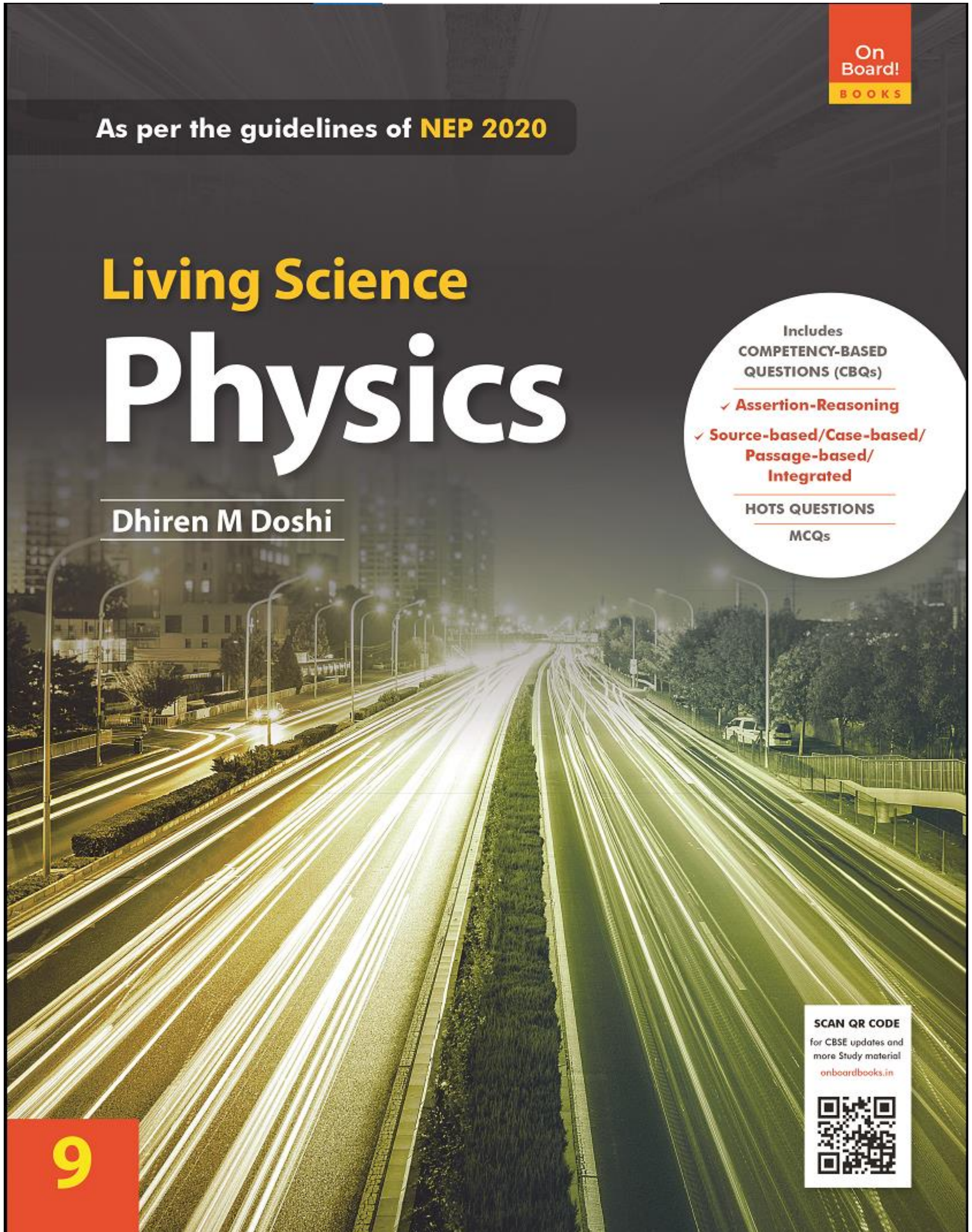

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Dhiren M Doshi

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CBSE
Living Science
Physics

Class 9

Chapter- 6 Sound

LEARNING OBJECTIVES

Production of Sound

❖Sound needs a medium to travel

Propagation of Sound

❖ Characteristics of wave motion

❖Classification of wave motion

Longitudinal Waves

❖Graphical representation of longitudinal waves

Transverse Waves

❖Graphical representation of transverse waves

Description of a Wave

❖Relation between time period and frequency

Characteristics of sound

Speed of Sound

Reflection of Sound

Echo and Reverberations

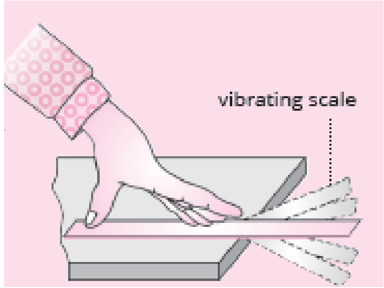
What is Sound?

Sound is a form of energy just like heat and light. It produces a sensation of hearing in our ears.

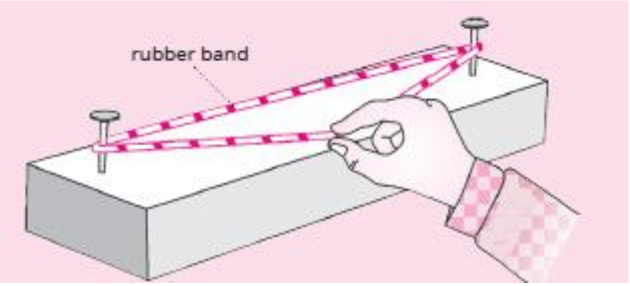
Production of Sound

Sound is produced when a body vibrates, i.e. sound is produced by vibrating bodies.

