Chapter – 12

Sound

Production of Sound

Sound: A sound is a form of energy that produces a sensation of hearing in our ears. The formation of sound involves the transformation of energy.

Production of Sound: A sound is produced by the vibrations of matter particles. When a body vibrates it produces sound in the form of waves.

Example:

1) When we clap, a sound is produced. Here, the mechanical energy generated due to the motion of our hand is converting into sound.

The sound is produced because when we strike both the hands, the hand vibrates which causes the production of sound.

2) When we pluck the strings of a guitar, they vibrate and produce sound.

The stretched strings of the guitar possessed the potential energy. When we plucked the guitar strings potential energy is converted into kinetic energy as the strings start vibration and this vibration of strings produces sound.

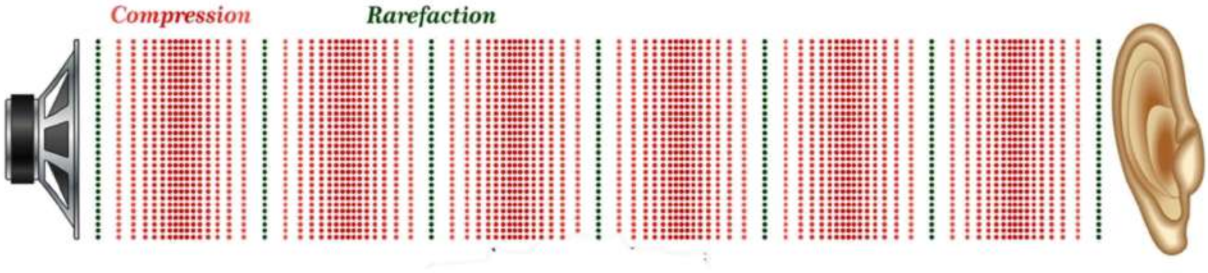
Tip: Remember, the rapid to and from motion is called vibration.

One vibration is complete when a vibrating object goes from one extreme position to another extreme position and comes back to its initial extreme position.

Propagation of Sound

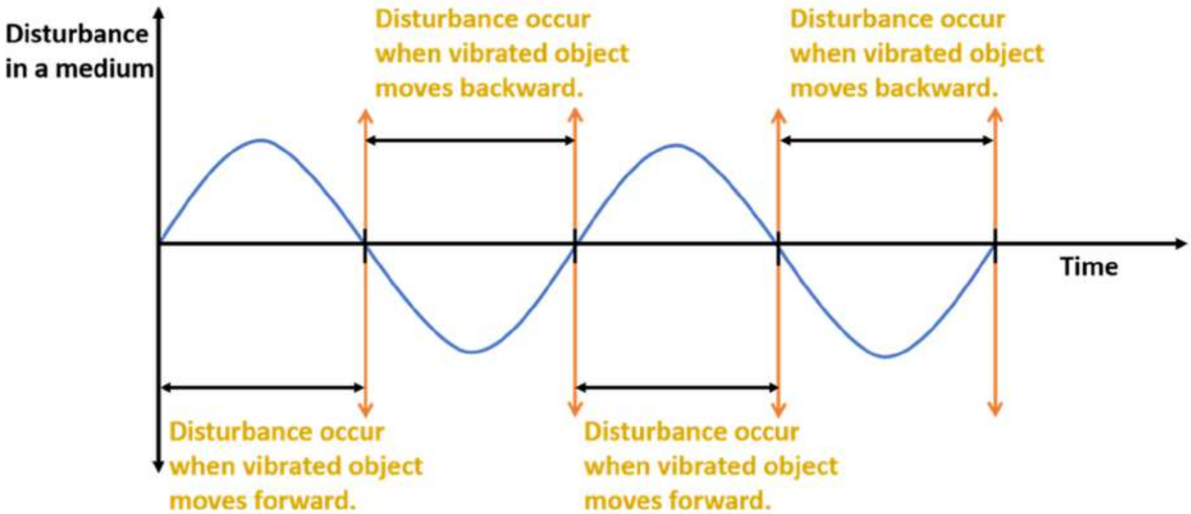
Propagation of Sound: Sound needs a medium to propagate and, the medium is the matter or substance through which sound transmit. It can be solid, liquid or gas.

