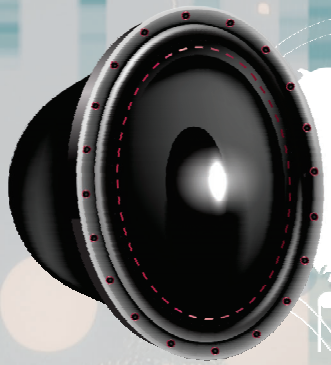
ALLEN®



SOUND

Waves

A wave is a repeating disturbance or movement that transfers energy through matter or space.

Waves are a form of travelling energy

- For waves, there is no net displacement of the particles (they return to their equilibrium position), but there is a net displacement of the wave. There are thus two different motions: the motion of the particles of the medium and the motion of the wave.
- Waves transfer energy, momentum and pattern of disturbances from one place to another.

Mechanical and non-mechanical waves

Mechanical Waves :

These waves require a medium for their propagation.

- A medium can be a solid, a liquid, a gas, or a combination of these.

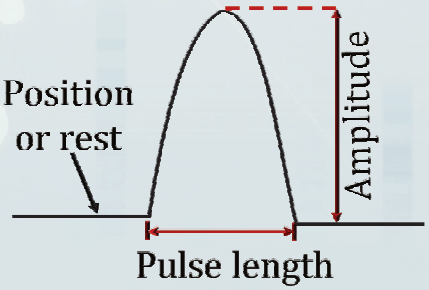
Non-mechanical waves :

These waves do not require any medium for their propagation. They can travel through space. These waves are also called electromagnetic waves.

Wave pulse :

A pulse is a single disturbance that moves through a medium.

- **Amplitude of a wave pulse :**
  The amplitude of a pulse is a measurement of how far the medium is displaced from rest.





Amplitude of an oscillating particle

The maximum displacement in either direction from the mean position (or rest position) of an oscillating particle is called its amplitude.

Periodic motion

A motion that occurs when an object moves in a repeated pattern (a cycle) over equal periods of time is called a periodic motion.

Examples : Wave motion, motion of an oscillating pendulum, uniform circular motion, all are periodic motions.

Oscillatory motion

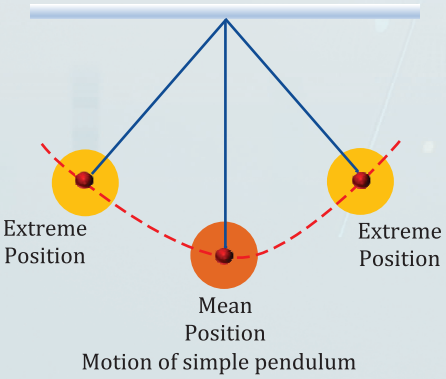
A motion that occurs when an object moves to and fro about its mean position over equal periods of time is called an oscillatory motion or vibratory motion.

Examples : Motion of a simple pendulum, motion of a vibrating stretched string, motion of an oscillating spring.

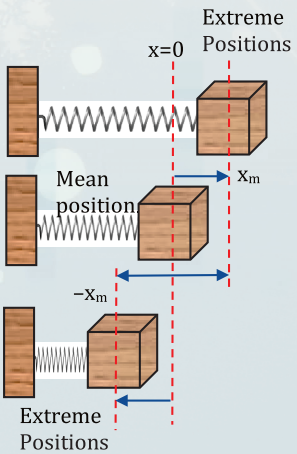
Equilibrium position (or mean position)

A position in the path of an oscillating particle at which the net force acting on the particle is zero is called its equilibrium position or mean position.

Examples : The vertical position or the lowest position of an oscillating pendulum is its equilibrium position or mean position (see figure).