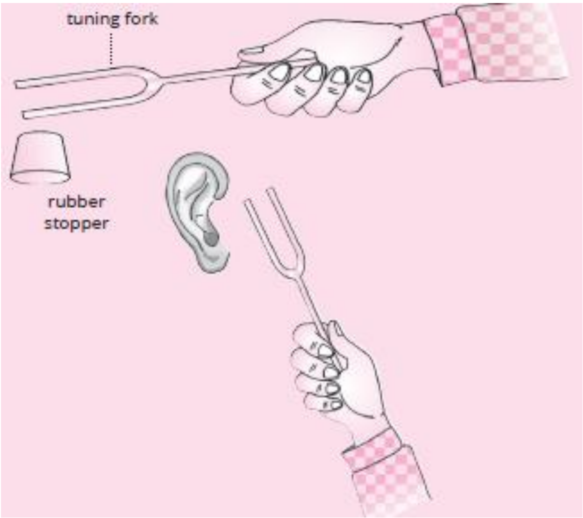
A vibrating body produces sound



A vibrating scale produces sound

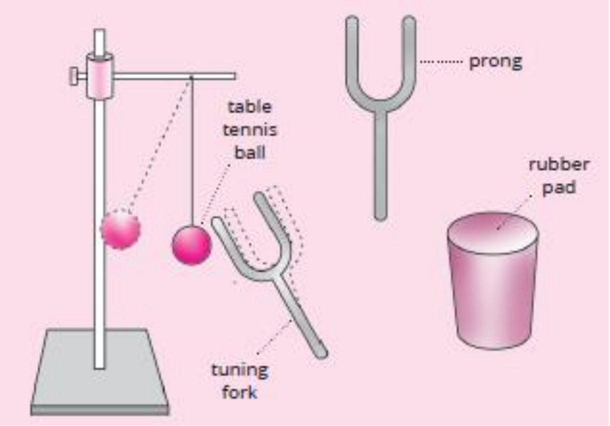


Stretched rubber band produces sound



Vibrating tuning fork produces sound

Vibrating tuning fork produces waves

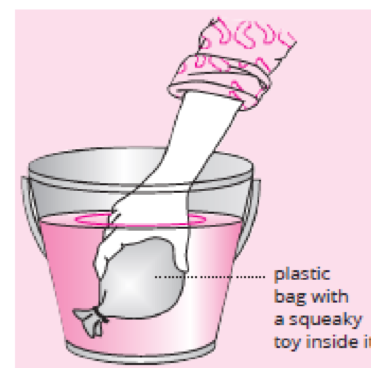


Tuning fork produces sound

Sound Needs a Medium to Travel

The substance or matter through which sound is transmitted is called a medium. The medium can be a solid substance, liquid or a gas. When a school bell rings, the solid bell vibrates and produces sound. The sound travels through air and finally reaches our ears. So, sound moves through a medium from the point of generation to the listener.

Sound can travel through solids and **s**ound travels through a solid medium better than through a gaseous medium.

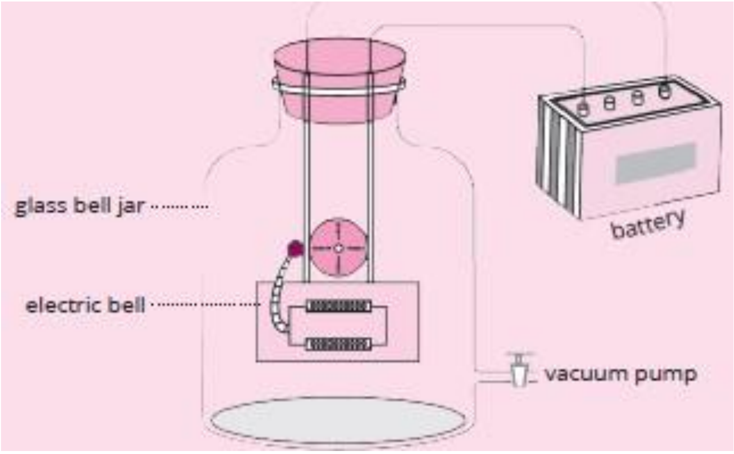


Sound can travel through liquids and sound can travel through a solid medium better than through a liquid medium.

Sound waves are called **mechanical waves** because they need a material medium (like solid, liquid or gas) for their propagation.

Sound Requires a Medium for Propagation

When the air is removed from the jar with the help of a vacuum Pump, the loudness of the sound slowly decreases until the sound becomes too faint. Finally, sound of the bell is not heard. When air is allowed to enter the jar gradually, the sound of the bell inside the jar slowly increases.



It shows that sound cannot propagate in the absence of a material medium.
So for the propagation of sound the following are necessary:

1. A vibrating source for the production of the sound.
2. A material medium for the sound to travel through.
3. The medium must be continuous and elastic.
4. A receiver to receive the sound.

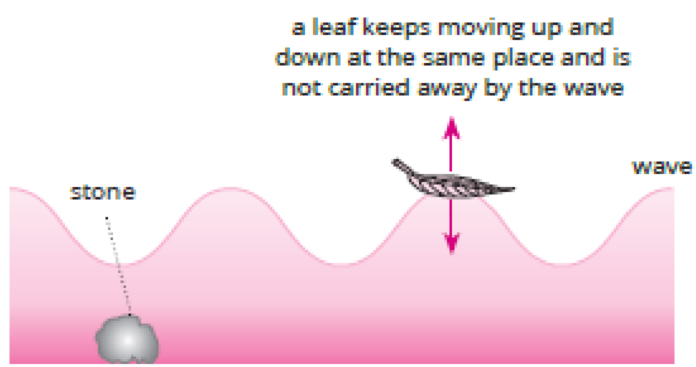
Note: Refer to Table 6.2 for Differences between sound waves and light waves

So, sound waves are called **mechanical waves** because they need a material medium (like solid, liquid or gas) for their propagation. There are waves (light waves or radio waves) which do not need any material medium for their propagation. They are called **electromagnetic waves**. They can travel even in vacuum.

Propagation of Sound

- Sound wave is the disturbance created by the source of sound in the medium that travels through the medium and not the particles of the medium.
- The material in which the wave motion is produced is called a medium.
- A wave is a disturbance that moves through a medium when the particles of the medium set neighbouring particles into motion.
- Wave motion is a vibratory disturbance produced in one part of the medium that travels to another part involving the transfer of energy but not the transfer of any matter with it.
- Sound is also an example of wave motion. The sound energy of our speech reaches the listener's ear through the vibratory motion of the air particles (wave motion).

a. Ripples produced in the water when a stone is dropped into a



b. Wave motion does not carry matter (material) away from or towards the source of disturbance

Characteristics of wave motion

a. Wave motion is a **periodic disturbance** travelling through a medium which is produced by a vibrating body.

b. Wave motion travels at a **constant speed** in all directions in a medium and **transfers energy** in the medium.

