

CHAPTER – 11



Waves and Sound

In our day to day life, we could hear sounds from various sources like human beings, cattles, birds, machines, vehicles, radio, televisions, bells, conch, pena, drums etc. You have also learnt that sound is one of the different forms of energy known to us, which can produce a sensation of hearing in our ears. In the previous chapters you have learnt about mechanical energy, chemical energy and the conservation of energy.

Whenever we speak or clap a sound is produced. In doing so we are utilising our energy, i.e. sound energy is obtained from the energy of our body. Which form of energy is used to produce sound? In this chapter we shall study to understand how sound is produced and how it is transmitted from the source to the ear receiving it through a medium.

11.1 Production of Sound

Sound is produced by the vibrational motion of a body. Let us take up the following activities to understand how sound is produced.

Activity.....11.1

You have acquainted with tuning fork in the previous class (class VII). Take a tuning fork and set it vibrating by striking one of its prongs on a rubber pad. And then bring it close to your ear but not touching. Touch one of the prongs of the vibrating tuning fork with your finger. Share what you have experienced on touching with your friends.

In the next observation, suspend a table tennis ball or a small plastic ball with the help of a thread from any available support. (Threading through the plastic ball can be done with a big needle and a thread putting a knot at the other end). Touch the ball gently with the prong of a vibrating tuning fork as shown in Fig 11.1. Observe what is happening and discuss with your friends.

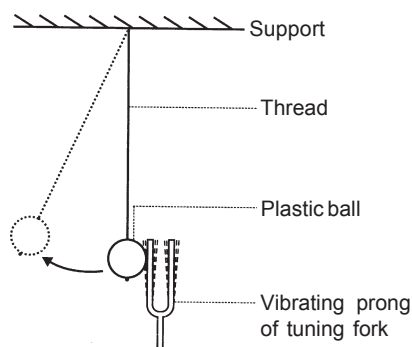


Fig.11.1: Vibrating tuning fork touching the plastic ball which was at rest

Activity.....11.2

Fill a glass tumbler with water up to the brim. Gently touch the water surface with one of the prongs of a vibrating tuning fork as shown in Fig.11.2 (a). Again, in the next observation dip the vibrating tuning fork in water as shown in Fig.11.2 (b).

Observe the surface of water in the tumbler in both cases. Discuss with your friends why this happens.

"Does the school bell give sound by itself ?.

From the above activities you can conclude that sound is produced only when the sounding objects are set into vibrations.

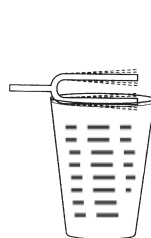


Fig.11.2(a)



Fig.11.2(b)

There are other means to produce sound from sounding objects. The means are plucking in sitar, guitar; rubbing in pena, violin; beating in pung, dhulok, drum; blowing in flute, clarinet, hexaphone; and shaking different objects. In all the above cases, we set the objects vibrating and only then sound is produced. The term vibration means a kind of rapid to and fro periodic motion of an object. Similarly, the sound of human voice is produced due to the vibration of the vocal cords. You must have seen a bird flapping its wings and accompanying a sound. Also try to understand how the buzzing sound accompanying a mosquito or a bee is produced. Keep a rubber band stretched between two fixed nails on the plank of desk or bench then pluck. You can hear a sound.

Activity.....11.3.

Prepare a list of different musical instruments so far available in your surrounding and discuss with your class-mate that which part or parts of the instrument vibrates or vibrate to produce sound from each of them.

11.2 Propagation of Sound

Vibrating objects produce sound. The matter or substance through which sound is transmitted is called a medium. The medium may be solid, liquid or gas and is extending from the source to the listener. As the object vibrates during the generation of sound, it sets the particles of the medium around it vibrating but they do not move bodily from the source to the listener.

In fact, the particle of the medium just in contact with the vibrating object is first displaced sideways from its equilibrium or rest position. It then exerts a force on the adjacent particle. As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. This process continues with the particles in the medium till the sound reaches the ear of the listener. This disturbance created by a source of sound in the medium travels through the medium but not the particles of the medium since the medium does not move as a whole. Here a wave is said to be produced.

A wave is a periodic disturbance that moves through the medium when the particles of the medium induce the neighbouring particles into motion. This type of propagation of disturbance can be experienced when you drop an object on the surface of water in a pond or lake as shown in Fig.11.3 (a) and (b).

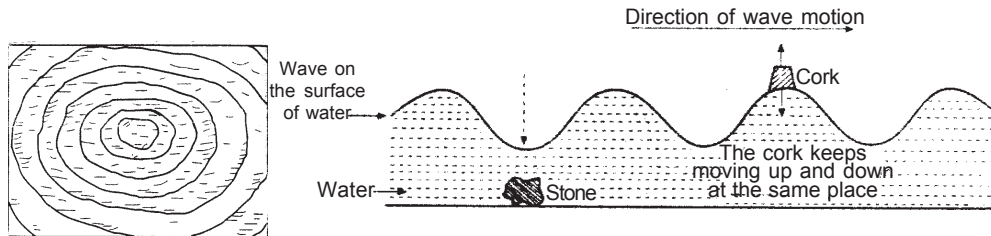


Fig.11.3: (a) circular water waves

(b) The floating particles only move up and down at the same place but are not carried away

As the disturbance reaches the floating particles, they move up and down periodically. The particles do not move forward themselves but the disturbance is carried forward in the direction of propagation.