Motion of simple pendulum

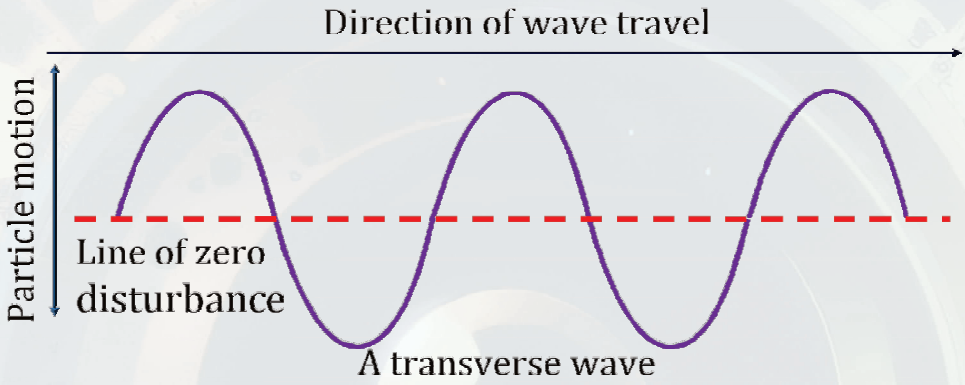


Motion of an oscillating spring

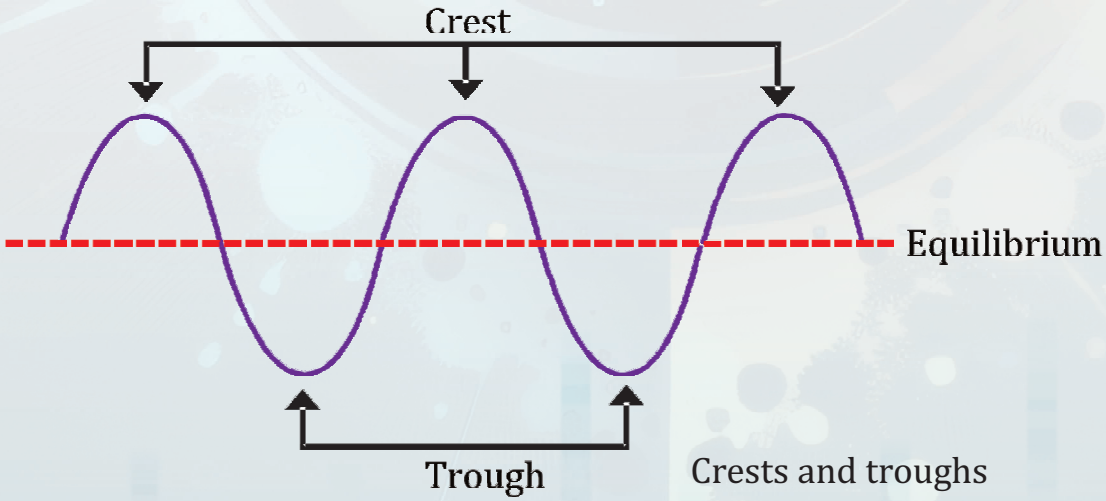


Transverse waves

A transverse wave is a wave where the movement of the particles of the medium is perpendicular to the direction of propagation of the wave.



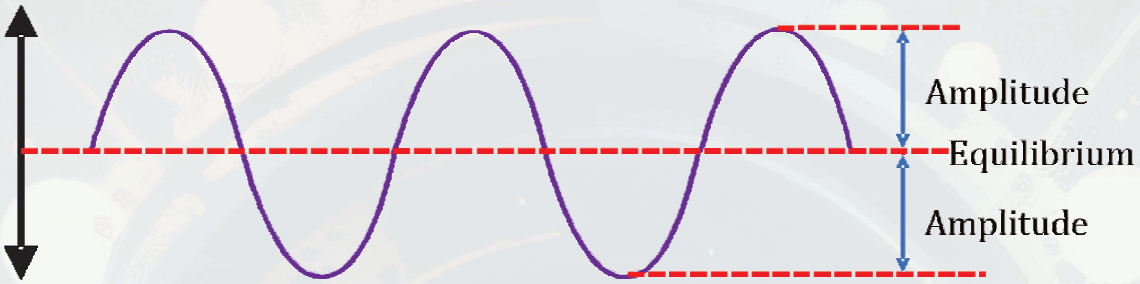
- **Line of zero disturbance :** It is the line at which the net force on the particles of the medium is zero.
- **Crest and trough :** Transverse waves consist of moving crests and troughs. A crest is the part of the transverse wave which is above the line of zero disturbance. A trough is the part of transverse wave which is below the line of zero disturbance.