When a sound travels through a medium, the particles in the medium simply vibrate about their mean position and they do not travel from one place to other. It is the disturbance(sound wave) that travels to propagate sound.



Tip: Remember, sound does not travel in a vacuum as it is vacant and no medium is present to propagate the disturbance in the medium.

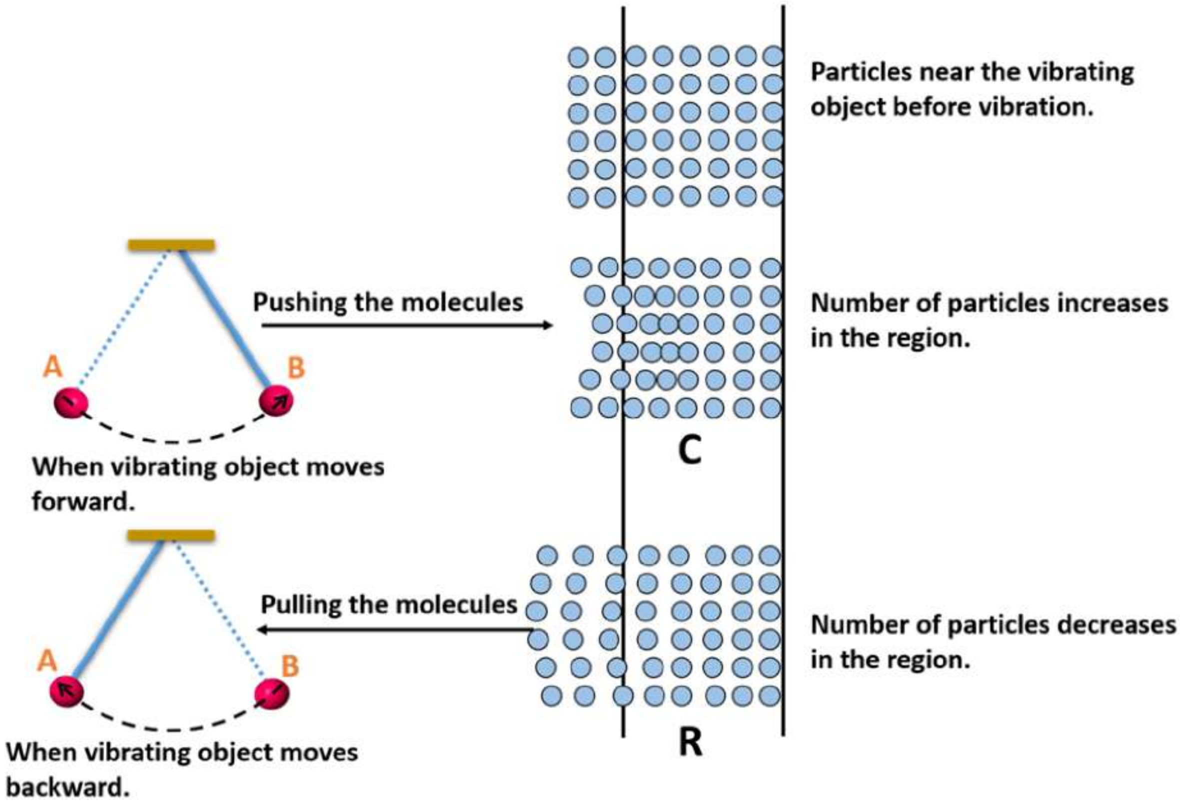
The disturbance in the medium is called wave and the sound is visualized as a sound wave like shown:



Example: How do the compression and rarefaction involve the variation in density and pressure?

Solution: A compression is a region of the medium in which particles are compressed i.e., particles come closer and the area of high pressure is created. Due to this, the distance between the particle becomes less as compared to the normal distance between them. Thus, there is a temporary decrease in the volume which increases the density of the medium as the volume is inversely proportional to the density.