This is what actually happens during the propagation of sound in a medium, hence the sound can be visualised as a wave. Such waves are characterised by setting the particles in a medium through the transformation of mechanical energy of the particles in the medium and are called "mechanical waves".

Most of the sounds listened by you come through air. When a vibrating object moves forward, it pushes and compresses the air adjacent to it creating a region of high pressure called compression i.e. a compressed region (C) shown in Fig.11.4. This compression moves forward from the vibrating object. When the vibrating prong moves backwards in course of its motion, it creates a region of low pressure called rarefaction (R) as shown in the same figure. As the prong vibrates back and forth rapidly, a series of compressions and rarefactions is formed in the air along the direction of propagation. This series of compressions and rarefactions constitutes the sound wave. The number of air particles per unit volume is larger in the compression regions than that in the rarefaction regions, because of higher pressure in compression and lower pressure in rarefaction. Thus, the propagation of sound can be visualised as propagation of density variations or pressure variations in the medium through which sound propagates. Since the compressions and rarefactions move parallel to the direction of propagation, the sound waves are called longitudinal waves.

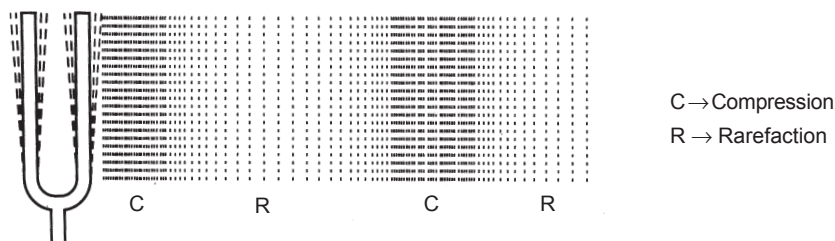


Fig.11.4: A vibrating tuning fork creating compression and rarefaction in succession

11.2.1 Sound waves need a medium for propagation

Any mechanical wave such as sound wave always needs a material medium like air, water (liquid), wood, steel etc. for its propagation. As such, sound waves cannot travel in vacuum. This property can be demonstrated by the following experiment.

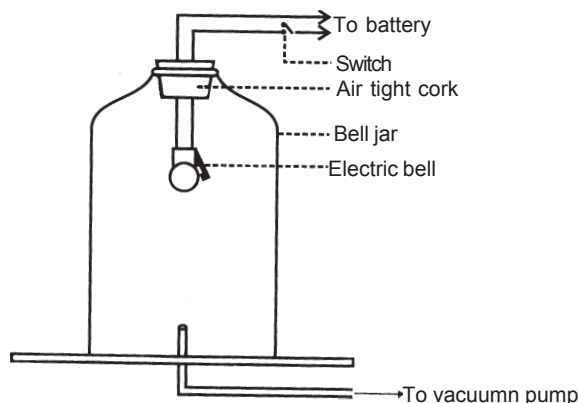


Fig.11.5: Bell jar experiment to show that sound cannot propagate in vacuum

Arrange the electric bell inside the bell jar and then place the jar on the platform of the vacuum pump. Now, close the switch S and you will be able to hear the sound of the bell. Now start the vacuum pump. Air will be pumped out of the bell jar gradually and sound will become fainter even though the bell is working with the same current from the battery. After some time when the air inside the jar is very less, you will be able to hear a very feeble sound. Now, stop the vacuum pump and allow the air to enter the jar slowly. As it continues, the sound will be louder. What will happen if the air inside the bell jar is completely pumped out?

Try to answer:

1. How sound is produced by bell at your school? Observe and explain.
2. The sound waves are also called mechanical wave. Why?

11.2.2 Sound Waves Are Longitudinal Waves

You have learnt from the above that sound propagates as longitudinal wave. This very property can be seen experimentally from the following activity 11.4.

Activity.....11.4

Take a long slinky of plastic and hold one end of it and fix the other end at a rigid support. Then stretch the slinky as shown in Fig.11.6 so that it must remain horizontal above the ground. Now, give it a sharp push towards the fixed end. What do you notice?

Try to move your hand pushing and pulling the slinky alternately through a small displacement along it and observe the features carefully. Any distinguishing mark on the slinky will move back and forth parallel to the direction of propagation of the

disturbance. The regions where the turns of the slinky become closer are called compressions (C) and the regions where the turns of the slinky are apart are called rarefaction (R). Now, you can see a series of alternate compressions and rarefactions throughout the length of slinky. This would be the same pattern in the case when sound propagates through air. Now you can compare the propagation of disturbance in a slinky with the propagation of sound in a medium. Besides, we have seen that the turns or particles of the slinky do not move from one place to other but they simply oscillate back and forth about their mean positions of rest parallel to the direction of propagation of disturbance along it.