Crests and troughs in a transverse wave



- **Amplitude :** The amplitude is the maximum displacement of a particle from its equilibrium position.

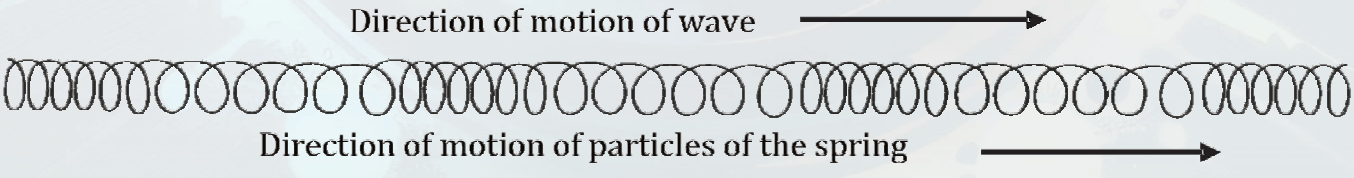


Amplitude of a transverse wave

- Transverse waves can be formed in solids and on the surfaces of liquids only.
- When a transverse wave propagates, there is no pressure changes in the medium.

Longitudinal waves

A longitudinal wave is a wave where the particles in the medium move parallel to the direction of propagation of the wave.

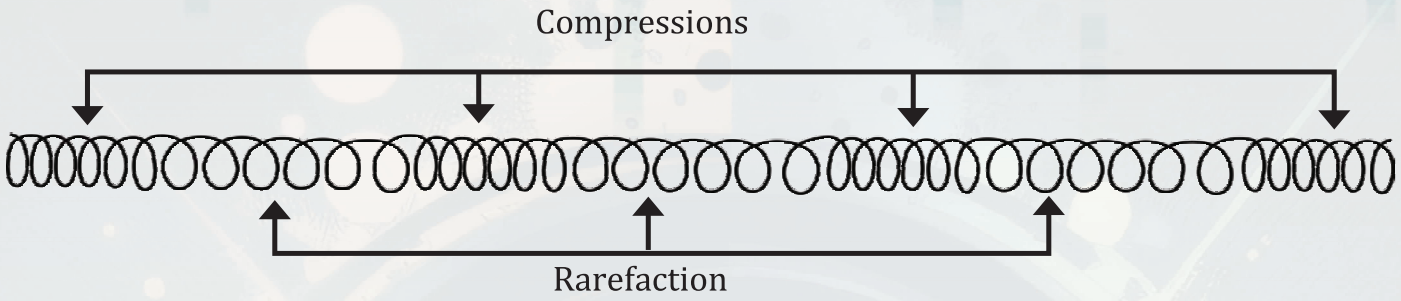


Longitudinal wave through a spring

- **Compression (or condensation) :** A compression is a region in a longitudinal wave where the particles are closer together than their normal separations.

- **Rarefaction :** A rarefaction is a region in a longitudinal wave where the particles are farther apart than their normal separations.





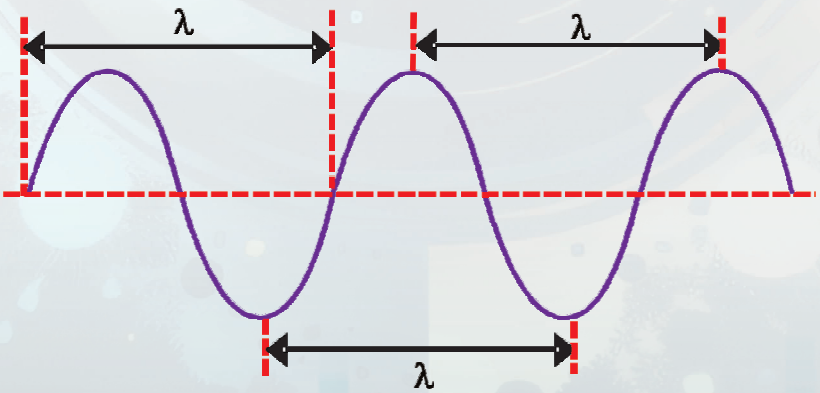
Compressions and rarefactions on a longitudinal wave

Some basic terms related to waves

Wavelength

- Also, the distance travelled by a wave when it completes its one cycle is called its wavelength. It is represented called lambda.

