SOUND

CONTENTS

➢ PERIODIC MOTION

(i) When a body repeats its motion continuously on a definite path in a definite interval of time then its motion is called **periodic motion.**

(ii) The constant interval of time after which the motion is repeated is called the **'Time period of motion.' (T)**

Example : Time period of hour hand is 12 hours.

➢ OSCILLATORY MOTION

(i) If a body in periodic motion moves along the same path to and fro about a definite point (equilibrium position), then the motion of the body is a vibratory motion or oscillatory motion

Note: Resultant force acting on the particle is zero in equilibrium condition.

(ii) It is to be noted here that every oscillatory motion is periodic but every periodic motion is not oscillatory

➢ INTRODUCTION TO WAVE MOTION

Most of us have seen the formation of ripples when a small stone (pebble) is dropped into a pond. The disturbances created by the stone in the water produces ripples which move outwards towards the shore of the pond.

If you examine the motion of a leaf floating near the disturbance for a short while on a steady day, you would see that the leaf moves up and down about its original position, but does not move away or towards the source of disturbance. This indicates that the disturbance (such as a water wave) moves from one place to another, but the water is not carried with it. The water particles simply move up and down their mean positions.

The formation of ripples on the surface of water is an example of wave motion.

◆ **Wave Motion :** The movement of a disturbance produced in one part of a medium to another involving the transfer of energy but not the transfer of matter is called wave motion.

Examples :

(i) Formation of ripples on the water surface.

(ii) Propagation of sound waves through air or any other material medium.

➤ CHARACTERISTICS OF WAVE MOTION

The main characteristics of wave motion are described below :

- In wave motion, the particles of the medium vibrate about their mean positions. The particles of the medium do not move from one place to another.
- A wave motion travels at the same speed in all directions in the given medium. The speed of a wave depends upon the nature of the medium through which it travels.
- During a wave motion, energy is transferred from one point of the medium to another. There is no transfer of matter through the medium.

➤ CLASSIFICATION OF WAVE MOTION

(A) On the Bases of Necessity of Medium Required

◈ MECHANICAL WAVES :

The wave which propagates only in a material medium are called elastic or mechanical waves.

Example : Sound waves, Water waves (ripples), Waves on stretched strings, Earthquake waves and the Shock waves produced by a supersonic aircraft are mechanical (or elastic) waves.

◈ ELECTROMAGNETIC WAVES :

Wave which do not require any material medium for their propagation are called. electromagnetic waves.

Example : Light waves, Radio waves, Television waves, and X-rays are electromagnetic waves. Thus, Light waves, Radio and Television waves, and X-rays can also travel through vaccum.

Difference between Mechanical waves & electromagnetic waves

	Mechanical waves	**Electromagnetic waves**
1.	Mechanical waves need a material medium for their propagation. These waves cannot travel through vacuum.	Electromagnetic waves do not need any material medium for their propagation. These waves can travel through vacuum.
2.	Speed of mechanical waves are low and depends upon the source and the medium through which they travel.	(EMW) a electromagnetic waves travel with the speed of light (3×10^8 m/s) in vaccum. The speed of an electromagnetic wave in any material medium is less than that in vaccum.
3.	Mechanical waves are due to the vibrations of the particles of the medium.	(EMW) a electromagnetic waves are not due to vibration of medium particles
4.	Mechanical waves may be longitudinal or transverse waves.	Electromagnetic are transverse waves.
5.	Example : Sound waves, water waves, string waves are mechanical waves.	Examples : Light waves, radio and TV waves, and X-rays are electromagnetic

(B) On the Basis of mode of Vibration of the Particle

◈ TRANSVERSE WAVES

A wave in which the particles of the medium oscillate about their mean position in a direction perpendicular to the direction of propagation of the wave is called a transverse wave.

Transverse waves can travel through solids and over the surface of liquids, but not through gases.

Examples : Following are the examples of transverse waves :

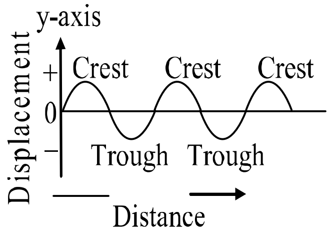
(i) The water waves (ripples) produced on the surface of water is transverse waves. In water waves, the molecules of water move up and down from their mean positions.

(ii) A pulse on a slinky when it is given a jerk is a transverse wave.

(iii) All electromagnetic waves, e.g., light waves, radio waves etc., are transverse waves.

(iv) The waves produced in a stretched string when plucked are transverse waves. When a string of sitar (a musical instrument) or guitar is plucked, transverse waves are produced in the string.

◆ **Graphical Representation :**



Displacement-distance graph for a transverse waves

(a) **Crest :** The highest point on the hump in a transverse wave is called a crest. Thus, the point of maximum positive displacement on a transverse wave is called a crest.

(b) **Trough :** The lowest point on the depression in a transverse wave is called a trough. Thus, the point of maximum negative displacement on a transverse wave is called a trough.

