Chapter 12: - Sound
Part-1

Sound
Sound is a form of energy which produces a sensation of hearing in our ears.

Production of Sound
Sound is produced due to the vibration of objects.
Vibration is a periodic back-and-forth motion of the particles of an elastic body or medium about a central position. It is also named as oscillation.
For example:
- Stretched strings of a guitar vibrate to produce sound.
- When membrane of a table is struck, it vibrates to produce sound.

Propagation of Sound
- The travelling of sound is called propagation of sound.
- Sound is propagated by the to and for motion of particles of the medium.
- When an object vibrates, the particles around the medium vibrate. The particle in contact with the vibrating object is first displaced from its equilibrium position. Each particle disturbs the other particle in contact. Thus, the disturbance is carried from the source to the listener.

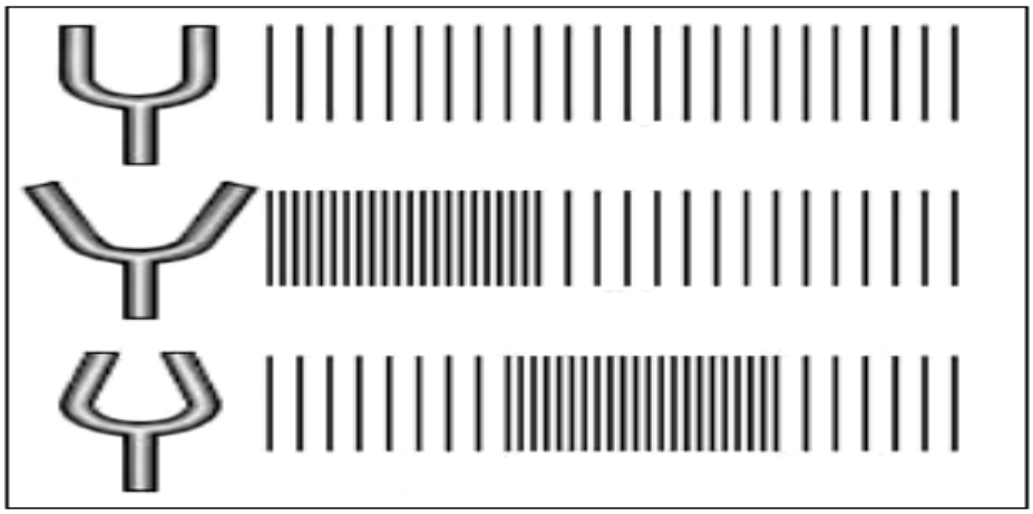


Fig. Representation of particle disturbance moving forward

Only the disturbance produced by the vibrating body travels through the medium but the particles do not move forward themselves.

Medium
- The matter or substance through which sound is transmitted is called a medium.
- A medium is necessary for the propagation of sound waves.
- The medium can be solid, liquid or gas.
- Sound cannot travel in vacuum.

Wave that requires medium to propagate is called Mechanical wave.

Wave

Wave is a phenomenon or disturbance in which energy is transferred from one point to another without any direct contact between them. For example: Heat, light and sound is considered as a wave.

Types of Waves

On the basis of direction of propagation, waves are categorized into two parts:

(i) **Longitudinal waves:** These are the waves in which the particles of the medium vibrate along the direction of propagation of the wave. For example: sound wave.

(ii) **. (ii) Transverse waves:** In this type of wave the particles of the medium vibrate in a direction perpendicular to the direction of propagation of the wave. For example: waves produced in a stretched string.

