

1. SOUND

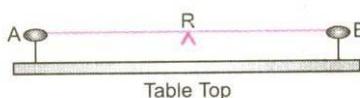
Sound is produced by various sources. Though sound is mechanical in nature, its perception is, of course, largely physiological.

1.1 PRODUCTION OF SOUND

When you clap your hands, a sound is produced. In order to know how sound is produced, let us perform the following two simple experiments.

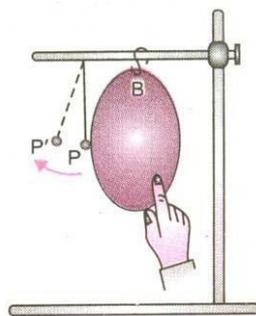
Experiment – 1

Stretch a metallic wire AB between two nails fixed on a table as shown in the figure. When we pluck the wire a sound is heard. If a V-shaped small paper rider (R) is placed near the centre of the wire, it starts vibrating. If the rider is placed at the centre of the wire, it flies off.



Experiment – 2

On striking a bell B with a hammer, it produces sound. On touching it with finger, we feel that the bell is in a state of vibration. A pith-ball, P, suspended near the bell moves from its equilibrium position P to P' as shown in figure.



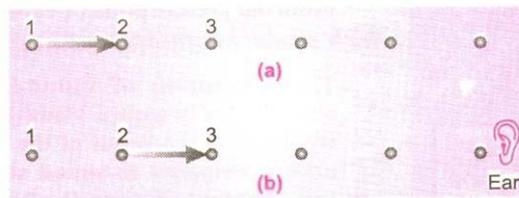
In the above activities we have produced sound by plucking and striking. We can also produce sound by scratching, rubbing, blowing, shaking, etc.

Thus, we conclude that sound is produced by setting the objects in vibration. Vibration means a kind of rapid to and fro motion of an object.

1.2 PROPAGATION OF SOUND

The sound produced by vibrating objects reaches the listener only when it passes through a medium which may be a liquid, a solid or a gas. Let us now briefly discuss as to how sound travels from the source point of generation to the listener.

- (i) The vibration of the object sets the particles of the medium around it vibrating.
- (ii) The particles do not travel from the vibrating object to the ear. A particle of the medium in contact with the vibrating object is first displaced from its equilibrium position as shown in the figure. This particle exerts a force on a neighbouring particle (2) which is displaced from its equilibrium position and also starts moving. After displacing particle (2), particle (1) comes back to its mean position, continuous till the particle near the listeners ear starts vibrating.



Thus, sound created by the source reaches the listener through the particles of the medium without any net transport of the medium.

1.2.1 Wave Nature of Sound

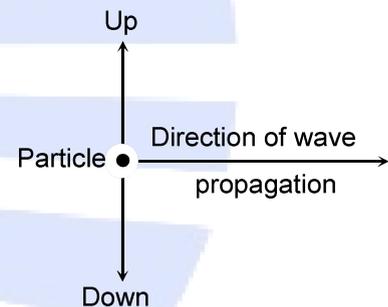
A wave is a vibratory disturbance in a medium which carries energy from one point to another, without there being a direct contact between the two points.

(a) Type of waves on the basis of material medium

- (i) **Elastic waves or mechanical waves** : Those waves which need a material medium for their propagation are called **elastic waves** or **mechanical waves** e.g., sound waves and water waves are elastic or mechanical waves.
- (ii) **Electromagnetic waves** : Those waves which do not need a material medium for their propagation are called **electromagnetic waves**. These waves can travel through vacuum as well as through medium e.g. light waves and radio waves are electromagnetic waves.
- (iii) **Seismic waves** : The disturbances inside the earth which cause waves moving in all direction are called **seismic waves**. It is these waves which cause earth quakes.

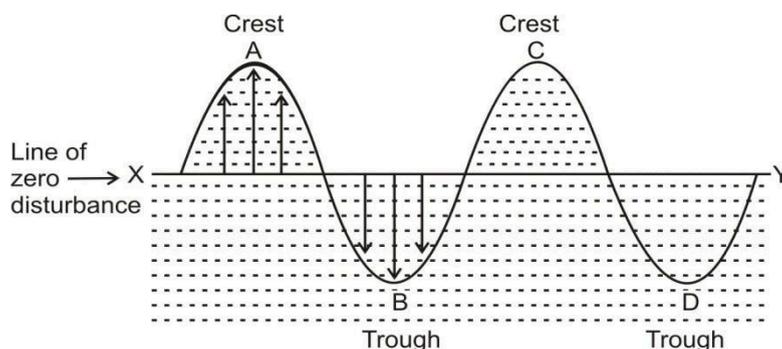
(b) Types of waves on the basis of its direction of propagation

- (i) **Transverse waves** : The waves in which the particles of the medium vibrate up and down 'at right angles' to the direction in which the wave is moving, are called transverse waves. Eg., light waves, radio waves, water waves etc.



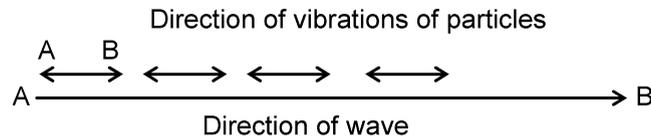
The water waves (or ripples) formed on the surface of water in a pond are transverse waves. This is because of the fact that in a water wave, the molecules of water move up and down in the vertical direction when the wave travels in the horizontal direction along the water surface. When a stone is dropped in a pond of water, transverse water waves are produced on the surface of water.