◈ LONGITUDINAL WAVES :

A wave in which the particle of the medium oscillate (vibrate) to and fro about their mean position in the direction of propagation of the wave is called a longitudinal wave.

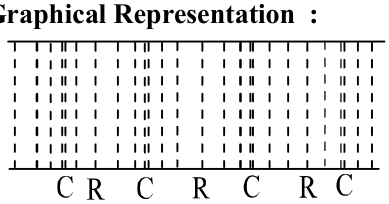
Longitudinal waves can be produced in any medium, viz., in solids, liquids and in gases.

Example :

(i) Sound waves are longitudinal waves.

(ii) The waves produced in a spring (slinky) by compressing a small portion of it and releasing are longitudinal waves.

◆ **Graphical Representation :**



(a) **Compression :** The part of a longitudinal wave in which the density of the particles of the medium is higher than the normal density is called a compression.

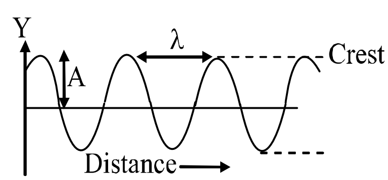
(b) **Rarefaction :** The part of a longitudinal wave in which the density of the particles of the medium is lesser than the normal density is called a rarefaction.

◈ Difference between Transverse & Longitudinal Wave

	Longitudinal	Transverse waves
1	In a longitudinal wave the particles of the medium oscillate along the direction of propagation of the wave.	In a transverse wave, the particles of the medium oscillate in a direction perpendicular to the direction of propagation of the wave
2	Longitudinal waves can propagate through solids, liquids, as well as gases.	Transverse waves can propagate through solids, and over the surface of liquids, but not through gases.
3	Longitudinal waves consist of compression and rarefactions.	Transverse waves consist of crests and troughs.

➢ TERMS USED FOR DEFINING WAVE MOTION

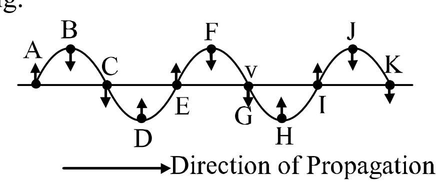
◆ **Wave Length :** The distance between two nearest points in a wave which are in the same phase of vibration is called the wave length. In simple words it is the length of one complete wave. It is denoted by lambda, λ.



◆ **Amplitude :** The amplitude of a wave is the magnitude of maximum displacement of the vibrating particles on the either side of their mean position. It is denoted by the letter A and its SI unit is metre (m).

◆ **Time-Period :** The time required to produce one complete wave (or cycle) is called time-period of the wave.

- **Frequency :** The frequency of an oscillating particle is the number of oscillations completed in one second. The unit of frequency is hertz (or Hz). The frequency of the wave is 1\T. It is generally represented by ν (nu)
- **Wave Velocity :** The distance travelled by the wave in one second is called the wave velocity. It is represented by 'v' and its unit is ms^{-1}.
- **Phase :** All the points on a wave which are in the same state of vibration are said to be in the same phase. Thus, in the wave shown in fig.



(a) Points B, F and J are in the same phase – all lie on the crests.

(b) Points D and H are in the same phase – both lie on the troughs.

(c) Points A, E and I are in the same phase. All these points are just about to start their vibration in the upward direction from their mean positions.

(d) Points C, G and K are in the same phase. All these points are just about to start their vibration in the downward direction from their mean positions.

◈ RELATION BETWEEN WAVE VELOCITY, FREQUENCY AND WAVELENGTH FOR A PERIODIC WAVE.

$$\text{wave velocity} = \frac{\text{distance covered}}{\text{Time taken}}$$

$$= \frac{\text{wave length}}{\text{Time taken}}$$

or $$v = \frac{\lambda}{T} \qquad ...(1)$$

since $\nu = \frac{1}{T}$, equation (1) can also be written as

$$v = \nu\lambda \qquad ...(2)$$

wave velocity = Frequency × wave length

Ex. 1 If 50 waves are produced in 2 seconds, what is its frequency ?

Sol. Frequency, $\nu = \frac{\text{Number of wave produced}}{\text{Time taken}}$

$$= \frac{50}{2} = 25 \text{ Hz}$$

Ex. 2 A source produce 50 crests and 50 troughs in 0.5 second. Find the frequency.

Sol. 1 crest and 1 trough = 1 wave

∴ 50 crests and 50 troughs = 50 waves

Now, Frequency, $\nu = \frac{\text{Number of wave}}{\text{Time}}$

$$= \frac{50}{0.5} = 100 \text{ Hz}$$

Ex. 3 Sound waves travel with a speed of 330 m/s. What is the wavelength of sound waves whose frequency is 550 Hz ?

Sol. Given velocity, v = 330 m/s,

Frequency, ν = 550 Hz

∴ wavelength, $\lambda = \frac{v}{\upsilon} = \frac{330}{550} = 0.6$ m

Ex. 4 The wave length of sound emitted by a source is 1.7×10^{-2} m. Calculate frequency of the sound, if its velocity is 343.4 ms^{-1}.