The speed of a wave depends upon the nature of the medium through which it travels and not on the nature or the motion of the source.

c. In wave motion, the **particles** of the medium **do not move** from one place to another. They only vibrate about their fixed positions passing on energy they possess from particle to particle.

d. During wave motion, the medium does not move as a whole. Only the **disturbance travels** through the medium.

e. Wave motion is possible only in that medium which possesses the properties of elasticity and inertia.

Classification of Wave Motion

Waves are classified into two groups on the basis of requirement of medium for the propagation of waves:

1. Mechanical waves (or elastic waves)

2. Electromagnetic waves

On the basis of the relative directions of the propagation of the wave with respect to direction of the periodic changes in the medium, the waves are classified into the following two groups:

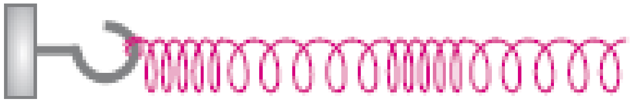
1. Longitudinal waves
2. Transverse waves

Longitudinal Waves

A wave in which the particles of the medium oscillate (vibrate) to and fro (back and forth) in the same direction in which the wave is moving is called a longitudinal wave.

Formation of longitudinal waves in a slinky

A long flexible spring is called a slinky. In the spring, at some places, the turns (or loops) are closer than that in the normal position.These regions are called **compressions**.



Longitudinal waves in a slinky showing compressions and rarefactions

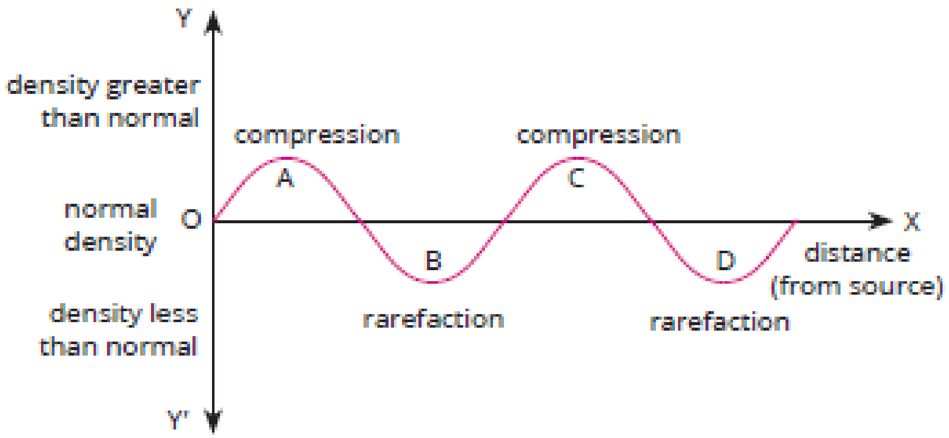
So, a **compression** is that part of a longitudinal wave in which the particles of the medium are closer to one another than they normally are and there is a momentary decrease in the volume of the medium.

In the same spring, at some places, the turns are farther apart than that in the normal position . These regions are called **rarefactions**.

A **rarefaction** is that part of a longitudinal wave in which the particles of the medium are farther apart than that in the normal position and there is a momentary increase in the volume of the medium.

Graphical Representation of Longitudinal Waves

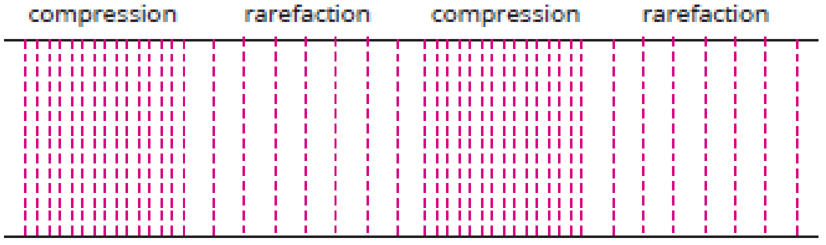
In a compression of a longitudinal wave, the density of the particles is high. In a rarefaction, the density of the particles is less than that in the normal.



Note: **Refer to** Table 6.3. for the differences between compression and rarefaction

Sound Wave is a Longitudinal Wave

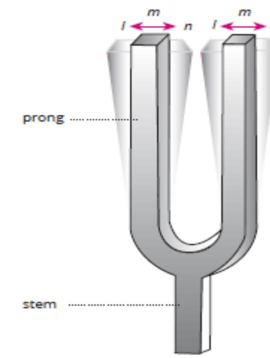
When a sound wave passes through air, the particles of air vibrate back and forth parallel to the direction of propagation of the sound wave. **It forms compressions and rarefactions.** So, sound waves in air are longitudinal waves.



Sound waves producing compressions and rarefactions

Vibration of a Tuning Fork

The vibrating prong of a tuning fork produces a source of alternating compression and rarefaction in air that travel forward with the speed of the wave.



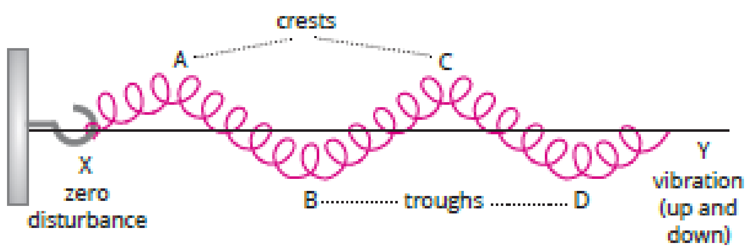
A vibrating tuning fork

Transverse Waves

A wave in which the particles of the medium oscillate (vibrate) up and down, i.e. perpendicular to the direction in which the wave is moving is called a transverse wave.

