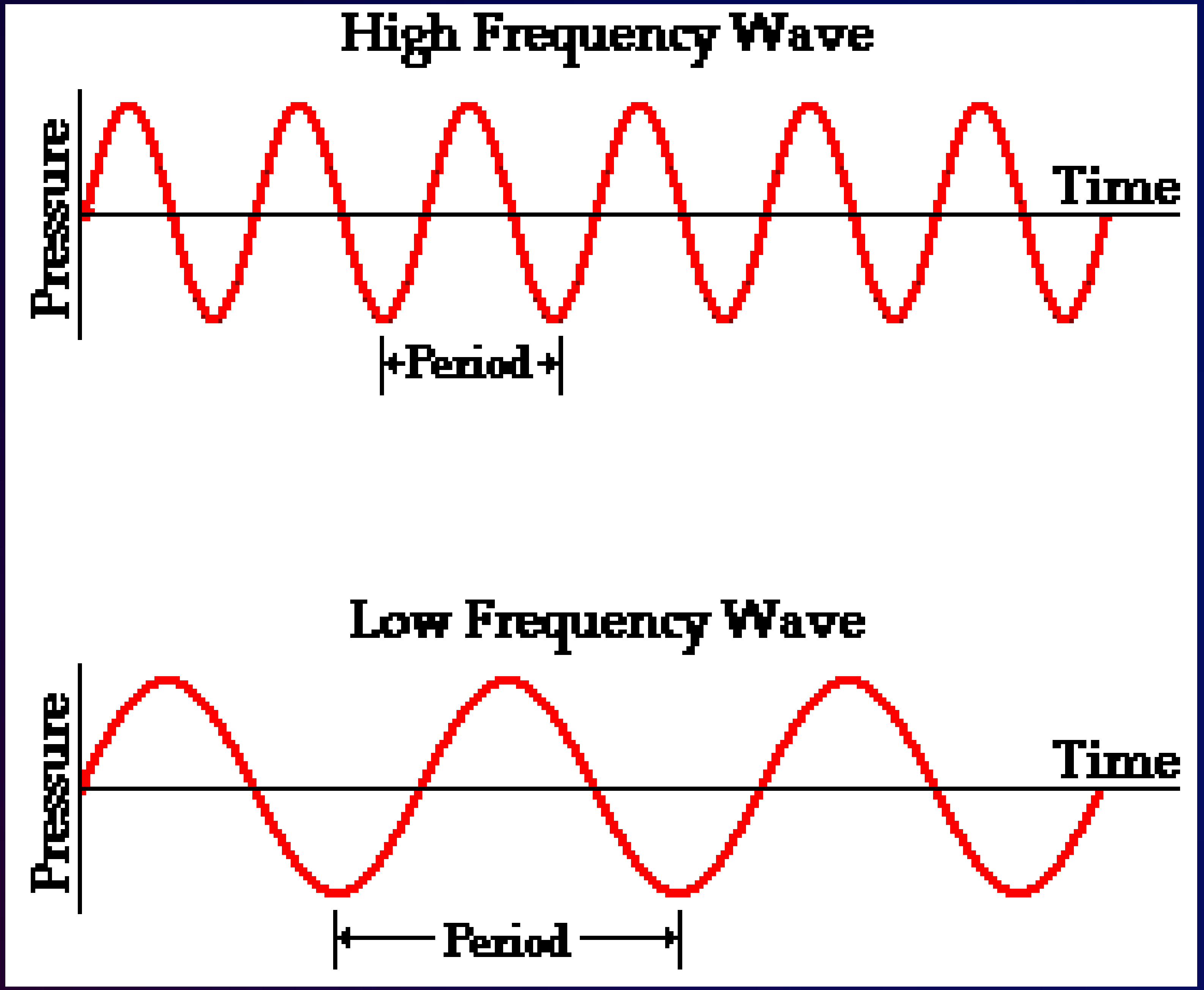

CHARACTERISTICS OF A SOUND WAVES
Frequency
Amplitude
Speed

Frequency (ν):

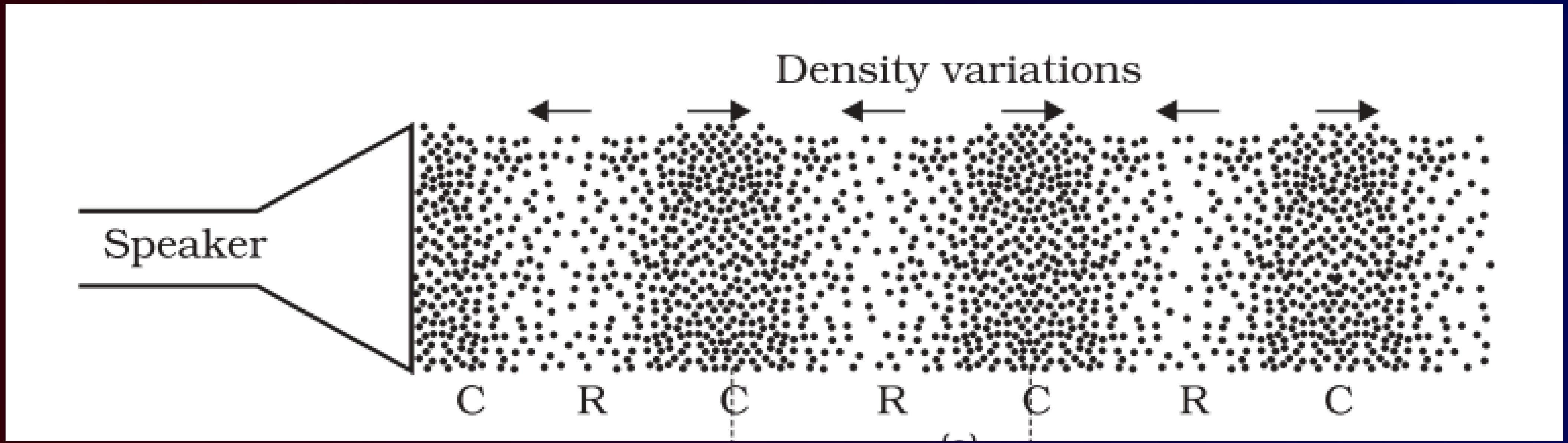
- **Frequency:** the number of oscillations (compressions and rarefactions) that pass a fixed point in one second.
- **SI Unit:** Hertz (Hz).
- **Related to the pitch of sound -** How the brain interprets frequency.

Higher frequency = Higher pitch.

- Example: A violin has a higher pitch due to its higher frequency compared to a drum.



Frequency (ν):



- When a sound wave propagates through a medium, the density of the medium oscillates between a maximum value (compression) and a minimum value (rarefaction).
- The time taken for one complete oscillation from maximum density to minimum and back to maximum defines the time period (T) of the wave.

$$T = \frac{time}{\#\ oscillations} \qquad f = \frac{\#\ oscillations}{time} \qquad T = \frac{1}{f}$$

Q. A tuning fork produces sound waves of frequency 500 Hz. Calculate the time period of the waves.

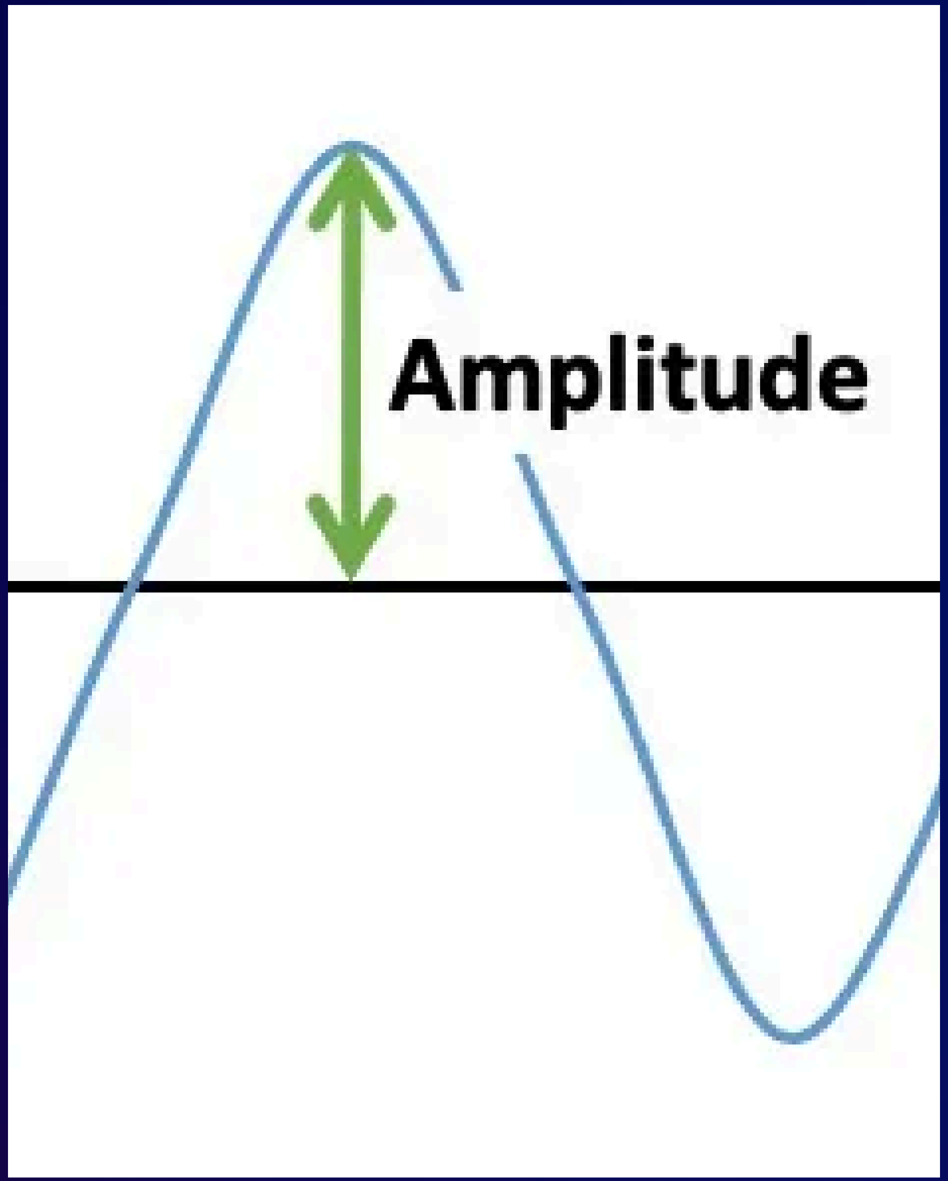
Amplitude (A):

