Chapter 11

SOUND

9th CLASS

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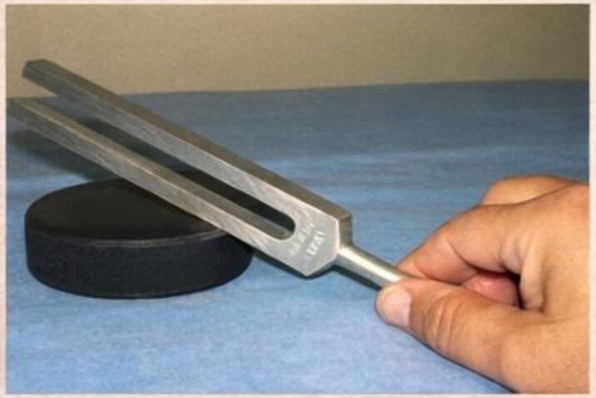
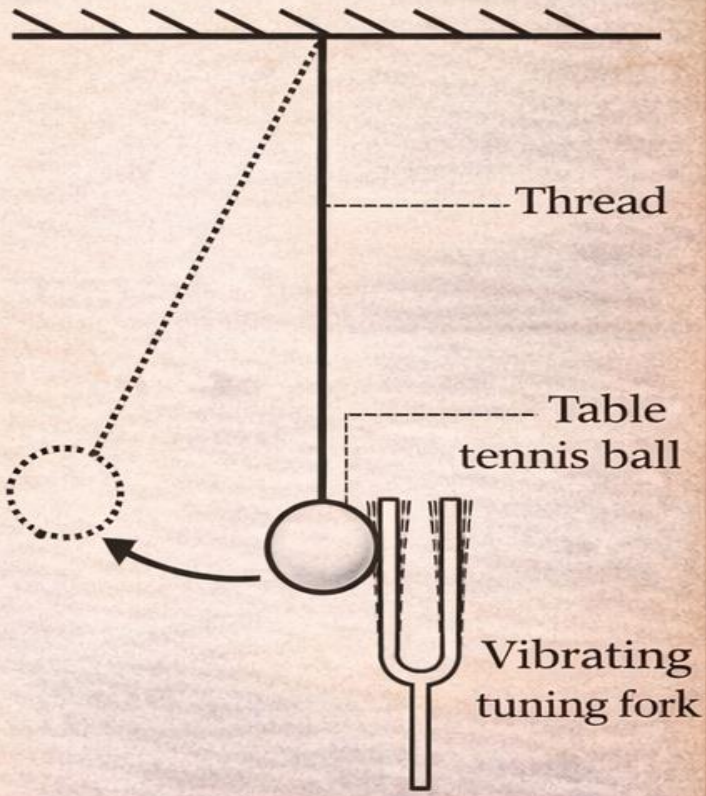
PRODUCTION OF SOUND

- **Sound** is a form of energy which produces a sensation of hearing.
- It is produced by **vibrating** objects.

Activity 1

- Strike a **tuning fork on a rubber pad** to set it vibrating.
- When brought near the ear, a sound can be heard.
- Touch one of the vibrating prongs with a finger. The vibration will stop.
- Suspend a table tennis or small plastic ball with a **thread.** Gently touch the ball with a vibrating prong. The ball moves.
- Suspend a table tennis or small plastic ball with a thread. Gently touch the ball with a vibrating prong. The ball moves.



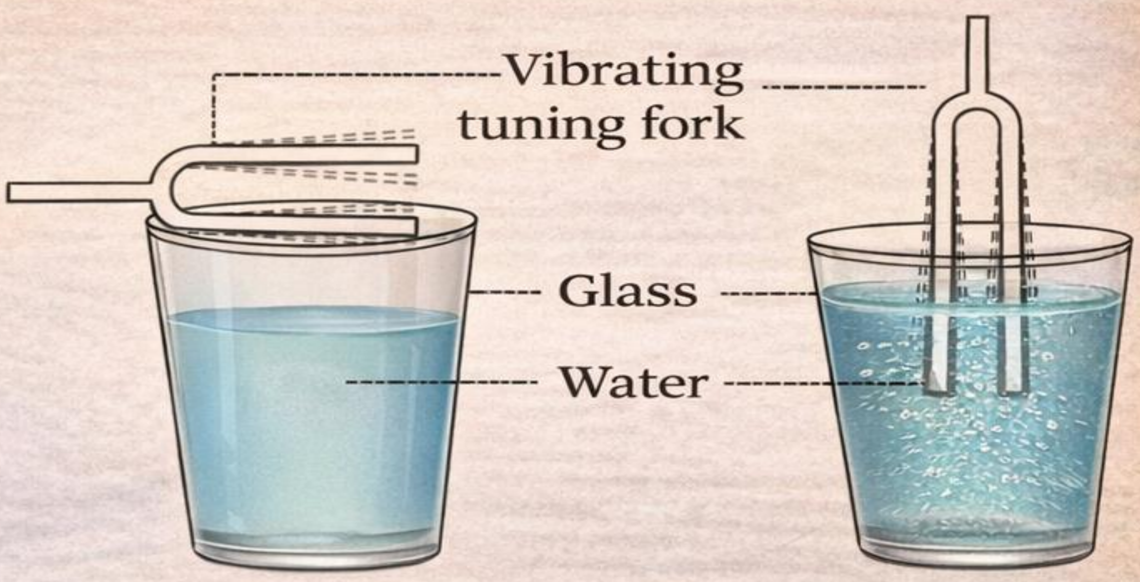


PRODUCTION OF SOUND

2 Activity 2

- Fill water in a beaker or a glass up to the brim. Gently touch the water surface with one prong of the vibrating tuning fork. It creates minimal vibrations in water.

- Dip the prongs of the vibrating fork in water. It causes more vibrations and disturbances.

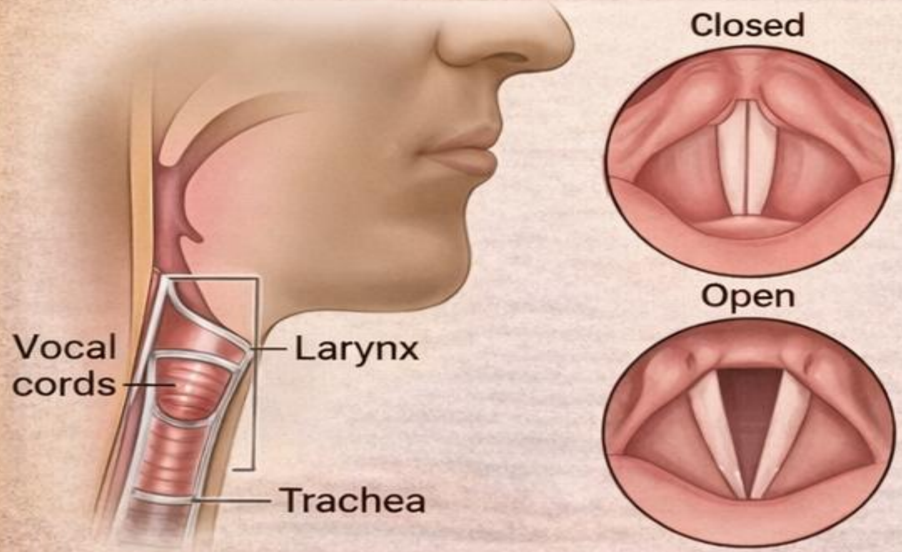


One of the prongs of the vibrating tuning fork touching the water surface

Both the prongs of the vibrating tuning fork dipped in water

PRODUCTION OF SOUND

- **Vibration** is a rapid to and fro motion of an object. E.g.,
- Vibrations in the vocal cords of human produce voice.
- In bees, vibration of wings produces buzzing sound. But flapping of bird's wings doesn't produce noticeable sound because flapping is slow.
- A stretched rubber band when plucked vibrates and produces sound.

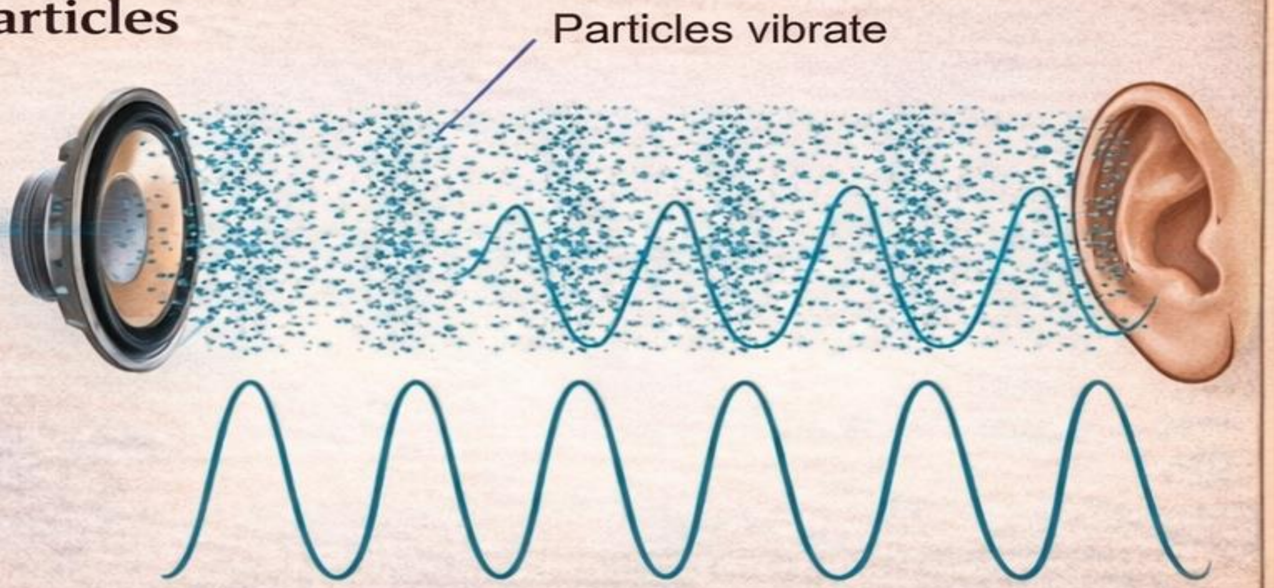


One of the prongs of the vibrating tuning fork

Both the prongs of the vibrating tuning fork

PROPAGATION OF SOUND

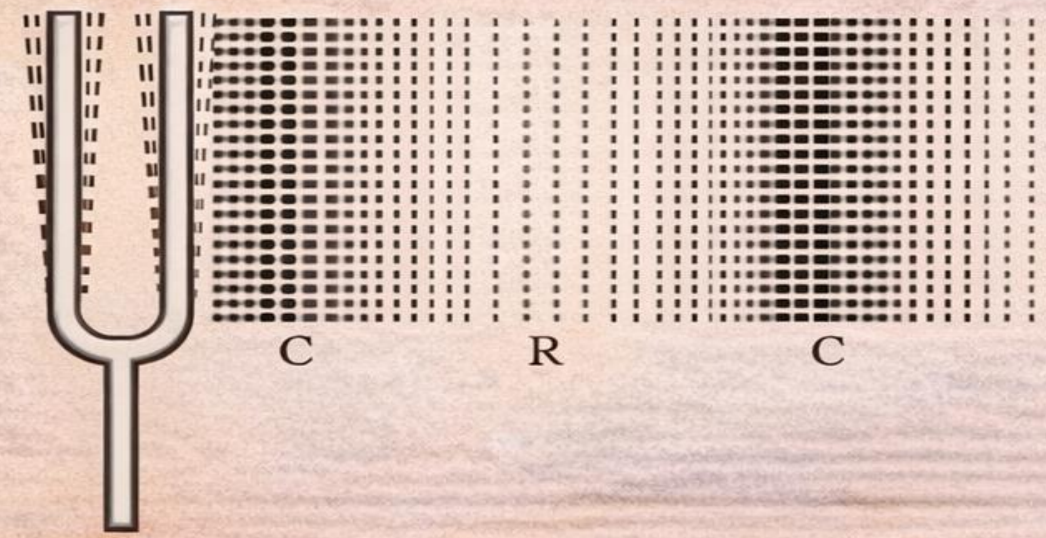
- Sound moves through a **medium** (solid, liquid, or gas) from the source to the listener.
- When an **object vibrates,** the **surrounding particles** of the medium also vibrate. So the particle is displaced from its equilibrium position and exert a force on the adjacent particle, causing it to displace. Then the first particle returns to its original position. This repeats until the sound reaches the ear. i.e., the **disturbance,** not the particles, travels through the medium.