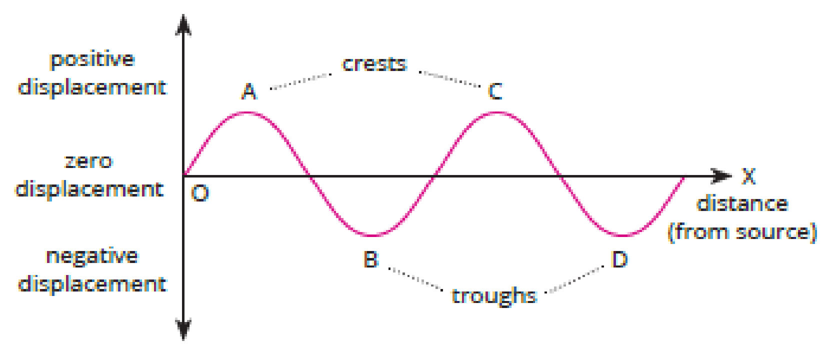
Formation of transverse waves in a slinky

The portion of slinky that moves up forms an 'elevation' called **crest** and that moves down forms 'depression' which is called **trough**.



Graphical Representation of Transverse Waves

When a transverse wave passes through a medium, then some particles of the medium are displaced above the line of zero disturbance whereas others are displaced below the line of zero disturbance.



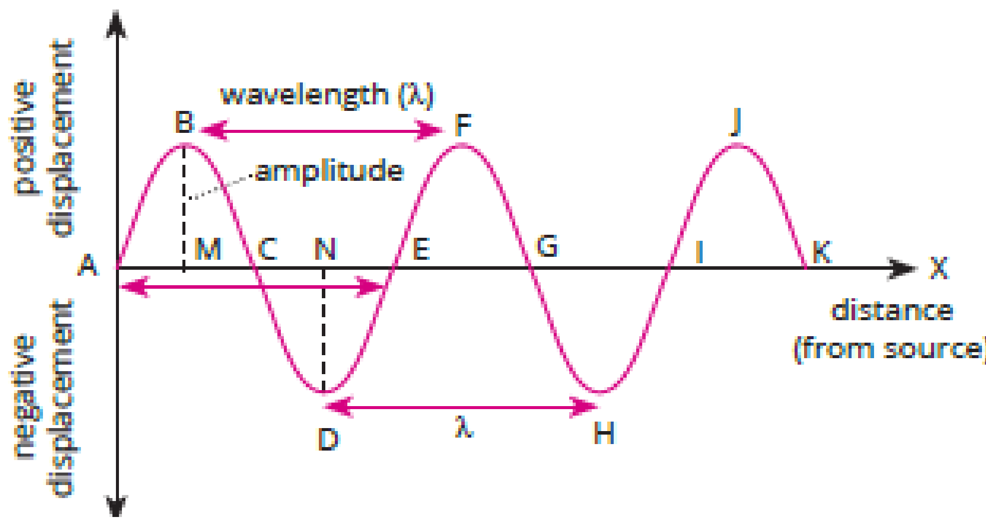
Description of a Wave

Quantities which describe the characteristics of a wave

1. Phase: The points on a wave which are in the same state of vibration are said to be in the same phase.

2. Wavelength: The wavelength of a wave is the length of one wave. The wavelength of a periodic wave is defined as the distance travelled by the wave during the time in which any particle of the medium completes one vibration about its mean position.

In transverse wave motion, the distance between two consecutive crests or between two consecutive troughs is called the wavelength. In longitudinal wave motion, the distance between two consecutive rarefactions or between two consecutive compressions is called the wavelength. Wavelength is denoted by λ (lambda). The SI unit of wavelength is metre (m).



Displacement-distance graph to describe the characteristics of a wave

3. Amplitude: The maximum displacement of the particles of a medium from their mean positions during the propagation of a wave is called the amplitude of the wave. The amplitude of a wave is denoted by *A*. The SI

unit of amplitude is metre (m).

4. Time period: The time required to produce one complete wave (or wave cycle) is called the time period of the wave. In other words, the time taken to complete one vibration is called time period. The time period of a wave is denoted by the letter *T*. The SI unit of time period is second (s).

5. Frequency: The rate at which waves are produced by a source is expressed by its frequency. **The frequency of a wave is defined as the number of waves produced per second.** Frequency is denoted by the letter *n*, *f* or the Greek letter ν called **nu**. The SI unit of frequency is hertz (Hz). The SI unit of frequency is hertz (Hz).

Relation between time period (*T*) and frequency (ν)

We know that the time required to produce one complete wave is equal to the time period (*T*) of the wave. So, if time period is measured in seconds, then

Number of waves produced in *T* s = 1

Number of waves produced in 1 s = 1/*T*
But the number of waves produced in one second
is equal to the frequency (v) of the wave. Therefore, v = 1/*T* Hz
Frequency = 1 / Time period (in seconds) Hz

6. Wave Velocity: The distance travelled by a wave in one second is called the velocity of the wave. The wave velocity is denoted by *v*. **The SI unit of wave velocity is metre per second (m/s or m s^{-1}).** The velocity of a wave depends upon the nature of the medium through which it travels.
Wave velocity = Distance travelled by a wave / Time taken

Relation between wave velocity (V) frequency (v) and wavelength (λ)
Wave velocity (V) = Distance travelled by a wave / Time taken

$$V = \lambda / T$$

or $$V = (1/T) \times \lambda$$

∴ $$V = v \times \lambda$$ [Since v = 1/*T*]

or Wave velocity = Frequency x Wavelength

Characteristics of Sound

There are three fundamental characteristics of a sound.

1. Pitch **2.** Loudness **3.** Quality

Pitch

It is the characteristic of a musical sound by which we can distinguish a shrill sound from a grave (hoarse) sound even though the two sounds have the same loudness. The pitch of a sound depends upon the frequency of vibration.

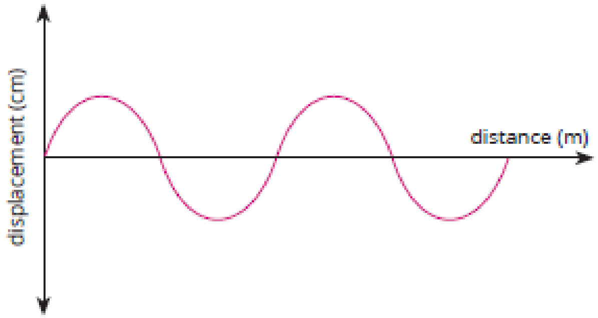
The voice of children and women is shrill as compared to the voice of men. This is because children and women have short vocal cords which, therefore, vibrate with a high frequency to produce a high-pitched voice. On the other hand, men have long vocal cords which vibrate with a low frequency to produce a low-pitched voice.