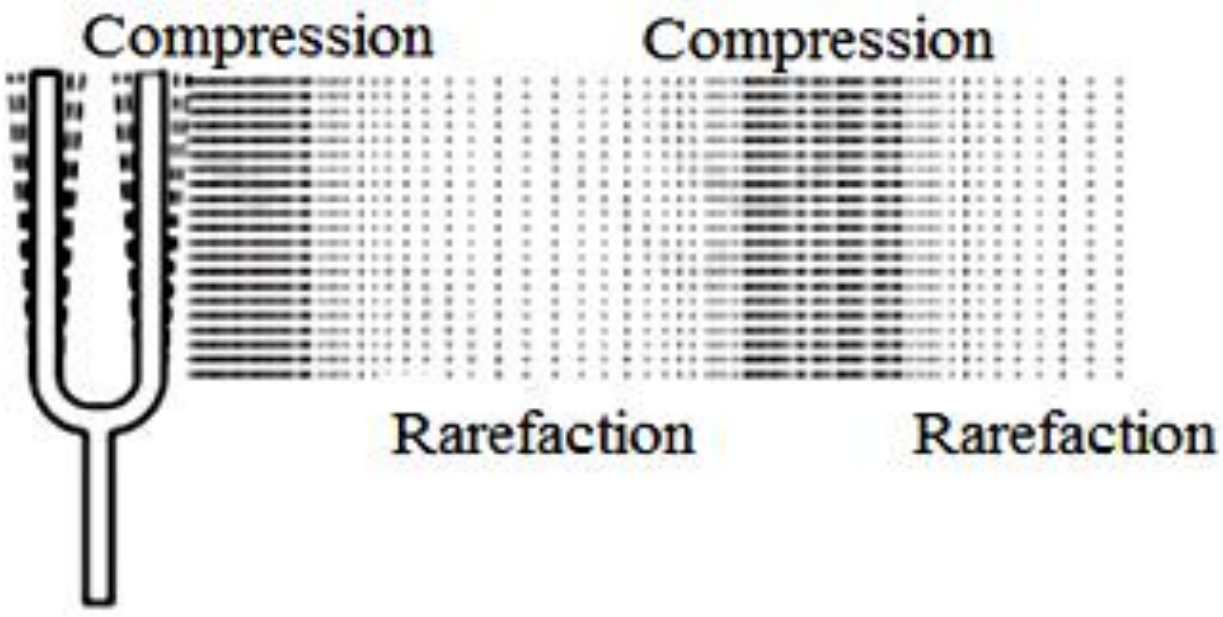
Another type of waves which do not require any medium for propagation are called electromagnetic waves. These waves can travel through vacuum also. For example, light waves, X-rays.

Compressions and Rarefactions:

- Compression is the part of wave in which particles of the medium are closer to one another forming the region of high pressure and density.

  Compressions are represented by the upper portion of the curve called **crest.**
- Rarefaction is a part of the wave where particles spread out to form a region of low pressure and density.

  Rarefactions are represented by the lower portion of the curve called **trough.**



Characteristics of a sound wave

Sound waves have following characteristics:
(1) Amplitude
(2) wavelength
(3) Frequency
(4) Time period
(5) Velocity

Amplitude

- The maximum displacement of each particle from its mean position is called amplitude.
- It is denoted by A.
- Its SI unit is metre (m).

Wavelength

- The distance between two nearest (adjacent) crests or troughs of a wave is called its wavelength.
- It is denoted by the Greek letter lambda (λ).
- Its SI unit is metre.

Frequency

- The number of vibrations per second is called frequency.
- The SI unit of frequency is hertz (Hz).
- The symbol of frequency is ν (nu).

Time period

- The time taken to complete one vibration is called time period.
- It is denoted by T.
- Its SI unit is second (s).
- The frequency of a wave is the reciprocal of the time period.
  i.e., $v = 1/T$

Velocity

- The distance travelled by a wave in one second is called velocity of the wave or speed of the wave.
- Its S.I. unit is metres per second (m/s).
- Velocity = Distance travelled/Time taken

$\Longrightarrow$ $v = \lambda/T$, where λ = wavelength of the wave travelled in one time period (T)

$\Longrightarrow$ $v = \lambda v$ (As $1/T = v$)

Thus, Velocity = Wavelength × Frequency

$v = \lambda v$ is called the wave equation.

Pitch and loudness of Sound

Pitch: It represents shrillness or flatness of sound.
It depends on the frequency of vibration. Higher the frequency of sound wave, the higher will be the pitch of sound and vice-versa.

Loudness: It is a measure of the sound energy reaching the ear per second.
It depends on the amplitude of the sound wave.

It is measured in decibel 'dB'.

Music And Noise: -

Music: It is the sound that is pleasant to hear. For example: Sound coming out of musical instruments)
Noise: It is the sound that is unpleasant to hear. For example: Sound produced by vehicles.

Tone and Note

Tone: A pure sound of single frequency is called tone.
Note: An impure sound produced by mixture of many frequencies is called a note.
For example: A musical note has tones of various frequencies.

Audible Frequency
The audible range of human ear is 20 Hz and 20,000HZ, i.e., the human ears can hear only those waves whose frequency lies between 20 Hz and 20,000HZ.