Sol. The relation ship between velocity, frequency and wave length of a wave is given by the formula $v = \nu \times \lambda$

Here, velocity, $v = 343.4 \text{ ms}^{-1}$

frequency ν = ?

and wavelength, $\lambda = 1.7 \times 10^{-2}$ m

So, putting these values in the above formula, we get :

$$343.4 = \nu \times 1.7 \times 10^{-2}$$

$$\nu = \frac{343.4}{1.7 \times 10^{-2}}$$

$$= \frac{343.4 \times 10^{2}}{1.7} = 2.02 \times 10^{4} \text{ Hz}$$

Thus, the frequency of sound is 2.02×10^{4} hertz.

Ex. 5 A wave pulse on a string moves a distance of 8m in 0.05 s.

(i) Calculate the velocity of the pulse.

(ii) What would be the wavelength of the wave on the same string, if its frequency is 200 Hz ?

Sol. (i) Velocity of the wave,

$$v = \frac{\text{Distance covered}}{\text{Time taken}} = \frac{8\text{m}}{0.05\text{s}} = 160 \text{ m/s}$$

(ii) Periodic wave has the same velocity as that of the wave pulse on the same string.

∴ Wavelength, $\lambda = \frac{v}{\nu} = \frac{160 \text{ m/s}}{200 \text{ Hz}} = 0.8$ m

Thus, the wavelength of the wave is 0.8 m.

Ex. 6 A person has a hearing range of 20 Hz to 20 kHz. What are the typical wavelengths of sound waves in air corresponding to these two frequencies ? Take the speed of sound in air as 340 m/s.

Sol. Given : $\nu_1 = 20$ Hz, V = 340 m/s

$$\therefore \lambda_1 = \frac{v}{\nu_1} = \frac{340}{20} = 17 \text{ m}$$

$\nu_2 = 20$ kHz = 20,000 Hz, v = 340 m/s

$$\therefore \lambda_2 = \frac{v}{\nu_2} = \frac{340}{20{,}000} = 1.7 \times 10^{-2} \text{ m} = 1.7\text{cm}$$

∴ The typical wavelengths are 17 m and 1.7 cm.

Ex. 7 A longitudinal wave is produced on a toy string. The wave travels at a speed of 30 cm/s and the frequency of the wave is 20 Hz. What is the minimum separation between the consecutive compressions of the string ?

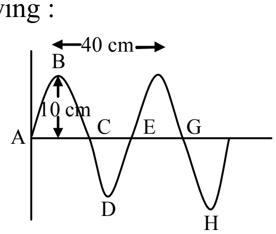
Sol. Given, Velocity, v = 30 cm/s

Frequency, $\nu = 20$ Hz

Minimum separation between the two consecutive compressions is equal to one wavelength λ and

$$\lambda = \frac{v}{\nu} = \frac{30\,\text{cm/s}}{20\,\text{Hz}} = 1.5 \text{ cm}$$

Ex.8 Wave of frequency 200 Hz produced in a string is represented in figure. Find out the following :



(i) amplitude
(ii) wavelength
(iii) wave velocity

Sol.(i) Amplitude = Maximum displacement = 10 cm

(ii) Wavelength λ = Distance between two successive crests = 40 cm

(iii) Now, frequency, n = 2 Hz

Wavelength, $\lambda = 40\text{cm} = 0.4$ m

∴ Wave velocity, $v = \nu\lambda = 200 \times 0.4$ m/s = 80m/s

Ex. 9 A stone is dropped into a well 44.1 m deep. The sound of splash is heard 3.13 seconds after the stone is dropped. Calculate the velocity of sound in air.

Sol. First we calculate the time taken by the stone to reach the water level by using the relation:

$$s = ut + \frac{1}{2}gt^2$$

Here s = 44.1 m, u = 0, g = 9.8 m/s^2

$$\therefore 44.1 = 0 \times t + \frac{1}{2} \times 9.8 \times t^2$$

or $t^2 = \frac{44.1 \times 2}{9.8} = 9$

or t = 3 s

Time taken by the sound to reach the top of the well

$t_2 = 3.13 - 3 = 0.13$ s

Now, speed of sound

$$= \frac{\text{Distance}}{\text{Time}} = \frac{44.1\text{m}}{0.13\text{s}} = 339.2 \text{ m/s}$$

➢ INTRODUCTION TO SOUND

◆ **Sound** is a form of energy that produces the sensation of hearing in our ears.
Frequency range of audible sound for human is between 20Hz to 20 KHz

◆ **Sound need Material to Travel :** You have learnt in previous section that vibrations produce sound. To produce vibrations, we need a material body. Therefore, we can say that a medium is needed for sound to travel. Sound can travel through air (or gases), liquids and solids, but not through vacuum.