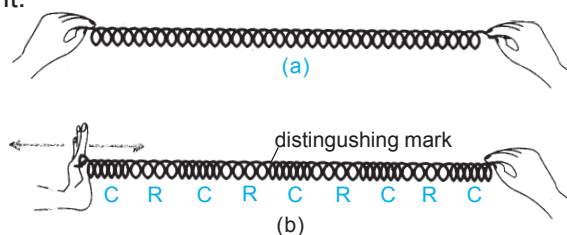


Fig.11.6: Longitudinal wave along a slinky

This is exactly how a sound wave propagates. That is why sound waves are said to be longitudinal waves.

There is also another type of wave, called transverse wave. In these waves the particles of the medium do not oscillate parallel to the direction of propagation but oscillate up and down, similar to the motion of floating bodies on the wave propagating over the surface of water see Fig.11.3 (b), about mean or average position when they are at rest. The direction of oscillation is perpendicular to the direction of propagation of the wave. Example of transverse wave is light i.e. light is a transverse wave. However, for light the oscillations are not of the particles of the medium or their pressure or density. Therefore light is not a mechanical wave. You will study more about transverse waves in higher classes.

11.2.3 Characteristics of A Sound Wave

A sound wave can be described by its three characteristics. They are (1) frequency (2) amplitude (3) speed.

You have learnt that when a sound wave propagates in a medium, the value of density and pressure of the medium changes above and below the average value. A sound wave, during its propagation, is shown graphically indicating how density and pressure of the medium change. Fig.11.7 (a) and (b) represent density and pressure variations respectively of the medium during the propagation of sound wave.

We already know that compressions are regions where particles are crowded together and represented by a level higher than the average. Thus the peak in the diagrammatic representation represents the maximum value of compression. As a result, the compressions are the regions of high density as well as high pressure.

Opposite to the compressions, rarefactions are the regions of low density as well as low pressure and are represented by a level lower than the average value. The lowest level or valley denotes the minimum of density as well as pressure. By convention, the peak is called the crest and the valley is called the trough of the wave, as shown in Fig.11.7 (c). The distance between two consecutive crests or troughs is called wavelength of the wave and is represented by λ (lamda, a Greek letter). Its SI unit is metre (m).

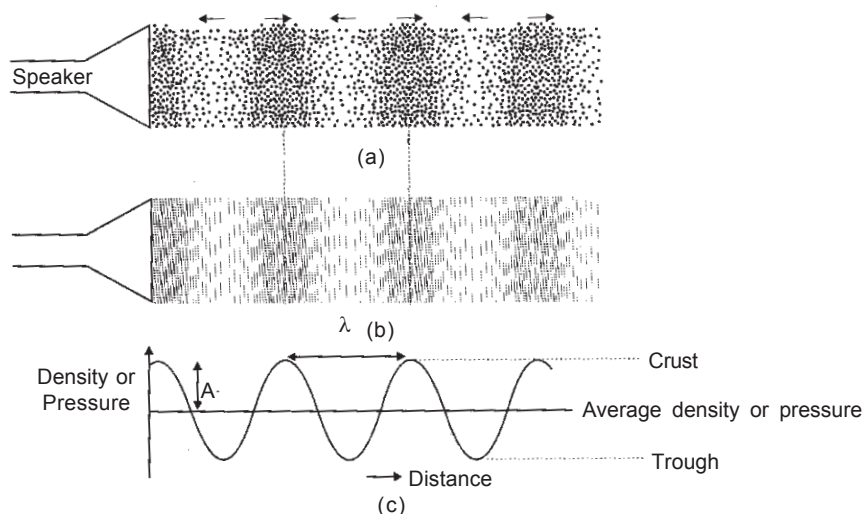


Fig. 11.7: Propagation of sound as Density variation (a); Pressure variation (b); (c) represents graphically the density and pressure variation

Suppose you are beating a drum. How many times you are beating the drum per unit time is called the frequency of beating of the drum. In other words the term frequency tells us how frequently an event occurs. From the discussions above we know that when sound is propagating from a source in a medium, the density of the medium oscillates between a maximum value to a minimum value. The event of change of density from maximum value to a minimum value then again to the maximum value is called one complete oscillation. The number of such complete oscillation per unit time is the frequency of the sound wave. If we can count the number of the compressions or rarefactions that cross a region in a unit time, we will get the frequency of the sound wave. It is usually represented by ν (Greek letter 'nu'). Its SI unit is hertz (symbol, Hz): In honour of Heinrich Rudolf Hertz, born on 22 February, 1857 in Hamburg, Germany.

The time taken by wave to produce two consecutive compressions or two consecutive rarefactions crossing a fixed point in the medium through which sound is propagating is called the time period of the wave. This is equal to the time taken for one complete oscillation in the density or pressure of the medium. It is represented by the symbol 'T' Its SI unit is second (S).