Reflection of sound

When sound waves strike a surface, they return back into the same medium. This phenomenon is called reflection.

Laws of reflection

There are two basic laws of reflection of sound:

(I) Angle of incidence is equal the angle of reflection.

(ii) The incident wave, the reflected wave and the normal all lie in the same plane.

Applications of Reflection of Sound

Many instruments work on the basis of multiple reflections of sound:

- Megaphone, loudspeakers, bulb horns, musical instruments like trumpets, shehnais etc. are designed to send sound by multiple reflections in a particular direction due to which the amplitude of sound waves adds up to increase loudness of sound.
- Stethoscope which is used by doctors to listen to the sounds from the human body, also works on principle of multiple reflections of sound. Here, sound of heartbeat reaches the doctor's ears by multiple reflections.
- In big halls or auditoriums sound is absorbed by walls, ceiling, seats, etc. So, a curved board (sound board) is placed behind the speaker. Then the voice of speaker suffers multiple reflections to increase its loudness so that his speech can be heard easily by audiences.

Try the following questions:

Q1. Is sound wave longitudinal or transverse.
Q2. Which characteristic of the sound helps you to identify your friend by his voice while sitting with others in a darkroom?
Q3. An airplane produces a sound wave with frequency of 5 KHz and wavelength 30 m. In how much time would the sound wave cover the distance of 4 Km?
Q4. A source is producing 15 waves in 3.0 s. The distance between a crest and a trough is 10.0 cm. Find: (a) the frequency, (b) the wavelength, and (c) the velocity of the wave.
Q5. A source is producing 1500 sounds waves in 3 seconds. If the distance covered by a compression and an adjacent rarefaction be 68 cm, find (a) frequency (b) wavelength and (c) velocity of sound wave.
Q6. A sound wave travels at a speed of 340m/s. If its wavelength is 2 cm, what is the frequency of the wave? Will it be in the audible range?
Q7. Can we hear the ringing of a mobile phone placed in a vacuum chamber?

Part-2

Echo

- Phenomenon of hearing back our own sound is called an echo.
- It is due to successive reflection of sound waves from the surfaces or obstacles of large size.
- To hear an echo, there must be a time gap of 0.1 second in original sound and the reflected sound.

Necessary Conditions for the formation of an Echo
There are two conditions to experience the echo of sound –

(I) Time gap between the Sound must come back to the person after 0.1 second.
(ii) For above condition, the reflecting surface must be at a minimum distance of 17.2m. It also depends on temperature.

Reverberation

- Persistence of sound wave for a long time because of repeated (multiple) reflections of sound are called reverberation.
- In big concert halls, due to the reverberation, sound may become blurred and distorted to be heard.
- To avoid reverberation, soft sound absorbent materials, such as curtains, plant fibre, compressed fireboard, carpets, etc. are used in the auditorium.

Light Travels Faster Than Sound

Speed of light in air = 3×10^8 m/s
Man hears sound of thunder only after he sees the flash of lightning. This is because light travels at a very great speed as compared to the speed of sound, we see the flash before the sound.

Infrasonic and Ultrasonic Waves

Infrasonic Waves:

- The waves having frequency less than 20 Hz are infrasonic waves.
- A vibrating simple pendulum produces infrasonic sounds.
- Elephants and whales produce infrasonic waves.
- Earthquakes produces infrasonic waves

Ultrasonic Waves:

- The waves having frequency more than 20,000 Hz are ultrasonic waves.
- Bats and rats can produce ultrasonic sounds.