$$Density = \frac{Mass}{Volume}$$



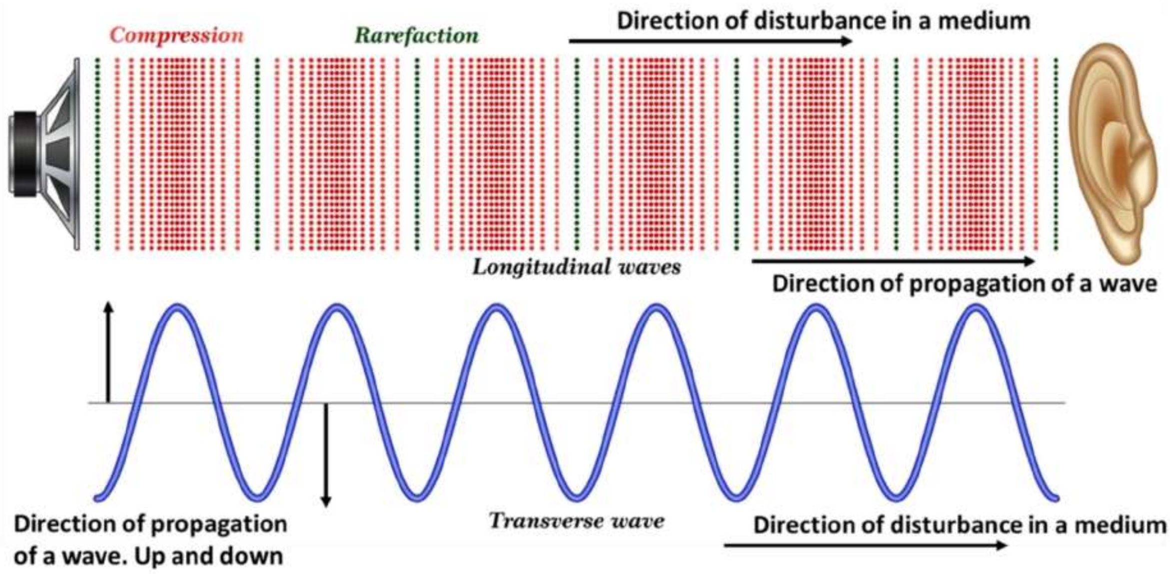
Similarly, in rarefaction, the particle gets farther apart, and the area of low pressure is created. Thus, there is a temporary increase in the volume which results in a decrease in density.

Tip: Remember, Sound waves are called mechanical waves. Because mechanical waves are the waves that need a medium for propagation. And, sound needs a medium to travel.

Although, light is not a mechanical wave. Light does not need a medium to travel, it can travel through the vacuum.

Longitudinal Waves: When the direction of disturbance in the medium and the direction of propagation of wave are in the same direction the wave is called the longitudinal wave. E.g. Sound waves are longitudinal waves.

Transversal Waves: When the direction of disturbance in the medium and the direction of propagation of wave are perpendicular to each other the wave is called the transversal wave. E.g. Light is a transversal wave.

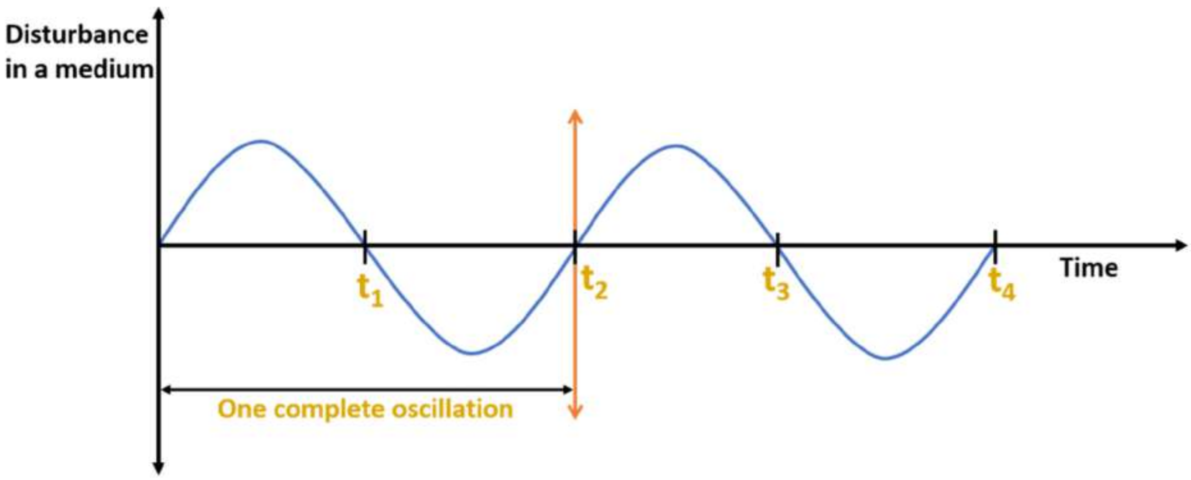


Example: If we hit on the drum surface, the wave produce is the longitudinal wave as the drum membrane moves outward and inward and the disturbance in the particles also moves in the same direction.