Thus the frequency and time period of a wave are related as

$$\nu = \frac{1}{T} \dots\dots\dots (11.1)$$

You must have heard the different musical instruments viz, pena, violin, flute, sitar etc. being played at the same time in an orchestra. The different sound waves travel to the same medium, that is air, at the same speed and arrive at your ear at the same time. But the sounds we receive are giving different sensation. This is due to the different characteristics associated with each of the sound waves. The characteristic of each sound wave is called its *pitch* and this is how the brain interprets the frequency of an emitted sound. The faster the vibration of the source, the higher is its frequency and the higher is the pitch, as shown in Fig 11. 8. Thus a high frequency or a high pitch sound corresponds to more number of compressions and rarefactions passing a fixed point of the medium in unit time. Objects of different sizes under different conditions vibrate at different frequencies to produce sound waves of different pitch.

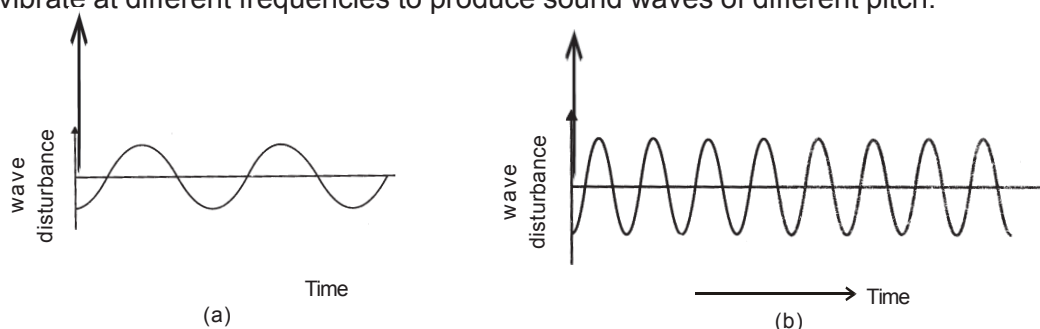


Fig.11.8: (a) Wave shape for a low pitched sound
(b) That for a high pitched sound

The magnitude of the maximum disturbance in the medium on either side of the mean value of density or pressure of the medium is called the amplitude of the wave, which is represented by the letter 'A' in Fig.11.7 (c). For sound the unit for amplitude is that of density or pressure. The amplitude of sound determines its loudness or softness.

The amplitude of sound wave depends upon the force with which a sounding object is made to vibrate. As an example, if we strike a table lightly, we hear a soft sound because the material of the table produces sound of less amplitude i.e. of less energy. If we hit the same table hard we can hear a loud sound. You try to explain.

A loud sound is associated with higher energy and can travel a larger distance than a soft sound. As sound wave moves away from the source, its amplitude as well as its loudness decreases. Fig.11.9 shows the wave shapes of a loud and a soft sound having the same frequency.

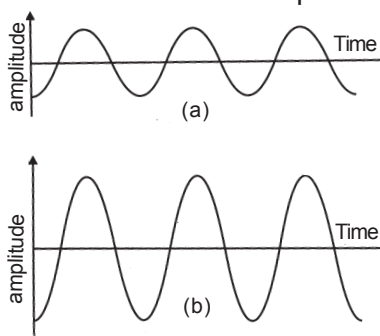


Fig. 11.9: (a) soft sound has small amplitude while

(b) louder sound has large amplitude

The other characteristic of sound which enables us to distinguish one sound from another having the same pitch and loudness is called *quality* or *timbre*. The sound which is more pleasant on hearing is said to be of a rich quality. A sound of single frequencies is called a *tone* whereas the sound which is produced due to a mixture of several frequency is called a *note*. A note is more pleasant to listen than a tone. Still there is also sound which is unpleasant to the ear and sound of this type is called *noise*. The musical sound is pleasant to hear and is of rich quality.

The speed of sound wave is defined as the distance which a compression or a rarefaction travels per unit time. We know that the wavelength (λ) of the sound wave is the distance travelled by the sound wave in one time period (T) of the wave. Thus, the distance travelled by the wave in unit time, which is speed by definition will be given by

$$v = \frac{\lambda}{T} = \frac{\text{distance travelled } (\lambda)}{\text{time taken (T)}}$$

$$\text{or } v = \lambda \nu \dots\dots\dots (11.2) \quad \because$$

That is, speed = wavelength $\times$ frequency.

N.B. The speed of sound remains almost the same for all frequencies in a given medium, under the same physical conditions.

The amount of sound energy crossing through a unit area per second is called the intensity of sound. You should not treat loudness and intensity as two interchangeable terms. They are not the same. Loudness measures the amount of sensation produced in the ear and hence depends upon the listener. Thus two sounds of equal intensity may produce different loudness when perceived by us. We may hear one as louder than the other simply because our ear detects it better.

Example 11.1

A sound wave has a wavelength 50 cm and of frequency 670 Hz. How long will it take to travel a distance of 1.34 km?

Solution:

Given, frequency, $\nu = 670$ Hz and wavelength $\lambda = 50$ cm = 0.5m.

From, speed of sound = wavelength $\times$ frequency, we get

$$\begin{aligned} v &= \lambda \nu = 0.5 \text{ m} \times 670 \text{ Hz} \\ &= 335 \text{ m/s.} \end{aligned}$$

Then, the time taken by the sound wave to travel a distance, $d = 1.34$ km = 1340 m is

$$t = \frac{d}{v} = \frac{1340 \text{ m}}{335 \text{ m/s}} = 4\text{s.}$$

Thus, the sound wave will take 4s to travel a distance of 1.34 km.