The '**elevation**' or '**hump**' in a transverse wave is called crest. In other words, a crest is that part of the transverse wave which is above the line of zero disturbance of the medium. In figure XY is the line of zero disturbance and A and C are the two crests of the transverse water waves.



The '**depression**' or '**hollow**' in a transverse wave is called trough. In other words, a trough is that part of the transverse wave which is below the line of zero disturbance.

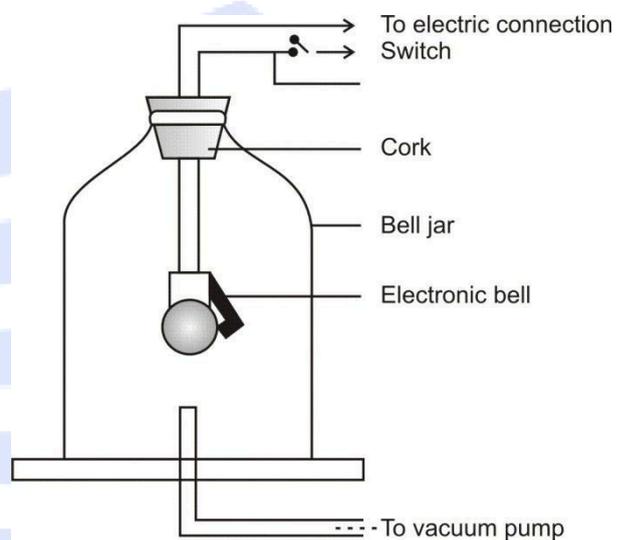
- (ii) **Longitudinal waves** : A wave in which the particles of the medium vibrate back and forth in the 'same direction' in which the wave is moving, is called longitudinal wave. Eg. – sound waves.



1.3 SOUND NEEDS A MEDIUM TO TRAVEL

Sound is a mechanical wave and needs a material medium like air, water, steel etc. for its propagation. It cannot travel through vacuum, which can be demonstrated by the following experiment.

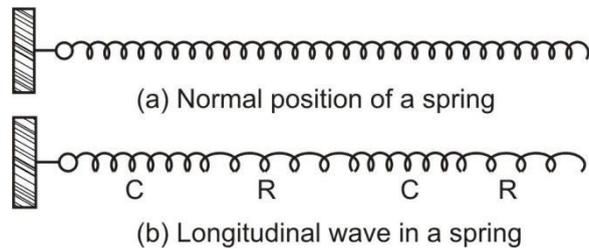
Take an electric bell and an airtight glass bell jar. The electric bell is suspended inside the airtight bell jar. The bell jar is connected to vacuum pump, as shown in figure. If you press the switch you will be able to hear the bell. Now start the vacuum pump. When the air in jar is pumped out gradually, the sound becomes fainter. When the air is completely ejected from the bell jar, no sound is being heard. Although, the bell is working alright and same current is passed through it, but no sound is being heard. It clearly shows that sound cannot travel without a material medium.



1.4 SOUND WAVES ARE LONGITUDINAL WAVES

Before we study about sound waves, let us understand the nature of longitudinal waves with the help of a slinky AB (It is a toy in the form of a long flexible spring which can be very easily extended or compressed).

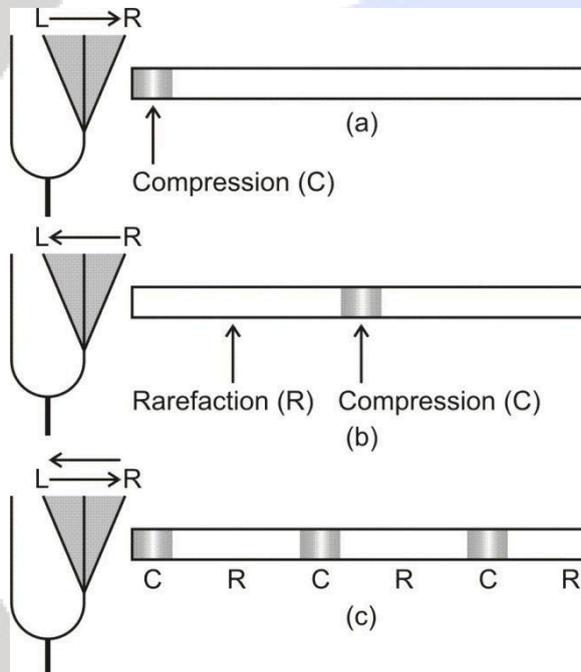
- The slinky is arranged in the horizontal position with its end B fixed. Initially when the slinky is neither compressed nor stretched, there is a fixed distance between its loops.
- If the free end of slinky is pushed forward a few loops near it are compressed. This region where the loops are closer to each other than the normal distance is called a **compression**.
- Now, if the slinky is pulled outwards, a few loops near it are pulled away from each other. This region where the loops of the slinky are farther apart than the normal distance is called a **rarefaction**.
- If pulling and pushing of the slinky is done at regular intervals, a series of compression and rarefactions are set up in the slinky.



1.4.1 Production of compressions and rarefactions near a source of sound

Air is the most common medium through which sound travels and it does so with the help of intervening layers of air. As discussed earlier, a source of sound puts the particles of the medium into vibratory motion. Let us consider a vibrating tuning fork as a source of sound.

- (a) When the right prong moves from left (L) to right (R), it compresses the layer of air in front of it. This results in the increase of the pressure as well as density of this layer. This layer (or region) of compressed air is called a compression.