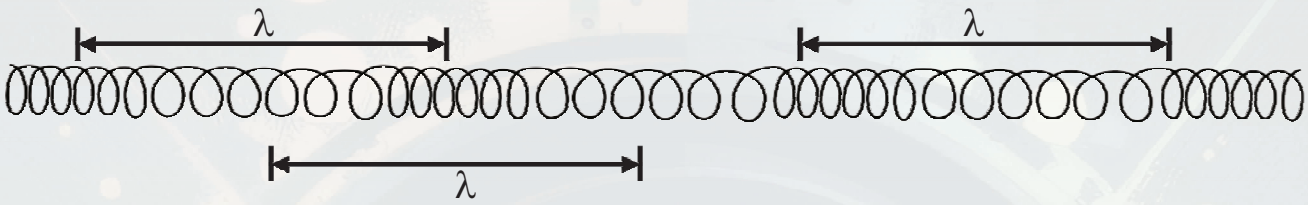
- The wavelength in a transverse wave refers to distance between peaks of two consecutive crests or two consecutive troughs.



Wavelength of a transverse wave

- The wavelength in a longitudinal wave refers to the distance between two consecutive compressions or between two consecutive rarefactions.





Wavelength of a longitudinal wave

- **Time period (or period) :** time taken to complete one oscillation of a wave is called time period or simply the period of the wave.

Frequency

- It can be defined as the number of oscillations per second.
  - For transverse wave, the frequency is the number of successive crests (or troughs) passing a given point in 1 second.
  - Unit of frequency (ν) : This unit is also called hertz (Hz).
    1 Hz = 1 cycle /sec or 1 oscillation/sec = 1 s^{-1}

- **Relationship between time period and frequency :**
  Frequency (ν) is the reciprocal of time period (T).

$$\boxed{\nu = \frac{1}{T}}$$

- **Wave speed (ν) :** Wave speed is distance travelled by the pattern of the wave per unit time. We know that in a time period T, the distance travelled by the wave is one wavelength (λ).

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

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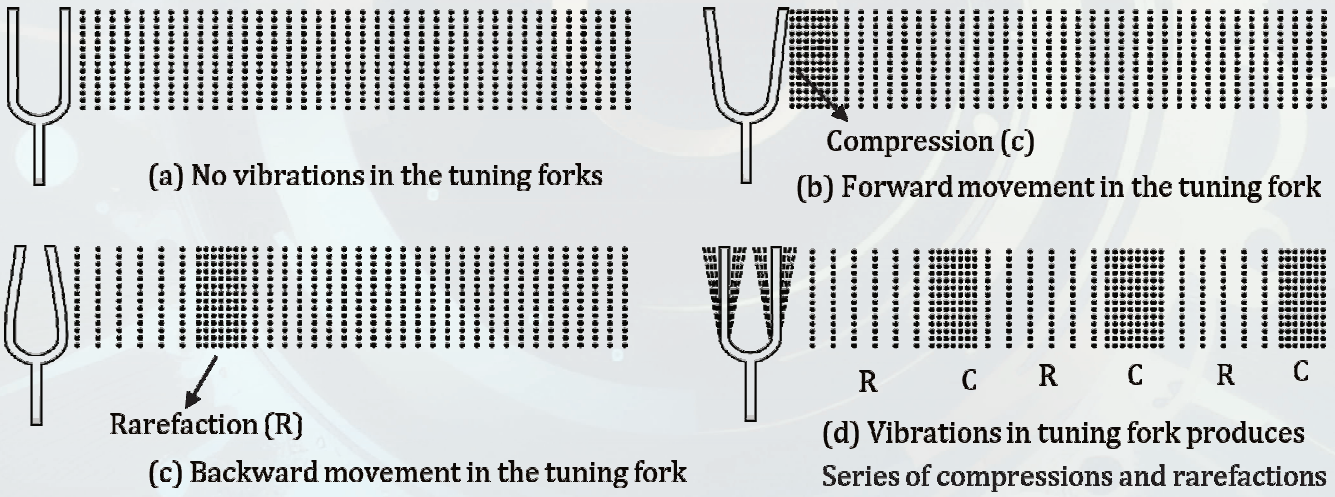
SOUND