Applications of Ultrasound

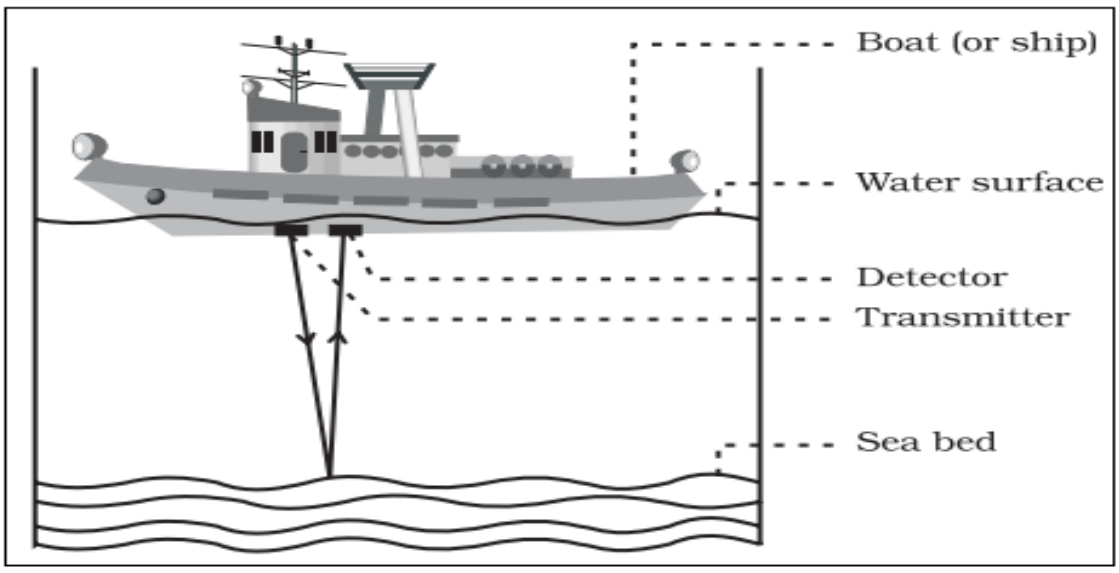
These are the sound waves having frequency more than 20,000 Hz. Due to the high frequency, ultrasound is associated with more energy and can penetrate up to a large extent. This characteristic of ultrasound makes it very useful for many purposes. Some of its uses are stated below:

- They are used to detect any deformities (flaws, cracks) in metal blocks or sheets.
- They are used to clean the hard-to-reach parts of machinery, like spiral tubes.
- Bats use ultrasound waves to find their prey. Bats produce high- pitched ultrasonic squeaks. These squeaks are reflected by objects such as prey's and are returned to the bat's ear. This allows a bat to know the distance of its prey.
- Dolphins use ultrasound to find fish and to detect sharks that may attack them.
- Ultrasound waves are commonly used for medical diagnosis and therapy, and also as a surgical tool.
- They are used to check the development of foetus during pregnancy to detect any abnormalities.
- They find their application in breaking stones formed in the kidneys into fine grains.
- **Echocardiography**: These waves are used to reflect the action of heart and its images are formed. This technique is called echocardiography.
- **Ultrasonography**: The technique of obtaining pictures of internal organs of the body by using echoes of ultrasound waves is called ultrasonography.

Sonar

Sonar stands for Sound Navigation and Ranging It is a device which is used to find distance, direction and speed of underwater objects like, water hills, valleys, icebergs, submarines, sunken ships etc.

Working of SONAR



Ultrasound sent by the transmitter and received by the detector.

- SONAR consists of a transmitter and a receptor or detector and is installed at the bottom of a ship.
- The transmitter produces and transmits ultrasonic waves. These waves travel through sea water and after striking the objects on the bottom of sea, are reflected back and received and recorded by the detector.
- The sonar device measures the time taken by ultrasound waves to travel from ship to bottom of sea and back to ship.
- Half of this time gives the time taken by the ultrasound waves to travel from ship to sea bed.
- Let the time interval between transmission and reception of ultrasound signal is t.

  Speed of sound through sea water is v

  Total distance travelled by waves = 2d.

  Then, $2d = v \times t$.

  This method of measuring distance is also known as 'echo-ranging'.

Human Ear

Structure of Human Ear

The human ear can be divided into three main parts: Outer ear, middle ear and inner ear.