- (b) When the prong moves from its right extreme (R) to left extreme (L), the air in front of it expands. As a result, the pressure (as well as density) of this layer decreases. This region of rarefied air is called a rarefaction.

Thus,

- A sound which propagates as a series of compressions and rarefactions is a longitudinal wave.
- A sound wave can be considered as propagation of pressure or density variations in the medium.

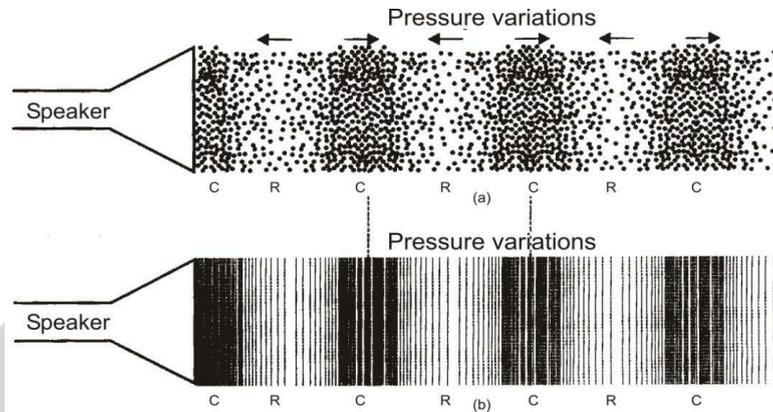
1.5 CHARACTERISTICS OF A SOUND WAVE

As already discussed, sound waves are produced due to variations in pressure and density of the medium. The various other characteristics are :

1.5.1 Compression and rarefaction

A compression is formed when particles of the medium lie closer to each other whereas a rarefaction is formed when the particles of the medium lie farther apart than the normal distance.

(a) **Compression** : A portion of the medium where a temporary increase in volume and consequently a decrease in density takes place when a sound wave passes through the medium. It is called a compression or a condensation.



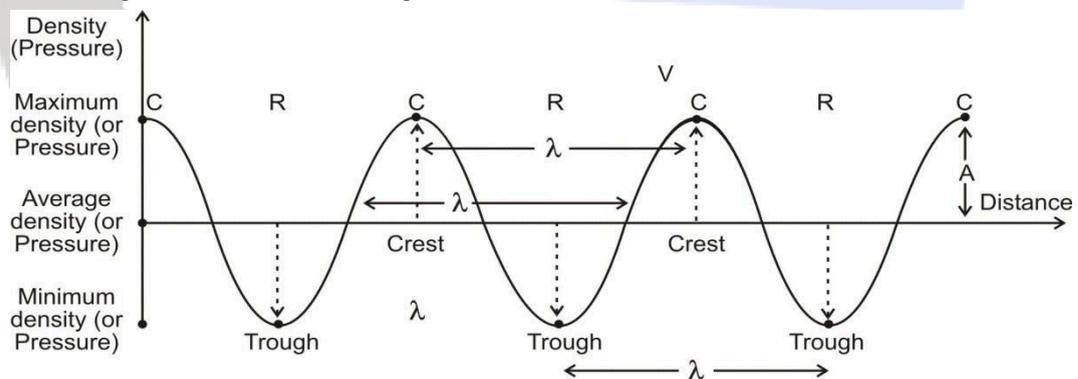
(b) **Rarefaction** : A portion of the medium where a temporary increase in volume and consequently a decrease in density takes place when a sound wave passes through the medium. It is called a rarefaction.

1.5.2 Graphical representation of sound wave

The graphical representation of sound wave is given below :

(a) **Crest** : The portion of the medium where the density (or pressure) has a value larger than its average value is called a crest.

(b) **Trough** : The portion of the medium where the density (or pressure) has a value smaller than the average value is called a trough.



The points of maximum density (or pressure) and minimum density (or pressure) are also called crests and troughs respectively.

(c) **Amplitude (A)** : The magnitude of the maximum disturbance in the medium on either side of the mean position is called the amplitude of the wave. It is usually represented by the letter A. In case of sound, the unit of A is the same as that of density or pressure.

(d) **Oscillation** : As is clear from the graph, the density (or pressure) of the medium oscillates between a maximum value and a minimum value. The change in density (or pressure) from maximum value to the minimum value and again to the maximum value is called an oscillation.

(e) **Frequency (ν)** : The frequency of a sound wave is defined as the number of complete oscillations in density (or pressure of the medium) per second. It is denoted by the symbol ν (Greek letter, nu).

Unit of frequency is **cycle per second (cps)** or s^{-1} or **hertz (Hz)** which is named after **Heinrich Hertz** (1857-1894).

Bigger units of frequency are kilohertz (kHz, 10^3 Hz) and megahertz (MHz, 10^6 Hz).

(f) Time Period (T) : The time taken for one complete oscillation in density (or pressure) of the medium is called the time period of the wave.

Time period of the wave is also defined as the time taken by its two consecutive compressions or rarefactions to cross a fixed point.

(g) Wavelength (λ) : The distance between two consecutive compressions or two consecutive rarefactions is called the wavelength of the wave. It is denoted by the symbol λ (Greek letter, lambda). Wavelength of a sound wave is also equal to the distance travelled by it in its periodic time (T). Unit of wavelength is **metre (m)**.