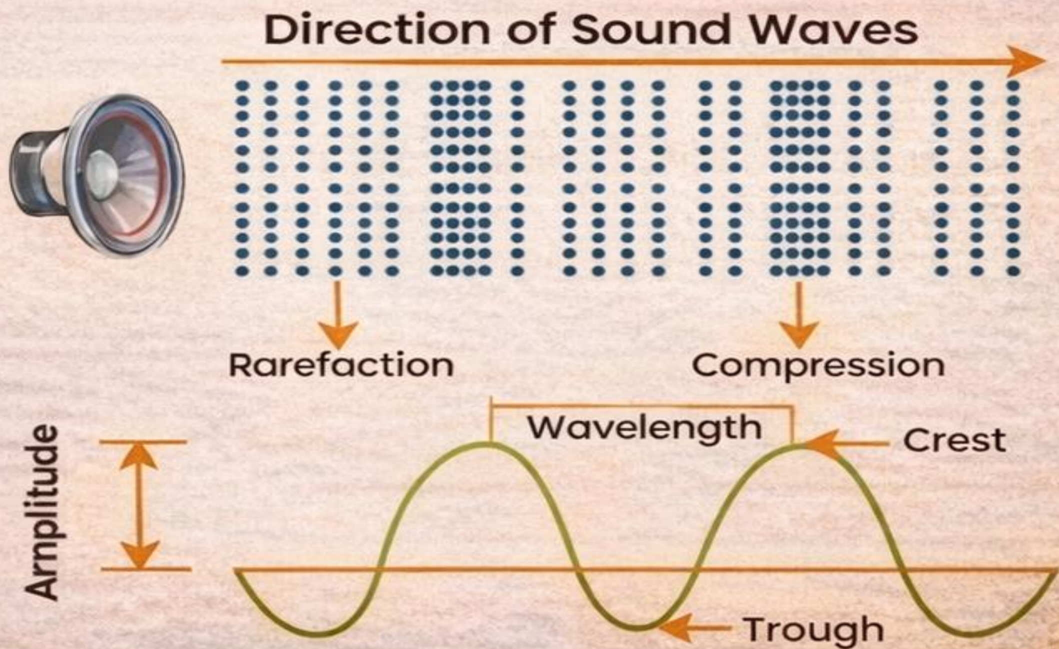
- A **wave** is a disturbance that moves through a medium by setting neighbouring particles into motion. Sound is a **mechanical wave** characterized by the motion of particles in the medium.

PROPAGATION OF SOUND

- **Air** is the most common medium for sound travel.
- As a vibrating object moves forward, it **compresses** the air, creating high-pressure region called **compression (C)**, which moves away from the object. When the object moves backward, it creates a low-pressure region called **rarefaction (R)**. The rapid back-and-forth movement forms a series of compressions and rarefactions that propagate as sound waves.

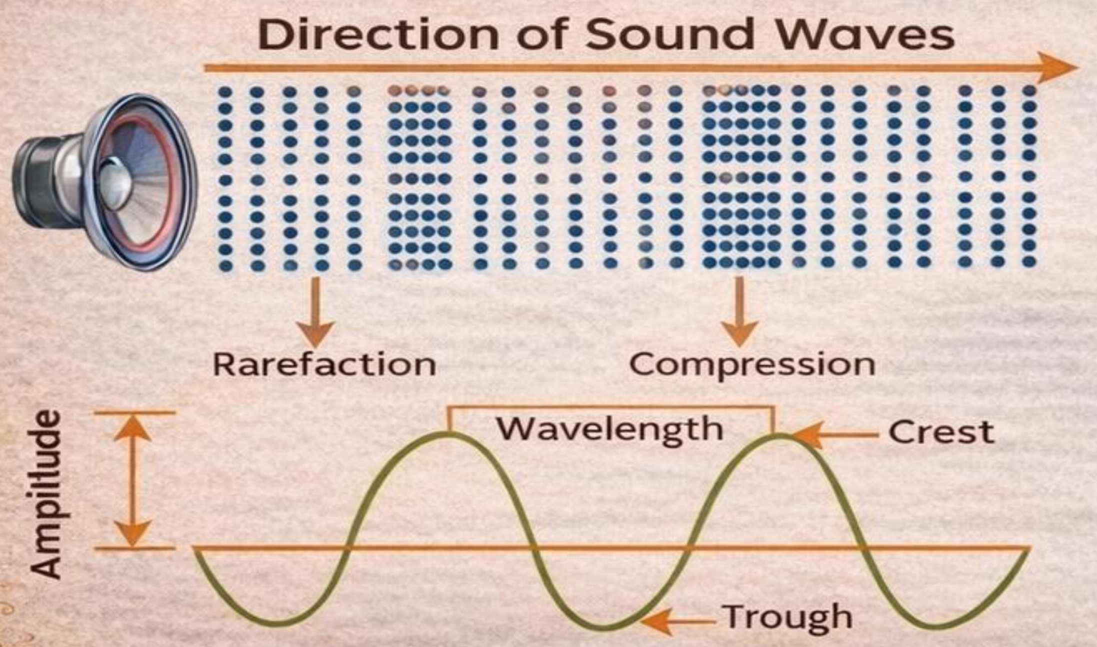


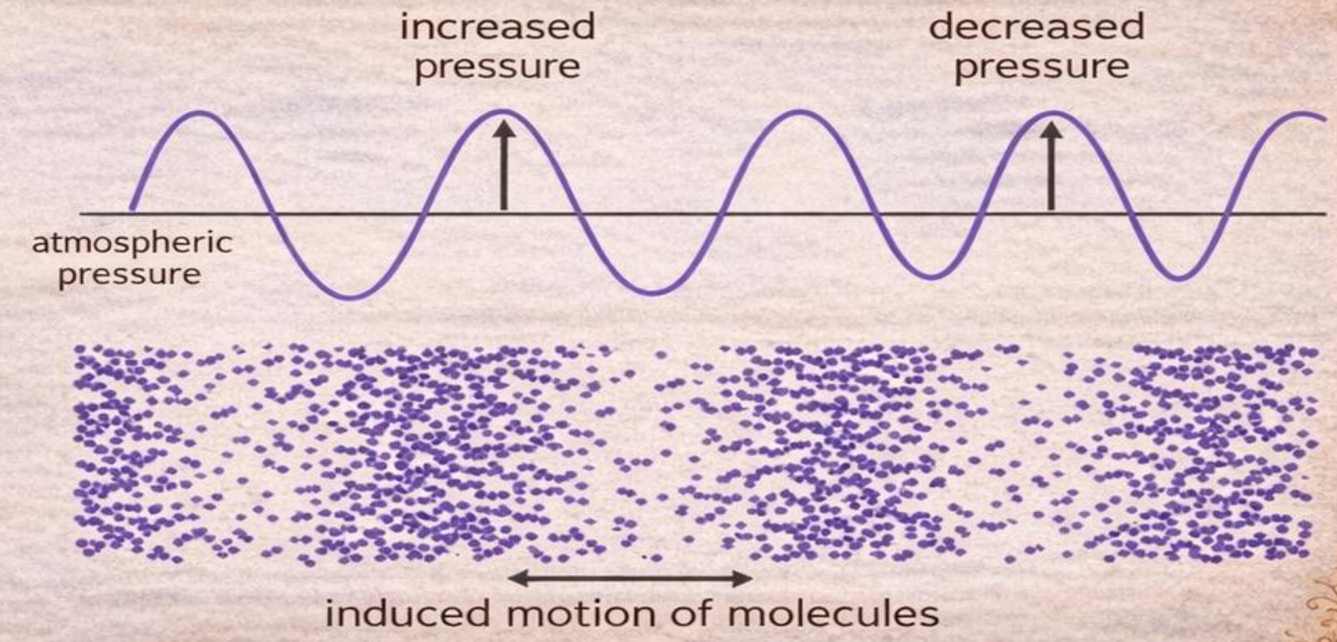
A vibrating object creating a series of compressions (C) and rarefactions (R) in the medium.



PROPAGATION OF SOUND

- **Pressure** is related to the **number** of particles of a medium in a **given volume.** More density of the particles gives **more pressure** and *vice versa*.
- Thus, propagation of sound can be seen as **propagation of density or pressure variations in** the medium.

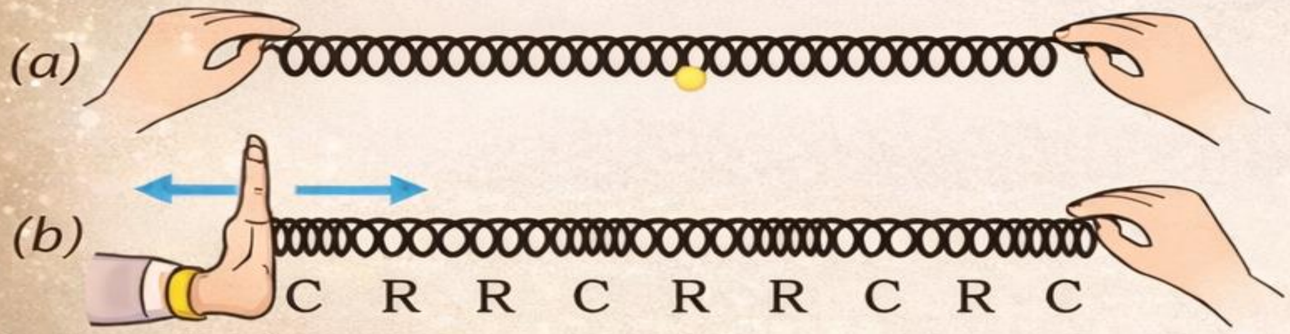


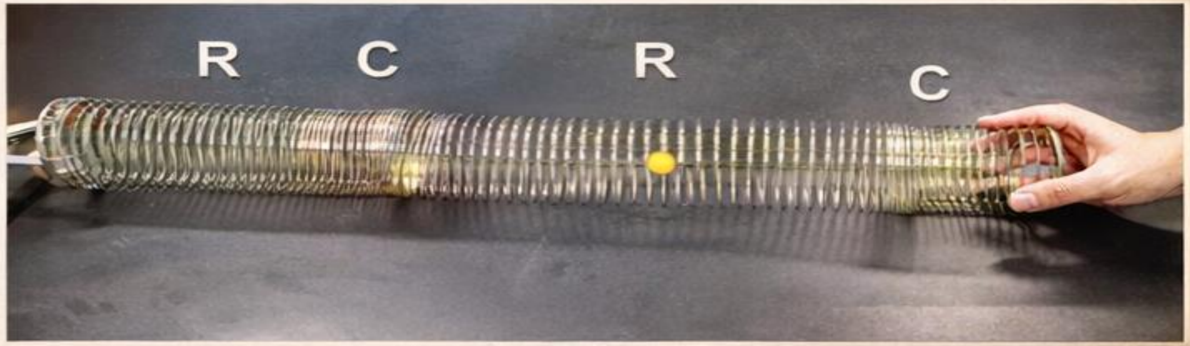


PROPAGATION OF SOUND

SOUND WAVES ARE LONGITUDINAL WAVES

- **Stretch** a slinky by holding its two ends.
- Give it a sharp push. A compression wave travels along the slinky.
- Push and pull the slinky alternately to see a series of compressions and rarefactions traveling along it.
- Mark a dot on the slinky. The dot will move back and forth parallel to the direction of the propagation of the disturbance.