The maximum displacement of particles from their equilibrium position during a wave oscillation.
Determines: Loudness of the sound.

- Loudness is a measure of the response of the ear to the sound

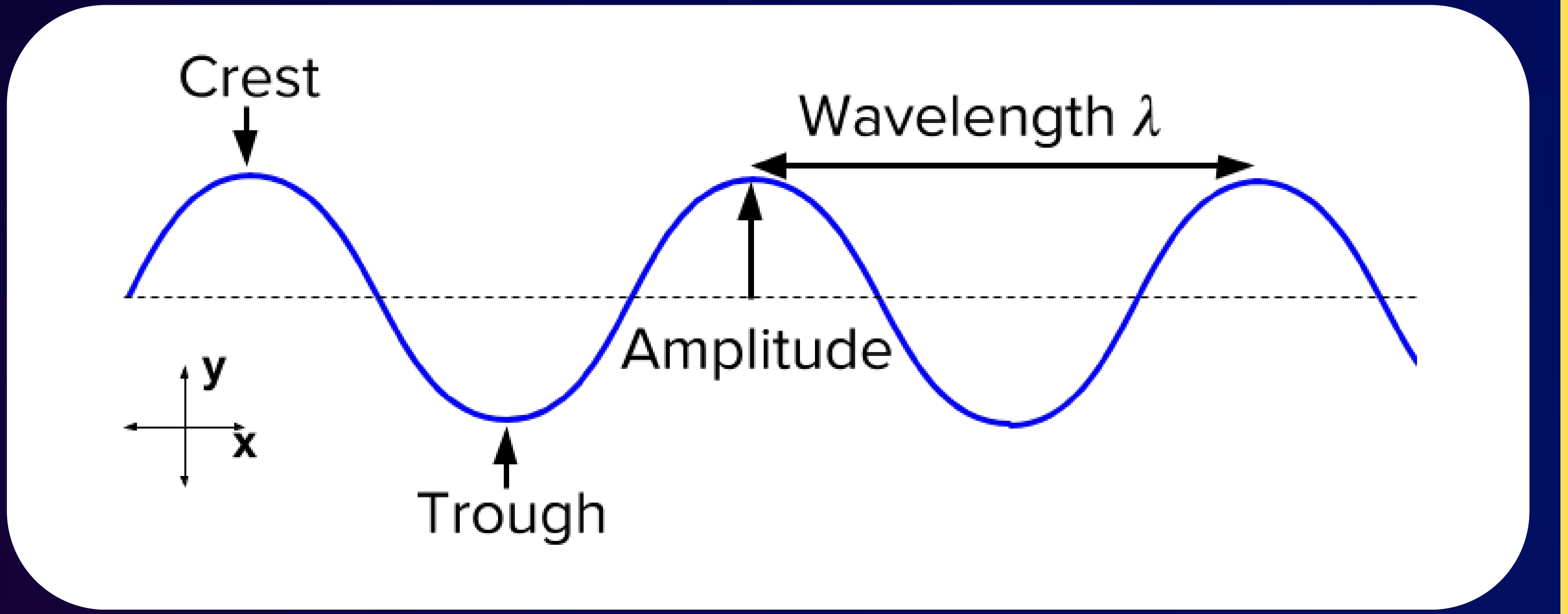
Larger amplitude → louder sound.
Smaller amplitude → softer sound.

- Behavior:
- As sound travels away from the source, its amplitude decreases, reducing its loudness.



Wavelength (λ):

The distance between two consecutive compressions (peaks or crests) or two consecutive rarefactions (troughs) in a sound wave.



- **SI Unit**: Meter (m).
- **Symbol**: lambda (λ).

- The wavelength is the physical distance over which the wave pattern repeats.

- Example: If a sound wave moves through air, the distance from one compression to the next compression or one rarefaction to the next rarefaction is its wavelength.

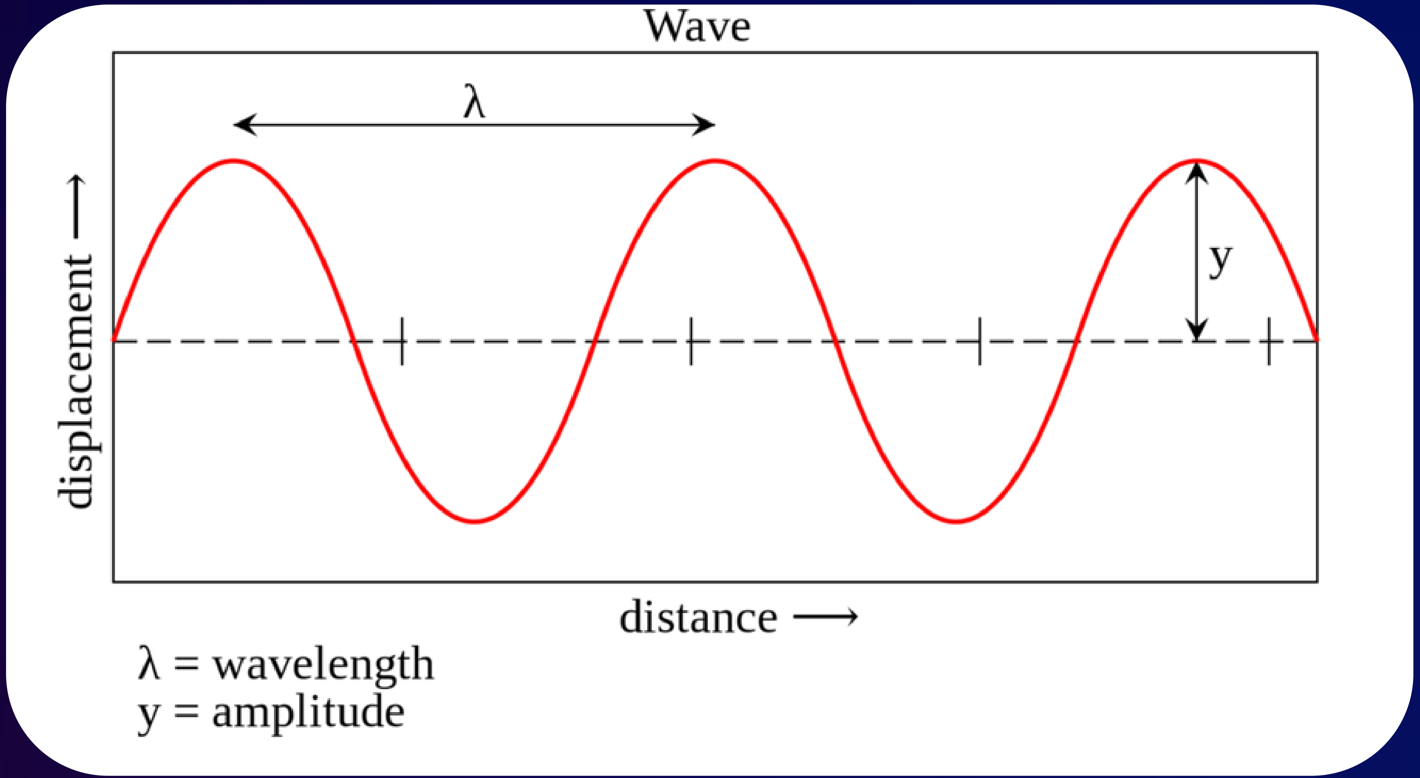
Speed (v):

- **The distance traveled by a sound wave per unit time.**

- **SI unit : m/s.**

Factors Affecting Speed:

- Depends on the nature of the medium (solid, liquid, or gas).
- Increases with temperature and density of the medium.
- Example: Sound travels faster in solids (e.g., iron) than in gases (e.g., air).