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

Try to answer:

1. What are wavelength, frequency, amplitude and periodic time of a sound wave? Which of the above quantities does not change when sound passes through different media?
2. What is the relation between frequency, wavelength of a sound wave and its speed in a medium.
3. Distinguish between intensity and loudness of sound.

11.2.4 Speed of Sound in Different Media

We know that the sound of thunder is heard a little later than the accompanying flash of light is seen. From this we can make out that sound travels with a speed which is much less than the speed of light. Sound propagates at a finite speed through a medium, depending on the temperature of the medium. The speed of sound in a medium increases with increasing temperature. For example, the speed of sound in air at 0°C is 331 ms^{-1} and 344 ms^{-1} at 22°C . Besides, the speed of sound is different in different media and decreases when we go from solid medium to gaseous medium. The different speeds of sound at a particular temperature in various media are listed in Table 11.1 below, for information.

Table 11.1: Speed of sound in different media at 25°C .

Nature of Medium	Substance	Speed in ms^{-1}
Solid	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
Liquid	Sea water	1531
	Distilled water	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

N.B. Try to understand, in which media – air, water or iron, does sound travel fastest at a particular temperature, from the above table.

11.3 Reflection of Sound

You might have perceived the sound of clapping by you when you clap hands standing at large distance from high wall or boundary wall of your school. This is the case where a sound wave strikes a hard surface like wall, it rebounds from that surface and comes back to the original medium. This phenomenon associated with sound wave is called the reflection of sound.

Like light sound is reflected at the surface of solid or liquid and follows the same laws of reflection as you have studied in earlier classes. The directions of incident sound and reflected sound make equal angles with the normal at the point of incidence and the three are in the same plane. Unlike light, obstacles of large size which may be polished or rough can reflect sound waves.

Activity 11.5

Prepare two long pipes out of chart or drawing paper. Arrange them on a table near a wall as shown in Fig.11.10. Keep a table clock near the open end of one of the pipes as shown and try to listen the sound of the clock at the open end of the other pipe. Adjust the positions of the pipes so that you can hear the sound of the clock with maximum loudness. Now, measure the angles subtended by the pipes with the normal to the surface of the wall and see the relationship between the angles.

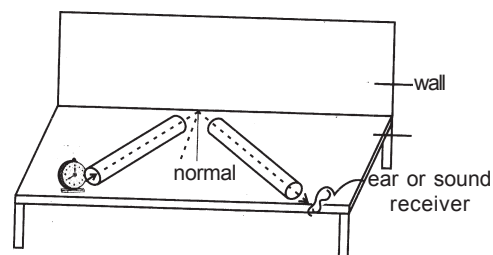


Fig. 11.10: Reflection of sound

11.3.1 Echo

You have learnt from the above that the process by which a wave changes its direction is reflection of wave. When the sound bounces back it is called an echo. As an example, when we shout or clap near a suitable reflecting object such as a tall building or a mountain or cliff we will hear the same sound after a time interval. Thus echoes are formed by the repeated reflection of the sound. This sound which we hear is called an echo.

In order to hear an echo, practically, there should exist a minimum distance between the source of sound and the reflecting surface or equivalently the time interval between the original sound and the reflected sound must be at least 0.1 s. This is so, because the sensation of sound persists in our brain for about 0.1 s. If we take speed of sound to be 344 m/s at a given temperature say at 22°C in air the sound must travel to the reflecting surface and reach back to the listener on reflection after 0.1 s or more. Hence, the total distance covered by the sound from the source to the reflecting surface and back to the position of source be at least $344 \text{ m/s} \times 0.1 \text{ s} = 34.4 \text{ m}$ i.e. distance covered by sound during 0.1s. Thus for hearing an echo clearly, the minimum distance between the source and reflecting surface must be half of the distance of 34.4 m i.e. 17.2 m. Repeated echoes may be heard due to successive or multiple reflections. The rolling of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds and the land.

11.3.2 Reverberation

Have you ever shouted in an empty room of your house surrounded by walls? The sound will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation of sound. This is an undesirable effect in public auditorium and big halls. The reverberation can be reduced by covering the roofs and walls of the auditorium with sound-absorbent materials like compressed fibreboard, rough plaster or draperies. The seat materials are also selected on the basis of their sound absorbing properties.

Example 11.2

An echo returned in 4s. What is the distance of the reflecting surface from the source, given that the speed of sound is 340 ms^{-1} ?

Solution:

Given, Speed of sound, $v = 340 \text{ ms}^{-1}$

Time taken for hearing the echo, $t = 4 \text{ s}$

Distance travelled by the sound $= v \times t = 340 \times 4$
 $= 1360 \text{ m}$

Since, the sound travels twice the distance between the source and surface, the distance between the source and surface is $1360/2 = 680 \text{ m}$.