1.5.3 Relation between frequency and time period

If the frequency of the wave is ν , then from the definition of frequency, time taken for completing ν oscillations = 1 second

and time taken for completing 1 oscillation = $\frac{1}{\nu}$ second

But time taken for completing 1 oscillation is the period (T) of the wave

$$\therefore T = \frac{1}{\nu} \quad \text{or} \quad \nu = \frac{1}{T} \quad \text{or} \quad \nu T = 1 \quad \dots(1)$$

1.5.4 Relation between speed of sound, frequency and wavelength

Speed of sound is the distance travelled by the sound wave per unit time. It is denoted by v and is measured in metre/second (m/s).

From the definition of wavelength,

Distance travelled by sound wave in a periodic time (T) = wavelength (λ) of the sound wave.

$$\therefore \text{speed of sound, } v = \frac{\text{distance}(\lambda)}{\text{time taken (T)}}$$

$$\text{i.e., } v = \frac{\lambda}{T} = \left(\frac{1}{T}\right)\lambda$$

But $\frac{1}{T} = \nu$ where ν is the frequency of the sound wave.

$$\therefore v = \nu\lambda \quad \dots(1)$$

If two of the three quantities are known, the third quantity can be obtained from equation (1).

Thus, to describe a sound wave, we need to know :

- speed
- frequency (or wavelength) and
- amplitude

1.6 SPEED OF SOUND IN DIFFERENT MEDIA

When we strike an object with a hammer the sound of hammering is heard a short while after the actual impact. Similarly, the sound of cracker is heard only after it has exploded.

The flash of lightning is seen first and thunder is heard later on. These observations reveal that

- Sound travels with a finite speed.
- Sound travels with a speed which is much less than the speed of light.

Thus, speed of sound depends upon :

- The elasticity and density of the medium through which it propagates.
- Temperature of the medium.

So, we can conclude that :

Speed of sound in solids > Speed of sound in liquids > Speed of sound in gases.

The speed of sound increases with increase in temperature of the medium. In air, it increases roughly by 0.61 m/s with rise of 1°C in temperature. The speed of sound in air at 0°C is 331 m/s and at 22°C, it is 344 m/s.

1.6.1 Sonic boom or shock waves

Source that move faster than the speed of sound are said to have supersonic speeds. Bullets, jet aircrafts, etc, often travel at supersonic speeds. When a sound, producing source moves with a speed higher than that of sound the energy emitted is unable to move in front of the source and is concentrated on the sides. This concentration of energy as it travels outward is called **shock wave**. It is not necessary for an object to have a vibrating source of sound in order to create a shock wave. The only condition necessary is that the object moves with a speed greater than the speed of sound. Sonic boom is an example of a shock wave produced by a distant supersonic aircraft and is clearly heard by an observer at rest on the ground. The energy carried by a sonic boom lasts only for a fraction of a second and is sometimes sufficient to crack glass windows and shatter buildings.

1.7 CHARACTERISTICS OF SOUND

When a violin and a piano are played together in an orchestra, sounds produced by these instruments travel through the air (medium) and reach the ear at the same time which shows that sounds received by the ear are of different nature.

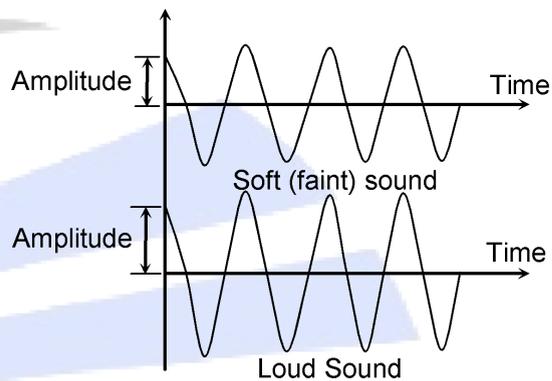
These sounds are distinguished by the following characteristics :

- Loudness or intensity
- Pitch or frequency
- Quality or timbre

1.7.1 Loudness

The sensation produced in the ear which enables us to distinguish between a loud and a faint sound is called loudness.

If a tuning fork is first struck softly and then hard, we hear a faint sound and a loud sound respectively. Since these sounds are produced by the same tuning fork, they have same frequency. But as shown in the figure the faint sound has a small amplitude whereas the loud sound has a large amplitude.



Thus, loudness of sound is :

- Directly proportional to as the square of the distance from the source of sound, i.e., closer the source to the listener, louder the sound.
- Directly proportional to the surface area of the vibrating body, i.e., larger the size of the vibrating body, louder the sound.
- Directly proportional to the density of the medium.

1.7.2 Intensity of sound

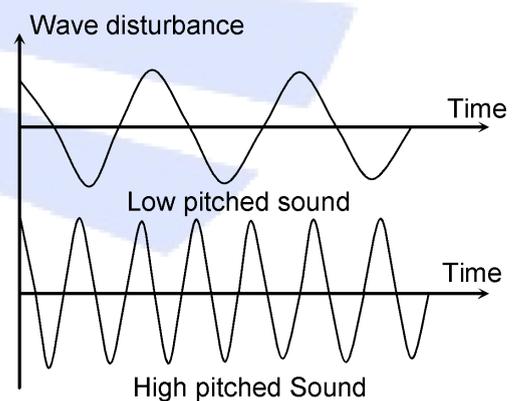
The intensity of sound at any point in space is defined as the amount of energy passing per unit area in a direction perpendicular to the area.

$$\frac{\text{energy}}{\text{area} \times \text{time}} = \frac{\text{Power}}{\text{area}}$$

Thus, intensity = $\frac{\text{Power}}{\text{area}}$

Unit of intensity = watt / metre² (W/m²)

Thus, intensity is a physical quantity that can be easily measured. Though loudness and intensity are closely related to each other, they are not one and the same thing different between loudness and intensity.