"A form of energy, produced by rapidly vibrating objects, that can be heard by the human ear is called sound."

Propagation of sound

- Sound is a mechanical wave which require material medium to propagate.
- Sound waves cannot travel through outer space, because space is very nearly a vacuum.

Understanding propagation of sound using a vibrating tuning fork



Speed of sound in different media

- The speed of sound is fastest in solids, faster in liquids, and slowest in gases.

Speed of sound depends on the temperature of the medium

- The speed of sound is maximum in gases as they are greatly affected by the increase or decrease in temperature.

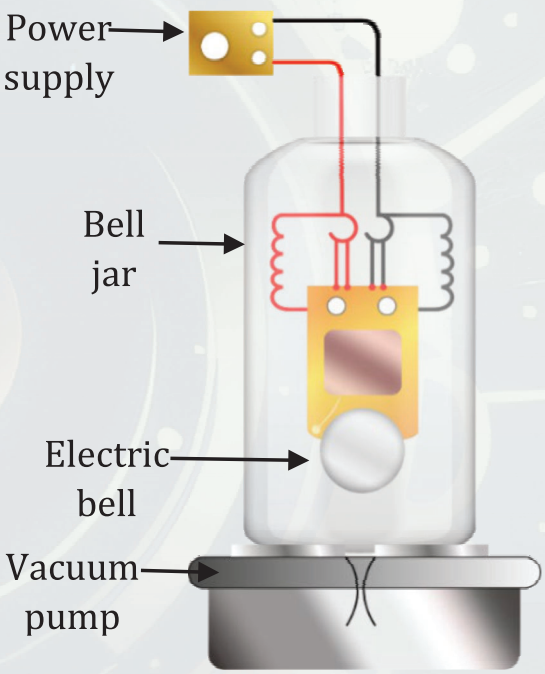


Sound needs a medium for propagation

- Mechanical waves require a material medium to travel. Sound is also a mechanical wave thus, it requires a material medium like air, water, steel, etc. for its propagation. It cannot travel through vacuum.

Bell jar experiment

- Take an electric bell and an airtight glass bell jar.
- The electric bell is suspended inside the airtight bell jar.
- The bell jar is connected to a vacuum pump.
- If you press the switch you will be able to hear the bell. Now start the vacuum pump.
- When the air in the jar is pumped out gradually, the sound becomes fainter, although the same current is passing through the bell. After some time when less air is left inside the bell jar you will hear a very feeble sound.



A bell jar experiment for sound

Speed of sound in different media

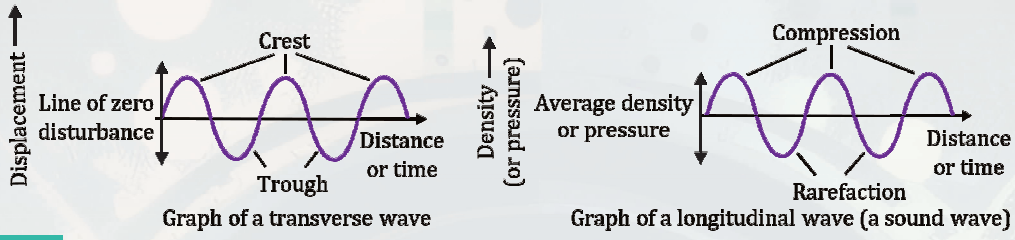
- Speed of sound is different in different media. Sound waves can travel through solids, liquids and gases. The speed of sound is fastest in solids, faster in liquids, and slowest in gases.