Speed of Sound in Different Media

Sound propagates at a finite speed, which is much slower than the speed of light. This explains why thunder is heard after lightning is seen.

- The speed of sound depends on the properties of the medium (solid, liquid, or gas) and its temperature.
- Sound travels **fastest in solids, slower in liquids, and slowest in gases**.
- As the **temperature of a medium increases, the speed of sound also increases.**
- Examples:
  - Speed of sound in air:
    - At 0°C: 331 m/s
    - At 22°C: 344 m/s

Table 12.1: Speed of sound in different media at 25 °C

State	Substance	Speed in m/s
Solids	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

Relation with between λ, v and ν

We know that, The speed of sound is defined as the distance a point on a sound wave (such as a compression or rarefaction) travels per unit of time.

Formula for Speed of Sound:

$$Speed = \frac{Distance}{Time} \rightarrow \mathrm{v} = \frac{\lambda}{T}$$

The frequency (ν\nuν) is related to the time period by

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

Substituting this into the equation:

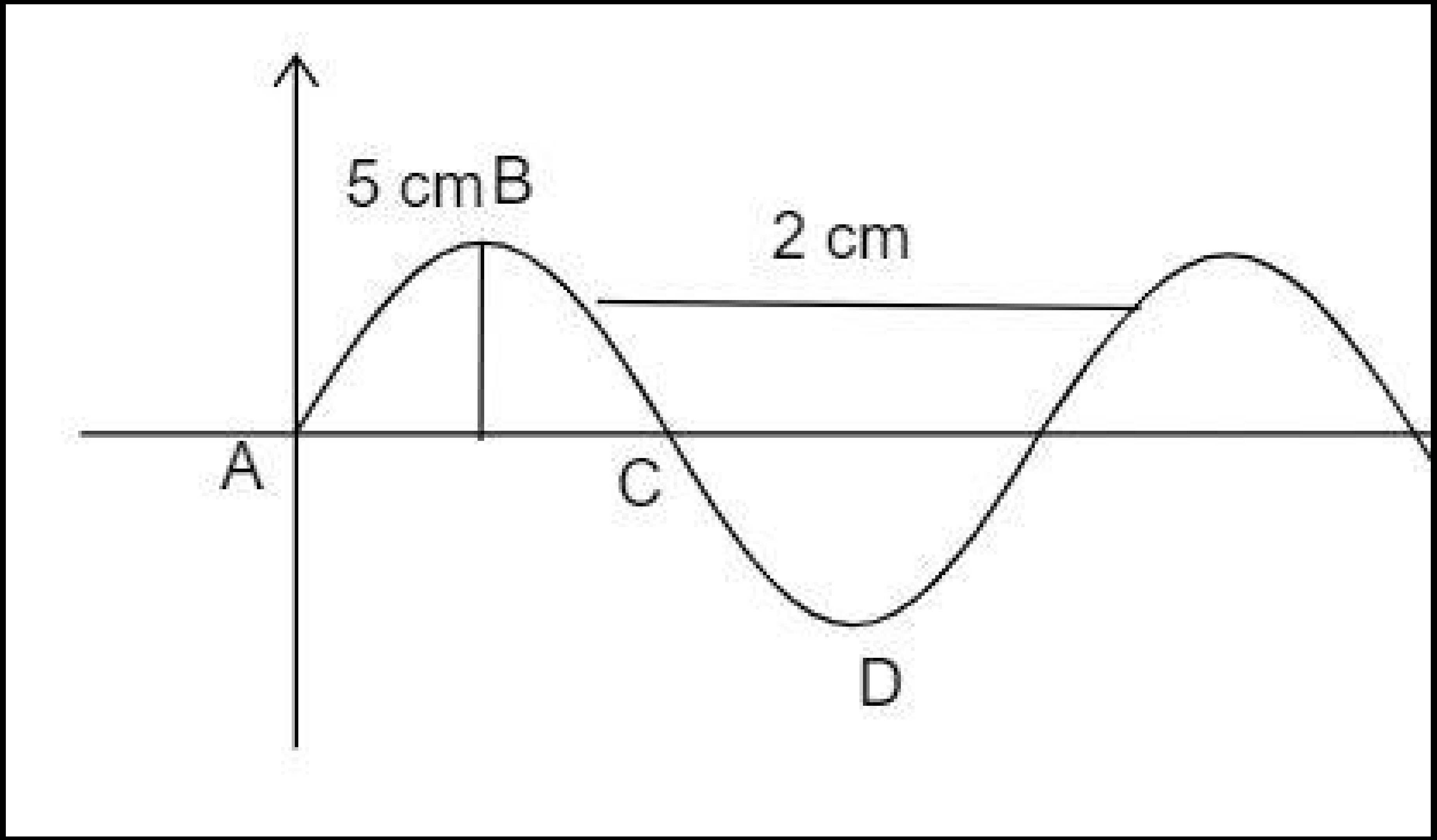
$$\mathrm{v} = \lambda\nu$$

Hence, the speed of sound = wavelength × frequency.

Q. A sound wave has a frequency of 2 kHz and a wavelength of 0.5 m. Calculate its speed.

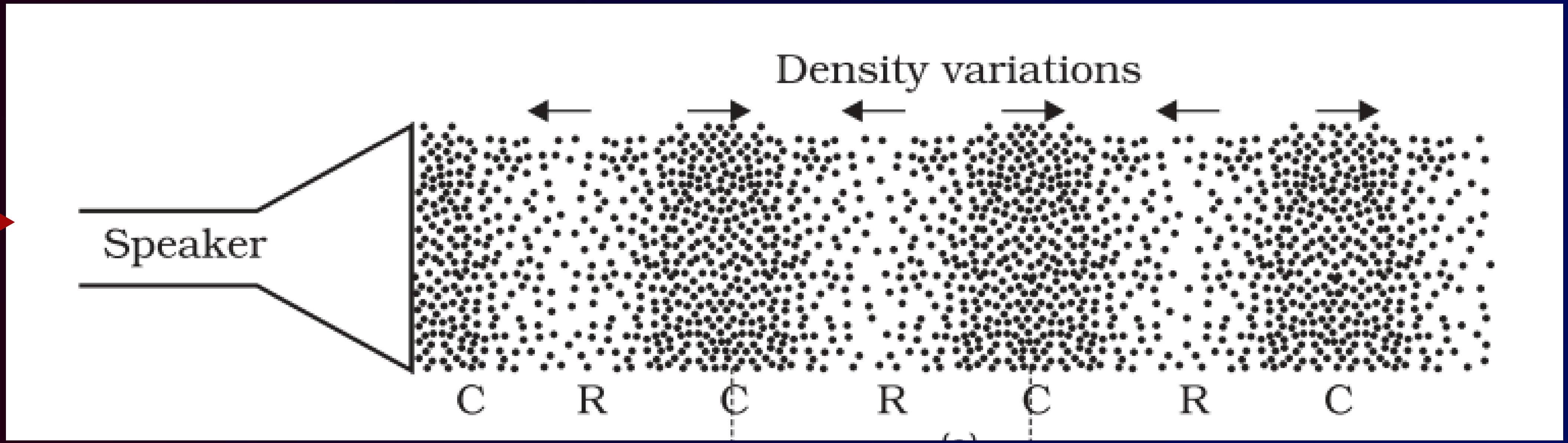
Q. A person hears the sound of a thunderclap 4 seconds after seeing the lightning. If the speed of sound in air is 340 m/s, calculate the distance of the thundercloud.

Q. In the figure, it is given that the wave of frequency 100Hz is produced in the string. Find its amplitude, wavelength, velocity and nature of the wave.

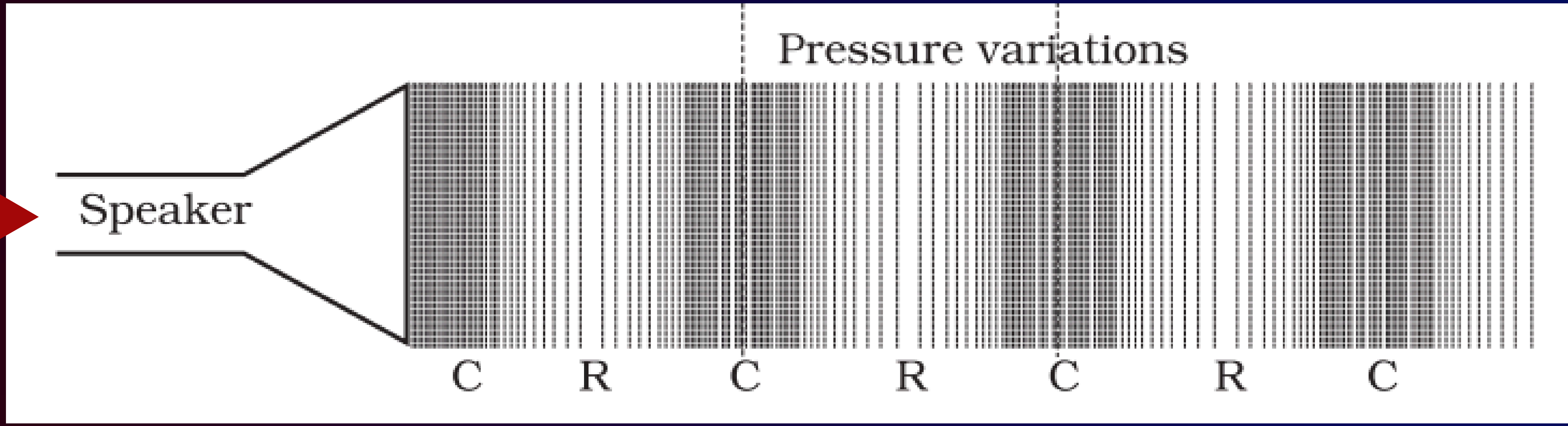


Q. A person is listening to a sound of 500 Hz while sitting at a distance of 450 m from the source of the sound. What is the time interval between successive compressions reaching the person from the source?