| S. No. | Loudness | Intensity |
|--------|---|---|
| 1. | It is not an entirely physical quantity. | It is a physical quantity which can be accurately measured. |
| 2. | It depends upon (i) sensitivity of the ear and (ii) intensity of sound. | It does depend upon the sensitivity of the ear. |
| 3. | It has a subjective existence. | It has an objective existence. |

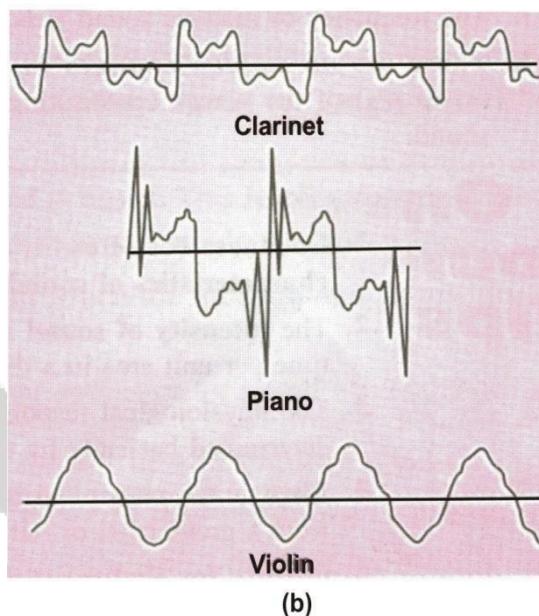
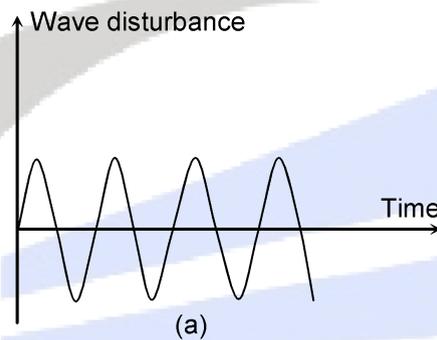
1.7.3 Pitch or frequency

Pitch is that property of sound which help in differentiating between a shrill sound and a grave (flat or dull) sound.

High pitched sounds are called **treble** and low pitched sounds are called **bass**. Pitch is directly proportional to the frequency. The voice of a lady is shriller than that of a man because the frequency of a women's ordinary voice is around 280 Hz and that of man is around 140 Hz.

1.7.4 Quality or timbre

The property of a sound which distinguishes it from another of the same pitch and loudness is called quality or timbre.



The figure (a) shows wave-form of the sound emitted by a tuning fork consisting of a single frequency. A sound of single frequency is called a **tone**.

The figure (b) represents the wave form of the sounds produced by a clarinet, a piano and a violin. These wave-forms are due to mixture of several frequencies. A sound produced due to a mixture of several frequencies is called a **note**.

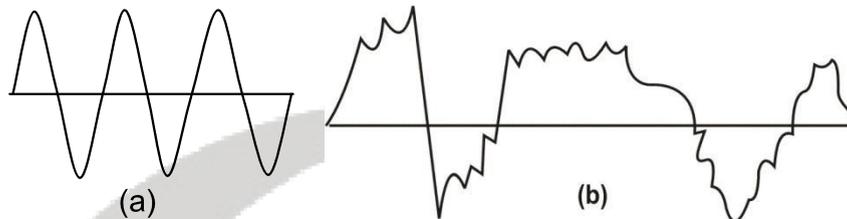
1.7.5 Music and noise

All sounds are categorized into :

(a) **Musical sound or music** : These sounds have a pleasant effect on the listener. Sounds produced by a tuning fork, musical instruments, singing of sounds, etc are few examples of

musical sound. A musical sound consists of a series of sound impulses following each other at regular intervals of time without sudden changes in amplitude (i.e., loudness). Such sounds are usually of high frequency.

- (b) **Noise** : These sounds has a pleasant (disagreeable or boring) effect on the listener. Rustling of leaves, murmuring of students, etc are some examples of noise. A noise consists of a series of sound impulses following each other at regular intervals of time and there are sudden changes in amplitude (i.e. loudness). Such sounds are of low frequency.



Both musical sound and noise are based on psychological response of the ear and brain to various types of sound. There is no clear line of demarcation between them on the basis of sensation these produce on the ear of the listener.

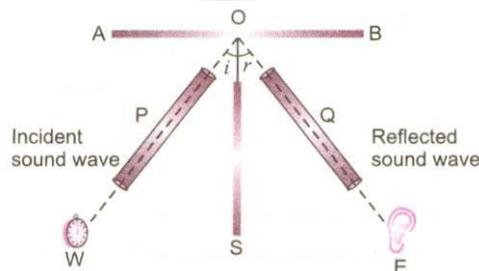
Differences between musical sound and noise

| S. No. | Musical Sound | Noise |
|--------|---|--|
| 1. | It has a pleasant effect on the ear. | It has an unpleasant effect on the ear. |
| 2. | It consists of a series of sound impulses which follow one another regularly. | The sound impulses do not follow one another regularly. |
| 3. | The frequency of musical sound is high. | The frequency of a noise is low. |
| 4. | There are no sudden changes in amplitude (loudness) of the waves constituting of a musical sound. | There are usually sudden changes in amplitude (loudness) of the waves forming a noise. |

2. REFLECTION OF SOUND

Sound waves, like light waves also get reflected when they fall on the surface of an obstacle. But unlike light wave, they do not necessarily require a polished surface for reflection. The following experiment establishes that reflection of sound follows the same laws as those for reflection of light.