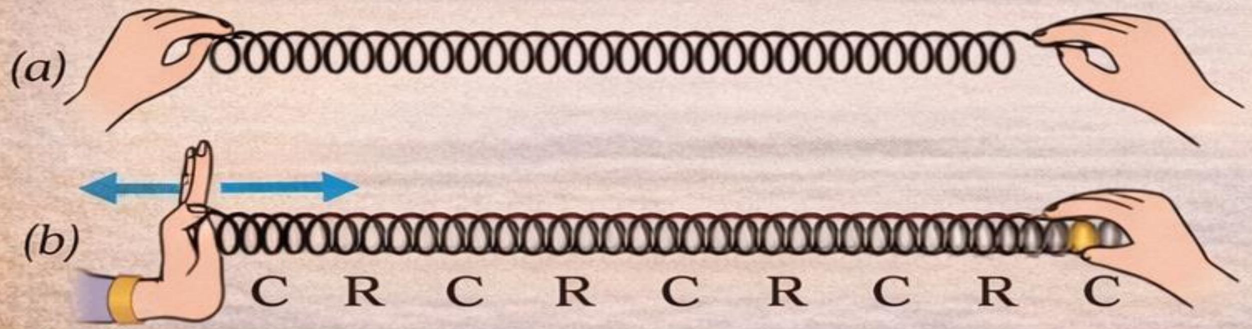


Longitudinal wave in a slinky

PROPAGATION OF SOUND

SOUND WAVES ARE LONGITUDINAL WAVES

- The regions where the coils become closer are called **compressions (C)** and the regions where the coils are further apart are called **rarefactions (R).**
- Sound propagates as a series of compressions and rarefactions, like a disturbance in a slinky. These are **longitudinal waves**. Here particles move **parallel to the direction** of wave propagation.
- Particles **oscillate** back and forth without traveling, enabling sound wave propagation. Thus, sound waves are **longitudinal waves.**

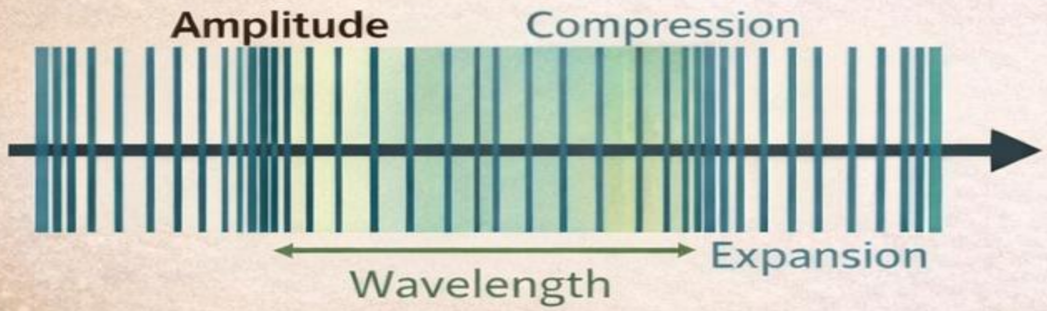


Longitudinal wave in a slinky

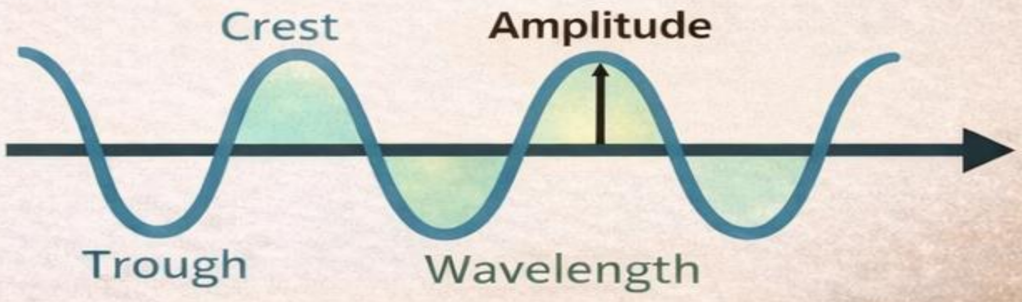
Propagation of Sound

Sound Waves are Longitudinal Waves

- **In a transverse wave,** particles **oscillate up and down** about their mean position, perpendicular to the direction of wave propagation. E.g., a pebble dropped in a pond creates **transverse waves.**
- Light is also a transverse wave, but its oscillations are not of medium particles or pressure or density. So it is **not a mechanical wave.**



Longitudinal waves

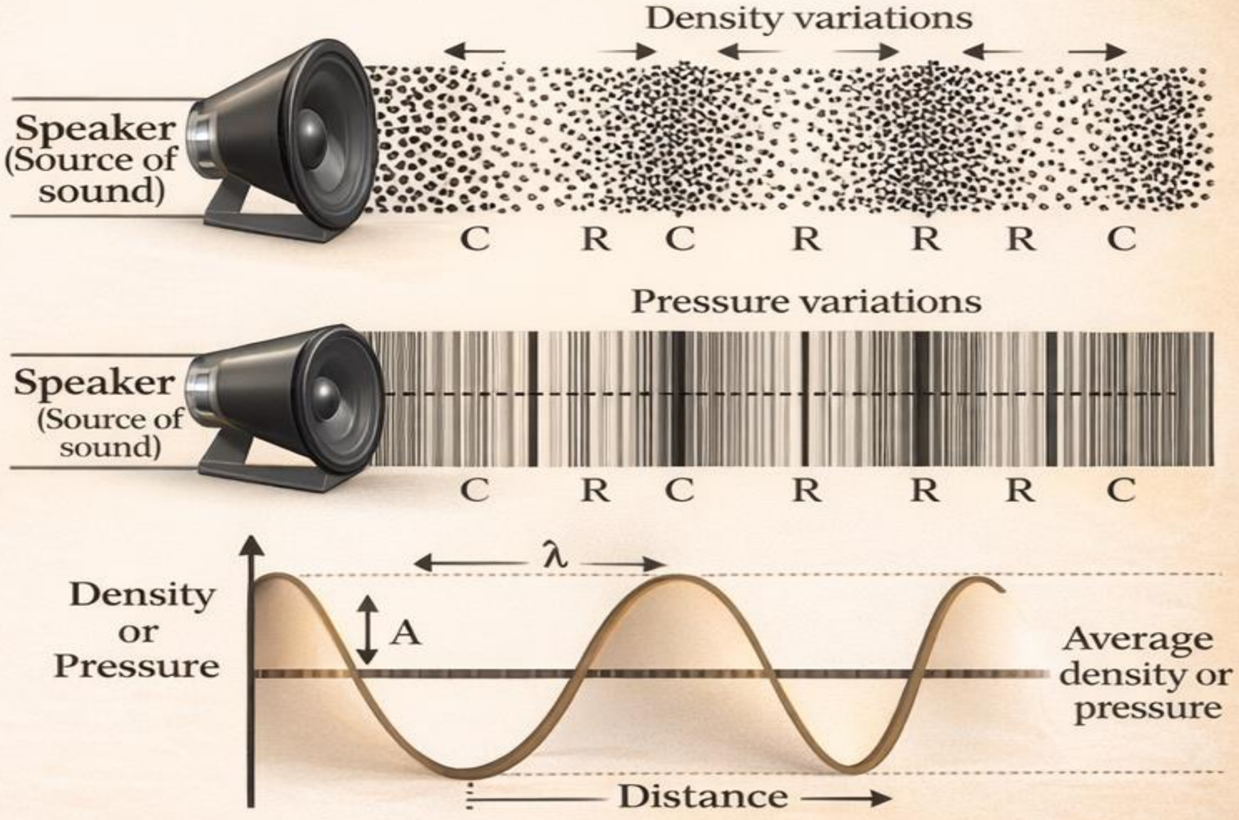


Transverse waves

PROPAGATION OF SOUND

CHARACTERISTICS OF A SOUND WAVE

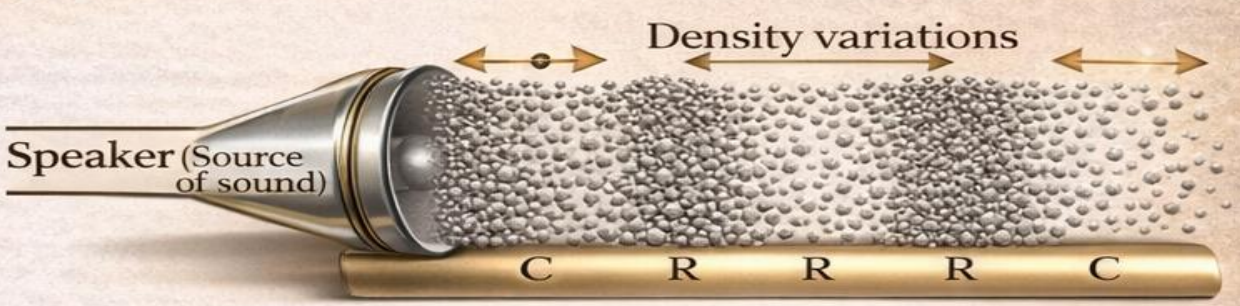
- A sound wave is described by its **frequency, amplitude** and **speed**.
- Graphically, a sound wave represents changes in density and pressure as it moves through the medium.
- The density and pressure at a given time vary with distance, oscillating above and below the average values.

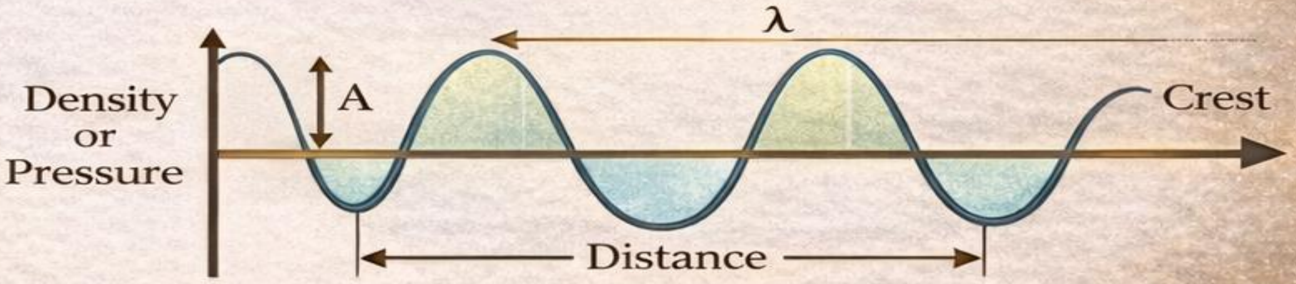


(a) & (b) Sound propagates as density or pressure variations
(c) represents graphically the density and pressure.

Characteristics of a Sound Wave

- **Compressions** are the regions where particles are crowded together. It is represented by the crest (peak or upper part of the curve). Here, density and pressure are high. The peak represents maximum compression.
- **Rarefactions** are low-pressure regions where particles are spread apart. It is represented by the **trough** (valley or lower part of the curve).





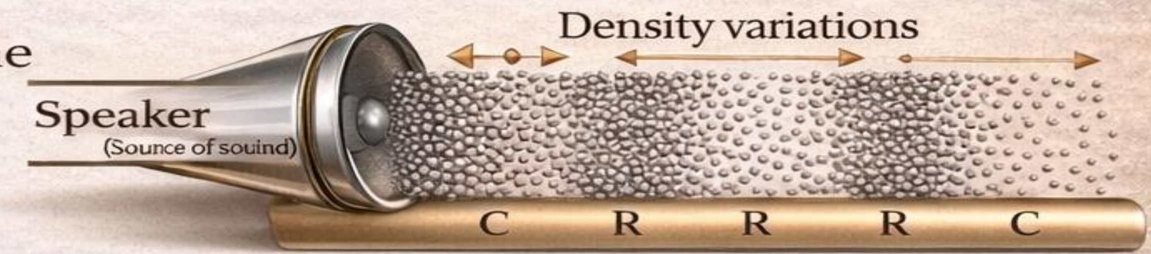
(a)

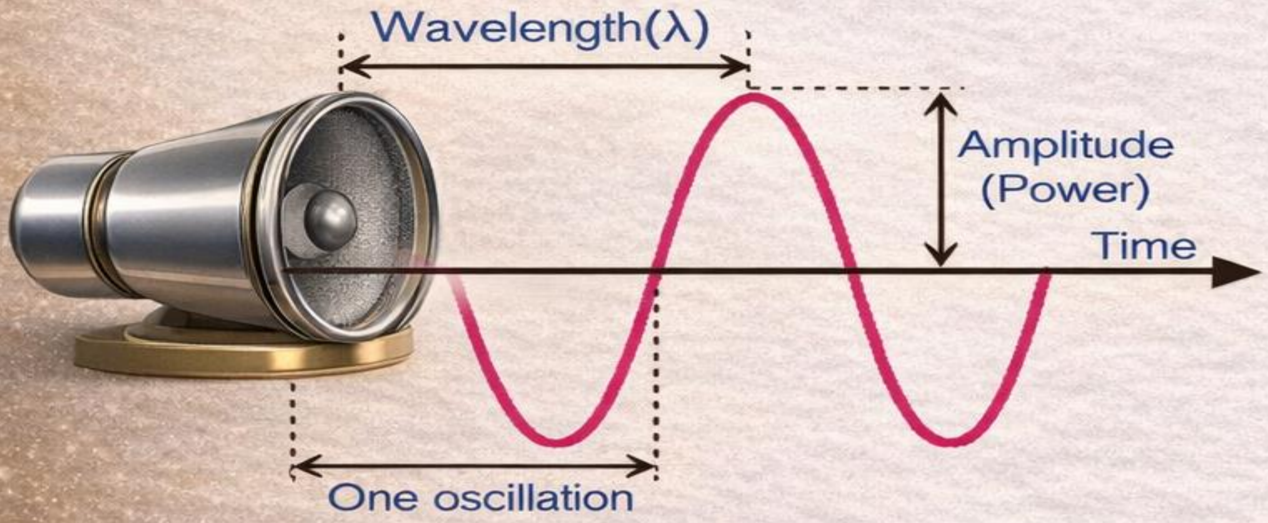
(a) & & (b) Sound propagates as density or pressure variations

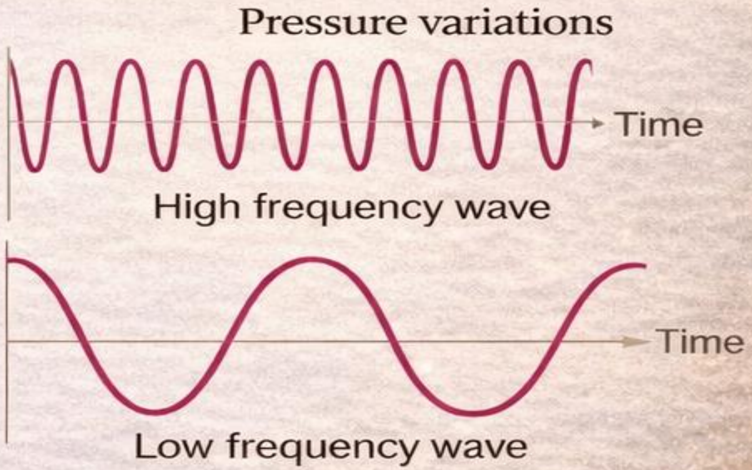
(c) represents graphically the density and pressure variations

CHARACTERISTICS OF A SOUND WAVE

- As sound propagates through a medium, the density of the medium oscillates between maximum and minimum values. One complete **oscillation** is the change from maximum density and back to maximum.
- The number of oscillations per unit time is called the **frequency** (ν) of the sound wave.