◆ **Speed of Sound :** The speed of sound is the rate at which sound travels from the sound producing body of our ears. The speed of sound depends on the

(i) **Nature of Material** (or medium) through which it travels. Speed of sound in air is 344 m/s.

(ii) **Temperature :** As the temperature increases the speed of sound in air increases.

(iii) **Humidity of Air :** Sound travel first in humid air.

◆ **The Time Gap between 'Seeing' and 'Hearing'** is due to the difference between the time taken by the light and the sound to travel from the source to the observer.

The speed of light high 3×10^8 meters per second (30 crore metres per second) and the speed of sound in the air under normal conditions is 344 metres per second. So, the light travels almost instantaneously, whereas sound takes some time.

◆ **Sound Wave are Longitudinal Waves :** Sound travels through air in the form of longitudinal waves.

➢ PRODUCTION & PROPAGATION OF SOUND

◆ **Production of sound**

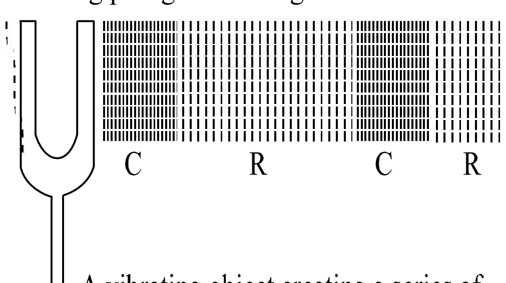
Sound is produced when an object vibrates (moves back and forth rapidly). In other word, sound is produced by vibrations of objects.

◆ **Propagation of sound**

When an object vibrates (and makes sound), then the air layers around it also start vibrating in exactly in the same way and carry sound waves from the sound producing object to our ears. Transmission of sound requires a material medium so it cannot travel through vacuum.

In laboratory a vibrating tuning fork is used for producing sound. During vibration, the prong of the tuning fork moves from one extreme position to another about its mean position (the position when it is at rest).

Let us now see what happens in the air near a vibrating prong of a tuning fork.



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

◈ **SOUND AS A LONGITUDINAL WAVE**

When a sound wave travels through the air, the molecules in the air oscillate to and fro about their mean positions in the direction of propagation of the sound wave. Therefore, *Sound waves are called longitudinal waves.*

The sound waves propagate in any material medium as a series of compressions or rarefactions.

◈ **SOUND WAVE CAN BE STUDIED IN TERMS OF PRESSURE AND DENSITY WITH DISTANCE AND TIME.**

Pressure & density is high for the particle whose amplitude is less, i.e. at compression state.

➢ CHARACTERISTIC OF SOUND

(A) LOUDNESS

Loudness of a sound depends on the amplitude of the vibration producing that sound. Greater is the amplitude of vibration, louder is the sound produced by it.

The loudness of a sound also depends on the quantity of air that is made to vibrate. Loudness of sound is measured in decibel (dB) unit.

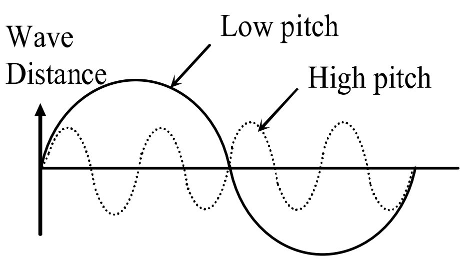
Sound	dB	Loudness
Rocket at take off	200	Dangerously loud
Aircraft engine	100–200	Painfully loud
Pneumatic drill	100	Very loud
Heavy traffic	90	Very loud
Loud music	90	Very loud
Ordinary coversation	40-60	Moderate
Whisper	20	Faint
Rustling of leaves	10	Very faint

(B) PITCH

The shrillness of a sound is called its pitch. The pitch of a sound depends upon its frequency. Higher the frequency of a sound, higher is its pitch.

The voice of a child or a woman has higher frequency than the voice of a man.

- The faster is the vibration of the source object, higher is the frequency and therefore higher is the pitch.
- Higher pitch of any sound corresponds to larger number of compressions and rarefactions passing a point per unit time.



Wave shape

The stretched membrane of a tabla or mridangam produces sound of a higher frequency (or of higher pitch).

(C) QUALITY

Quality of a sound is also called timbre. *The quality of sound is the characteristic which enable us to distinguish between the sounds produced by different sources.*

The more pleasant sound is said to be of rich quality.

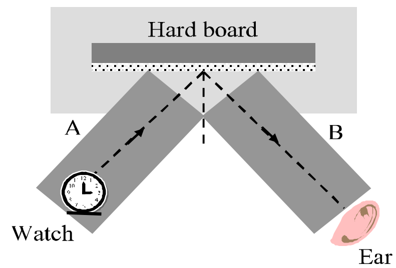
A sound of single frequency (called pure sound) is called a tone.

A tuning fork produces the sound of a single frequency. The sound which is a mixture of several frequencies is called an impure sound (or note) is pleasant to listen.

Different instruments, depending on their shape and size, produce different number of harmonics of different relative loudness. As a result, the sound produced by an instrument can be distinguished from that produced by other instruments.