Time Period: Time taken by a vibrating object for one complete oscillation is called the time period of the sound wave.

Time period is represented by the symbol T. The SI unit to measure the time period is second (s).

Example: In a wave representation of a sound as shown below.

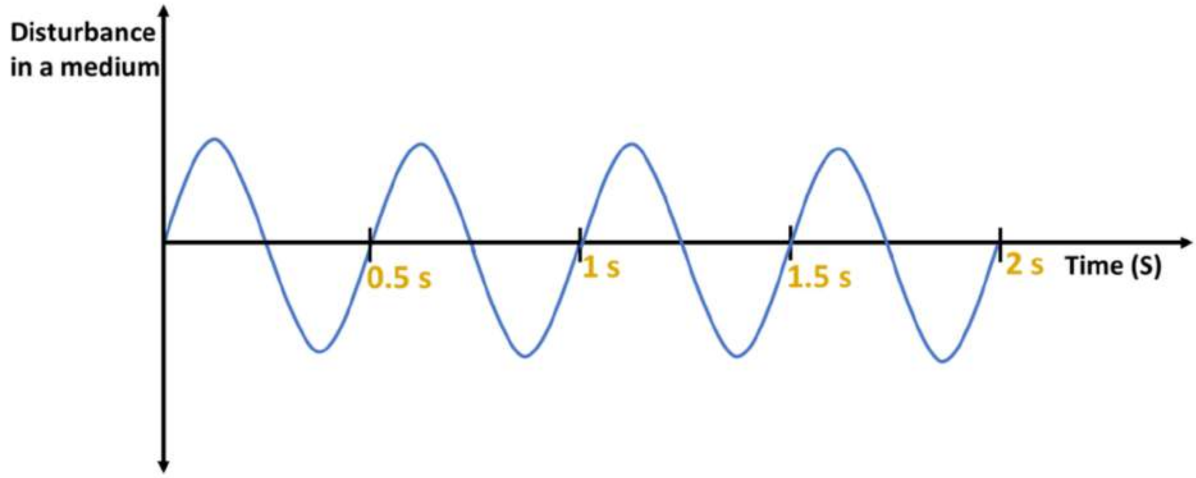


The sound wave takes time t_2 to complete one oscillation. Therefore, the time period of a sound wave, in this case, is t_2 seconds.

Frequency (ν): The number of oscillations made per second is called the frequency of oscillation. It is denoted with the Greek symbol nu (ν). Frequency is expressed in hertz (Hz).

$$Frequency = \frac{Number\ of\ oscillations}{Time\ Taken}$$

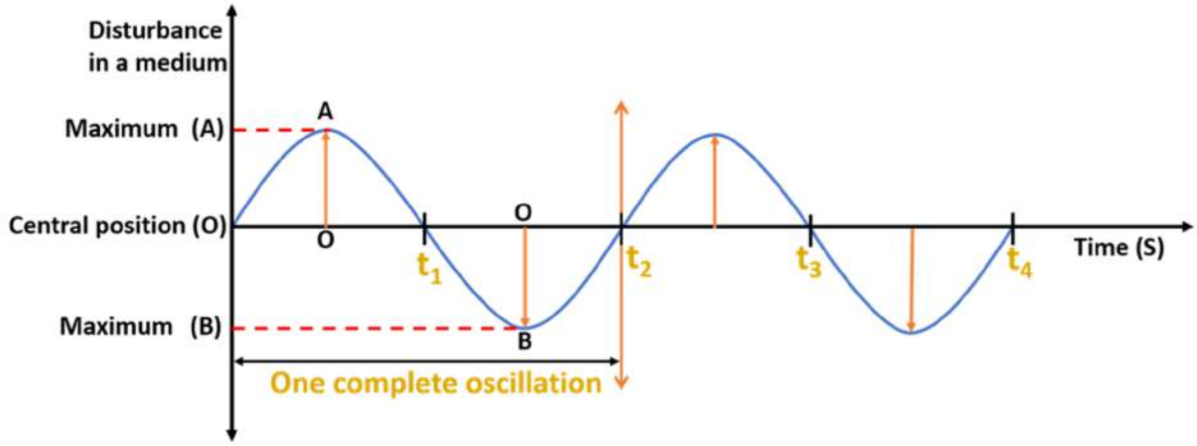
Example: Find out the frequency of the sound wave shown below.