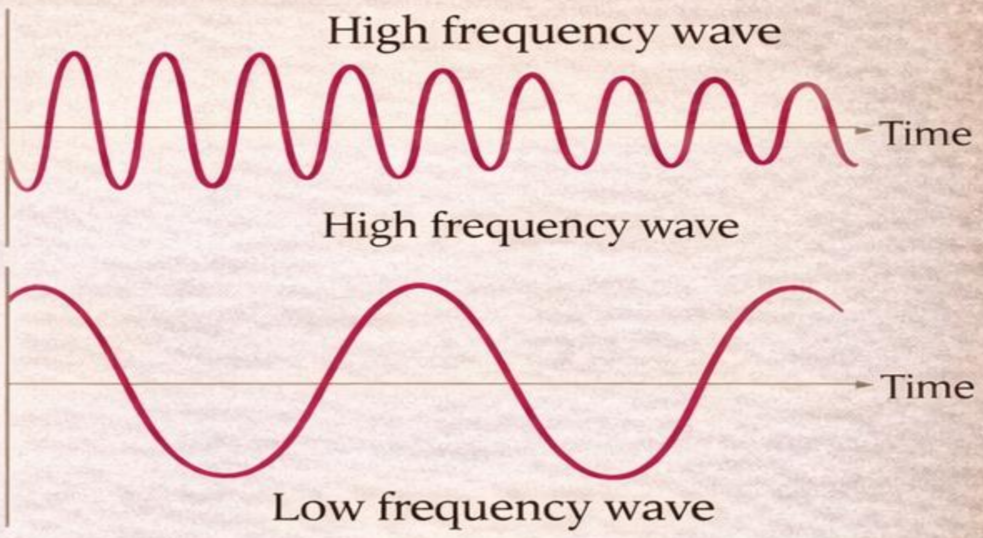


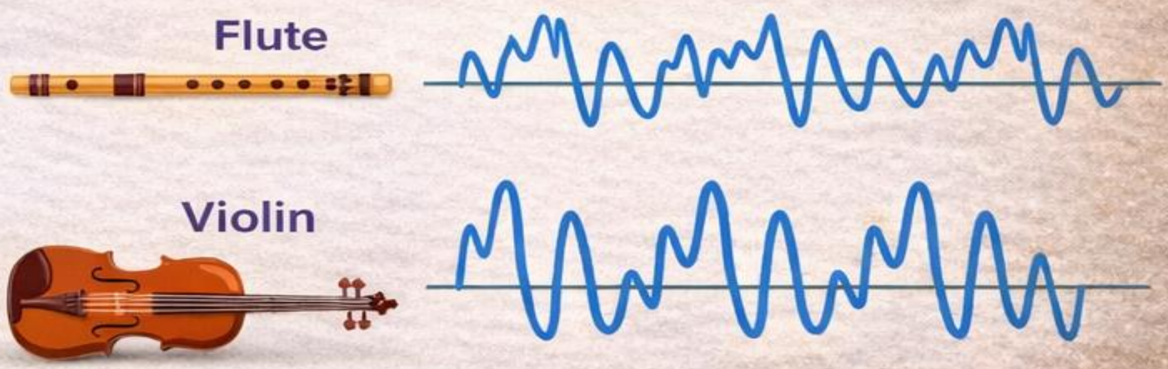


Frequency (ν) = number of oscillations per second | **SI unit: Hertz (Hz)**

CHARACTERISTICS OF A SOUND WAVE

- The time taken for one complete oscillation (i.e., time taken by two consecutive compressions or rarefactions to cross a fixed point) is called the **time period (T)**. Its SI unit is **second (s)**.
- Frequency and time period are related as: $\upsilon = \frac{1}{T}$
- Consider a violin and a flute are played simultaneously in an orchestra. Both sounds travel through the same medium (air) at the same speed and reach the ear at the same time. However, the sounds differ due to their distinct characteristics, such as pitch.

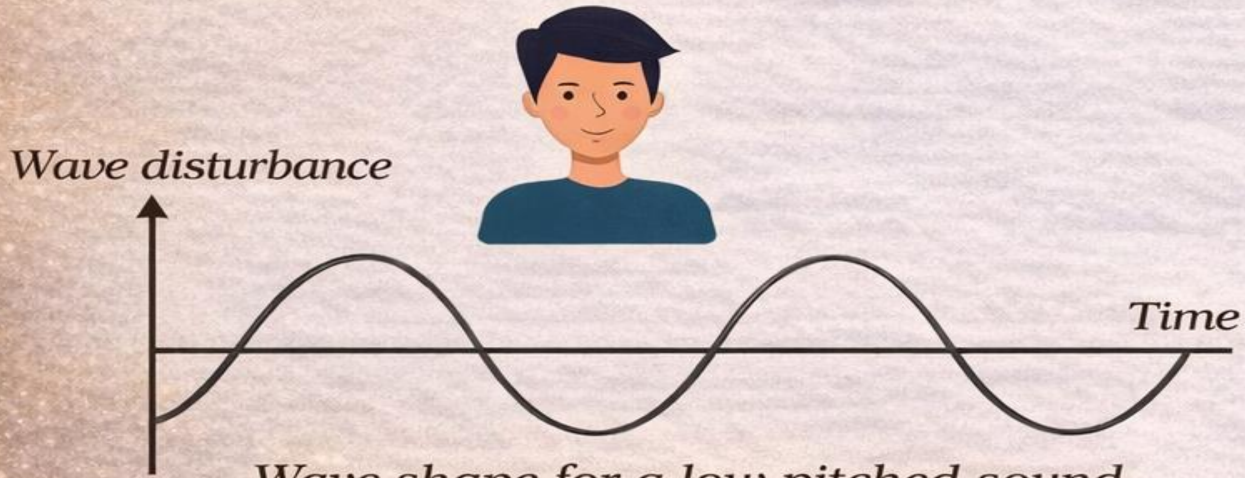




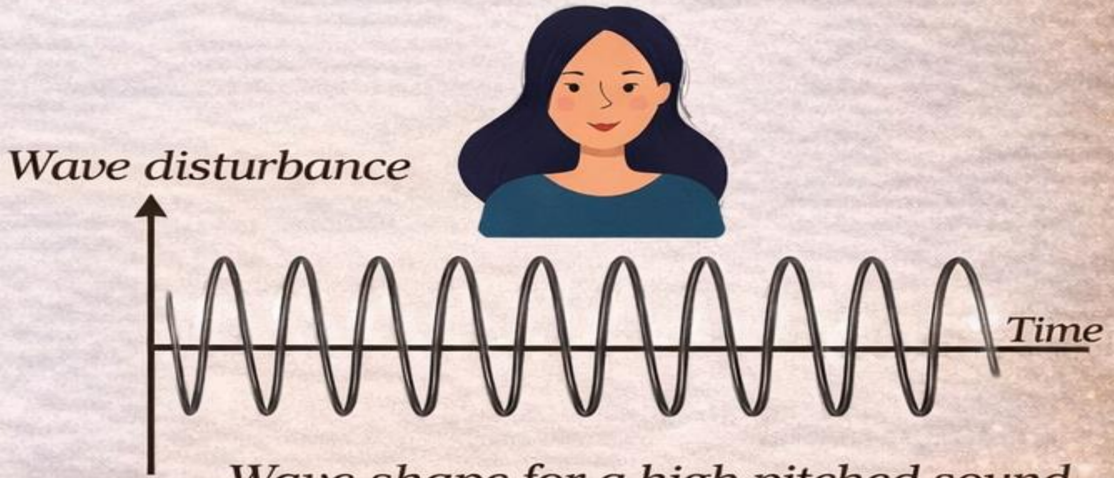
Frequency (υ) = number of oscillations per second | SI unit: **second (s)**

CHARACTERISTICS OF A SOUND WAVE

- How the brain interprets the frequency of a sound is called its **pitch.**
- **Faster vibrations** result in **higher frequency** and **pitch.** Thus, a high pitch sound corresponds to more compressions and rarefactions passing a fixed point per unit time.
- Objects of different sizes and conditions vibrate at different frequencies to produce sounds of different pitch.



Wave shape for a low pitched sound



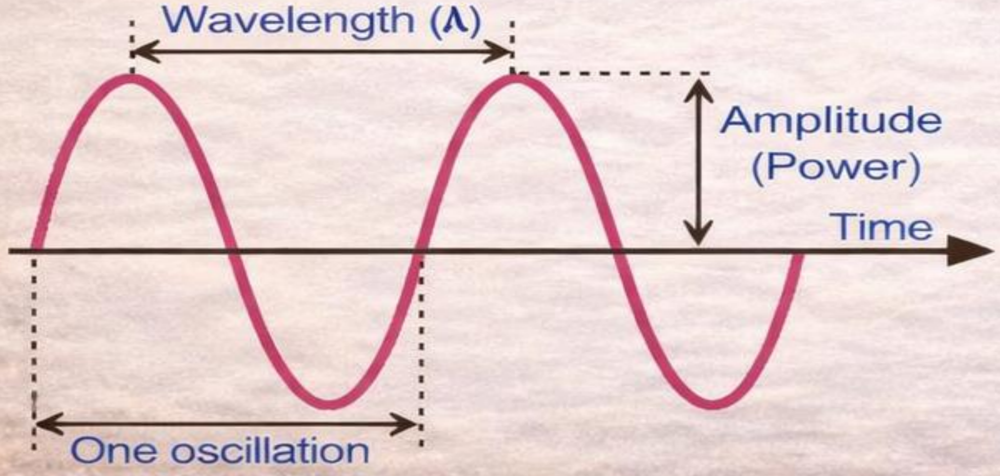
Wave shape for a high pitched sound

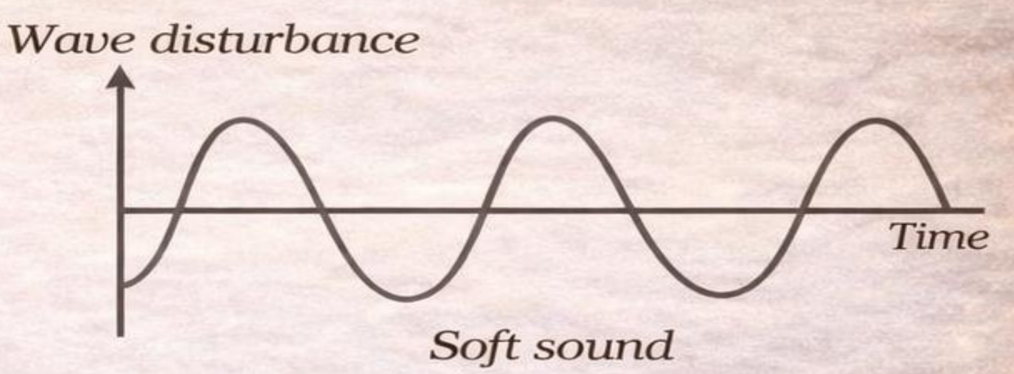
Low pitch sound has low frequency

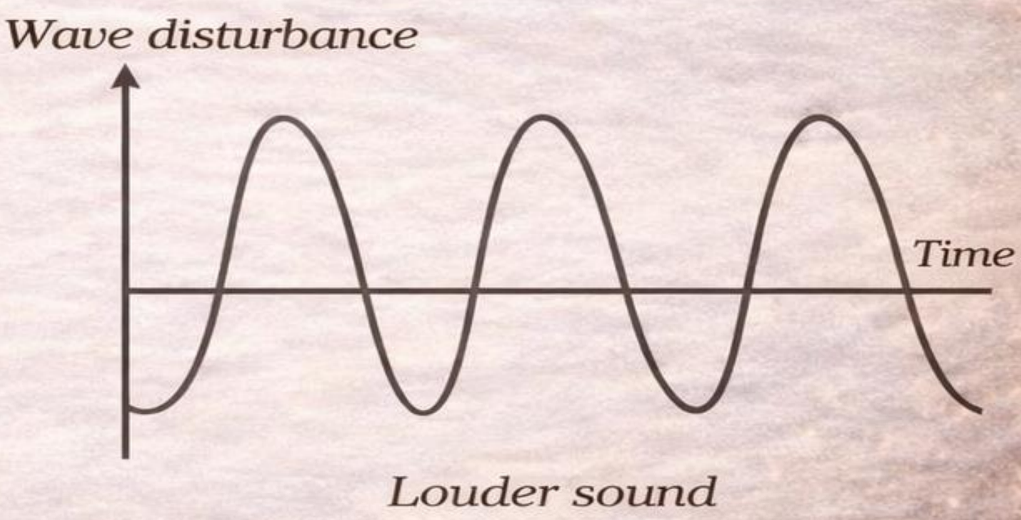
High pitch sound has high frequency

CHARACTERISTICS OF A SOUND WAVE

- The magnitude of the maximum disturbance in the medium on either side of the mean value is called the **amplitude (A)** of the wave. For sound, its unit is that of density or pressure.
- The loudness or softness of a sound is determined by its amplitude.