➤ REFLECTION OF SOUND

Sound waves like light waves also get reflected from plane and spherical surfaces. During reflection, sound waves obey the laws of reflections. The reflection of sound from a hard surface can be observed by performing a simple experiment on the equipment as shown in fig.



Reflection of sound from a hard surface

- Sound waves have much longer wavelength than the light waves. Therefore unlike light waves, sound waves do not need smooth surfaces for suffering reflection. That is why, a brick wall, a wooden board, a row of trees, a hill etc. serve as the reflectors of sound waves.
- *To have an appreciable reflection of sound waves from any surface, it should have dimensions equal or larger than the wavelength of the sound waves falling on it. That is, a smaller object will not reflect the sound waves of larger wavelength.*

◈ ECHO

The sound returning back towards the source after suffering reflection from a distance obstacle (a wall, a row of building etc.) is called an echo.

When the sound is reflected repeatedly from a number of obstacles, more than one echoes, called multiple echoes are heard. Multiple echoes may be heard one after the other when sound gets repeatedly reflected from distant high rise buildings or hills. The rolling of thunder is an example of multiple echo formation.

The two sounds–one direct and the other echo, can be heard distinctly provided the distance between the observer and the reflecting surface is large enough to allow the reflected sound to reach him without interfering with the direct sound. Since the sensation of sound persists for 1/10 second after it is produced, the echo can be heard distinctly only if it reaches at least 1/10 second after the original sound is produced.

- **Minimum distance between the observer and the obstacle for echo to be heard :**

Let

Distance between the observer and the obstacle = d

Speed of sound (in the medium) = v

Time after which echo is heard = t

Then, $t = \frac{2d}{v}$ or $d = \frac{vt}{2}$

We know

Speed of sound in air at 25ºC = 343 ms^{-1}

For an echo to be heard distinctly,

$t \geq 0.1$ s

Then $d \geq \frac{343ms^{-1} \times 0.1s}{2}$

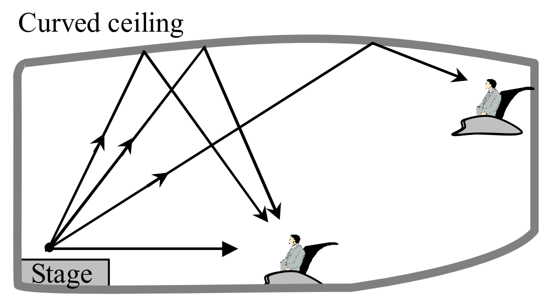
or $d \geq 17.2$ m

Thus, *the minimum distance (in air at 25ºC) between the observer and the obstacle for the echo to be heard clearly should be 17.2 m.*

The speed of sound increases with a rise in temperature. Therefore, the minimum distance in air between the observer and the obstacle for an echo to be heard clearly at temperatures higher than 25ºC is more than 17.2 m. In rooms having walls less than 17.2 m away from each other, no echo can be heard.

REVERBERATION

The repeated reflection that results in the persistence of sound in a large hall is called reverberation.



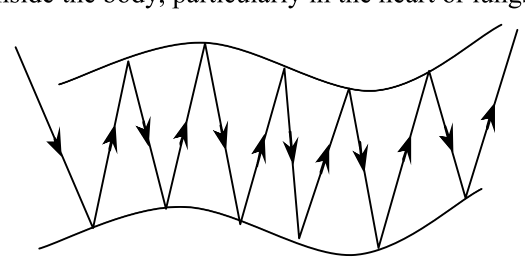
Excessive reverberation in any auditorium/hall is not desirable because the sound becomes blurred and distorted. The reverberation can be minimised/reduced by covering the ceiling and walls with sound absorbing materials, such as, fiber-board, rough plaster, draperies, perforted cardboard sheets etc.

PRACTICAL APPLICATIONS OF MULTIPLE REFLECTION OF SOUND

Some simple devices based on multiple reflection of sound are,

- Stethoscope
- Megaphone, Loudhailer, Horns
- Trumpet, Shehanais
- Curved ceiling of concert hall/conference hall/cinema hall
- Soundboards

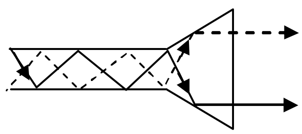
Stethoscope : Stethoscope is a medical diagnostic instrument based on multiple reflection of sound waves. This is used by doctors for listening to the sounds produced inside the body, particularly in the heart or lungs.



◆ **Megaphone :** Megaphone is a horn-shaped tube. Megaphones are used for addressing a small group of people.

Speaking tube is a hollow tube– one end is the speaker's end, whereas the other one is the listener's end.

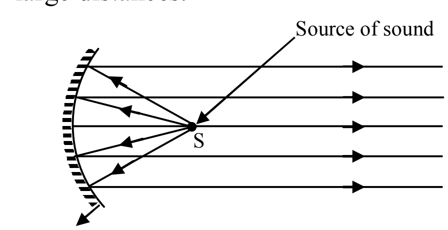
In these devices, the sound waves suffer reflection repeatedly and the energy of the waves remains confined to the tube. The sound waves are prevented from spreading out.