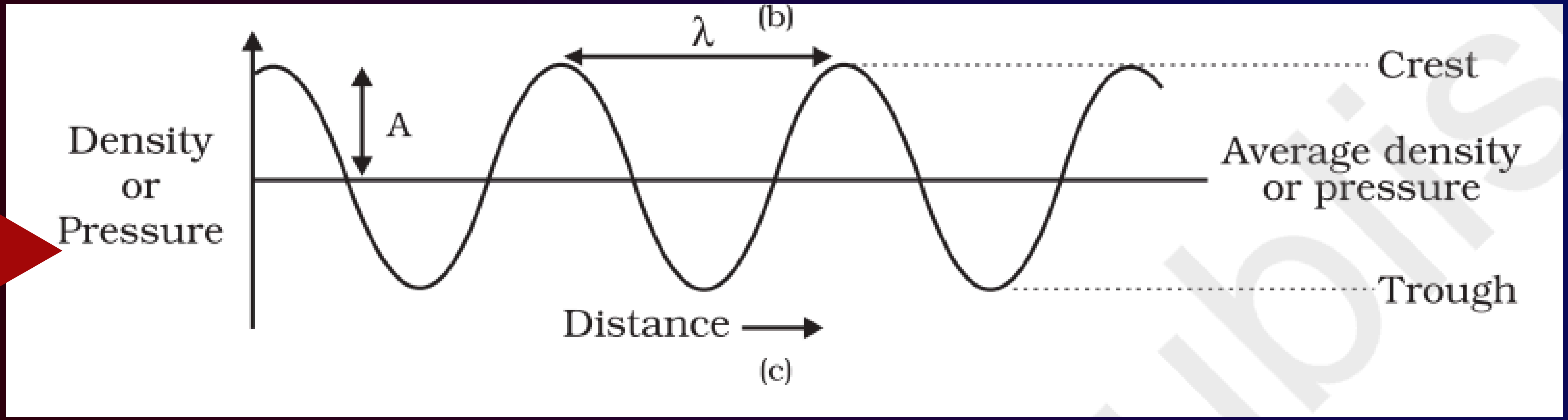
Effect of sound on density:



Effect of sound on pressure:



Graph for the density and pressure variations:



All Important Terms!

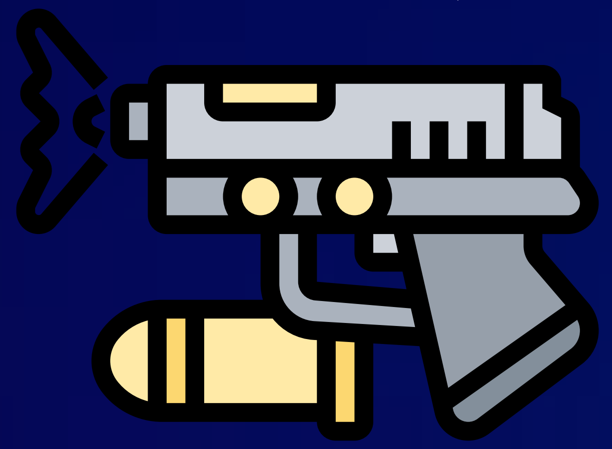
Term	Definition
Compression (C)	The region in a sound wave where particles are crowded together, resulting in high density and pressure. Represented by the peaks in the wave graph.
Rarefaction (R)	The region in a sound wave where particles are spread apart, resulting in low density and pressure. Represented by the troughs in the wave graph.
Wavelength (λ)	The distance between two consecutive compressions or rarefactions in a sound wave. Its SI unit is metre (m).
Frequency (ν)	The number of oscillations or waves passing a given point per unit time. It is represented by the Greek letter nu (ν) and its SI unit is Hertz (Hz).
Time Period (T)	The time taken for one complete oscillation of the wave (from one compression to the next or one rarefaction to the next). Its SI unit is seconds (s).
Amplitude (A)	The maximum disturbance or displacement in the medium from its mean position. It determines the loudness of sound; larger amplitude means louder sound.

Term	Definition
Pitch	How the brain interprets the frequency of sound. Higher frequency results in a higher pitch.
Loudness	The measure of the ear's response to sound, dependent on the amplitude of the sound wave. Louder sounds have greater amplitude and energy.
Intensity	The amount of sound energy passing through a unit area per second. Intensity is a physical property and independent of human perception.
Speed of Sound (v)	The distance traveled by a sound wave in a unit of time. It is the product of wavelength and frequency: $v=\lambda\nu v = \lambda\nu v=\lambda\nu$. The speed of sound remains almost constant for all frequencies in the same medium under identical conditions.
Trough	The lowest point in a sound wave, corresponding to rarefaction.
Crest	The highest point in a sound wave, corresponding to compression.
Mechanical Wave	A wave, such as sound, that requires a medium (solid, liquid, or gas) to propagate.

Supersonic Speed and Sonic Boom

Supersonic Speed: When an object travels faster than the speed of sound, it is moving at supersonic speed.

- Examples: Bullets, jet aircraft.



Sonic Boom:

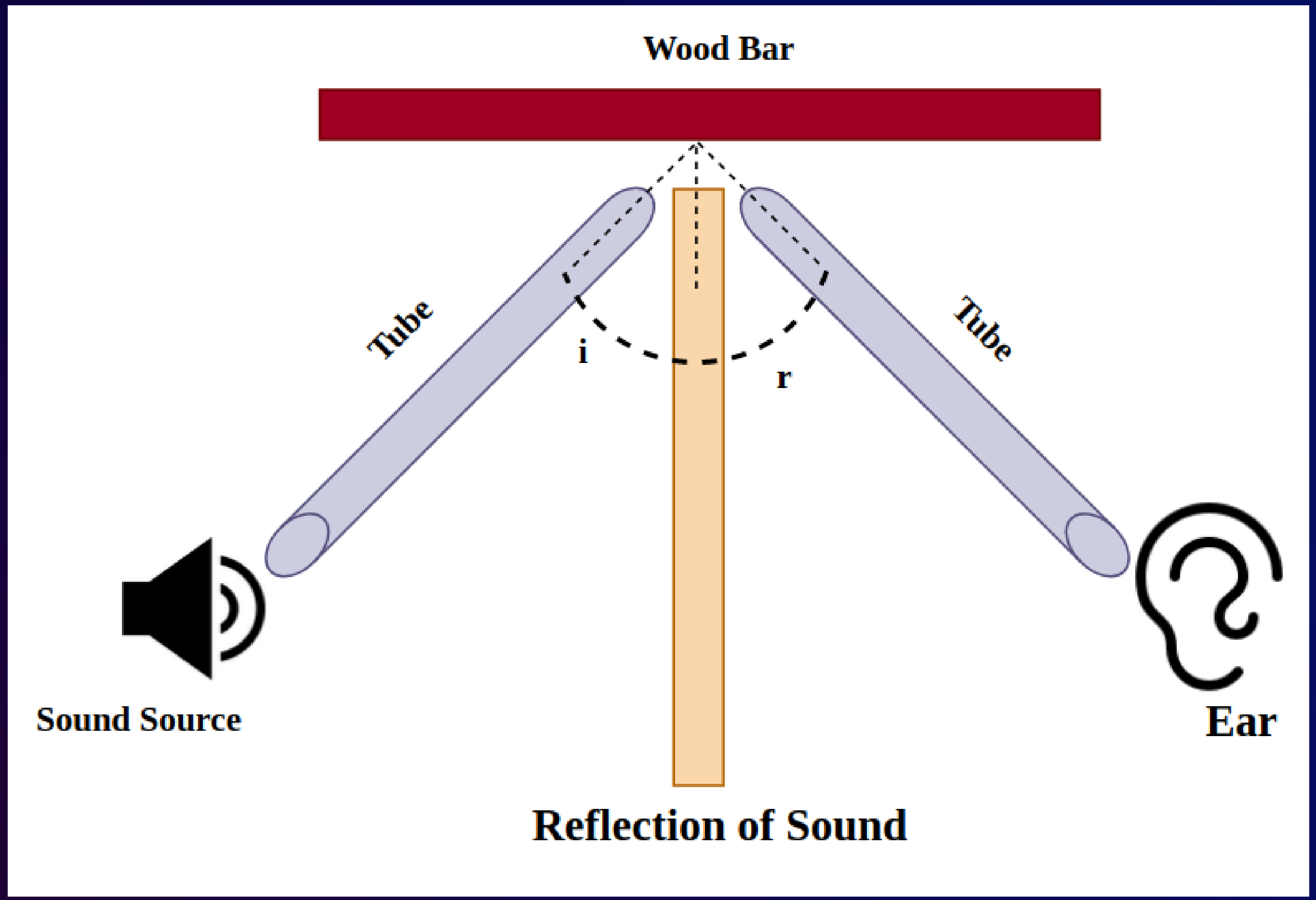
- A sharp and loud sound produced when a supersonic object generates shock waves in the air.
- These shock waves carry significant energy, causing intense air pressure variations.
  - Effects: Can shatter glass.
    - May damage buildings

Reflection of Sound

Like light, sound also bounces back when it falls on a hard surface. It is called reflection of sound. The laws of reflection of light are also applicable to reflection of sound.

i. The incident sound wave, the reflected sound wave and normal at the point of incidence lie in the same plane.