Speed of sound depends on the temperature of the medium

Speed of sound depends on the temperature of the material through which the sound waves are travelling. The more frequent the collisions are, the faster the speed of sound is in the material. For example, the speed of sound in air at 0°C is 331 m/s; at 20°C, it is 343 m/s.



Graphs of waves



Graph of a transverse wave

Graph of a longitudinal wave (a sound wave)

Audible

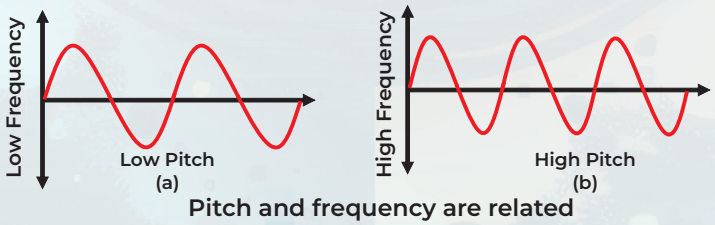
- The sounds of frequencies between 20 Hz and 20,000 Hz that can be detected by the human ear is called audible sounds.

Inaudible

- The sounds of frequencies less than about 20 Hz and those higher than 20,000 Hz cannot be detected by the human ear. Such sounds are called inaudible sounds.
- Frequencies of less than 20 Hz are called infrasonic sounds.
- Frequencies that are higher than 20,000 Hz are called ultrasonic sounds.

Characteristics of audible sounds

- Pitch : The frequency of an audible sound wave determines how high or low we perceive the sound to be, which is known as pitch.



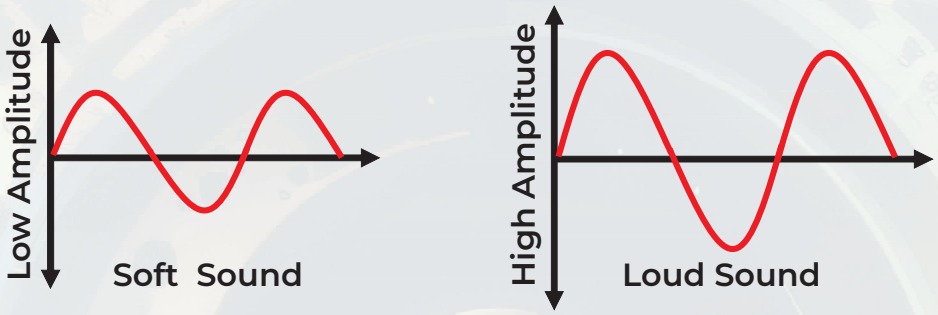
Pitch and frequency are related

Loudness

- The loudness of the sounds humans perceive relates to the intensity of the sound.
- Sound intensity is energy carried by the sound per unit time per unit area.
- Sound intensity is usually measured in watt/(meter)^2 or (W/m^2).



Unit of loudness : The loudness is expressed in a unit called decibel (dB). On the decibel scale, 0 dB (= 10^{-12} Watt/m^2) is called the threshold of hearing.



- Intensity of sound (or any wave) is proportional to the square of the amplitude of the sound (or wave). $\boxed{I \propto A^2}$
- Another unit for measuring loudness is Bel.

$$\boxed{1 \text{ decibel} = \frac{1}{10} \text{bel}}$$

- **Quality (or timbre) :** Quality of a sound is the property by which two sounds of the same pitch (or frequency) emitted by two different sources can be distinguished from each other.
- **Tone :** A sound of single frequency is called a tone or pure tone. For example, a tuning fork produces a single frequency i.e, a pure tone.
- **Note :** The sound which is produced due to a mixture of several frequencies is called a note and is pleasant to listen to.