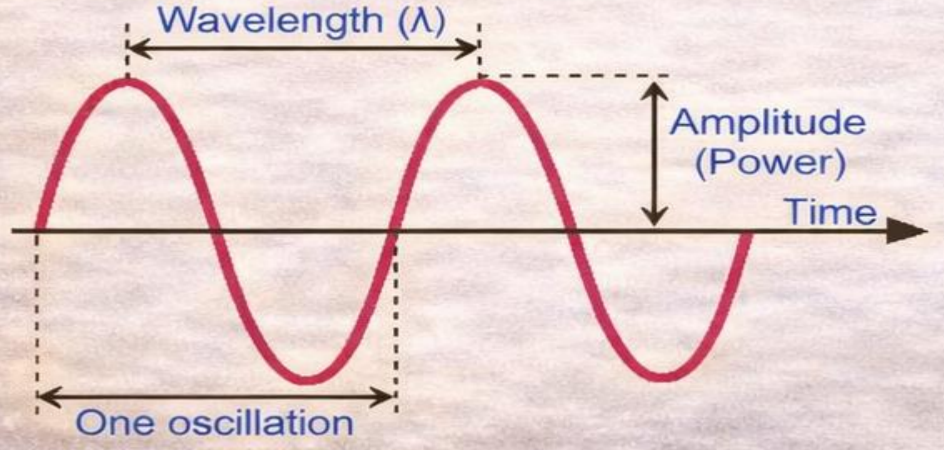


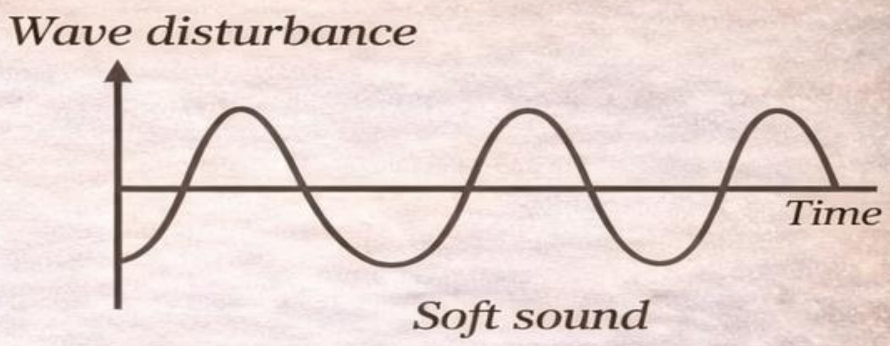


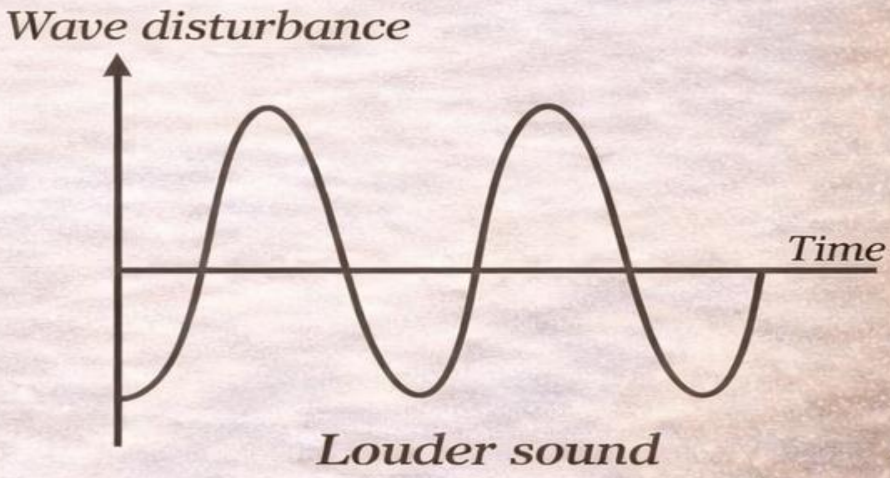
Soft sound has small amplitude
louder sound has large amplitude.

CHARACTERISTICS OF A SOUND WAVE

- Amplitude depends on the force causing vibration of an object. A light strike on a table produces a soft sound with lower amplitude (less energy). A hard hit results in a louder sound with greater amplitude.
- As the sound wave spreads out from its source, its amplitude and loudness decrease.





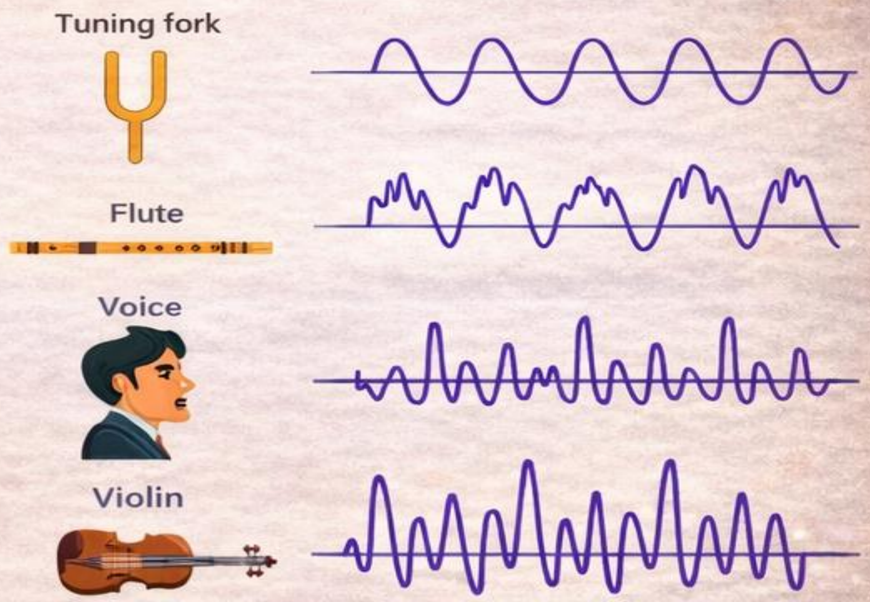


Soft sound has small amplitude and louder sound has large amplitud

CHARACTERISTICS OF A SOUND WAVE

- The **quality (timbre)** of sound is the characteristic that distinguishes sounds with the same pitch and loudness. A **richer quality** makes sound pleasant.
- A sound of single frequency is called a **tone.**
- A sound produced by a mixture of several frequencies is called a **note** and is pleasant to listen to.
- **Noise** is unpleasant to the ear.
- **Music** is pleasant to hear and is of rich quality.

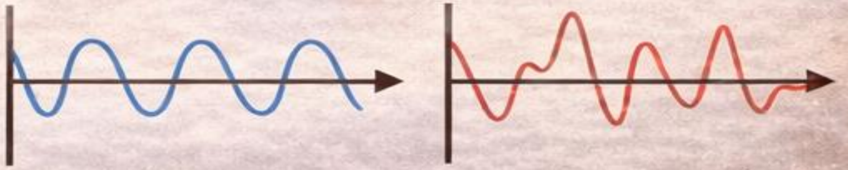
Timbre



Noise

Music

Tone Noise



Tone Noise

CHARACTERISTICS OF A SOUND WAVE

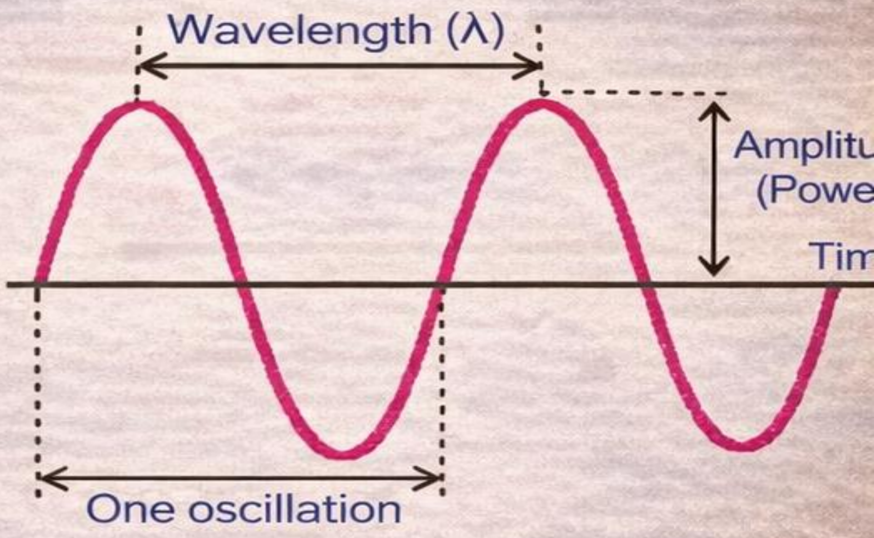
- The speed of sound is defined as the distance which a point on a wave, such as a compression or a raefaction, travels per unit time.

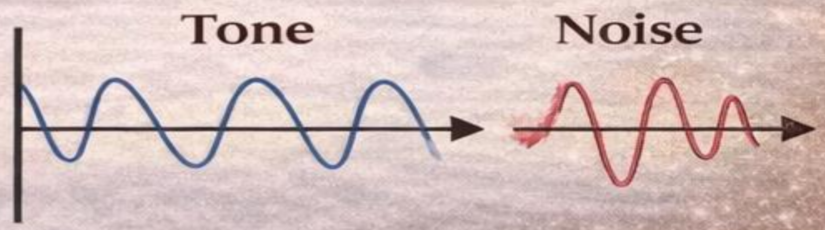
Speed, $v = \text{distance} / \text{time} = \frac{\lambda}{T} = \frac{\lambda}{T}$

$\nu = \frac{1}{T}$ Hence, $v = \lambda \nu$

i.e., speed = wavelength × frequency

Speed of sound is almost the same for all frequencies in a given medium under the same physical conditions.





Characteristics of a Sound Wave

Example

A sound wave has a frequency of 2 kHz and wave length 35 cm. How long will it take to travel 1.5 km?

Solution

- Frequency, ν = 2 kHz = 2000 Hz
- Wavelength, λ = 35 cm = 0.35 m
- Speed of the wave, $v = \lambda \nu$

  = 0.35 m × 2000 Hz = 700 m/s

$$t = \frac{d}{v} = \frac{1.5 \times 1000\ \text{m}}{700\ \text{m s}^{-1}} = \frac{15}{7}\ \text{s}$$

= 2.1 s

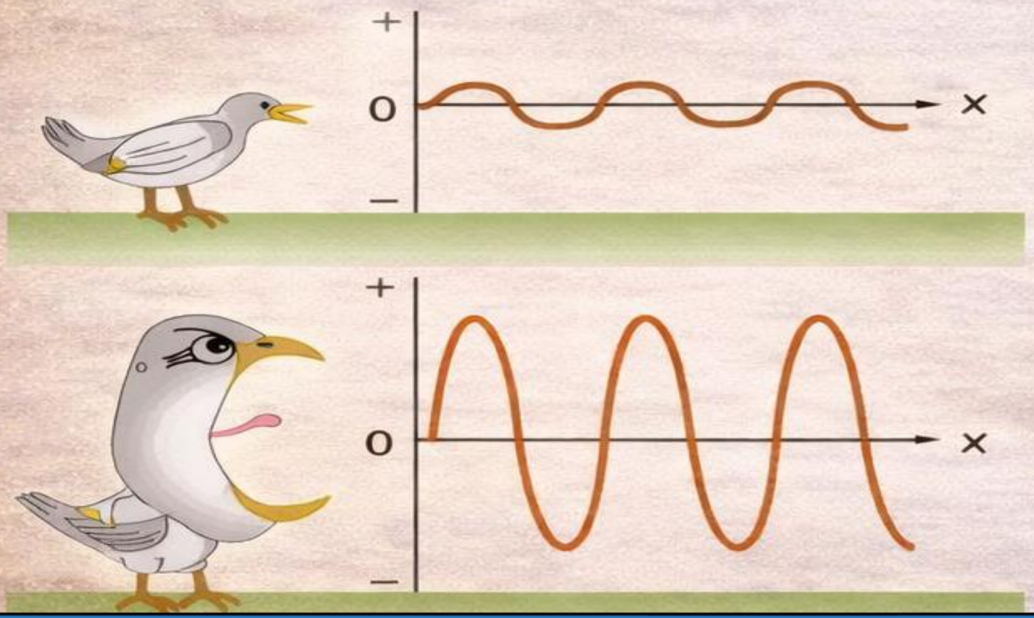
Solution

Time taken by wave to travel a distance, *d* of 1.5 km

$$t = \frac{d}{v} = \frac{1.5 \times 1000\ \text{m}}{700\ \text{m s}^{-1}} = \frac{15}{7}\ \text{s}$$