It is for this very reason that loudspeakers also have horn-shaped opening.

◆ **Ear Trumpet (or Hearing Aid) :** Ear trumpet or hearing aid is used by the persons who are hard of hearing. The sound waves received by the wide end of the trumpet are reflected into a much narrower area, leading it to the ear. This increases amplitude of the vibrating air inside the ear and helps in improving hearing.

◆ **Sound Boards and Curved Ceiling and Walls in Large Halls :** The arched ceiling and walls of large halls or auditorium often reflect the sound waves. These reflected sound waves interfere with the words of the speaker. This problem is solved by hanging curtains, putting up screens or by using sound boards. A sound board is often a concave rigid surface. The speaker is located at the focus of the sound board placed behind the speaker. The sound board the reflected sound waves parallel. This enable the sound to reach large distances.



The sound board prevents the spreading out of the sound waves in different directions.

Ex. 10 A girl hears the echo of his own voice from a distance hill after 3 second. The speed of sound in air is 340 m/s. What is the distance of the hill from the girl ?

Sol. Let d be the distance of the hill from the girl. Total distance travelled by the sound in going and coming back = 2d

Now,

$$v = \frac{\text{Totaldistance travelled}}{\text{Timetaken}} = \frac{2d}{t}$$

$$\Rightarrow 340 = \frac{2 \times d}{3}$$

$$\Rightarrow d = 510 \text{ m}$$

➢ AUDIBLE, ULTRASONIC AND INFRASONIC WAVES

(a) Audible Wave :

The human ear is sensitive to sound waves of frequency between **20 Hz to 20 kHz**. This range is known as audible range and these waves are known as audible waves.

Ex. Waves produced by vibrating sitar, guitar, organ pipes, flutes, shehnai etc.

(b) Ultrasonic waves :

A longitudinal wave whose frequency is above the upper limit of audible range i.e. **20 kHz,** is called ultrasonic wave. It is generated by very small sources.

Ex. Quartz crystal

(c) Infrasonic wave :

A longitudinal elastic wave whose frequency is below the audible range i.e. **20 Hz,** is called an infrasonic wave. It is generally generated by a large source.

Ex. Earthquake.

➢ ULTRA SOUND

- The sound waves having frequency higher than 20,000 Hz is called ultrasonic waves or ultrasound. Human beings cannot hear ultrasound. Dogs, bats and dolphins can hear ultrasound. For example bats and dolphins can hear sound waves having frequencies of about 150,000 Hz. Bats and dolphins detect the presence of any obstacle by hearing the echo of the sound produced by them.

  Ultrasound finds many technological applications.

  Characteristics of Ultra Sound :

  Ultrasound (or ultrasonic waves) are found very useful due to the following reasons :

  - Ultrasound (or ultrasonic) waves are high frequency sound waves. So these waves have short wavelength. These short wavelength sound waves can be reflected back from the smaller objects. Thus, ultrasound can detect smaller objects (< 1 cm size). The sound waves in the audible range cannot detect or 'see' objects smaller than having size ranging from a few tens of centimeters to a few metres.
  - Ultrasound beam is more directional and can be aimed towards any target just like a torch. These waves remain undeviated over long distances.

➢ APPLICATIONS OF ULTRASOUND

Some important applications of ultrasound are described below :

- **In ultrasonic spectacles for blind people :** Such a spectacle is fitted with a transmitter and a receiver. The receiver produces a high or low sound in the person's ear depending upon whether the object causing the echo is near or far.
- **For medical use :** Ultrasound is used to detect any infirmity / deformity in the unborn baby (X-rays cannot be used for this purpose because X-rays may harm the unborn baby). In this method, an ultrasonic transmitter / receiver is moved across the mother's stomach. Different tissues (skin, muscles, bones) reflect the sound waves differently to produce many echoes. The machine uses these echoes to construct a picture on the screen. Any deformity / infirmity in the baby can be detected and proper treatment could be prescribed.

  This technology has been misused for knowing the sex of the unborn baby. It has been noticed that many people force the would-be mother to have an abortion if the unborn baby is identified to be a female baby. This practice is unethical and a social crime. Our Government has banned such practices. We all should work together to eradicate this social menace.
- **In echocardiography :** In this medical diagnostic technique, ultrasonic waves are used to construct the image of the heart.
- **For determining the depth of sea :** Ships use ultrasound to determine the depth of the sea by echo-sounding method. A transmitter on the ship sends ultrasound towards the sea-bed and the receiver receives the echo. From the time gap between the two signals, the depth of the sea can be estimated. This is illustrated below.
- **For clearing hard to reach places :** Ultrasonic waves are also used for clearing hard to reach places, such as spiral tube, odd shaped machine parts / components, electronic components etc. The object to be cleaned is kept in the 'cleaning solution' and the solution is subjected to the ultrasonic waves. The high frequency (ultrasonic) waves stir up the dust / dirt particles. These particles get detached and the object is thoroughly cleaned.