Loudness

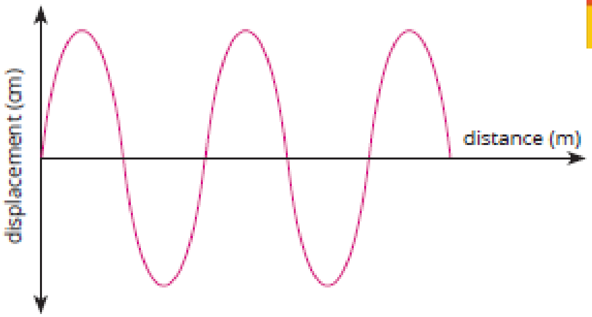
Loudness is the characteristic of a sound by which a loud sound can be distinguished from a faint sound even though both have the same pitch. Loudness is a sensation as perceived by the listener. It is a measure of the response of the ear to the wind. Loudness depends upon the intensity of sound near the ear.

Factors affecting the loudness of sound

1. **Amplitude of vibration of the source:** Greater the amplitude of vibration of the source, the greater is the intensity (and hence, loudness) of sound and vice versa.



Smaller amplitude produces a soft sound.



Larger amplitude produces a loud sound.

2. Surface area of the vibrating body: The greater the surface area of the vibrating body, the greater is the loudness of sound. A large drum will produce a louder sound than a small drum.

Loudness increases with an increase in the area of vibrating body

3. **Distance from the vibrating body:** The less the distance between the listener and the source, the louder is the sound heard by the listener and vice versa.

4. Density of the medium : The loudness of sound is directly proportional to the density of the medium through which it propagates, i.e. the greater the density of the medium, the louder is the sound.

5. Presence of resonant bodies: The loudness of sound is increased due to the presence of other resonant bodies near the source of sound.

6. Motion of the medium: If wind is blowing in the direction of propagation of sound, loudness is increased.

Measurement of loudness of sound

The loudness of sound is measured in decibels (dB). Every time another 10 dB is added to the sound level, the loudness is multiplied by 10.

Quality or timbre

Timbre is the characteristic of a sound that enables us to distinguish between two sounds of the same pitch and loudness produced by two different sources. It depends upon the waveform of the sound.

The quality of a musical note depends on the waveform. We can easily distinguish between the sounds of a sitar and a piano by their different waveforms, though they may have the same loudness and the same pitch.

Tone and Note

A sound of single frequency is called a **tone.** A tuning fork produces a sound of single frequency. A sound which is produced due to a mixture of several frequencies is called a **note**.

Speed of Sound

The speed of sound is defined as the distance which a point on a wave, such as a compression or a rarefaction, travels per unit time.

Factors affecting the speed of sound

1.Nature of medium: The speed of sound in different media is different. This is because the molecules are packed closer in solids and liquids than in air (or gas). Since molecules undergo vibrations, they do so more efficiently when they are closer.

2. Effect of density: The speed of sound depends on the density of the medium. It has an inverse relationship, i.e. if the density of the medium is more, the speed of sound in that medium will be less.

3. Effect of temperature: The speed of sound depends on the temperature of the medium. With an increase in temperature, the speed of sound increases.

4. Effect of wind: The velocity of sound in air is affected by the velocity of wind because wind drifts the medium (air) along its direction of motion.

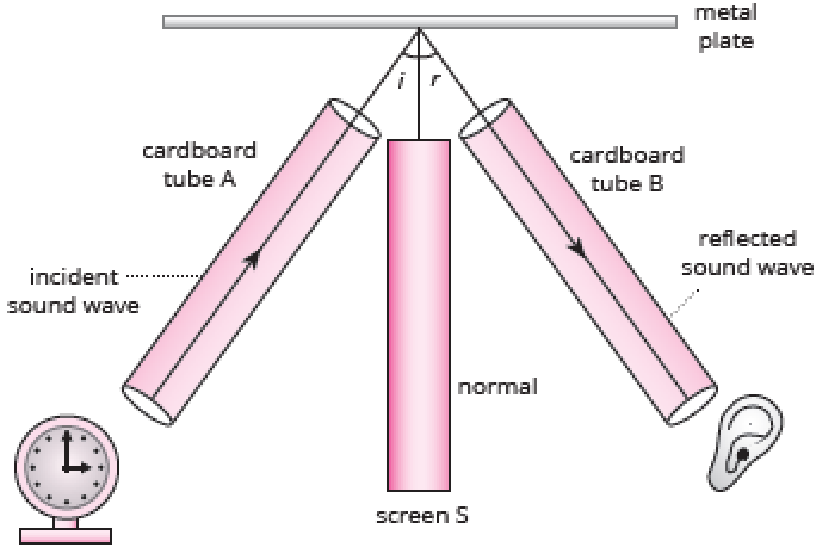
5. Effect of humidity: The presence of water vapour in air reduces the density of air, i.e. Density of moist air < Density of dry air
Therefore, Velocity of sound in moist air > Velocity of sound in dry air
Hence, the velocity of sound in moist air is greater than the velocity of sound in dry air. That is why sound travels faster on a rainy day than on a dry day.

Sonic Boom

When a body is travelling at a speed greater than the speed of sound (346 m/s), we say that the body is travelling at supersonic speed. So, a body is said to travel at supersonic speed if its speed is more than the speed of sound (346 m/s). Bullets, jet aircraft, rockets, etc. move with supersonic speed.