CHARACTERISTICS OF A SOUND WAVE

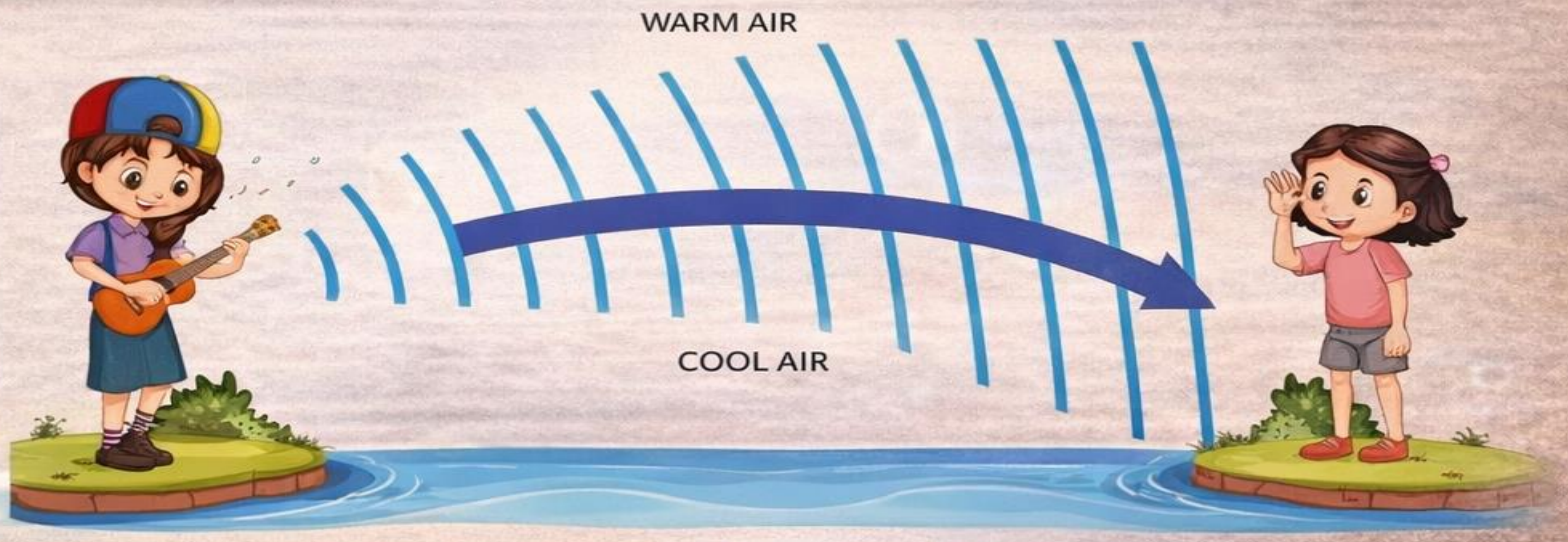
- The amount of sound energy passing through unit area per second is called the **sound intensity**.
- **Loudness and intensity are not the same.** Loudness measures the **ear's response** to sound.
- Even two sounds have equal intensity, one sound may be heard as louder than the other because our ear detects it better.



Fire alarm and subwoofer's basss have same intensity but different loudness.

Speed of Sound in Different Media

- Sound propagates through a medium at a finite speed.
- The delay between **hearing thunder and seeing lightning** shows that **sound travels much slower than light.**
- Speed of sound in a medium is affected by temperature. It decreases from solid to gas. As **temperature increases,** the speed of sound also **increases**. E.g., speed of sound in air is 331 m s^{-1} at 0 °C and 344 m s^{-1} at 22 °C.

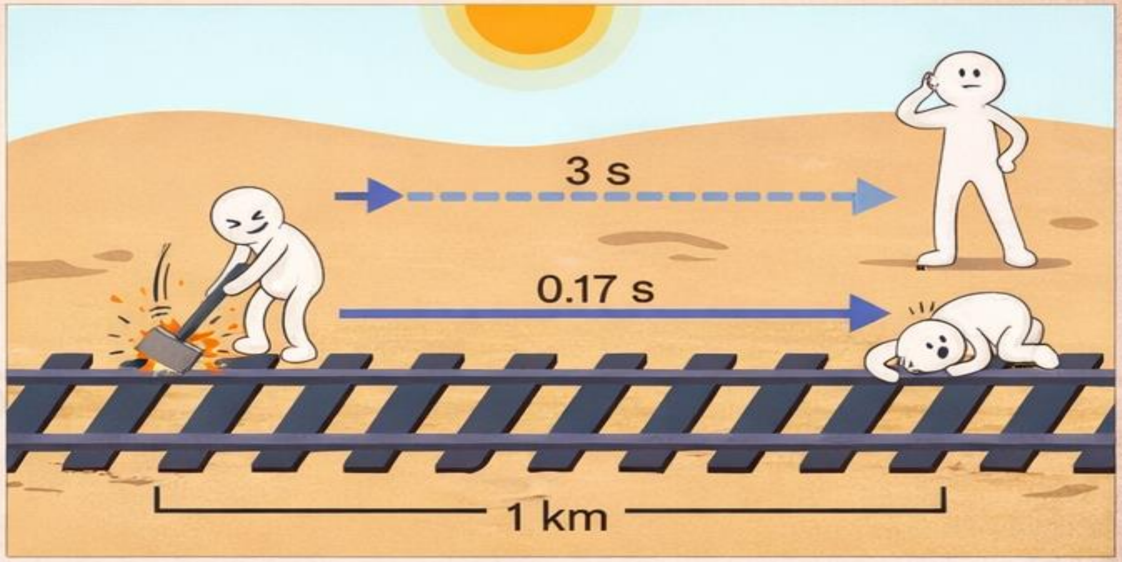


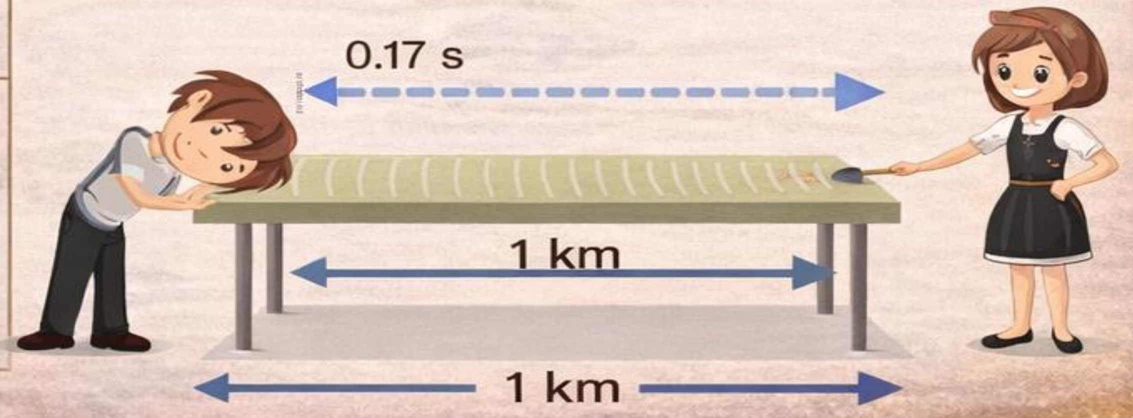
331 m s^{-1} at 0 °C and 344 m s^{-1} at 22 °C

Speed of Sound in Different Media

Speed of Sound in Different Media

State	Substance	Speed in m/s (at 25°C)
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

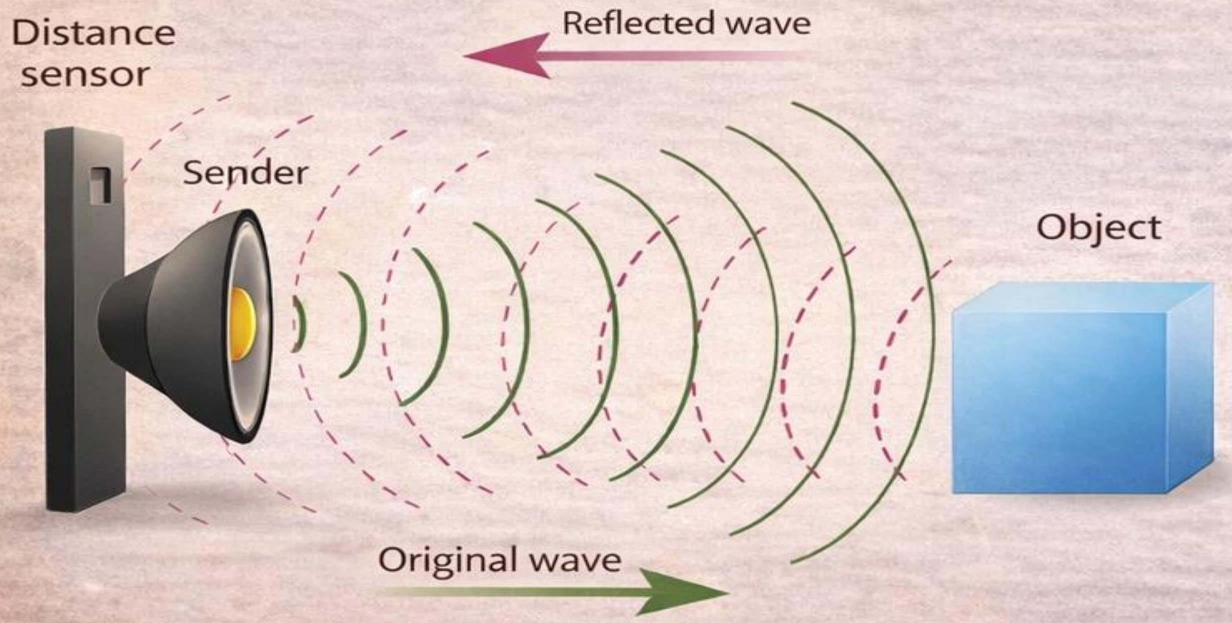


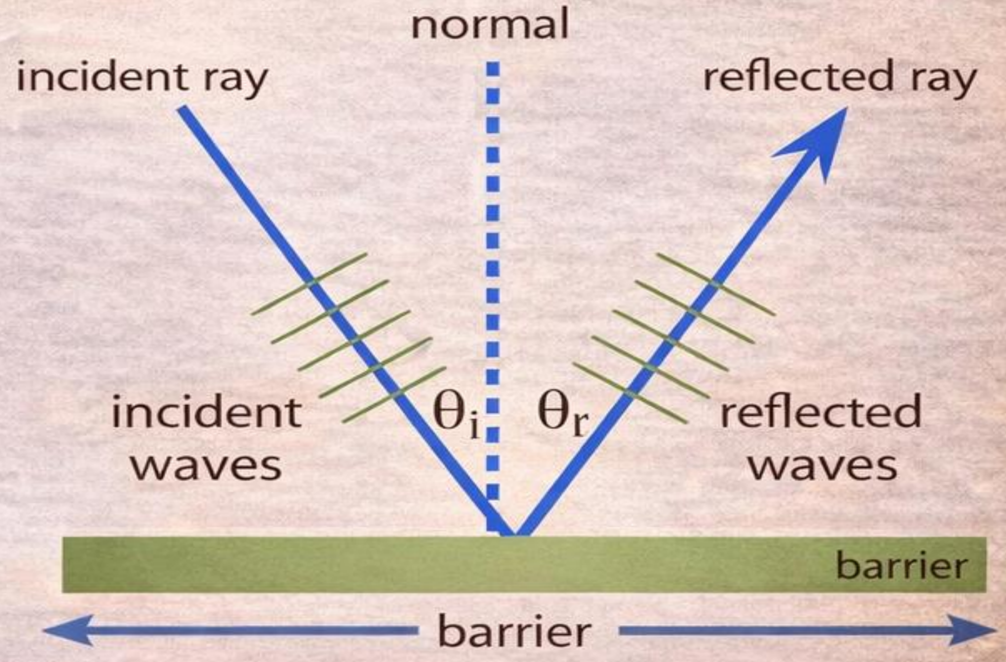


Reflection of Sound

- Sound bounces off solids or liquids like a rubber ball bounces off a wall.
- Like light, sound reflects at the surface of a solid or liquid according to the **same laws of reflection.** The **angles of incidence** and reflection are **equal** to the normal at the point of incidence, all within the same plane. Reflection requires a large obstacle, polished or rough.