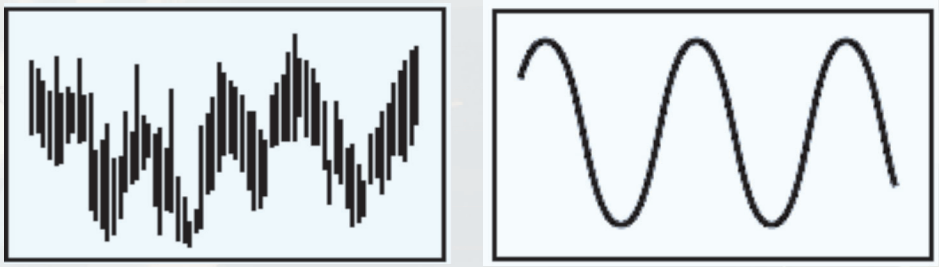
Sonic boom

SUBSONIC	SONIC	SUPERSONIC
When the speed of any object is less than the speed of sound, it is said to be travelling at subsonic speed.	When the speed of any object is equal to the speed of sound, it is said to be travelling at sonic speed.	When the speed of any object exceeds the speed of sound, it is said to be travelling at supersonic speed.



Noise and music

We hear different types of sounds around us. Some sounds are pleasing while some sounds cause discomfort to us. Suppose construction work is going on in your neighbourhood.

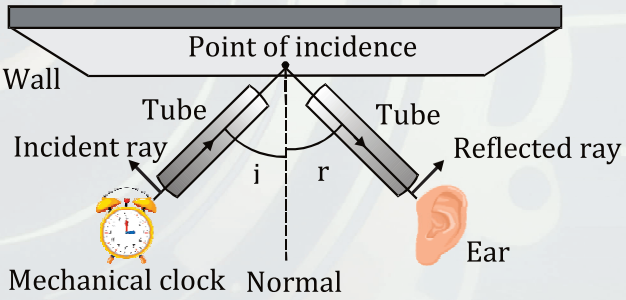


(a) Noise (b) Music

Waveforms of noise and music

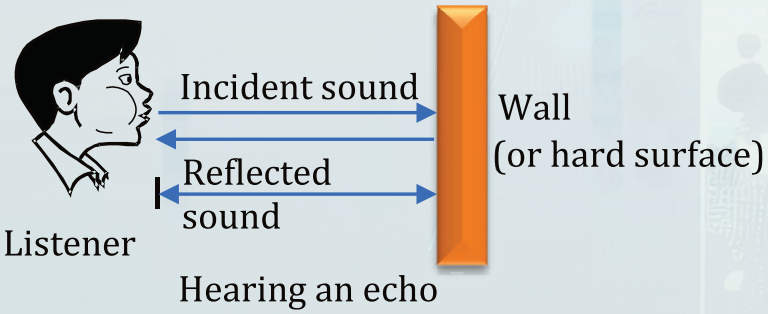
Reflection of sound

Just as a mirror reflects light, when sound waves radiating out from a source strike a rigid obstacle, the angle of reflection of the sound waves equals the angle of incidence.



The reflection of sound waves

- **Echo :** If we shout or clap near a suitable reflecting object such as a tall building or a mountain, we will hear the same sound again a little later. This sound which we hear is called an echo.



Hearing an echo

$$\text{speed, } v = \frac{\text{total distance travelled}}{\text{time taken}} = \frac{2s}{t}$$



Reverberation

- The repeated reflection that results in this persistence of sound is called 'reverberation'.Reverberation characteristics are important in the design of concert halls, theatres, etc.