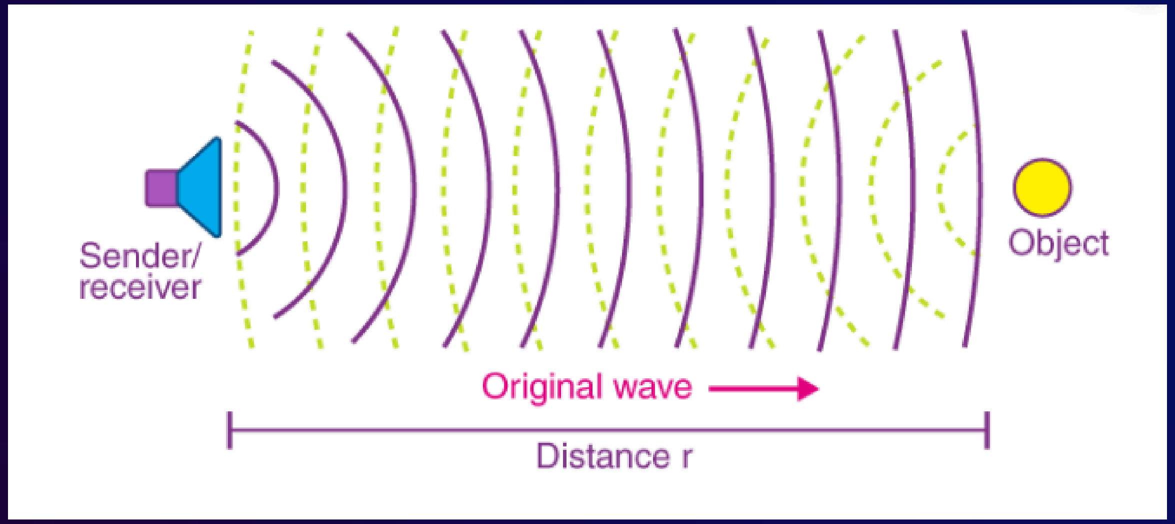
ii. Angle of reflection of sound is always equal to the angle of incidence of sound.



Echo

The phenomenon where a sound produced is heard again due to reflection is called an echo.

To hear a distinct echo sound, the time interval between the original and reflected sound must be at least 0.1s, as sound persists in our brain for about 0.1s. The minimum distance for obstruction or reflective surface to hear an echo should be 17.2 m. Multiple echoes can be heard due to multiple reflections.



Reverberation

- *Reverberation is the persistence of sound caused by repeated reflections from walls, ceilings, and other surfaces in an enclosed space.*
- *It occurs when a sound continues to be heard even after the source stops producing it.*
- *In large spaces such as auditoriums or halls, excessive reverberation is undesirable as it distorts sound clarity, making speech or music difficult to understand.*

To reduce reverberation:

- *Walls and Roofs: Covered with sound-absorbing materials like compressed fibre board, rough plaster, or draperies.*
- *Seats: Designed with sound-absorbing materials to minimize reflection.*
- *These measures help improve sound quality and ensure clear acoustics in large spaces.*

USES OF MULTIPLE REFLECTION OF SOUND

1. Megaphones, Horns, and Musical Instruments:

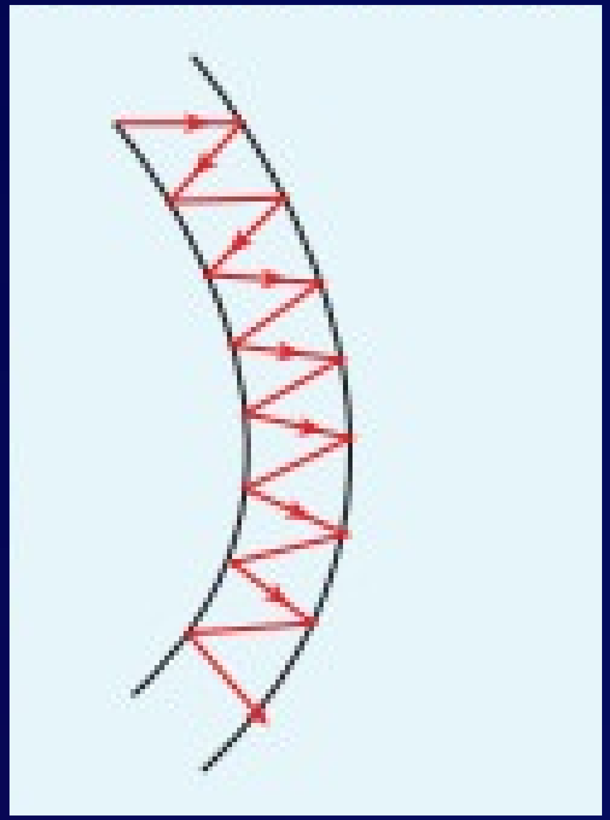
- **Devices like megaphones, horns, and instruments such as trumpets and shehnais are designed to focus sound in a specific direction.**
- **These devices use a tube with a conical opening to reflect sound waves successively, guiding most of the sound energy forward without spreading it in all directions.**

2. Stethoscope:

- ***A stethoscope is a medical instrument used to listen to sounds produced within the body, such as heartbeats or lung sounds.***

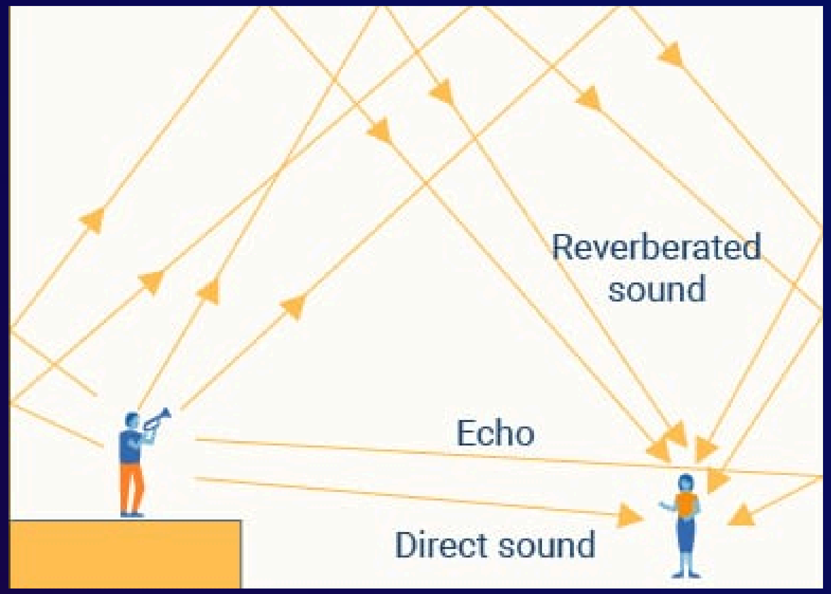
USES OF MULTIPLE REFLECTION OF SOUND

- *In a stethoscope, sound waves are transmitted to the doctor's ears through multiple reflections of sound within the tubes.*



3. Acoustic Design of Halls:

- *The ceilings of concert halls, conference halls, and cinema halls are often curved to ensure that sound, after reflection, reaches all parts of the space uniformly.*
- *Sometimes, a soundboard is placed behind the stage to reflect sound evenly across the width of the hall, enhancing sound distribution for the audience.*



Q. What is reflection of sound waves?

A. When sound waves bounce off a surface, it’s called reflection of sound waves.

Q. State the difference between echo and reverberation.

A. Echo - An echo is a single reflection of a sound wave.
Reverberation-Reverberation is the result of multiple reflections

Q. Mention some of the applications of multiple reflection of sound.

A. Applications of multiple reflection of sound:

(i) Stethoscopes - Used by doctors to hear patient’s heartbeat.

(ii) Musical Instruments - Instruments like trumpets, meghaphones, and loudspeakers are designed to amplify the sound waves and to make them louder.

(iii) Concert halls - These halls is designed in curve structure so that sound relects and reaches all corners of the room.

Range of Hearing

Audible Range:

The normal range of human hearing covers frequencies from approximately 20 Hz to 20,000 Hz (20 kHz). This range is not equally sensitive across all frequencies; our hearing is most sensitive to frequencies between 2 kHz and 4 kHz.