- (i) Place a large plane board, **AB** of a metal or wood in the vertical position as shown in the figure.
- (ii) Take two hollow metallic tubes **P** and **Q** of same size and place them in the plane of the paper and in positions inclined to the board.



- (iii) A cardboard screen **S** is placed between the two tubes so that the sound produced by the watch does not reach the ear directly.

- (iv) Hold a small watch **W** at the free end of the tube **P** and try to hear the ticking sounds of the watch by positioning the ear at **E**.
- (v) The position where the ticking sound of the clock is the loudest the tubes **P** and **Q** are found to be inclined to **S** at the same angle.
- (vi) If the tube **Q** is lifted slightly vertically upwards, no sound is heard.

From the above experiment we obtain the following two laws for the reflection of sound waves. These laws are :

First law : The angle of reflection (r) is always equal to the angle of incidence (i)

i.e., $\angle r = \angle i$ or $i = r$

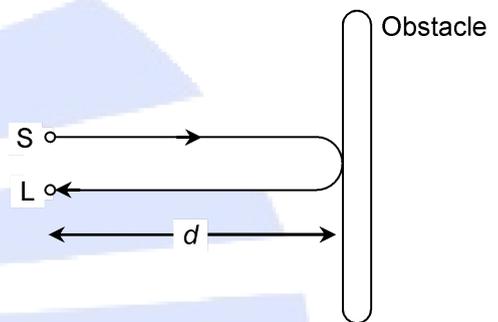
Second law : The incident wave, the reflected wave and the normal (at the point of incidence, all lie in the same plane.

2.1 ECHO

An echo is defined as the phenomenon of repetition of sound of a source by reflection from an obstacle.

It is a very common experience that when we utter a few words in a high domed hall the words are repeatedly heard on account of reflection from the original sound, the obstacle must be situated at a suitable distance.

The sensation of sound lasts in our brain for $(1/10)$ of a second. This property is called persistence of hearing.



2.1.1 Multiple echoes

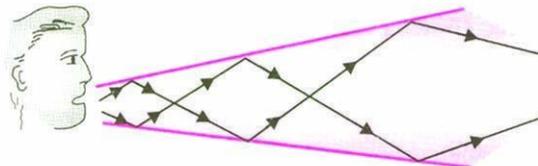
When sound is repeatedly reflected from a number of obstacles at suitable distance, many echoes are heard one after the other. This constitutes multiple echoes.

Examples :

- Multiple echoes are heard when some sound is produced between two distant buildings or cliffs.
- The rolling sound of thunder is on account of multiple echoes due to successive reflections from a number of reflecting surfaces such as mountains, clouds, land, rocks and various layers of air of different densities.

(a) **Uses of multiple reflection of sound** : The phenomenon of multiple reflection of sound is put to many uses as described below :

- (i) **Megaphone** : To confine the sound waves so that they travel in a particular direction, a megaphone is used. Sound waves which are now confined in a particular region by their multiple reflections from the walls of the tube travel larger distance than without the help of the tube. Horns, musical instruments like trumpets etc, are based on the principle.



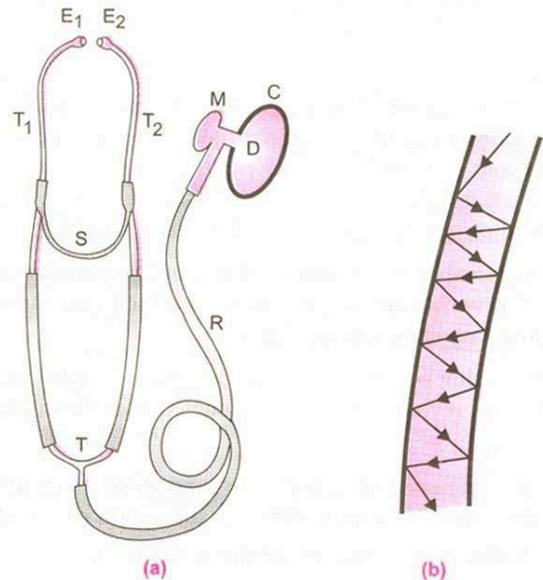
- (ii) **Ear trumpet** : It is a sort of machine used by persons who are hard of hearing. The sound energy received by the wide end of the trumpet is concentrated into a much smaller area at the narrow end by multiple reflections. This makes the otherwise inaudible sound audible to the user.

(iii) **Hearing aid** : An ear trumpet is a mechanical device helpful only to a person with mild hearing loss. It is an electronic device which is battery operated and is used by people with severe hearing loss. A hearing aid is fitted with a microphone which converts sound waves into electrical signals. An electronic amplifier amplifies these signals which are then fed to a speaker in the hearing aid. The speaker converts the amplified electrical signals into sound which is sent to the ear for clear hearing.

(iv) **Stethoscope** : It is a medical instrument used frequently by doctors for making a rough diagnosis of the diseases existing inside the body at places which are either inaccessible or accessible only through major operations.