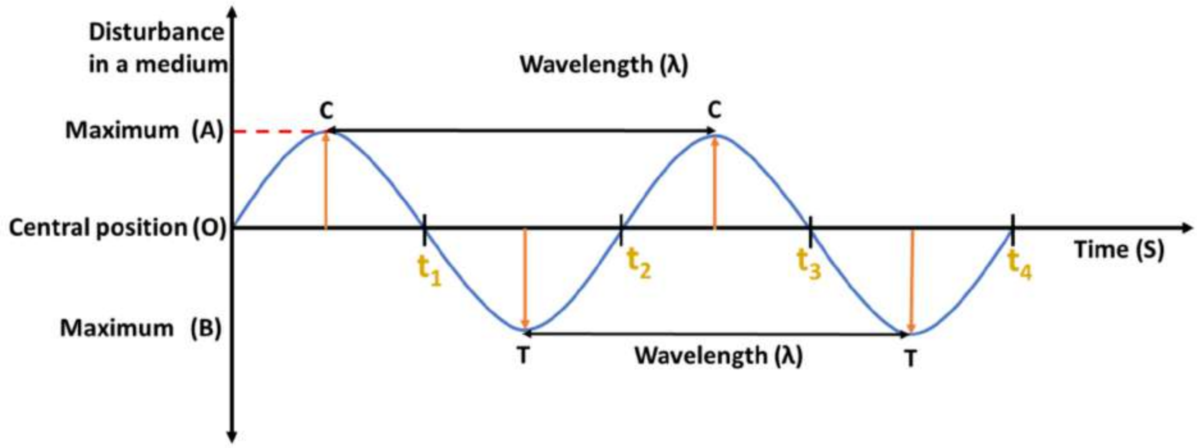
Solution: The frequency of the sound wave is 2 Hz because it completes two oscillations in 1 sec.

Amplitude: The maximum displacement of the vibrating object from the central position is known as the amplitude of the oscillation. Amplitude is measured in meters.

Example: In the sound wave given below, the maximum displacement is OA and OB. Therefore, OA or OB is the amplitude of this sound wave.



Wavelength (λ): Wavelength is the distance between two consecutive compressions or two consecutive rarefactions. It is denoted with a Greek letter lambda(λ). The wavelength is measured in meters.



Loudness: The volume of a sound is the loudness or softness of sound. The loudness is expressed in a unit called decibel (dB).

The loudness of sound is directly proportional to the square of the amplitude of the vibration producing the sound.

Loudness = $(\text{Amplitude})^2$

Pitch: It is a characteristic of sound which help to distinguish between different sounds of the same loudness.

The pitch of a sound is directly proportional to its frequency. When the frequency of the sound increases its pitch also increase.

Tone: A sound of a single frequency is called a tone.

Note: A sound produce with a mixture of several frequencies is called a note.

Intensity of Sound: The amount of sound energy passing each second through the unit area is called the intensity of sound.

$$Intensity = \frac{Energy \times Time}{Area}$$

The SI unit of intensity of a sound is $Jm^{-2}s^{-1}$.

Speed of Sound: The speed of a sound is defined as the distance travelled by the point on a wave, such as compression or rarefaction per unit time.

$$Speed = \frac{Distance}{Time}$$

Here, Distance is the wavelength of the sound wave λ.

And, the time is the time period of the sound wave.

We can replace $\frac{1}{T} = \nu$ (Frequency).

So, the speed of a sound can be written as:

$$Speed = \lambda\nu$$

Tip: Remember, the speed of sound depends on the medium in which it propagates and on the temperature of the medium. The speed of sound is independent of its frequency although the frequency of the sound affects its shrillness.