Inaudible Range:

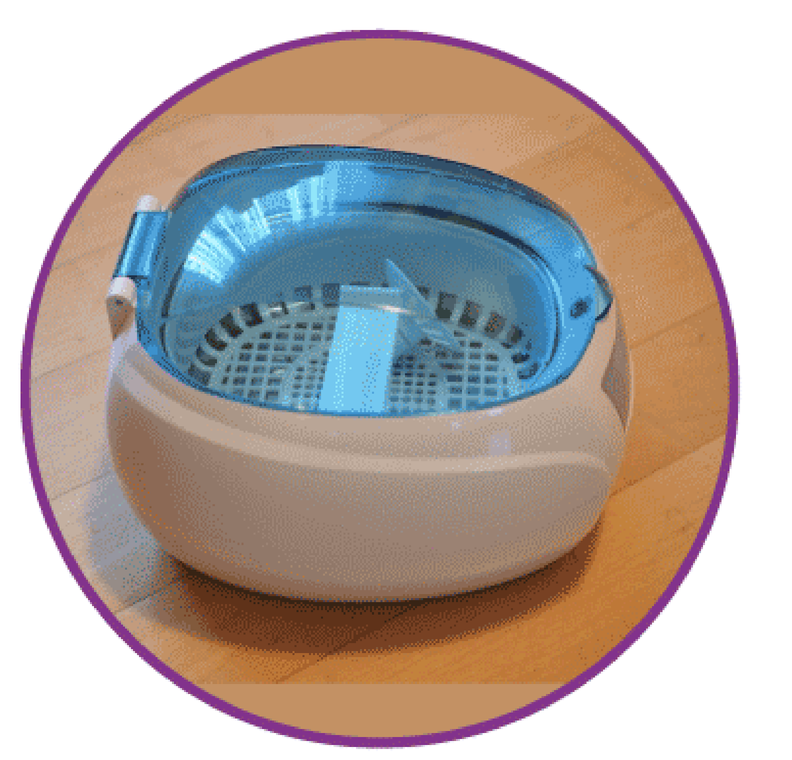
- **Infrasound:** Frequencies below 20 Hz are known as infrasound. Humans cannot hear these frequencies, but they can still have physiological effects on the body. Infrasound is sometimes produced by natural events like earthquakes or by man-made sources.

- **Ultrasound:** Frequencies above the audible range (above 20 kHz) are referred to as ultrasound. Humans cannot hear ultrasound, but some animals, such as bats and certain marine mammals, have the ability to hear and use ultrasonic frequencies for various purposes like navigation and communication.

Applications of Ultrasound

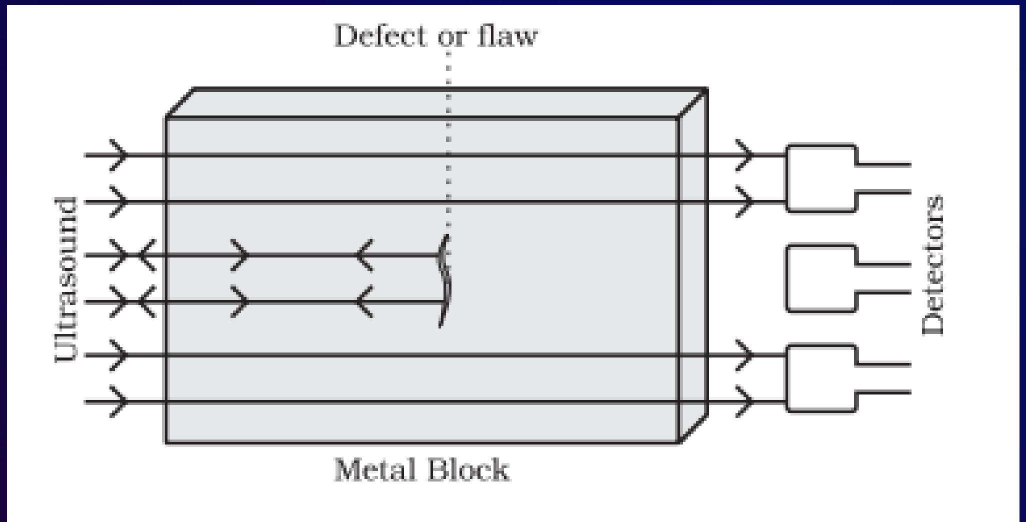
1. Cleaning:

- Cleans hard-to-reach areas like spiral tubes, odd-shaped parts, and electronic components.
- Ultrasonic waves detach dust, grease, and dirt in a cleaning solution.



2. Flaw Detection:

- Detects cracks and defects in metal blocks used in structures like buildings, bridges, and machinery.
- Ultrasound reflects back from defects, indicating their presence.



3. Medical Applications:

Echocardiography:

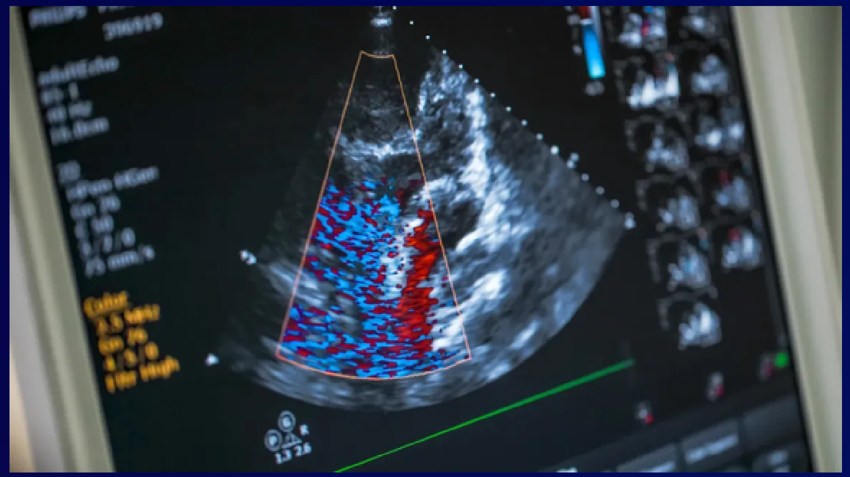
- Ultrasound reflects from heart parts to create images of the heart.

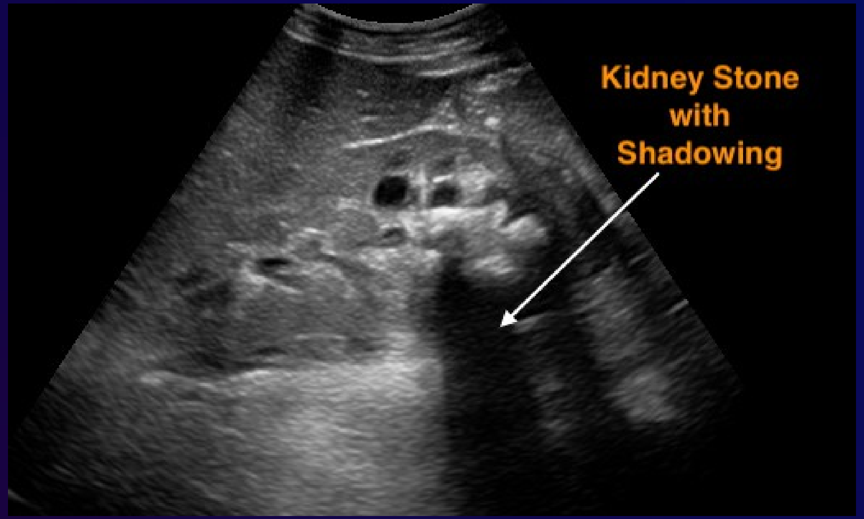
Ultrasonography:

- Generates images of internal organs (e.g., liver, kidney, gall bladder, uterus).
- Used to detect stones, tumors, and abnormalities in organs.
- Helps in examining fetal development during pregnancy.

Kidney Stones:

- Breaks kidney stones into fine grains, which are expelled through urine.





Advantages Over Ordinary Sound:

- Longer-wavelength sounds bend around defects and are unsuitable for precise detection.
- Ultrasound provides clear, reliable results for industrial and medical uses.

Q. What is the difference in the speed of sound in solids, liquids and gases?

A. The speed of sound is fastest in solids, slower in liquids and the slowest in gases.

Q. What is the audible range of the human ear?

A. The audible range of the human ear is 20 Hz to 20,000 Hz.

Q. State the difference between Infrasound and Ultrasound.

A. Difference between Infrasound and Ultrasound are as follows:

INFRASOUND	ULTRASOUND
These include sounds of frequencies below 20Hz.	These include sounds of frequencies above 20,000 Hz.
These sounds are produced by objects vibrating very slowly.	These sounds are produced by objects vibrating very rapidly.