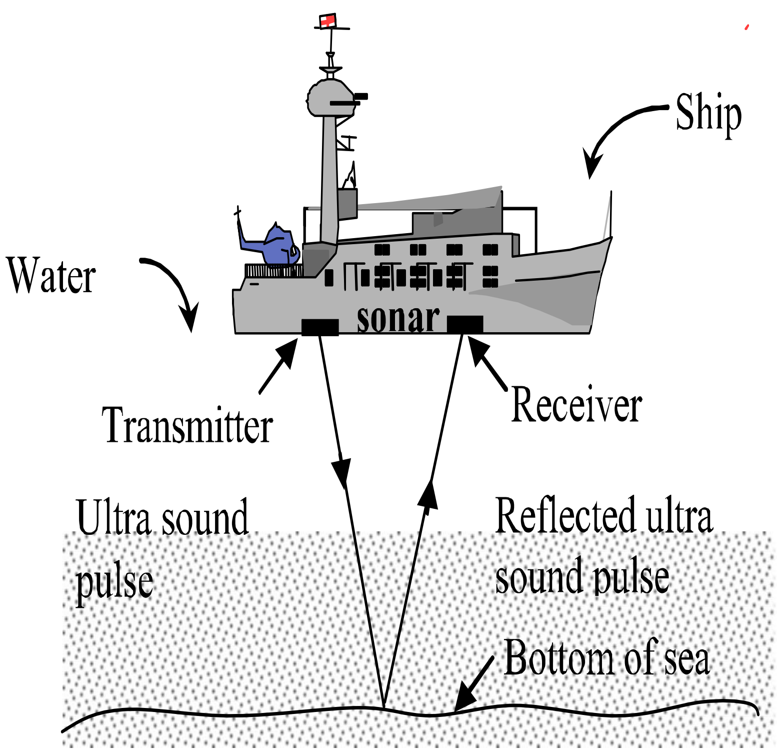
- Bats fly in the darkness of night without colliding with other objects by the method of echolocation. Bats emit high frequency ultrasonic squeaks while flying and listen to the echoes produced by the reflection of their squeaks from the objects in their path. From the time taken by the echo to be heard, bats can judge the distance of the objects in their path and hence avoid it by changing the direction. Bats search their prey at night by the method of echolocation.

◈ SONAR :

The word 'SONAR' stands for
Sound Navigation and Ranging.

(A) Principle of Sonar : Sonar is an apparatus which is used to find the depth of a sea or to locate the under water things like shoals of fish, enemy submarines etc. Sonar works by sending short bursts of ultrasonic sound from a ship down into sea water and then gets echo produced by the reflection of ultrasonic sound from under-water objects like bottom of sea, shoal of fish, a submarine.

(B) Working of Sonar :



(i) A transmitter (for emitting ultrasonic waves) and (ii) a receiver (for detecting ultrasonic waves). Now suppose a sonar device is attached to the under-side of a ship and we want to measure the depth of sea (below the ship). To do this the transmitter of sonar is made to emit a pulse of ultrasonic sound with a very high frequency of about 50,000 hertz. This pulse of ultrasonic sound travels down in the sea-water towards the bottom of the sea. When the ultrasonic sound pulse strikes the bottom of the sea, it is reflected back to the ship in the form of an echo. This echo produces and electrical signal in the receiver part of the sonar device. The sonar device measures the time taken by the ultrasonic sound pulse to travel from the ship to the bottom of the sea and back to the ship. Half of this time gives the time taken by the ultrasonic to travel from the ship to the bottom of the sea.

d = Depth of sea

v = Velocity of sound in sea water

t = time recorded by the recorder

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

Ex.11 The ultrasonic waves take 4 seconds to travel from the ship to the bottom of the sea and back to the ship. What is the depth of the sea ? (Speed of sound in water = 1500 m/s.)

Sol. The time taken by the ultrasonic sound waves to travel from the ship to the sea-bed and back to the ship is 4 seconds. So, the time taken by the ultrasonic sound to travel from the ship to sea-bed will be half of this time, which is $\frac{4}{2} = 2$ seconds. This means that the sound takes 2 seconds to travel from the ship to the bottom of the sea

Now, $\text{Speed} = \frac{\text{dis tan ce}}{\text{Time}}$

So, $1500 = \frac{\text{Distance}}{2}$

And, Distance = 1500 × 2m = 3000m

Ex.12 A submarine emits a sonar pulse which returns from the underwater cliff in 1.02 s. If the speed of sound in salt water is 1531 ms^{-1}, how far away is the cliff ?