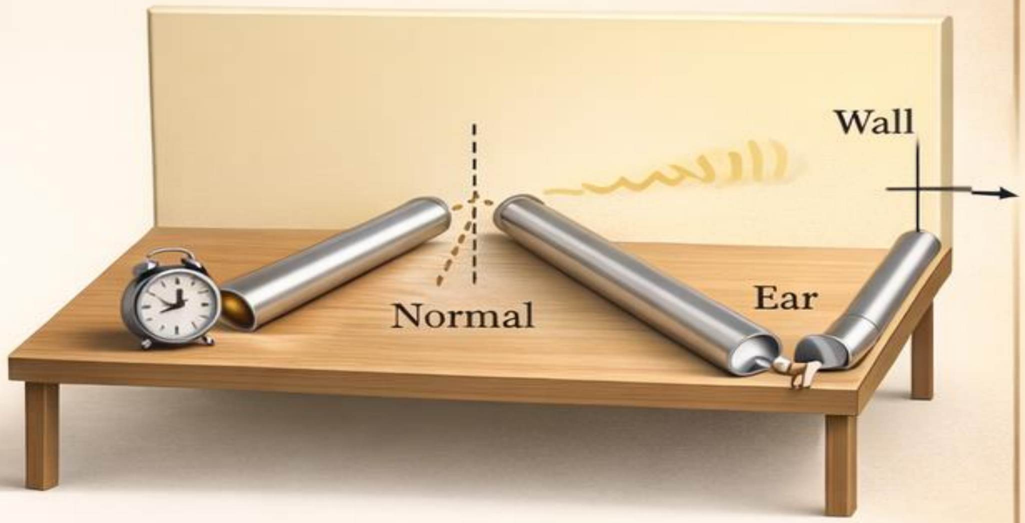
- Sound bounces off solids or liquids like a rubber ball bounces off a wall.





REFLECTION OF SOUND

Activity

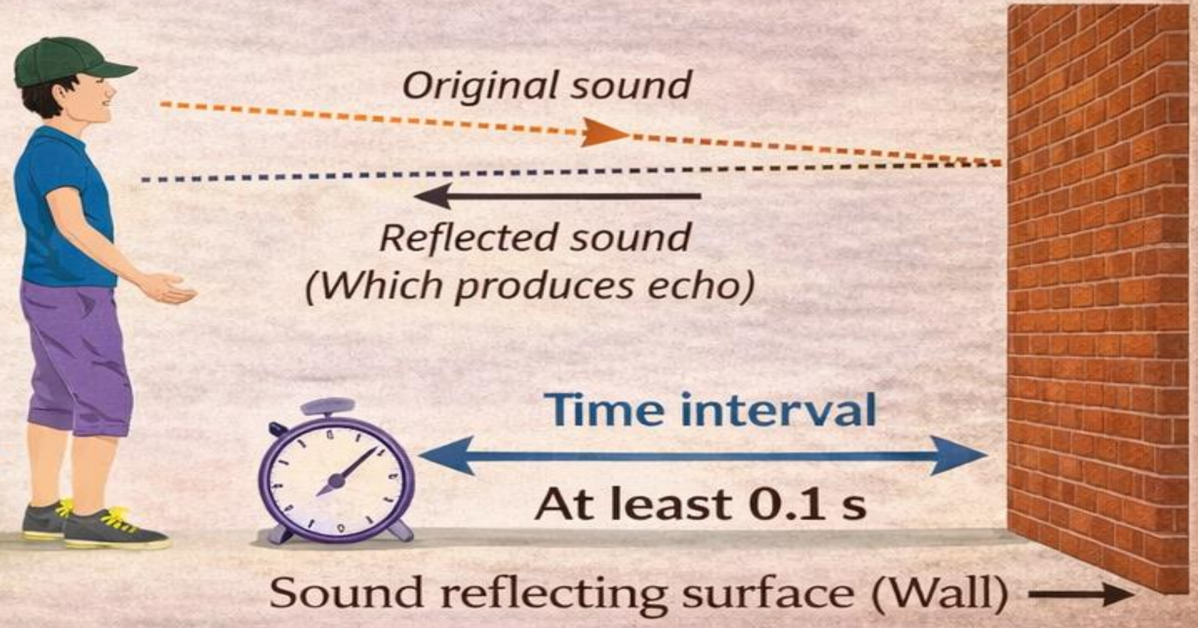


- Arrange two identical pipes on a table near a wall.
- Keep a clock near the open end of one pipe and try to hear the sound of the clock through the other pipe.
- Adjust the pipes to best hear the clock's sound.
- Measure the angles of incidence and reflection. The angles are equal.
- Lift the pipe on the right vertically to a small height. The sound will become harder to hear.

REFLECTION OF SOUND

ECHO

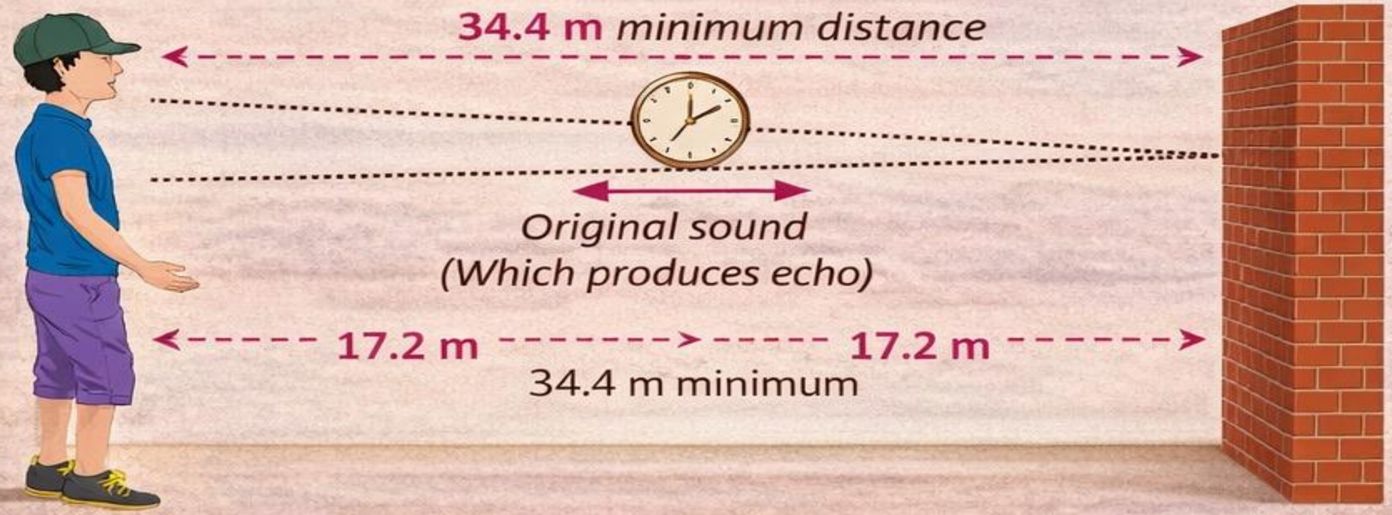
- It is the repetition of a shout or clap heard later after reflecting off an object like a building or mountain.
- The sensation of sound persists in brain for **0.1 s.**
- To hear a distinct echo, the time interval between the orginal sound and reflected one must be at least **0.1 s.**



Reflection of Sound

ECHO

- If the speed of sound is 344 m/s at 22 °C, the total distance traveled by the sound (to the reflecting surface and back to listener) must be at least 34.4 m (344 x 0.1 s).
- Thus, to hear distinct echoes, the minimum distance from the source to reflecting surface must be **17.2 m** (half of total distance). This distance varies with the temperature of air.
- Echoes can occur multiple times due to successive reflections. E.g., the rolling of thunder is due to repeated reflections of sound from clouds and the land.

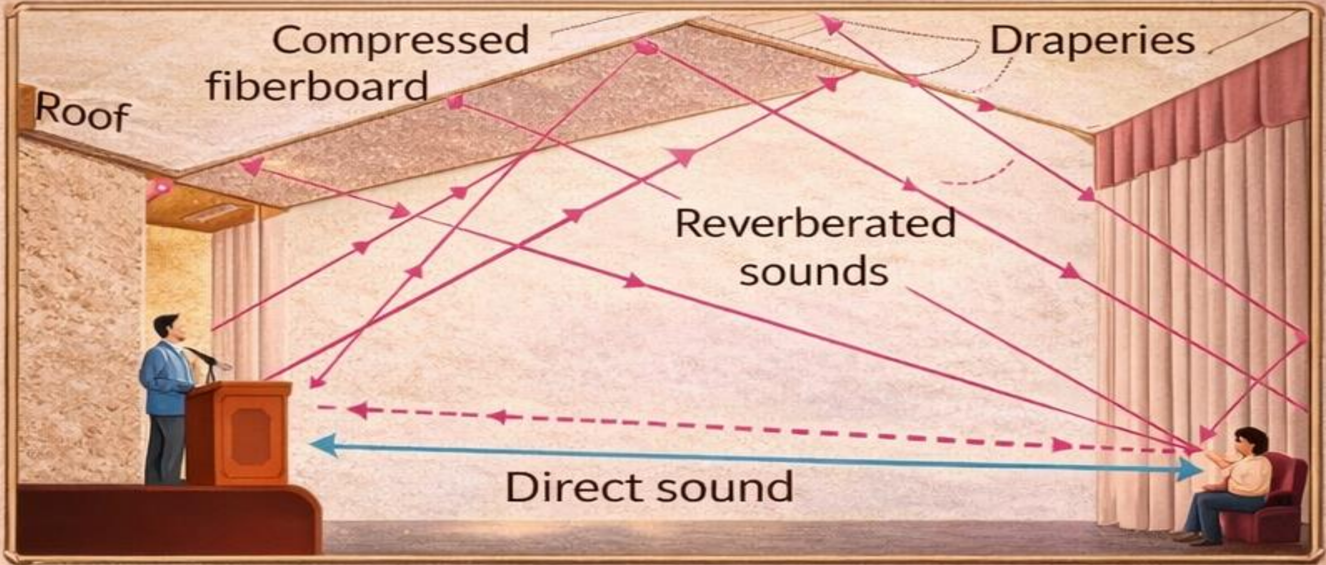


Echoes can occur multiple times due to successive reflections. E.g., the rolling of thunder is due to

REFLECTION OF SOUND

REVERBERATION

- In a big hall, sound persists through repeated reflections from the walls until it is inaudible. This persistence of sound due to repeated reflections is called **reverberation.**
- Excessive reverberation in auditoriums is undesirable. To reduce it, sound-absorbent materials such as compressed fiberboard, rough plaster, or draperies are used on the roof and walls. Seat materials are also chosen for their sound-absorbing properties.



- Compressed fiberboard
- Rough plaster
- Draperies

REFLECTION OF SOUND

EXAMPLE

A person clapped near a cliff and heard the echo after 2 s.

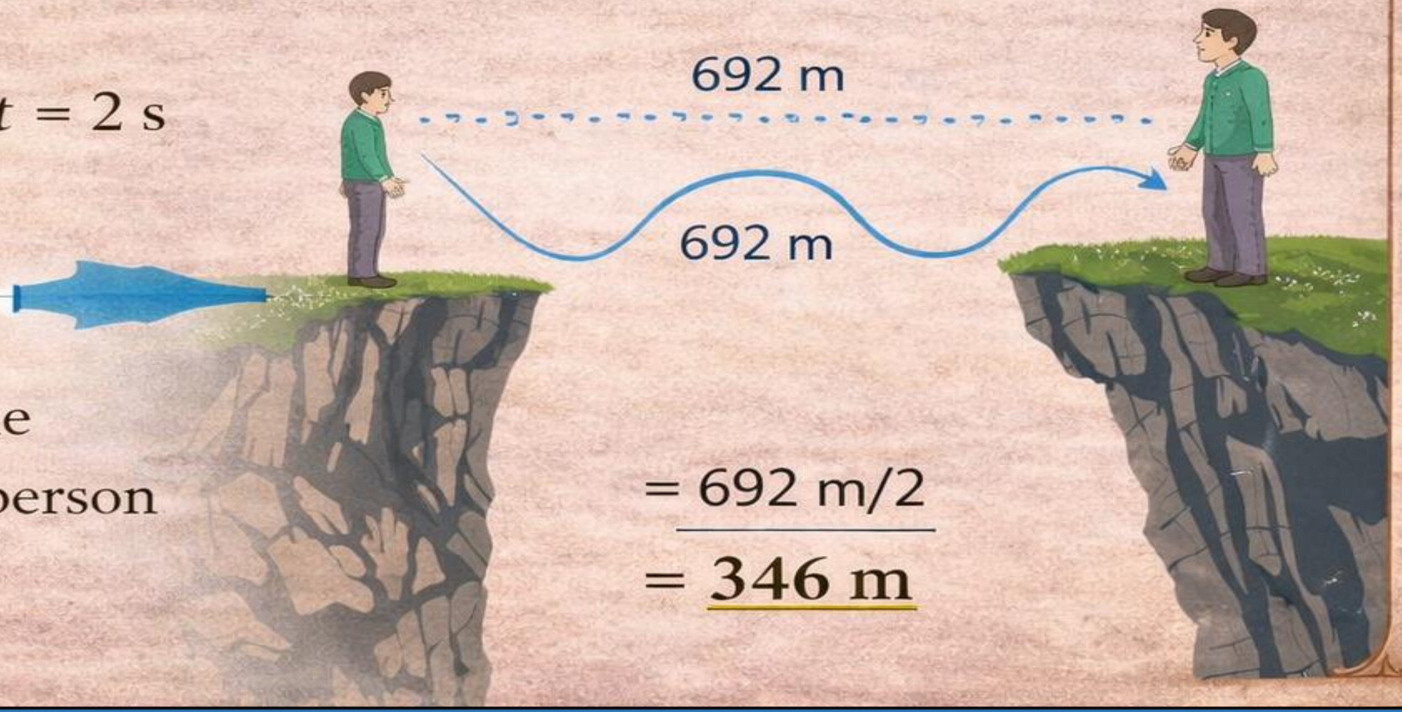
What is the distance of the cliff from the person if the speed of the sound is taken as 346 m s^{-1}?