SONAR System

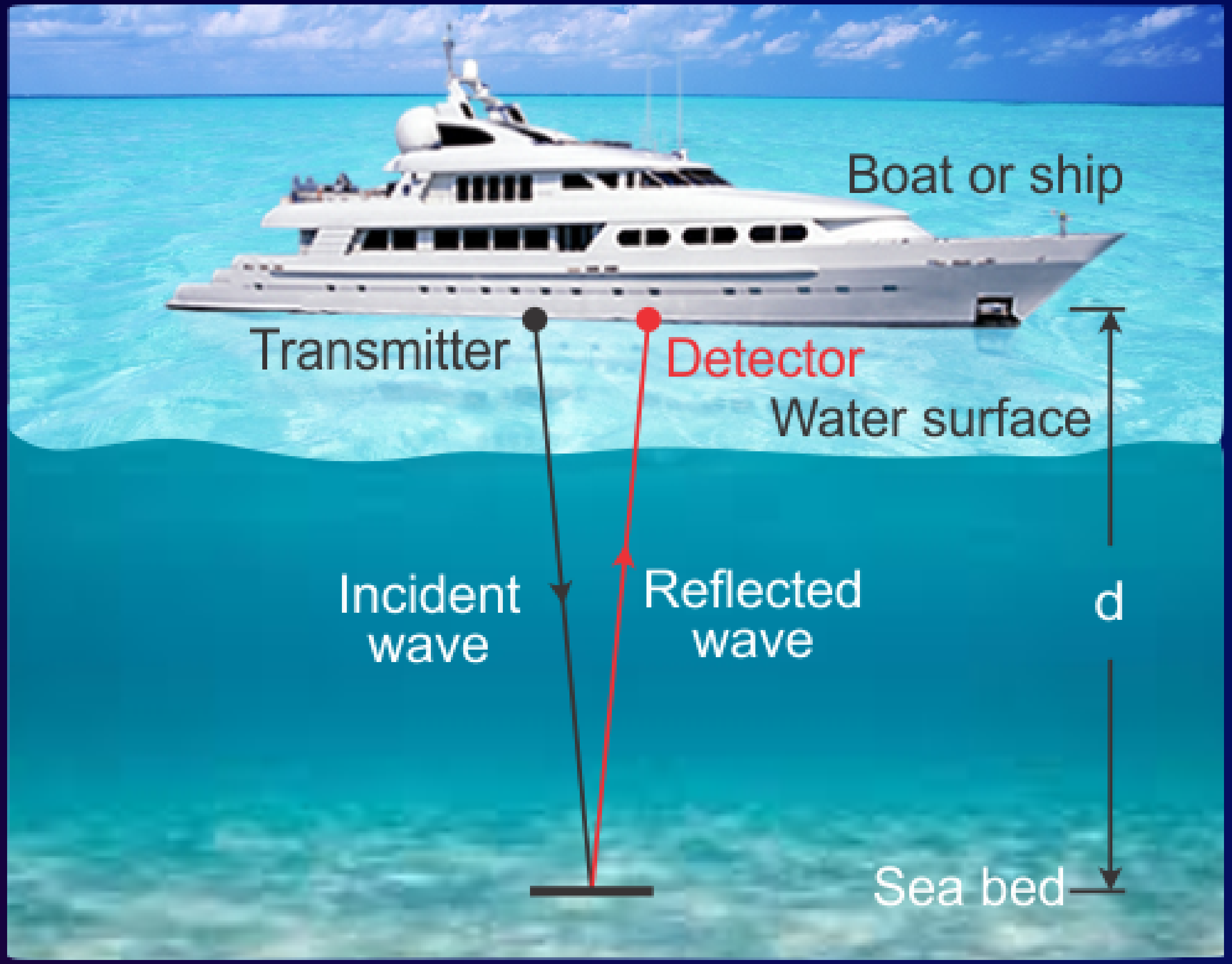
- The word **‘SONAR’ stands for ‘Sound Navigation And Ranging’**.

- SONAR is a technique that uses ultrasonic waves to measure the distance, direction, and speed of underwater objects.

How SONAR Works (Components):

- **Transmitter:** Produces and sends ultrasonic waves.

- **Detector:** Receives reflected waves and converts them into electrical signals.



SONAR System

SONAR System

Process:

- Ultrasonic waves are transmitted through water.
- The waves reflect back upon striking an object, such as the seabed or a submerged obstacle.
- The detector captures these reflected waves, and their travel time is analyzed to determine the object's distance.

Formula:

- The total distance 2d traveled by the ultrasonic wave is:

$$2d = v \times t$$

- Rearrange to calculate d:

$$\boxed{d = \frac{v \times t}{2}}$$

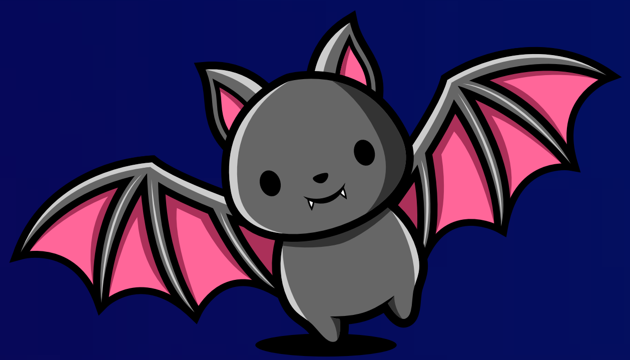
Where:
d: Depth or distance of the object.
v: Speed of sound in water.
t: Time interval between transmission and reception.

SONAR System

Applications of SONAR:

- **Measuring Sea Depth:** Determines the depth of oceans and seas (echo-ranging method).
- **Underwater Exploration:** Locates underwater features like hills, valleys, submarines, icebergs, and sunken ships.

Use of Ultrasound by Animals:

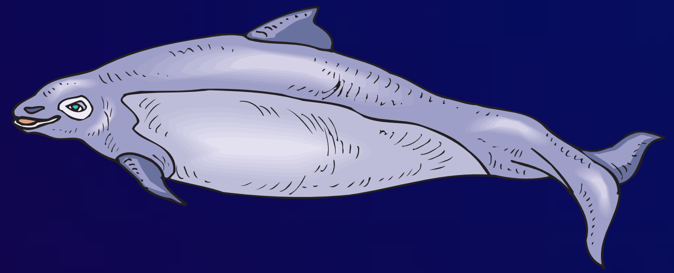


Bats:

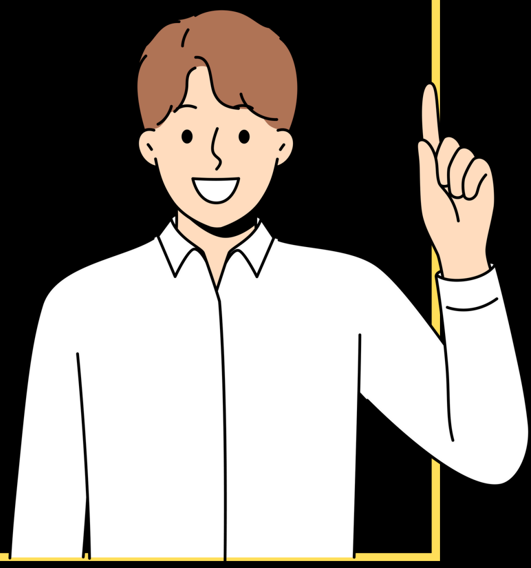
- Emit high-pitched ultrasonic squeaks to locate prey and navigate obstacles in the dark.
- Reflected waves provide information about the object’s location and nature.

Porpoises:

- Use ultrasound for navigation and finding food in dark environments.



Q. A ship sends out ultrasound that returns from the seabed and is detected after 3.42s. If the speed of ultrasound through seawater is 1531 m/s, what is the distance of the seabed from the ship?