Sol. Given : Speed of sonar pulse, V = 1531 ms^{-1},
Time interval of return journey of the pulse, t = 1.02s
Let the distance of the underwater cliff be S.
For distance S of the cliff, the pulse travels a total distance of 2S in return journey.
From relation, distance = speed × time

$$2S = vt$$

We have, $$S = \frac{vt}{2}$$

$$S = \frac{1531 ms^{-1} \times 1.02 s}{2}$$

$$S = 780.8 \text{ m}$$

◈ REASON FOR USING ULTRASONIC WAVES IN SONAR

(i) Ultrasonic waves have a very high frequency due to which they can penetrate deep in sea water without being absorbed.

(ii) Ultra sonic waves cannot be confused with the noise, such as the voice of engines of ship. It is because the ultrasonic waves are not perceived by human ear.

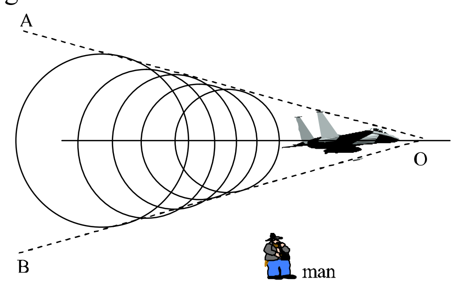
➤ SONIC BOOM

When a body moves with a speed which is greater than the speed of sound in air, it is said to be travelling at supersonic speed jet fighters, bullets, etc, often travel at supersonic speed, and when they do so, they produce a sharp, loud sound called a sonic boom.

The source moves at a speed greater than that of sound, sound waves travelling at the speed of sound, are left behind. The high-pressure layers due to sound waves originating at different points bunch together as shown in figure. Actually, these layers fall on the surface of an imaginary cone of which OA, OB is a part. The total pressure on the surface of this cone is very high. The source is at the apex of this cone. As the source moves ahead, it drags the cone together with it. when the surface of the cone reaches a person, the ears experience a sudden increase in pressure. After the surface crosses him, the pressure is suddenly reduced. This causes the person to hear a sharp, loud sound-the sonic boom.

A region consisting of a very-high-pressure layer followed by a lower-pressure layer travels through the space together with the cone. This is called a shock wave. This shock wave gives rise to the sonic boom when it reaches a person.

The shock waves produced by supersonic aircraft have enough energy to shatter glass and even damage weak structure.

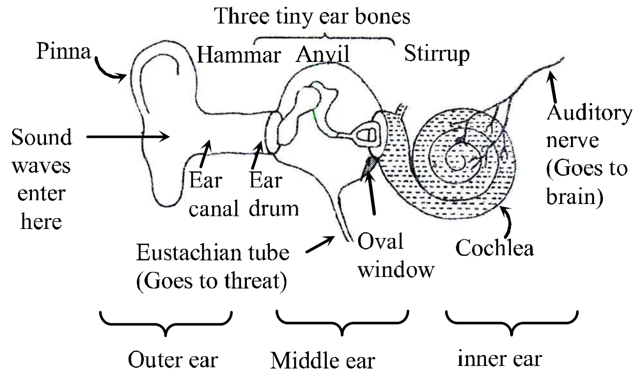


➤ THE HUMAN EAR

(a) Structure of human ear :

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

The part of ear which we see outside the head is called outer ear. The outer ears consists of broad part called pinna and about 2 to 3 centimeters long passage called ear canal. At the end of ear canal there is a thin, elastic and circular membrane called ear-drum. The ear-drum is also called tympanum. The outer ear contains air. The middle ear contains three small and delicate bones called hammer, anvil and stirrup. These ear bones are linked to one another. One end of the bone called hammer is touching the ear-drum and its other end is connected to the second bone called anvil. The other end of anvil is connected to the third bone called stirrup and the free end of stirrup is held against the membrane over the oval window of inner ear. The middle ear also contains air. The lower part of middle ear has narrow tube called 'eustachian tube' going to the throat. Eustachian tube connects the middle ear to throats and ensures that the air pressure inside the middle ear is the same as that on the outside



The inner ear has a coiled tube called cochlea. One side of cochlea is connected to the middle ear through the elastic membrane over the oval window. The cochlea is filled with a liquid. The liquid present in cochlea contains nerve cells which are sensitive to sound. The other side of cochlea is connected to auditory nerve which goes into the brain.

(b) Working of human ear :

Sound waves from outside are collected by the outer ear (called pinna) and reach the eardrum through the auditory canal. When the sound waves strike the eardrum, (tympanic membrane) it starts vibrating. These vibrations are passed on to the oval window by three bones (called the hammer, anvil and stirrup) which act as a lever with the pivot at point P. They magnify the force of the vibrations.

The oval window has a smaller area than the eardrum. So, this increase pressure on the oval window and on the liquid in the cochlea.

The vibrations of the liquid in the cochlea affect thousands of auditory nerves which send message to the brain.

Our ears are very delicate and fragile organs. Proper care must be taken to keep them in healthy state.

Some suggestions to keep the ears healthy are given below :

- Never insert any pointed object into the ear. It can damage the eardrum and make a person deaf.
- Never shout loudly into someone's ear.
- Never hit anyone hard on his / her ear.