Speed of sound is higher in solid as compared to liquid and higher in liquids as compared to gases. An increase in temperature increases the speed of sound and vice-versa.

Example: The sound of a frequency 20Hz is moving with a speed of 344 m/s. What will be the wavelength of this sound wave?

Solution: We know the relation between the speed of sound, its wavelength and the frequency as, Speed = wavelength x frequency

$$v = \lambda\nu$$

And, $\lambda = \frac{v}{\nu}$

Now, using this relation for calculating the wavelength of a sound having a frequency of 20Hz

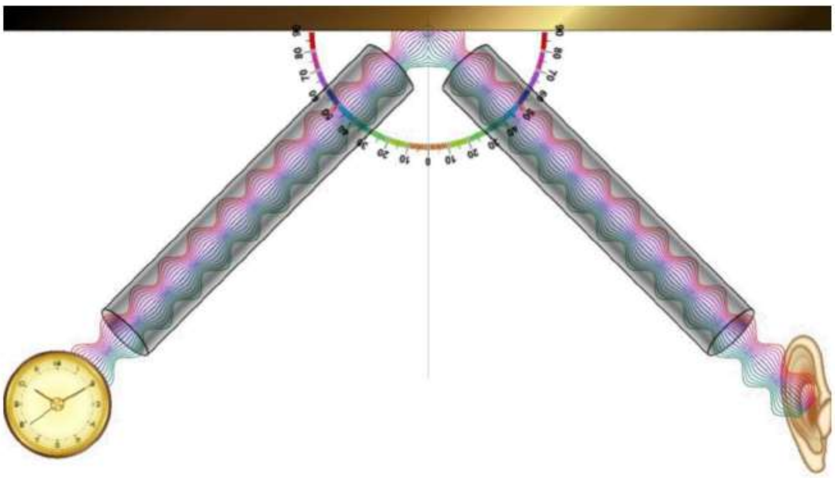
$$\lambda = \frac{344}{20}$$

$$\lambda = 17.2\ m$$

17.2 m

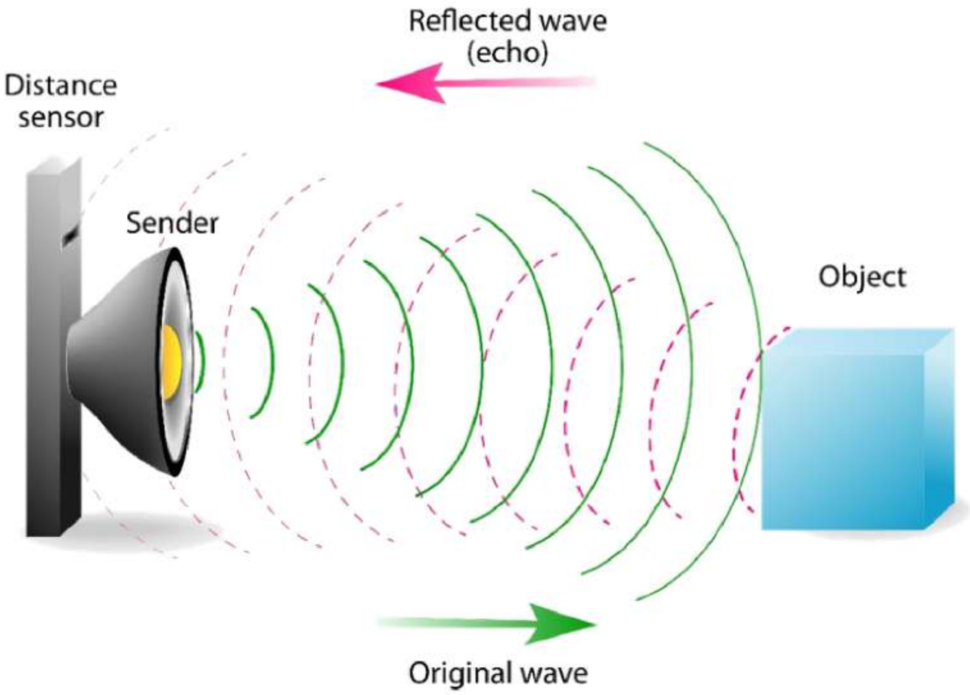
Reflection of Light

Reflection of Sound: Sound is reflected on the surface of a solid or liquid like the light ray and follows the same law of reflection that light obeys.