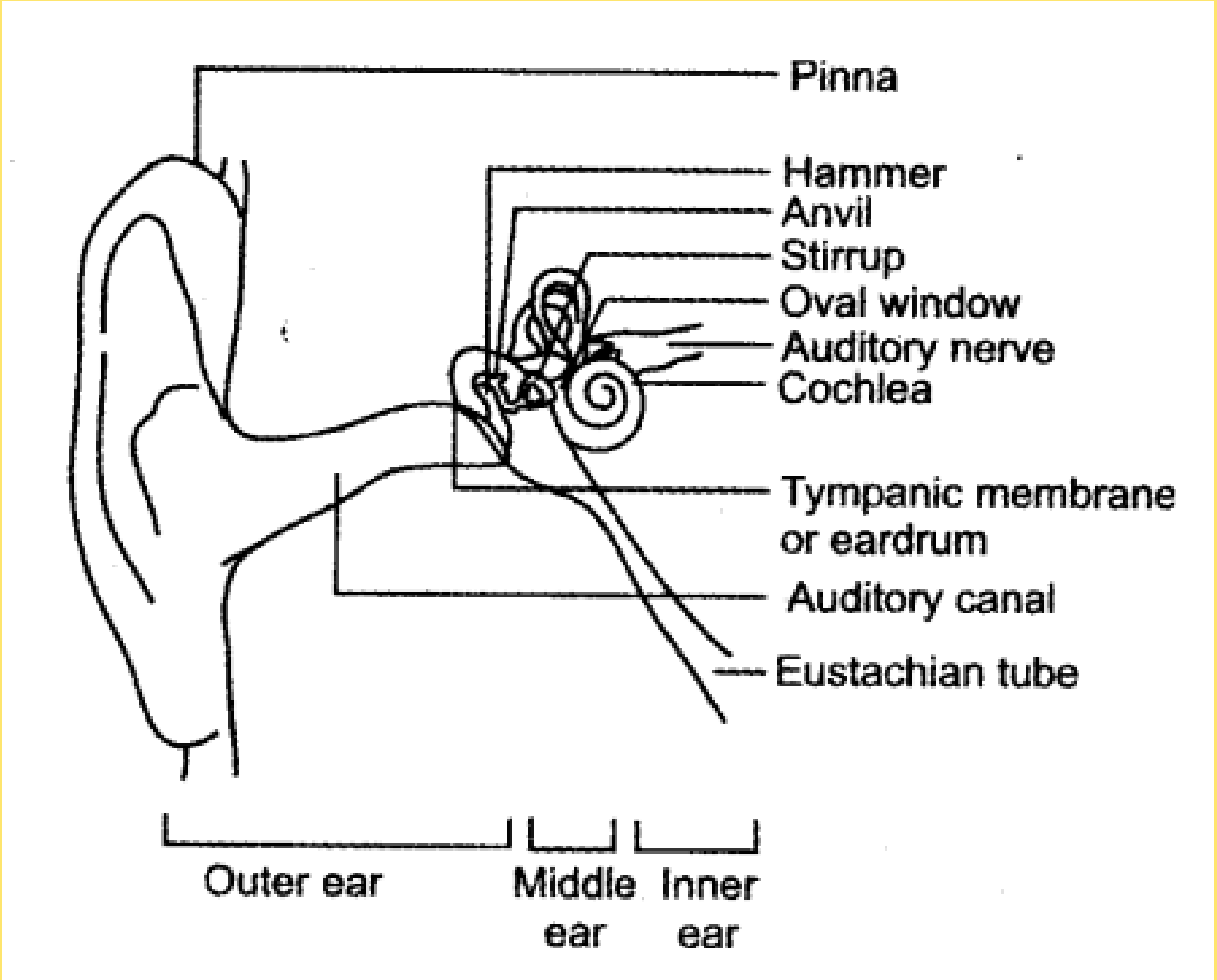


Structure of Human Ear

Hearing is the process by which the ear converts pressure variations in air, caused by sound waves, into electrical signals that are transmitted to the brain via the auditory nerve for interpretation.

The ear consists of three parts : **outer ear, middle ear and inner ear.**

The ears are the sense organs which help us in hearing sound.



Structure of Human Ear

Part of the Ear	Definition and Function
Outer Ear (Pinna)	Collects sound from the surroundings and channels it into the auditory canal.
Auditory Canal	A tube-like structure that directs sound waves toward the eardrum.
Eardrum (Tympanic Membrane)	A thin membrane that vibrates in response to pressure variations caused by sound waves (compression and rarefaction).
Middle Ear (Bones)	Contains three small bones (hammer, anvil, stirrup) that amplify the vibrations from the eardrum.
Inner Ear (Cochlea)	Converts pressure variations into electrical signals using sensory cells.
Auditory Nerve	Transmits the electrical signals from the cochlea to the brain for interpretation.

Working of Human Ear

- When compression of sound wave strike the ear drum, the pressure on the outside of ear drum increases and pushes the ear drum inwards.
- While during refraction ear drum moves outwards. Thus, ear drum starts vibrating back and forth.
- These vibrations are increased by three bones and middle ear transmits these amplified pressure variations received from sound waves to inner ear.
- In the inner ear the pressure variations are turned into electric signals by the cochlea.

Q. Why do we hear the sound produced by humming bees, but not the sound of vibrations of a pendulum?

Q. A person hears an echo after 2 seconds. If the speed of sound is 343 m/s, calculate the distance of the reflecting surface.

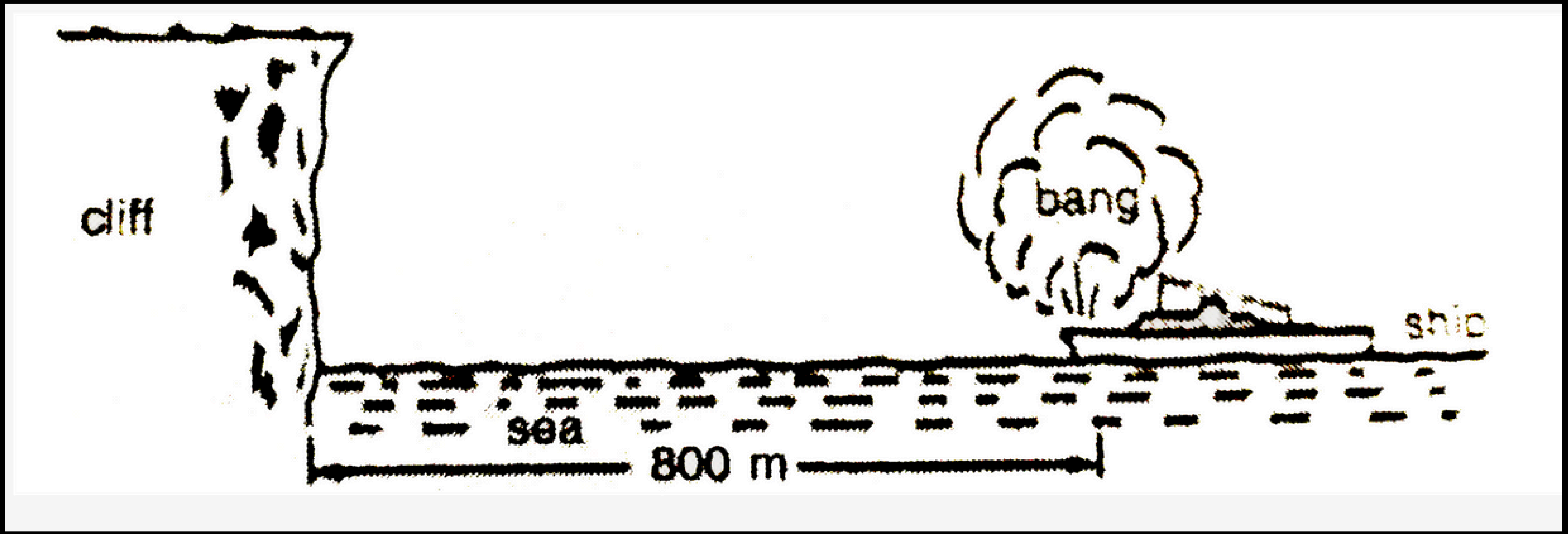
Q. Give Reasons:

a. Flash and thunder are produced simultaneously, but thunder is heard a few seconds after the flash is seen.

b. An echo is heard faster on a hot day than on a cold day.

Q. Why is a dog considered most suitable by the police for detective purposes?

Q. The drawing shows a ship 800 m from a cliff. A gun is fired on the ship. After 5 seconds the people at the front of the ship hear the sound of the gun again.



(a) What is the name of this effect?
(b) What happens to the sound at the cliff?
(c) How far does the sound travel in 5 seconds?
(d) Calculate the speed of sound.

Q. The frequency of a source of sound is 100Hz. How many times does it vibrate in a minute?

A. The frequency of a source of sound is 100 Hz then it means that the number of compressions and rarefactions passing a given point in 1 second are 100.

So, in a minute number of compressions and rarefactions passing a given point will be = 100×60

$= 6000$

Hence, the given source of sound vibrates 6000 times in a minute.

Q. A person clapped his hands near a cliff and heard the echo after 5 s. What is the distance of the cliff from the person if the speed of the sound, v is taken as 346 m/s?

A. Given that,

The time taken by the echo to reach back to the source (t) = 6s

Velocity of the sound (v) = 346 m/s

Distance between person and cliff (d) = v X t

As sound travels back and forth to form an echo and hence time is twice.

Now dividing the time take by 2 we get actual time (T) = 6/2 = 3

Therefore, the distance from person to the cliff (d) = 346 X 3 = 1038 m

The distance between the person and the cliff is 1038 meters.

Q. Suppose you and your friend are on the moon. Will you be able to hear any sound produced by your friend?

A. No, you will not be able to hear any sound produced by your friend on the moon.
Reason: Sound requires a medium (such as air, water, or solid materials) to propagate. On the moon, there is no atmosphere — it is a vacuum. Since there is no medium to carry the sound waves, the sound produced by your friend cannot travel to your ears.

TOP 5 MCQs

1. When a sound wave travels through air, the air particles:

a. Move permanently from one place to another
b. Vibrate along the direction of the wave
c. Vibrate perpendicular to the direction of the wave
d. Do not move at all

TOP 5 MCQs

2. The speed of sound is maximum in:

a. Solids
b. Liquids
c. Gases
d. Vacuum

TOP 5 MCQs

3. The loudness of a sound depends on its:

a. Frequency
b. Amplitude
c. Wavelength
d. Velocity

TOP 5 MCQs

4. The time period of a wave is 0.01 seconds. What is its frequency?

a. 10 Hz
b. 50 Hz
c. 100 Hz
d. 200 Hz

TOP 5 MCQs

5. The range of audible frequencies for the human ear is:

a. 0 to 1000 Hz
b. 20 to 20,000 Hz
c. 50 to 15,000 Hz
d. 20 to 50,000 Hz

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- Mitochondria