Reflection of Sound

The bouncing back of sound waves when it strikes a hard surface (like walls, metal sheets and plywood) is called the reflection of sound.
Sound can be reflected from any hard surface, whether smooth or rough, shining or dull. Just like the laws of reflection of light, there are laws of reflection of sound that must be obeyed



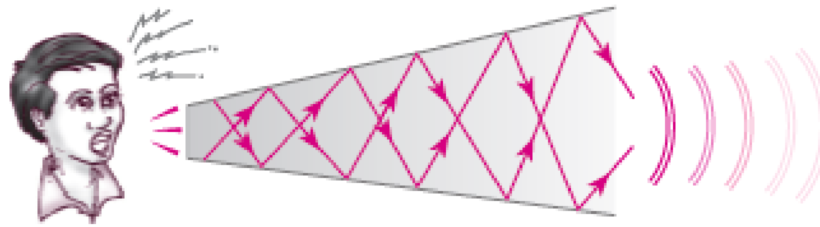
According to the laws of reflection of sound:

1. The angle of incidence is equal to the angle of reflection of sound, i.e. $\angle i = \angle r$.
2. The incident sound, the normal and the reflected sound, all lie in the same plane.

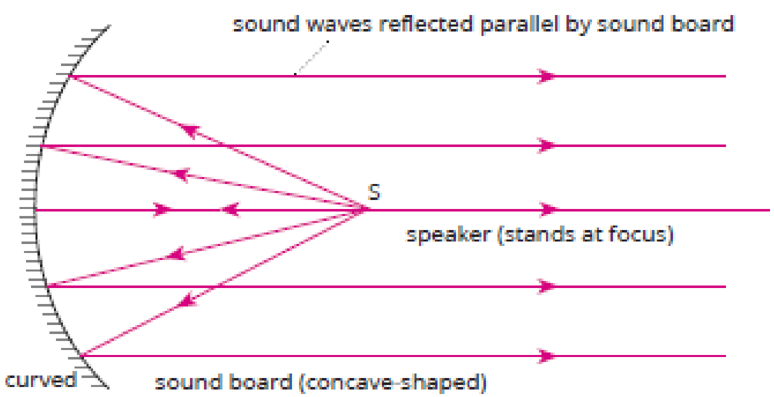
Practical applications of of reflection of sound

The reflection of sound is utilised in the working of simple devices like megaphones, sound boards, stethoscope and ear trumpets.

1. Megaphone (or speaking-tube): A megaphone is a horn-shaped tube that is used to address a small gathering of people at places like tourist spots, fairs, market places and during demonstrations.



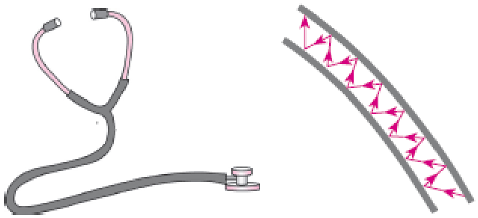
One end of the megaphone tube is narrow and the other end is quite wide. When a person speaks into the narrow end of the megaphone tube, the sound waves produced by his voice are prevented from spreading out by successive reflections from the wider end of the megaphone tube. Due to this, the sound of the voice of the person can be heard over a longer distance.



2. Sound boards: The ceiling and walls of large halls or auditoriums often reflect the sound waves. These reflected sound waves interfere with the words of the speaker. This problem is solved by using sound boards. A sound board is a concave board (curved board) that is placed behind the speaker.

The speaker is made to stand at the focus of the concave sound board. The concave surface of the sound board reflects the sound waves of the speaker parallel towards the audience and hence prevents the spreading of sound in various directions. Due to this, the sound reaches large distances and even the people sitting at the back of the hall can hear the speaker's speech clearly.

3. Stethoscope: It is a medical instrument used to detect and study sounds produced within organs such as the heart and lungs prior to treatment. The stethoscope consists of a bell and diaphragm (receiving head), connected by a Y-joint and rubber tubing to the ear pieces



Echo

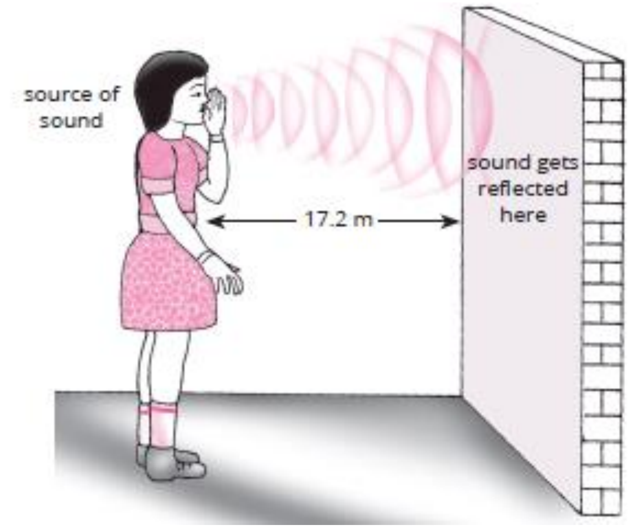
An echo is a repetition of the original sound heard after the sound is reflected from a distant, dense and rigid object (such as a high building, cliff, etc.).
It has been found that the sensation of sound persists in our ears for 0.1 second or one-tenth of a second, after the original sound dies off. This time is called **persistence of hearing**.

Calculation of minimum distance to hear an echo

Speed of sound = 344 m/s (at 22 $^{\circ}$ C in air)
Time taken = 1 /10 (persistence of hearing)
Distance travelled = ?

Now, putting these values in the above formula, we get
Distance travelled = 344 $\times$ 1/ 10 = 34.4 metres

Thus, the distance travelled by sound in going from us (the source of sound) to the sound reflecting surface (wall), and then coming back to us should be 34.4 metres. So, our distance from the sound-reflecting surface (like a wall, etc.) to hear an echo should be half of 34.4 metres which is 34.4/2 = 17.2 metres. From this, we conclude that the minimum distance from a sound-reflecting surface to hear an echo is 17.2 metres



Conditions for the formation of echoes

1. The minimum distance between the source of sound and the reflector should be 17.2 metres

2. The size of the reflector must be large

3. The intensity or loudness of the sound should be sufficient for the reflected sound reaching the ear to be audible.

Whispering Gallery

We can experience extraordinary sound effects in the form of echoes at **Gol Gumbaz, Bijapur (Karnataka)**. Even a whisper at the end is amplified and heard very clearly at different ends. A similar gallery is there at **St. Paul's Cathedral in London (UK)**.