Echo: The repetition of a sound caused by the reflection of the sound wave is called an echo.

Reverberation: The repeated reflection of a sound from the walls, ceiling and floor of the hall that results of a sound caused by the reflection of sound.



Tip: While solving questions having echo scenario remember in the time interval the echo is heard, the sound covers twice the distance between the source and the obstacle. Sound reaches the obstacle and get reflected back to the listener. So, consider twice of distance when solving numerical.

Example: Why do we not hear an echo in the room which is occupied with objects?

Solution: Because we can hear the echo when there is a minimum time gap of 0.1 seconds in the original sound and the reflected sound. When the room is occupied with objects, the sound reflects back from the objects in less than 0.1 sec and we did not hear the echo. For hearing echo, there should be at least a distance of 17.2 m between the source of sound and the body from which sound is reflected. In small rooms this is not the case, hence, echoes are not heard.

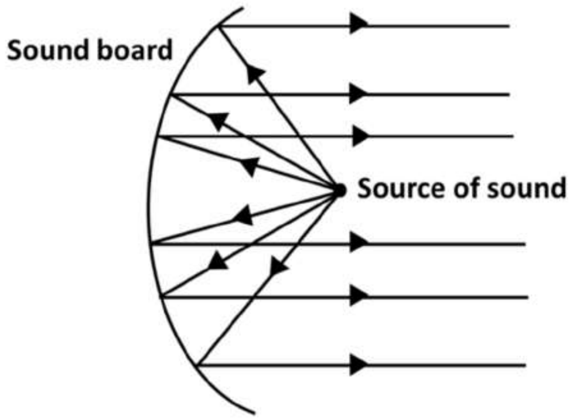
Uses of Multiple Reflection of Sound:

1) **Design of instruments like megaphones, loudspeakers, horns:** These instruments are designed to send the sound in a particular direction without spreading all around. The conical opening reflects sound waves successively towards the audience. The amplitude of a sound wave also adds up in these instruments that increase the loudness of a sound.

2) Stethoscope: It is a medical instrument used for hearing sounds in the human body mainly the heart and lungs. The sound of the heartbeats reaches the doctor's ears by the multiple reflections of the sound wave in the rubber tube of the stethoscope.

3) Curved ceilings for multiple reflections: The ceiling of concert halls, conference halls and cinema halls are made curved so that sound after reflection from the ceiling reaches all the parts of the hall.

4) Curved board (Sound board): Sometimes the sound in big halls are absorbed by wall, ceilings, seats etc. So, a curved board is placed behind the stage that helps audience to hear the sound easily because of the multiple reflections of sound from the soundboard.



Range of Hearing

Range of hearing: For the human ear, the range of audible frequencies is roughly from 20 Hz to 20,000 Hz.

Infrasound: Sounds of frequencies less than 20 Hz are known as infrasonic sound or infrasound.

Animals like elephants, whales and rhinoceroses produce infrasonic waves.

Ultrasound: Sounds of frequencies greater than about 20 kHz are known as ultrasound.

Animals like dogs, dolphins, bats and rats can hear ultrasound. Bats and rats can also produce ultrasonic sounds.

Note: Human ears are not able to detect either infrasonic sound or ultrasonic sound. Hence, the sounds of these frequencies are called inaudible sounds.

Example: A sound wave having a time period of 0.04 seconds. Does this sound is audible to human beings?

Solution: It is given that the time period of the sound wave, T = 0.04 sec

Let the frequency of the sound wave = f

We know that,

Frequency of sound wave f = $\frac{1}{T}$

Therefore, f = $\frac{1}{0.04}$

f = 25 Hz

Thus, the frequency of the sound wave is 25 Hz.

We know that the audible range for human beings is 20Hz to 20kHz.

Hence, the sound will be audible to humans as it is in the audible range.

Applications of Ultrasound

Applications of Ultrasound:

(i) Ultrasound is used to clean hard to reach parts of objects such as spinal tubes, odd-shaped parts, electronic components etc.

(ii) Ultrasound is used to detect cracks and flaws in metal blocks in industries like construction without damaging them.