- Speed of sound, $v = 346 \text{ m s}^{-1}$
- Time taken for hearing the echo, $t = 2 \text{ s}$
- Distance travelled by the sound

$= v \times t = 346 \text{ m s}^{-1} \times 2 \text{ s} = 692 \text{ m}$

In 2 s sound has to travel twice the distance between the cliff and the person

= **346 m**

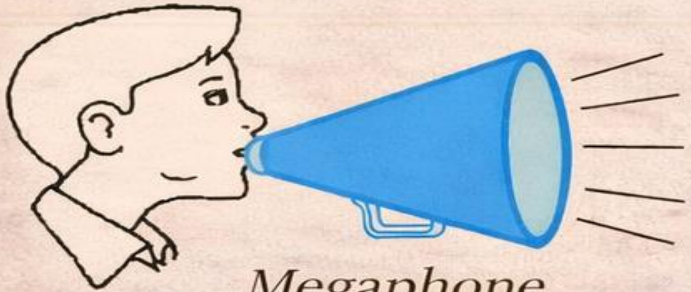


= 692 m/2

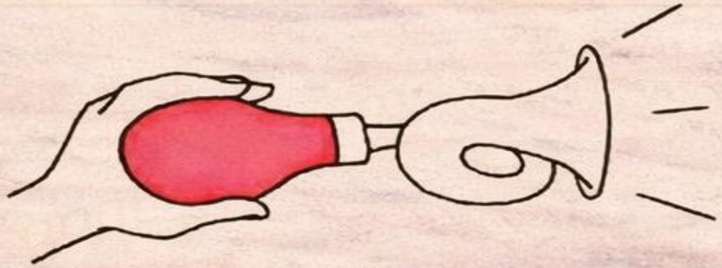
= **346 m**

USES OF MULTIPLE REFLECTION OF SOUND

1. **Megaphones (loudhailers), horns, musical instruments** like **trumpets** and **shehnais**, are designed to send sound in a particular direction. They use a tube and a conical opening to reflect and guide most sound waves towards the audience.



Megaphone



Horn

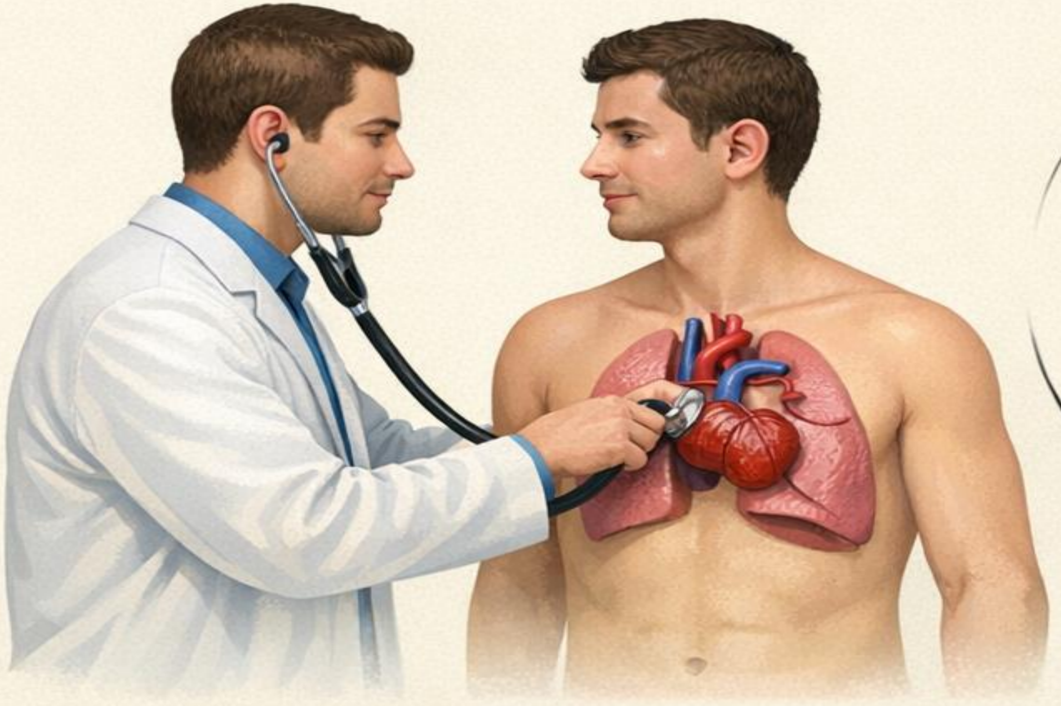
Trumpet

Shehnai

REFLECTION OF SOUND

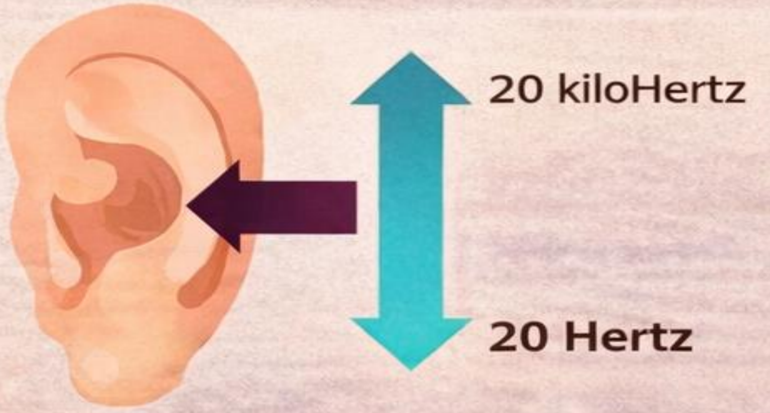
Uses of multiple reflection of sound

2. **Stethoscope** is used to listen to internal body sounds, mainly in the heart or lungs. The sound of heartbeat reaches the doctor's ears by multiple reflection of sound.



RANGE OF HEARING

- The audible range of sound for human is **20 Hz** to **20000 Hz** (one Hz = one cycle/s).
- Children under the age of five and some animals (e.g., dogs) can hear up to 25 kHz (1 kHz = 1000 Hz).
- As people age, their ears become less sensitive to higher frequencies. Frequencies below 20 Hz are called **infrasonic sound** or **infrasound**. If we could hear infrasound, we would hear the vibrations of a pendulum just as we hear the vibrations of the wings of a bee.

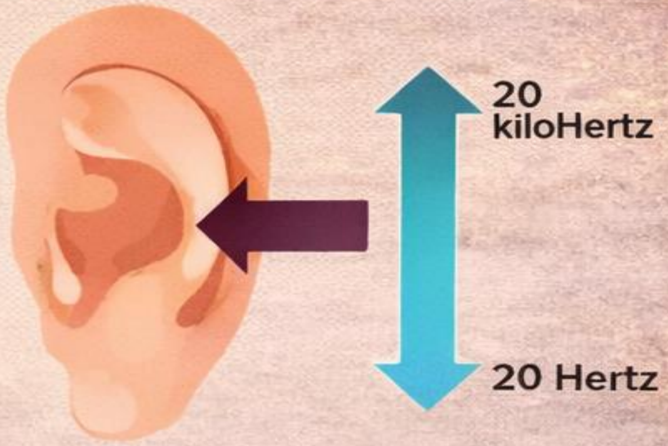


RANGE OF HEARING

- *Rhinoceroses communicate using* **infrasound** *of frequency as low as 5 Hz.*
- **Whales & elephants** produce sound in the infrasound range.
- Some animals get disturbed before earthquakes.
- **Earthquakes** produce **low-frequency infrasound** before the main shock waves begin which alert the animals.

RANGE OF HEARING

- **Frequencies higher than 20 kHz** are called **ultrasonic sound** or **ultrasound**. They are high frequency waves.
- Ultrasound is produced by animals like dolphins, bats, rats, and porpoises. Certain moth families can detect the high-frequency squeaks of bats, allowing them to sense nearby bats and escape capture.



RANGE OF HEARING

Hearing Aid

- It is an electronic, battery-operated device.
- It receives sound through a microphone which converts the sound waves to electrical signals.
- These signals are amplified by an amplifier and sent to a speaker, which converts them back into sound for clearer hearing.

APPLICATIONS OF ULTRASOUND

Ultrasounds can travel along well-defined paths even in the presence of obstacles.

1. **Ultrasound cleans hard-to-reach parts** (e.g., spiral tubes and electronic components) by using ultrasonic waves in a cleaning solution to remove **dust, grease, and dirt.**

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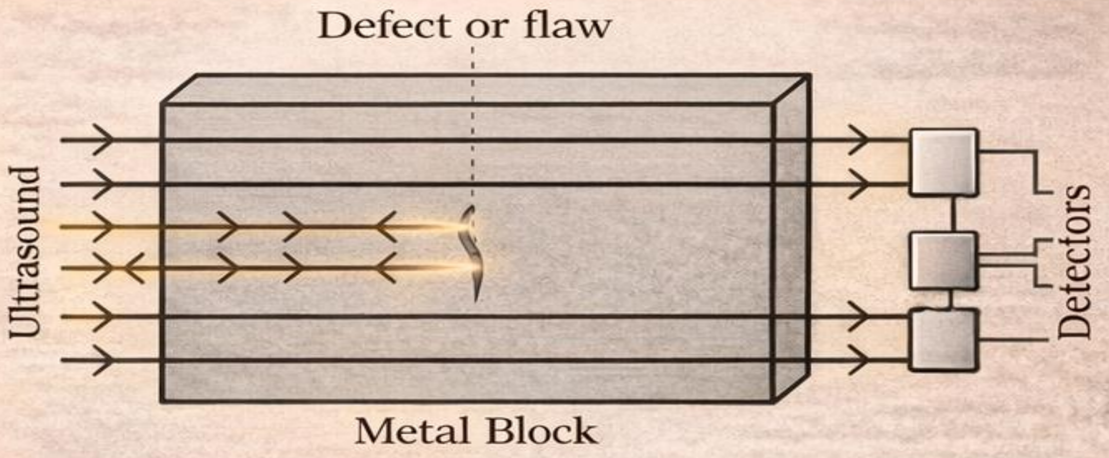
(e.g., spiral tubes and electronic components) by using ultrasonic waves in a cleaning solution to remove dust, grease.



2. **It detects cracks and flaws in metal blocks** used in contruction and scientific equipment. Ultrasonic waves pass through the metal, and detectors identify reflected waves from defects.

Ordinary sound of longer wavelengths cannot be used for such purpose as it will bend around the corners of the defective location and enter the detector.

APPLICATIONS OF ULTRASOUND

3 Ultrasonic waves can reflect parts of the heart to create its image. This technique is called **echocardiography**.

4 **It can break small kidney stones** into fine grains which are then flushed out with urine.

Ordinary sound of longer wavelengths cannot be used for such purpose as it will bend around the

APPLICATIONS OF ULTRASOUND

5 **Ultrasound scanner** is an instrument which uses ultrasonic waves to create images of internal organs, such as the liver, gall bladder, uterus, and kidneys.

Ultrasonic waves travel through the tissues and are **reflected** from regions where **tissue density changes**. These waves are converted into **electrical signals** to generate images of the organ. These are displayed on a monitor or printed on film. This technique is called **ultrasonography.**

It helps to detect **abnormalities (stones or tumours)** and monitors congenital defects and **growth abnormalities** of the **foetus.**

It helps to detect **abnormalities (stones or tumours)** and monitors congenital defects and growth abnormalities of the **foetus.**


thank you