Reverberations: When a number of echoes of the original sound are heard, each echo being fainter than the preceding one, such multiple echoes are called reverberations.

During the construction of large halls or auditorium, the following measures are taken to reduce reverberation:

1. The large plane surfaces of the walls and roofs are covered with sound absorbing materials like compressed fireboard and rough plaster.

2. Floors are carpeted (using sound absorbing material).

3. Heavy curtains are kept at the entrance and exit doors.

4. Sound absorbing panels are kept near the stage.

Audible and Inaudible Sounds : The sound whose frequency lies between 20 Hz and 20000 Hz, which we are able to hear is called audible sound. So, the audible range of human ear is 20 –20000 Hz. Inaudible sounds having frequency less than 20 Hz are known as infrasonic sounds.

Inaudible sounds having frequency more than 20000 Hz are known as **ultrasonic sounds.** We cannot hear ultrasonic sounds too.

- Animals like dolphins, bats and porpoises produce ultrasonic sounds or ultrasound.
- Dogs can hear up to 25000 Hz (25 kHz). There are special whistles known as **Galton's whistle** that can produce sounds of frequency more than 20000 Hz. The owners of dogs can use these whistles to give signals to their dogs without the knowledge of any person located nearby.

Applications of Ultrasound

Ultrasounds are high frequency waves which can penetrate deep inside a body even in the presence of obstacles. Ultrasounds are used extensively in industries, medicine and technology.

Uses of ultrasound in industries

1. Effective cleaning agent: When some engines and machines are used in industries, the particles of dust, grease and dirt reach in places like odd-shaped parts of machines, electronic components, etc. Cleaning of such particles is very difficult. Ultrasound can be used to clean such particles present in hard-to-reach places.

2. Detection of cracks in metal blocks: Metallic components are generally used in construction of big structures like buildings, bridges, machines and also scientific equipment. But if there is a small defect, crack or a hole, the ultrasound gets reflected back from that defect or crack. The ultrasound Sound detectors indicate the presence of crack or hole in the metal block.

Uses of ultrasound for medical purpose

1. Ultrasonography: The technique of obtaining images of the internal organs of the body by using ultrasonic waves is called ultrasonography.

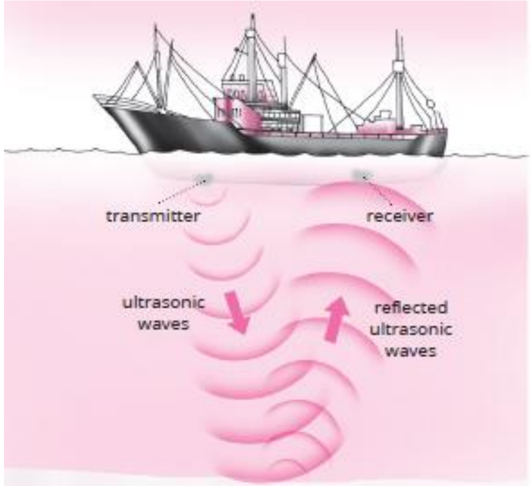
2. Echocardiography: The technique of obtaining images (pictures) of the heart of the body by using ultrasonic waves is called echocardiography.

3. Detection of fetal abnormalities: Ultra-sonography is also used for the examination of the foetus during pregnancy. It is also used to detect some fetal abnormalities. This diagnosis allows appropriate treatment to be given during pregnancy and child birth.

4. Breaking of kidney stones: Kidney stones are hard deposits which can grow inside a person's kidneys. They can be painful and dangerous to life. Ultrasonic waves are directed towards kidneys. These waves break the stones into tiny pieces so they can pass out of the kidney along with the urine.

Uses of ultrasound in technology

1. SONAR (SOund Navigation And Ranging): Sonar is a device which is used to find the depth of a sea, or to locate underwater objects like enemy's submarine, sunken ships and shoals of fish.



A sonar apparatus consists of two parts:

a. transmitter for emitting ultrasonic waves, and

b. receiver-cum-recorder for receiving reflected ultrasonic waves

The receiver-cum-recorder receives the echo and measures the time taken (t) by the ultrasonic waves to travel from the ship to the bottom of the sea, and back to the ship. We can calculate the depth of the sea by using the formula:

Velocity of sound (in water)

$$v_w = 2 \times \text{Distance } (d) \,/\, \text{Time taken } (t)$$

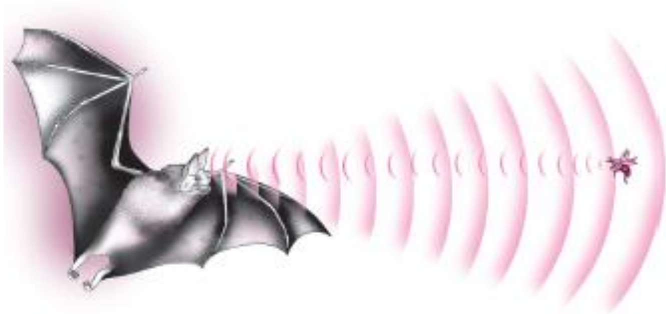
or

$$d = (v_w \times t) / 2$$

2. RADAR (RAdio Detection And Ranging): In air, radar is used to detect the presence of obstacle and finding its distance (or range) by using the echo method.

Echolocation

A method in which animals like bats, dolphins and porpoises emit ultrasonic waves and listen to their echoes to find their prey, avoid obstacles and move around without vision is called echolocation.