(iii) Ultrasound is used in ultrasound scanners by doctors to investigate the internal organs of the human body such as the liver, gall bladder, kidneys etc. The technique of obtaining pictures of internal organs is called ultrasonography.

(iv) Ultrasonic waves are used to reflect from the various parts of the heart to form the image of the heart that inform about its functioning. This technique is called echocardiography (ECG).

(v) Ultrasound is used to break small stones in the kidneys into fine grains.

SONAR: SONAR stands for Sound Navigation and Ranging.

- SONAR is a device that uses ultrasonic waves to measure the distance, direction and speed of underwater objects.
- SONAR consists of a transmitter that produces ultrasonic waves and a detector that received the reflected back sound.
- If the time interval between transmission and receiving of ultrasound signal is 't', the speed of the sound wave in seawater is 'v' and the distance between the obstacle and the ship is 'd'. The total distance covered by the signal in time 't' = 2d

So, by using the relation

Distance = Speed x Time

$2d = v \times t$

Fact: Bat uses the same process as SONAR device to catch prey.

Example: A ship is fitted with a sonar device. The time taken by the sonar device to send a sound signal and receive the echo back after hitting the object is 3 seconds. If the speed of a sound in water is 1400 m/s. Calculate the distance between the object and the ship.

Solution: Given that the speed of sound in water is 1400 m/s and the time taken to send the signal and receive it back in 3 seconds.

Therefore, total distance covered by the sound wave = speed x time

$= 1400 \times 3 = 4200$ m.

Since, the sound signal has covered the distance twice, first when the signal was sent and second after the sound signal was hit by the object and received back.

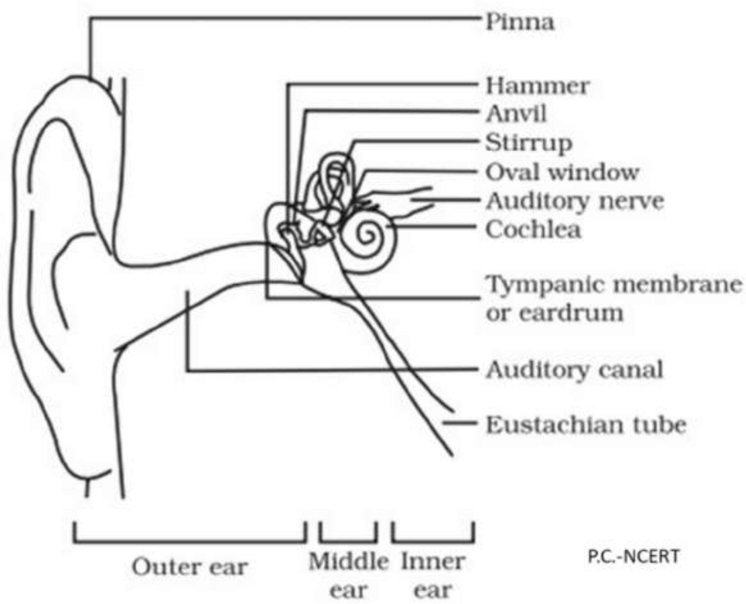
Thus, the distance between the object and the ship will be half of the total distance calculated.

Therefore, the distance between the object and the ship = $\frac{4200}{2}$ = 2100 m

Note: We can also solve this question directly using 2d = v x t.

Structure of Human Ear

Working of Human Ear: The structure of the ear is classified into three parts outer ear, middle ear and inner ear.



- **Outer ear:** The outer is called **Pinna**. It collects the sound from surroundings and passes it in the middle ear through the **auditory canal.**

- **Middle ear:** At the end of the **auditory canal** there is a thin elastic membrane called the **eardrum**. When compression of sound strikes the eardrum, the eardrum pushes inward and while the rarefaction eardrum moves outward. Thus, the eardrum starts vibrating.

The middle ear consists of three bones **hammer, anvil and stirrup**. These bones amplify the vibration and the amplified sound waves passes from the middle ear to the inner ear through the **oval window**.

- **Inner ear:** In the inner ear the **oval window** is connected with a coiled tube structure called **cochlea** that converts pressure variations into electrical signals.

The other side of the **cochlea** is connected to the **auditory nerve** which sends these electrical signals to the brain and the brain interprets them as sound.