Construction : As shown in figure (a), a stethoscope consists of :

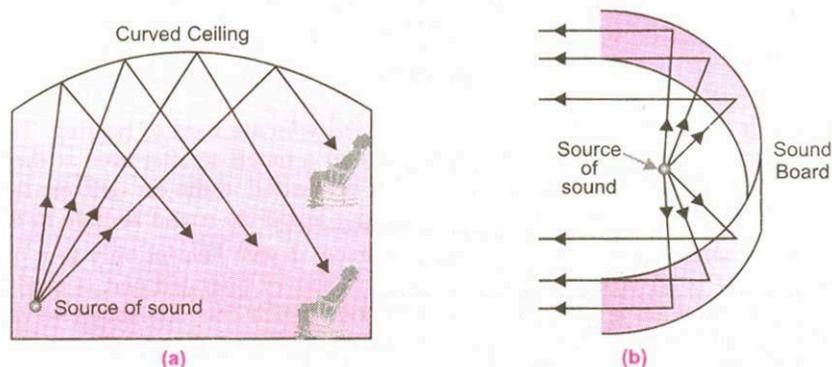
- A metallic disc C having a very sensitive diaphragm D encased in it.
- A cone M over the metallic disc is connected to a rubber tubing R .
- A three way metal tube T connects R to the earphones E_1 and E_2 through metal tube T_1 and T_2 .
- A spring S helps in adjusting the distance between the earphones E_1 and E_2 .



Working : The metal case C containing the diaphragm is gently pressed against the part of the body to be examined. The vibrations of this part are communicated to the diaphragm D which starts vibrating. As shown in figure, these vibrations suffer multiple reflections in the tubes R , T , T_1 and T_2 and ultimately reach the earphones. The original sound produced by the part of the human body is exactly reproduced in the earphones and a preliminary diagnosis of the ailment is made.

(v) **Concerts halls, Cinema halls and conference halls**

- The ceilings of these halls are curved. This enables the sound to reach all corners of the hall after reflection from the ceiling as shown in figure.



- A sound board, which is a curved (parabolic or concave) sound reflecting surface is placed behind the stage, the source of sound is located at the focus of this reflecting surface.

2.2 REVERBERATION

When a sharp sound is made in a hall, the listener cannot hear it as such. It is found to get prolonged. The intensity of sound first reaches a maximum and then falls till it becomes inaudible. It is interesting to note that a sound wave suffers 300 reflections in a room of ordinary size before becoming inaudible.

Thus, **the phenomenon of persistence or prolongation of audible sound after the source has stopped emitting sound is called reverberation. The time for which reverberation persists until it becomes inaudible is called reverberation time.**

2.2.1 How is reverberation reduced?

Since reverberation is due to repeated reflections of sound waves from the ceiling, floor, walls etc. of a hall or an auditorium, we can reduce it by increasing the absorption of sound energy. To achieve this :

- (i) The walls are covered with some sound absorbing material like felt, fiberboard, glass wool etc. or by heavy curtains with folds.
- (ii) The floor is carpeted.
- (iii) The furniture is upholstered.
- (iv) False ceiling of a suitable sound absorbing material is used.

3. RANGE OF FREQUENCIES

There are three categories of longitudinal mechanical waves which cover different ranges of frequencies.

Sound waves or audible waves : These waves have frequencies which lie between 20 Hz to 20 kHz. This range of frequencies is called the audio-frequency (a.f. range) to which human ear is sensitive. These waves are generated in a variety of ways such as musical instruments, human vocal cords, insects and loudspeakers.

Infrasonic waves or infrasound : Those longitudinal waves whose frequencies are below 20 Hz are called infrasonic. Earthquake waves are an example. During earthquakes, low frequency infrasound of frequency as low as 5 Hz whereas whales and elephants also produce sound in the infrasound range. In some instances, however, infrasound has proved dangerous. It is found that at very low frequencies of 5 Hz to 10 Hz, certain organs of the body tend to resonate, leading to vibration-induced illness. This resonating of one organ leads to rubbing against another, thereby producing noticeable ill effects.

Ultrasonic waves or ultrasound : Those longitudinal waves whose frequencies lie above 20 kHz are called ultrasonic waves, ultrasonics or ultrasounds. Though human ear cannot detect these waves, certain creatures such as mosquito, fish, dog and bat show response to these frequencies.

3.1 APPLICATIONS OF ULTRASOUND

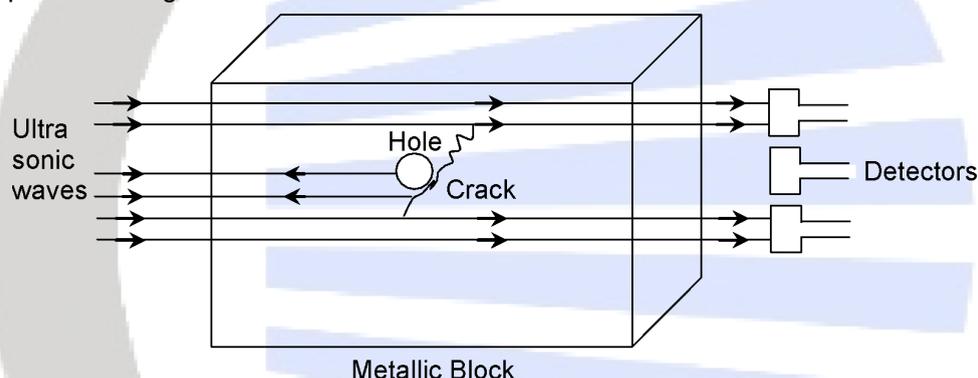
In contrary to audible sounds (which have lower frequencies), ultrasound can be obtained in the form of a narrow beam which can travel along well-defined paths even in the presence of obstacles. Such well-defined narrow beams of ultrasonic waves find application in many fields.