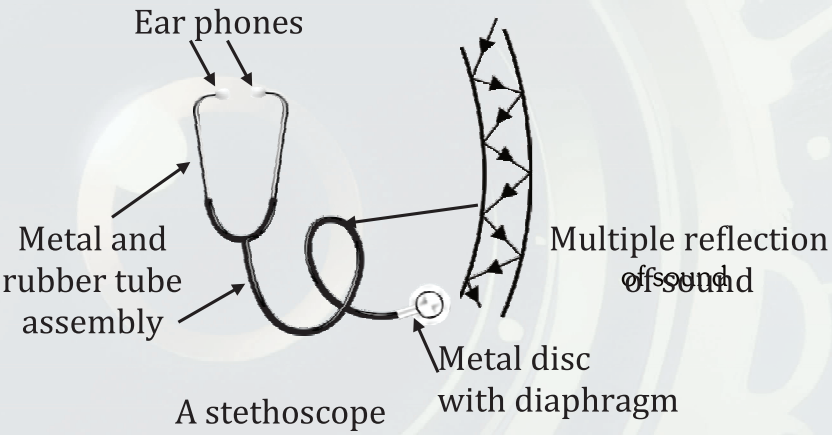
Uses of multiple reflection of sound



Megaphone



Horn



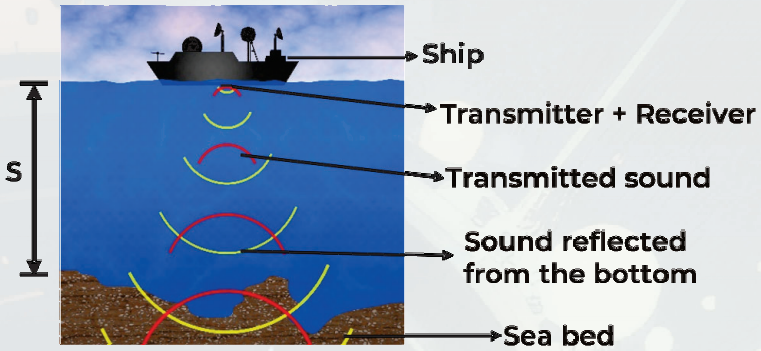
Applications of ultrasound

- Cleaners
- Detectors
- Medical diagnostics
- Echocardiography
- Ultrasonography



SONAR

SONAR stands for SOund NAvigation and Ranging. This process is used to determine the depth of water under a boat or ship.



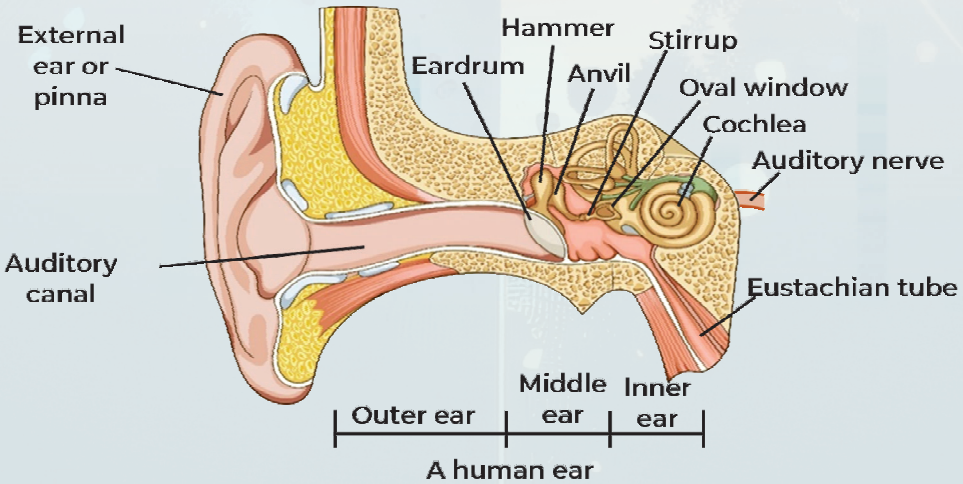
The human ear

- Your ears are organs that detect and analyse sound. Located on each side of your head, they help with hearing and balance.

Human ear consists of three sections

- OUTER EAR
- MIDDLE EAR
- INNER EAR

- **Working :** Human ear is a sense organ responsible for hearing and body balance. The outer ear receives the sound waves and transmits them down the ear canal to the eardrum. This causes the eardrum to vibrate and sound is produced.





Hearing impairment

The total hearing impairment is rare and it is usually from birth itself. Partial disability is generally the result of a disease, injury or age.

Hearing aid

A hearing aid is an electronic device that amplifies sounds for people with hearing impairments.



Echolocation



Ranges of hearing for some animals:
(1) Dogs : 15 Hz – 50,000 Hz
(2) Cat : 60 Hz – 65,000 Hz
(3) Porpoise : 150 Hz – 150,000 Hz