11.3.3 Uses of Echo or Multiple Reflection of Sound

1. Stethoscope is an instrument used by doctors for listening to the sounds produced within the human body and animals, chiefly in the heart or lungs. In this instrument the sound of the patient's heart beat reaches the doctor's ears by multiple reflection of sound from the boundary of the pipe, as shown in Fig. 11.11.

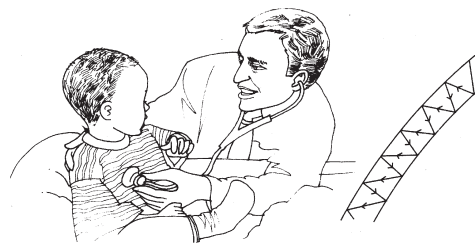
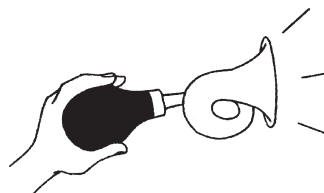


Fig. 11.11: Stethoscope

2. Megaphones or loudhailers, horns are all designed so that sound will travel in a particular direction without spreading in all directions as shown in the Fig. 11.12 (a) and (b)



(a) Megaphone



(b) Horn

Fig.11.12: (a) Megaphone (b) Horn

A tube followed by a conical opening is used to reflect the sound successively, in these instruments. This design is to guide most of the sound waves from the source to the audience in the forward direction.

3. You might have seen the curve shaped structures at the ceiling of cinema halls and auditorium. This is to reflect sound wave in order to reach all corners of the hall or auditorium. In very large halls, a large curved surface is sometimes placed at the stage so that sound waves after reflecting from the surface spread equally across the length and width of the hall. Such curve surface is called soundboard and is shown in Fig.11.13.

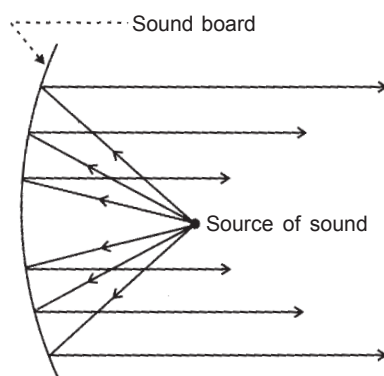


Fig. 11.13: Sound board and reflection of sound

11.4 Range of Hearing

Through investigation it is accepted that the audible range of sound for human beings extends from about 20 Hz to 20,000 Hz. Children under the age of five and some animal such as dogs can hear up to 25 kHz (1 Hz = one cycle/sec; 1 kHz = 1000 cycle/sec). As people grow older their ears become less sensitive to higher frequencies.

Sounds having frequencies less than 20 Hz are called infrasonic sound. Human ear cannot perceive infrasonic. Rhinoceroses communicate using infrasound of frequency as low as 5Hz. Whales and elephants produce sound in the infrasound range. It is observed that some animals get disturbed before earthquakes.

Earthquakes produce low- frequency infrasound before the main shock waves begin which possibly alert the animals. Frequencies higher than 20 kHz are called ultrasonic or ultrasound. Ultrasound is produced by dolphins, bats and porpoises. Moths of certain families have very sensitive hearing equipments. These moths can hear the high frequency squeaks of the bat and know when a bat is flying nearby and are able to escape the capture. Rats also play games by producing ultrasound.

11.5 Ultrasound And Its Application

Ultrasonics or ultrasonics are high frequency mechanical waves. Such waves can travel along the well defined paths even in presence of obstacles and exhibit the properties of audible sound waves. Ultrasonics are used in industries (cleaning, detection of flaws or cracks), for medical purposes (echocardiography, ultrasound scanner, breaking of small stones formed in kidneys; sterilization) and navigation purposes.

(a) Cleaning – It is used to clean electronic components, spiral tubes and odd shaped parts located at hard to-reach places in glass-ware. Objects to be cleaned are placed in a cleaning solution where the ultrasound waves is sent into. Due to shaking at ultrasonic frequency the particles of dust, grease and dirt get detached and drop out. Thus the objects get thoroughly cleaned.

(b) Detection of flaw – The defects like cracks or flaws which are invisible from outside sometimes present in metal blocks used in the construction of buildings, bridges, heavy machines and also in scientific equipments. Such defect reduces the strength of the structures. Ultrasound can be used to detect such defects. In the process, ultrasonic waves are allowed to pass through the metal block and detectors are used to detect the transmitted waves. The ultrasound gets reflected back from the boundary of flaws or cracks, if present at all and the transmitted waves can not reach the detector as shown in Fig.11.14.

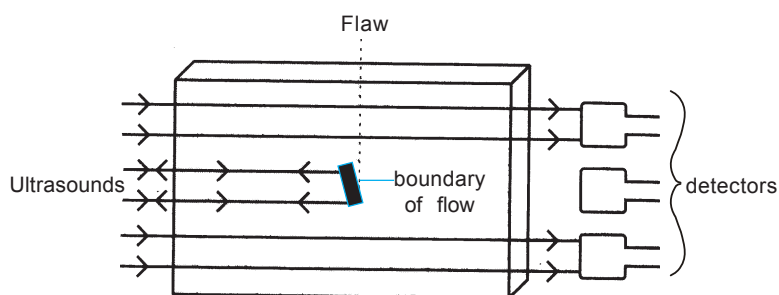


Fig.11.14: Ultrasound is reflected back from the defective locations

(c) Echocardiography– It is a technique in which ultrasonic waves are made to reflect from various parts of the heart and to form the sonic image of the heart.