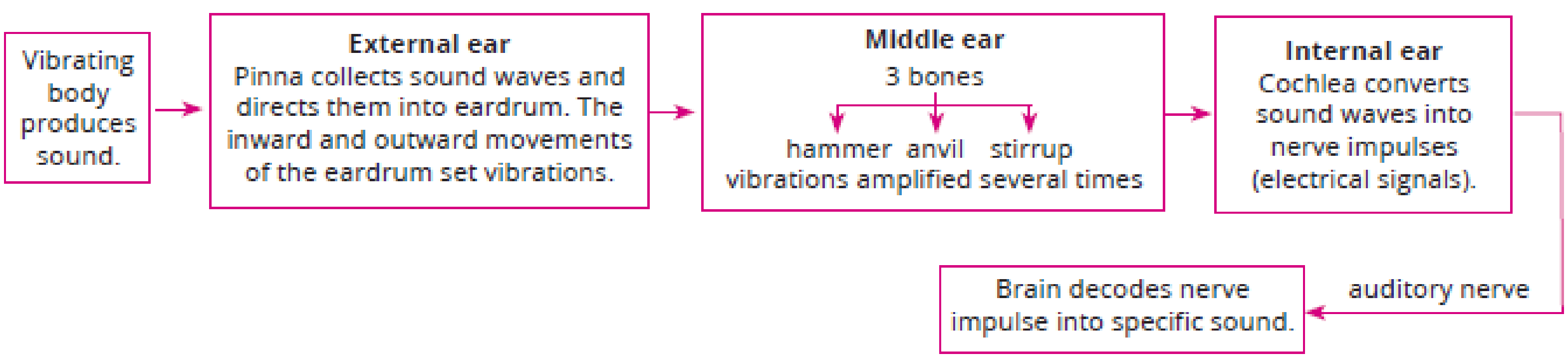


The bat emits ultrasonic waves (shown in colour) that strike the insect and are reflected back to the bat. The bat uses the echolocation method to detect the insect's position.

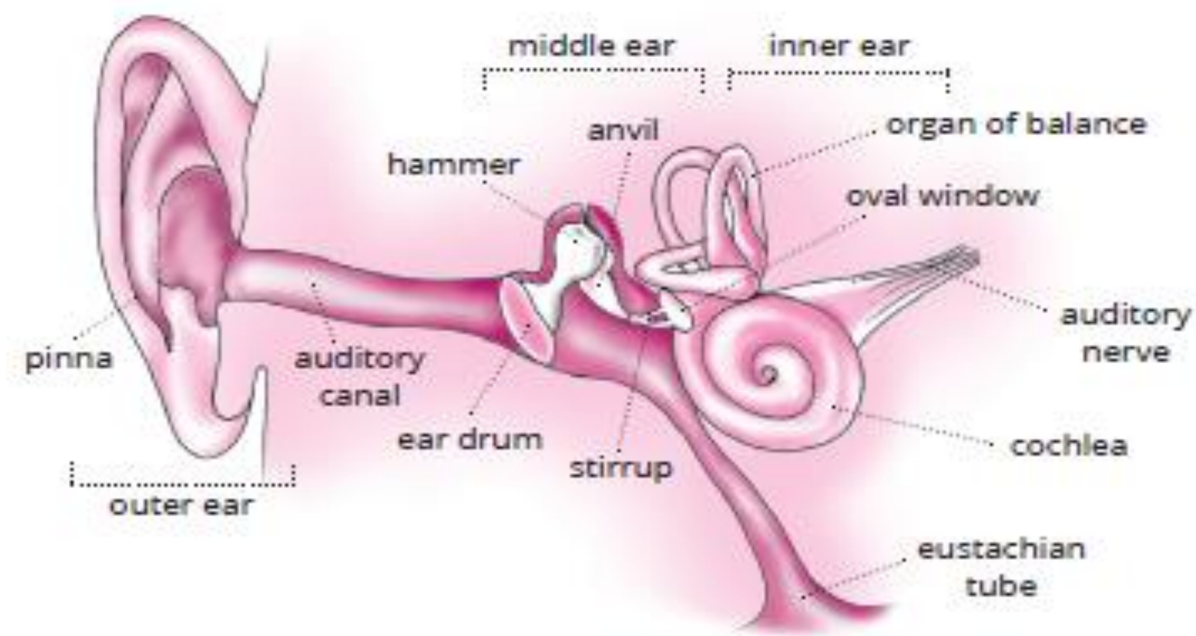
Structure and Working of Human Ear

Our ear is divided into three parts :**1.** External Ear **2.** Middle Ear **3.** Internal Ear

Working of the human ear



Parts of the human ear



Care of ears

The human ear is the most important and delicate organ which needs special care. The following points should be kept in mind:

1. Do not clean the middle ear using a matchstick or any other pointed object as this can damage the eardrum and can make a person deaf.

2. Do not shout loudly into someone's ear.

3. Do not hit someone on the ear, because a sudden change of pressure caused due to loud noise or heavy blow may damage the eardrum.

4. Consult a doctor, in case of any pain in the ear.

Summary

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

2. Medium: The substance or matter through which sound is transmitted is called a medium. Sound cannot travel in vacuum.

3. Wave: It is a disturbance that moves through a medium when the particles of the medium set neighbouring particles into motion.

4. Amplitude: The maximum displacement of the particles of a medium from their mean positions during the propagation of a wave is called the amplitude of the wave.

5. Time period: The time required to produce one complete vibration is called the time period. Its SI unit is second.

6. Frequency: The frequency of a wave is defined as the number of waves produced per second. Its SI unit is hertz.

7. Wave velocity: The distance travelled by a wave in one second is called the velocity of the wave. Velocity = Frequency $\times$ Wavelength.

8. Pitch: It is a characteristic of a musical sound by which we can distinguish a shrill sound from a grave sound even though the two sounds have the same loudness. The pitch of a sound depends upon the frequency of vibration.

9. Loudness: It is a sensation as perceived by the listener. It is a measure of the response of the ears to the sound. It depends upon the intensity of sound near the ear.

10. Quality of sound (timbre): It is the characteristic of a sound that enables us to distinguish between two sounds of the same pitch and loudness produced by two different sour

11. Note: A sound which is produced due to mixture of several frequencies

12. Speed of sound: It is defined as the distance which a point on a wave, such as a compression or rarefaction travels per unit time.

13. Reflection of sound: The changing of direction of sound when it strikes a hard surface is called reflection of sound.

14. Echo: It is the repetition of the original sound heard, after it is reflected from a distant, dense and rigid object.

15. Infrasonic sounds: Inaudible sounds having frequency less than 20 Hz are known as infrasonic sounds.

16. Ultrasonic sounds: Inaudible sounds having frequency more than 20,000 Hz are known as ultrasonic sounds.

17. Sonar: It is a device which is used to find the depth of a sea or to locate underwater objects like enemy’s submarine, sunken ships and shoals of fish.