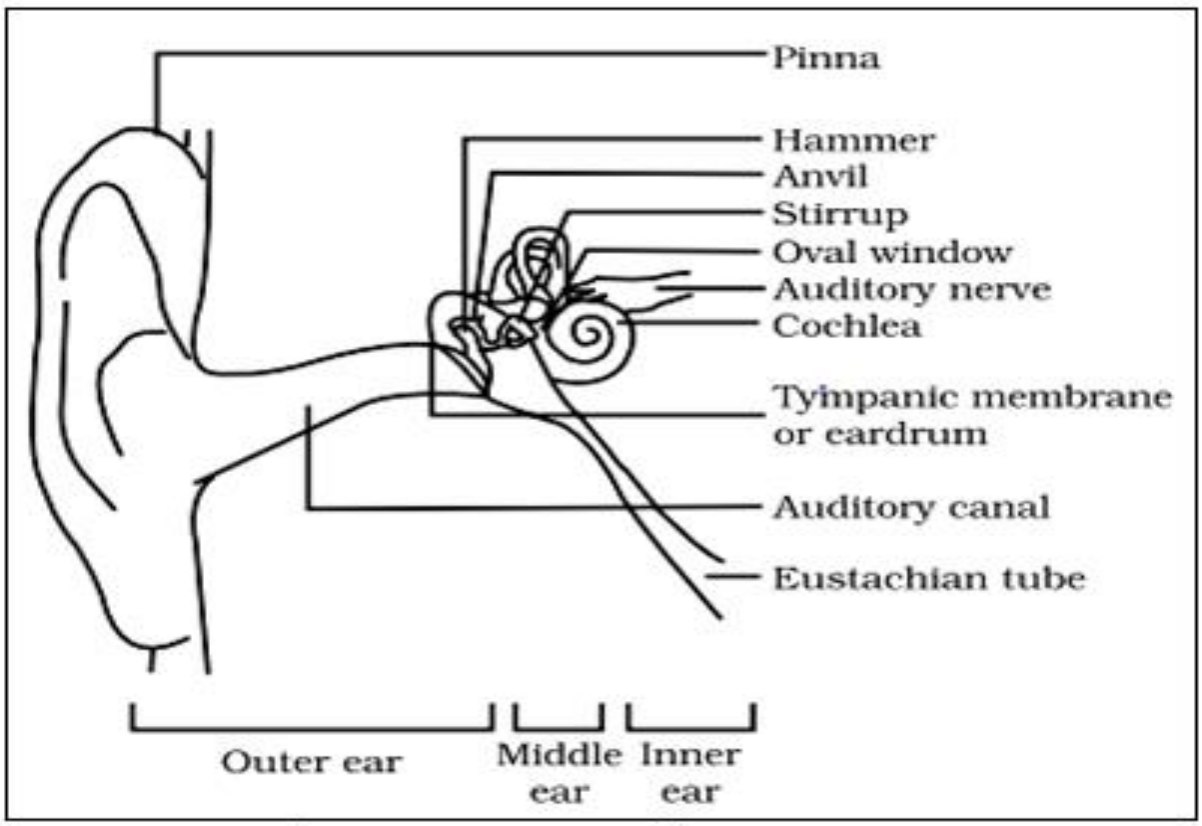


Fig. Structure of human ear

- **Outer Ear:** The outer ear is outside the body and is also called pinna. It extends into the ear canal. Ear canal is filled with air.
- **Middle Ear:** The middle ear is composed of the ear drum or tympanum (it is an elastic membrane, circular in shape) and the bone ossicles. There are three bone ossicles, namely, the hammer, the anvil and the stirrup.
- **Inner Ear:** The internal ear is composed of a cochlea and three semi-circular canals. The cochlea is filled with liquid. The cochlea makes the hearing apparatus and the auditory nerve from it goes to the brain.
  Eardrum is the intersection of the outer and middle ear.
  Oval window is the intersection of middle and inner ear.
- **Working of Human Ear:** The outer ear called pinna collects the sound waves. The sound waves pass through the ear canal to a thin membrane called eardrum. The eardrum vibrates. The vibrations are amplified by the three bones of the middle ear called hammer, anvil and stirrup. The middle ear then transmits the sound waves to the inner ear. In the inner ear the sound waves are converted into electrical signals by the cochlea and sent to the brain through the auditory nerves. The brain then interprets the signals as sound.

Try the following questions:

Q1. Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?
Q2. An echo is returned in 3 s. What is the distance of the reflecting surface from the source, given the speed of sound is 342 ms-1
Q3. Why are the ceilings of concert halls curved?
Q4. A submarine emits a sonar pulse, which returns from an underwater cliff in 1.02 s. If the speed of sound in salt water is 1531 m/s, how far away is the cliff?
Q5. An explosion takes place at the moon. After what time would it be heard at the earth?
Q6. How does the sound produced by a vibrating object in a medium reach your ear?
Q7. How do bats navigate even in the dark?
Q8. A submarine emits a sonar pulse, which returns from an underwater cliff in 1.02 s. If the speed of sound in salt water is 1531 m/s, how far away is the cliff?