(d) Ultrasound scanner– This is an instrument used for getting images of internal organs of human body by using ultrasonic waves. It helps the doctors to detect abnormalities in the organs such as liver and stones in gall bladder, uterus, kidney etc of the patient. In this technique the ultrasound waves are made to travel through the tissues of the body and to get reflected from a region where there is a change of tissue density. The reflected waves are converted into electrical signals that are used to generate images of the organs. Finally, these images are then displayed on a monitor or printed on a film, to be used by the doctors for diagnosis. This technique is called "Ultrasonography" which is also used for examination of the foetus during pregnancy to detect congenital defects and growth abnormalities.

Ultrasound may be employed to break small stones formed in the kidneys into fine grains. These grains get flushed out with urine.

(e) Sterilization – Ultrasonic waves can destroy unicellular organisms. Bacteria perish under the action of ultrasonic waves and this principle is used in the sterilization of water and milk.

(f) Navigation – Ultrasonic waves are used to measure the depth of seabed, direction and speed of under water objects in a device known as SONAR which stands for SOund Navigation And Ranging. Sonar consists of a transmitter and a detector for ultrasonic waves. Both are installed in a boat or a ship as, shown in the diagram of Fig.11.15.

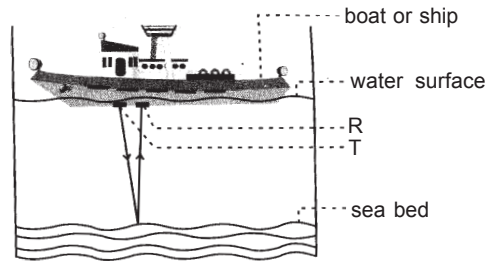


Fig. 11.15

The waves generated by the transmitter travel through the water and after striking the object on the seabed which cannot be seen by the eyes, get reflected back and are received by the detector. Actually, the detector transforms the reflected ultrasonic waves into electrical signals exactly interpreting the pattern of object on the seabed. The distance of the object reflecting the sound can be estimated by knowing the speed of sound in water and time lag between the transmitted and received signals of sound. If 'd' is the distance or depth of the seabed then the total distance traversed by the signal inside the water is $2d$. Thus $2d = v \times t$ where 'v' is the velocity of sound in seawater and 't' is the time elapsed between the transmitted and received signals. The method is also called echo-ranging and the technique is used to determine the depth of the sea and to locate underwater icebergs, sunken ships, valleys and hills etc.

Example 11.3

The time elapsed between the transmitted and received signals of a sonar system of a ship is 3.5 sec. If the velocity of sound in sea water is 1532m/s, find the depth of the sea bed from the ship.

Solution:

Time between the signals, $t = 3.5$ sec

Speed of ultrasound in seawater = 1532m/s

Distance travelled by ultrasound signal = $2d$

Where d is the depth of the seabed in metre.

Thus, $2d = \text{speed of sound in seawater} \times \text{time}$
 $= 1532 \times 3.5 = 5362$ m.

$$\therefore d = \frac{5362}{2} = 2681 \text{ m.}$$

Hence, the depth of the seabed is 2.681km.

11.6 Structure of Human Ear

We can perceive sound with the help of an extremely sensitive device called 'ear'. How do we hear? It is established that the auditory nerve of our ear converts the pressure variations in air with audible frequencies into electric-like signals that travel

to the brain via the auditory nerve. The auditory aspect of human ear is described below. The outer ear which is called 'pinna' collects the sound from the surroundings. The collected sound passes through the auditory canal. At the end of the auditory canal there is a thin membrane called the ear drum or tympanic membrane. When the compression of the wave reaches the ear-drum the pressure on the outside of the membrane increases and forces the eardrum inward. Similarly, the eardrum moves outward when a rarefaction reaches it, in turn. In this way the eardrum vibrates. The vibrations are amplified several times by three bones (the hammer, anvil and stirrup) in the middle ear. The middle ear transmits the amplified pressure variations received from the sound wave to the inner ear. In the inner ear the pressure variations are turned into electrical signals by the cochlea. These electrical signals are sent to the brain via the auditory nerve and the brain interprets them as sound.