- Industry
- Medical science
- Communication (SONAR)

3.1.1 Industrial uses of ultrasound

The various uses of ultrasound in industries are as follows :

- Cleaning instruments and electronic components** : The cleaning is done by the method called **cavitation** or **coldboiling**. An instrument that needs cleaning but whose parts cannot be reached directly is placed in a liquid. The ultrasonic waves passing through the liquid produce tiny bubbles where the rarefaction of the ultrasonic wave reaches. When the compression of the wave reaches these bubbles, the bubbles are compressed until they implode (explode inward). This leads to the creation of several small localized shockwaves. These shock waves blast away any dirt or contamination from the unreachable portions, Usually, frequencies in the range of 20 kHz to 30 kHz are used for this purpose.
- Plastic welding** : Application of small pressures and ultrasonic vibration to two similar surfaces produce sufficient thermal energy to bond the surface together.
- Detecting flaws and cracks in metal blocks** : To construct big structures like buildings, bridges, machines and scientific equipment, a large number of metallic blocks are assembled together. Cracks and holes within the blocks, which are invisible from outside, reduce the strength of a structure. To detect these flaws (cracks and holes) in a block, ultrasonic waves are passed through it.



3.1.2 Medical uses of ultrasound

- Echocardiography** : It is used to study the heart-valve action. An image of the heart is obtained by getting ultrasonic waves reflected from various parts of the heart.
- Ultrasonography** : It involves sending ultrasonic waves to various organs (like brain, liver, kidneys) in the body and looking at the reflected or transmitted waves. Using ultrasonography, stones in gall-bladder and kidneys or tumors in different organs can be detected. Ultrasonography is also used in prenatal examinations.
- Therapeutic uses** : Ultrasound is used for treatment of neuralgic and rheumatic pains.

3.1.3 Sonar

It is an acronym which means **SO**und **N**avigation **A**nd **R**anging.

A sonar is a device which measures the distance, direction and speed of objects lying under water using ultrasonic waves.

A sonar, which is installed in a ship or a boat, consists of (i) a transmitter and (ii) a detector. The ultrasonic waves produced by the transmitter travel through water. After getting reflected by the object on the seabed, these waves are picked up by the detector. The detector converts the reflected ultrasonic waves into electrical signals which are properly recorded.

Let t = time interval between the transmission and reception of the reflected ultrasound waves,

v = speed of sound through sea water,

d = distance of the object that reflected the ultrasound.

Clearly, total distance travelled by the ultrasound = $2d$

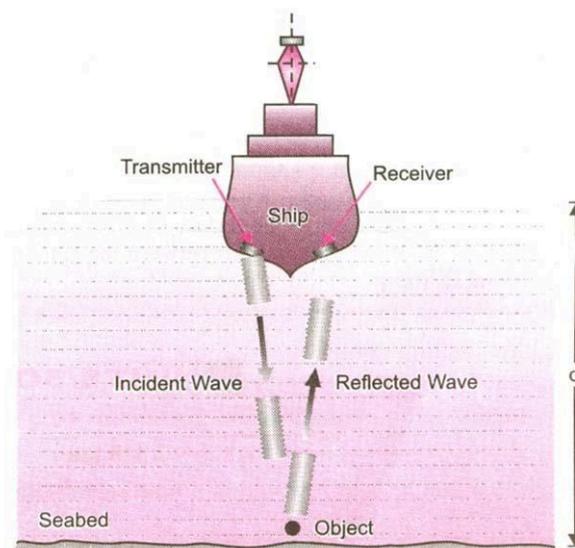
As distance = speed \times time

$$2d = vt$$

or
$$d = \frac{vt}{2}$$

The above method of finding the distance of an object is called **echo-ranging** as it is based on echo principle. The sonar technique is used to :

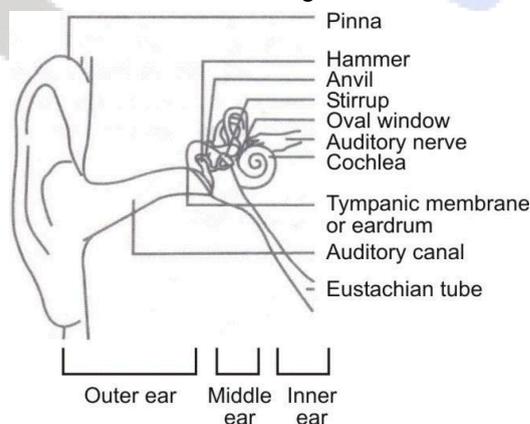
- (i) determine depth of the sea, called **echo depth ranging**.
- (ii) locate underwater hills, valleys, icebergs, submarines and sunken ships.
- (iii) to locate the position of other ships or submarines.
- (iv) Ship to ship communication.



The advantage of using ultra sonic waves is that these waves cannot be heard without the aid of special instruments.

4. STRUCTURE OF HUMAN EAR

We hear with an extremely sensitive device called the ear. It allows us to convert pressure vibrations in air with frequencies 20 Hz to 20 kHz into electric signals that travel to the brain via auditory nerve.



Auditory parts of human ear

The outer ear is called Pinna. It 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 eardrum or tympanic membrane. When compression of the medium produced due to vibration of the object reaches the eardrums, the pressure on the outside of the membrane increases and forces the eardrum inward. Similarly the eardrum moves outward when a rarefaction reaches. In this way, the eardrum vibrates. The variations are amplified several times by these bones (the hammer, anvil and stirrup) in the middle ear which acts as levers. The middle ear transmits the amplified pressure vibrations 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.