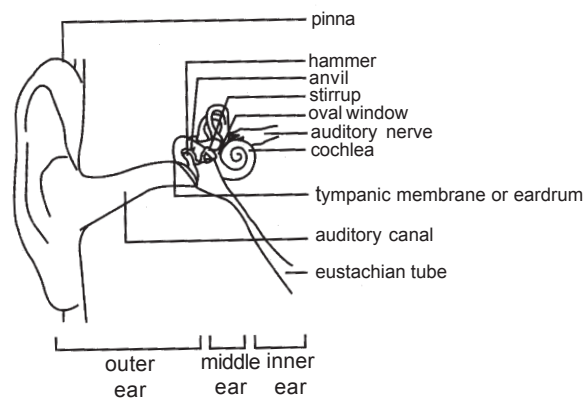
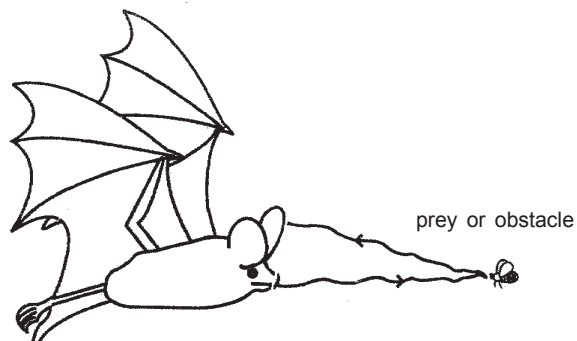


Fig. 11.16: Auditory parts of human ear.

(1) Hearing Aid: A hearing aid is an electronic device operated with the help of battery and used by persons with hearing loss. The hearing aid receives sound through a microphone. The microphone converts the sound waves to electrical signals. These electrical signals are amplified by an amplifier. The amplified signals (electrical) are given to a speaker of the hearing aid which converts the amplified signals to sound and sends to the ear for clear hearing.

(2) Ultrasonic squeaks of bat:

As mentioned earlier, bats search out their prey and fly in dark night by emitting and detecting the reflections of Ultrasonic waves. The high pitched Ultrasonic squeaks of the bat are reflected from the obstacles in the form of prey and returned to the bat, as shown in the figure. The nature of reflections reveals the bat where the prey is and what is it like. It is also of the opinion that some marine animals use ultrasound for navigation and location of prey in the dark.



POINTS TO REMEMBER

- (i) When a disturbance created in a medium travels to another part without involving a transfer of any material with it, the motion of the disturbance is called wave motion.
- (ii) A wave does not transfer material from place to place but it transfers energy wherever it travels.
- (iii) Sound is produced due to vibration of different objects.
- (iv) Sound travels as longitudinal wave through a material medium, forming successive compressions and rarefactions in the medium.
- (v) Since sound wave belongs to mechanical wave, it cannot travel in vacuum.
- (vi) In the propagation of sound wave the change in density from one maximum value to the minimum value again to the maximum value and vice-versa, makes one complete oscillation.
- (vii) The distance between two adjacent compressions or rarefactions is called one wavelength ' λ ' of the wave.
- (viii) The time taken for one complete oscillation is called the time period or periodic time of the wave.
- (ix) The number of complete oscillations per unit time is called the frequency ' ν ', $\nu = \frac{1}{T}$ or $\nu T = 1$.
- (x) The speed ' v ' of sound wave in a medium is given by relation, $v = \nu \times \lambda$ and depends on the nature and temperature of the propagating medium.
- (xi) The incident and reflected sound waves make equal angles with the normal to the reflecting surface at the point of incidence and the three lie in the same plane.
- (xii) For hearing a distinct reflected sound from a source, the time interval between the original sound and the reflected sound must be at least 0.1 s, which is the persistence of sound.
- (xiii) Repeated reflections of sound in an auditorium is the cause of reverberation.
- (xiv) The pitch, loudness, intensity of sound are determined by the corresponding wave properties.
- (xv) The amount of sound energy passing through unit area in one second is called the intensity of sound.
- (xvi) The normal audible range of hearing for human ear lies in the range of 20 Hz – 20 kHz.
- (xvii) Sound waves with frequencies less than 20 Hz are termed "infrasonic" and those above 20 kHz are termed 'ultrasonic'.
- (xviii) Ultrasound had applications in industry, medical and navigation (SONAR).

EXERCISES

1. Define sound and explain how is it produced ?
2. Explain the formation of compressions and rare factions in air near a source of sound.
3. Define wavelength, periodic time and frequency of a wave.
4. Derive the relation between wavelength, frequency and time period of a periodic wave.
5. When you call your friend by name, do you produce a wave pulse of sound or a periodic wave?
6. Show graphically how density of air varies with distance when a periodic sound wave travels in it. Show the graphs for two instants of time differing by half of periodic time.
7. Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?
8. Does sound follow the same laws of reflection as light does? Explain.
9. Describe an experiment to show that sound needs a medium to propagate.
10. Give two practical applications of reflection of sound waves.
11. What is loudness of sound? On which factors does it depend?
12. Explain the working and application of a SONAR.
13. A sound waves travels in a medium at a speed of 340m/s. If its wavelength is 1.7cm, What is the frequency? Will it be an audible sound?
(20×10^3 Hz; audible)
14. Explain the working of human ear.
15. A source of sound produces 20 crests and 20 troughs in 0.2s. Find the frequency of the wave.
(100 Hz)
16. The time period of a periodic wave is 0.02s. At a particular position there is a crest at $t = 0$. A trough will appear at this position at 't' equal to
 - (A) 0.005s
 - (B) 0.01s
 - (C) 0.015s
 - (D) 0.02s