Science – Class IX

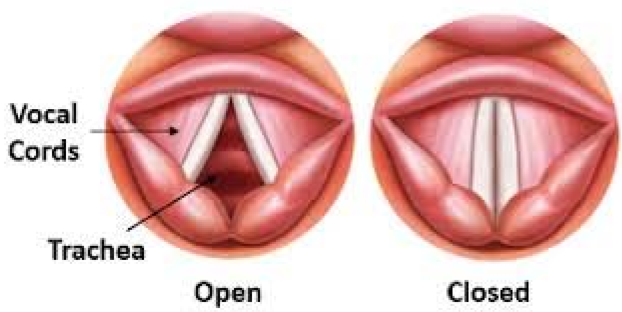
Chapter 12: Sound (Physics)

Introduction

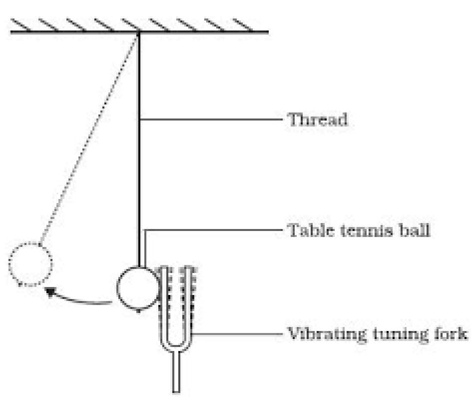
- The sensation felt by our ears is called sound
- Sound is a form of energy which makes us hear
- Law of conservation of energy is also applicable to sound
- Sound travels in form of wave.

Production of Sound

- Sound is produced when objects vibrates or sound is produced by vibrating objects. Vibration is the rapid to and fro motion of an objects.
- A stretched rubber band when plucked vibrates and produce sound.
- The energy required to make an object vibrate and produce sound is provided by some outside source (like our hand, wind etc.)
- Example: Sound of our vice is produced by vibration of two vocal cords in our throat. Open vocal cord and closed vocal cord.



- Sound of drum or table is produced by vibration of its membrane when struck.
- In a laboratory experiments, sound is produced by vibrating tuning fork. The vibration of tuning fork can be shown by touching a small suspended cork ball with a prong of the sounding tuning fork. The cork ball is pushed away with a great force.



Science – Class IX

Chapter 12: Sound (Physics)

Sound can be produced by following methods:

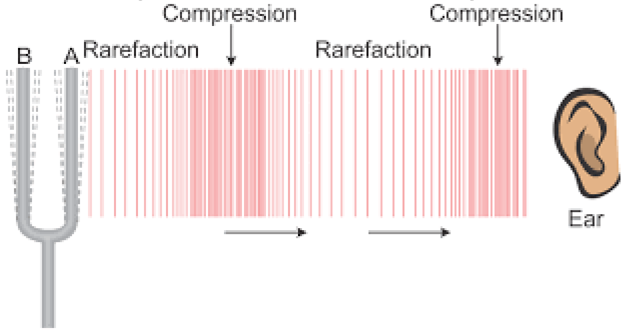
(i) By vibrating string (sitar)
(ii) By vibrating air (flute)
(iii) By vibrating membrane (Table and drum)
(iv) By vibrating plates (bicycle bell)
(v) By friction in objects
(vi) By scratching or scrubbing the objects etc.

Propagation of Sound

- The substance through which sound travels is called a medium
- The medium may be solid, liquid or gas.
- When an objects vibrates, then the air particles around it also start vibrating in exactly the same way and displaced from their stable position.
- These vibrating air particles exert a force on nearby air particles so they are also displace from their rest position and start to vibrate.
- This process is continued in the medium till sound reaches our ears.
- The disturbance produced by the sound travels through the medium (not the particles of the medium).
- A wave is a disturbance that moves through a medium when the particles of the medium set neighboring particles into motion.
- Sound waves are characterized by the motion of particles in the medium and are called mechanical waves.
- So sound travels in wave form known as mechanical waves.
- Air is the most common medium through which sound travels. When a vibrating object moves forward, it pushes and compresses the air in front of it creating a region of high pressure. This region is called a compression (C).
- When the vibrating objects moves backwards, it creates a region of low pressure called rarefaction (R).
- When body vibrates back and forth, a series of compression and rarefaction is formed in air resulting in sound wave.
- Propagation of sound wave is propagation of density variations or pressure variations in medium.

Science – Class IX

Chapter 12: Sound (Physics)

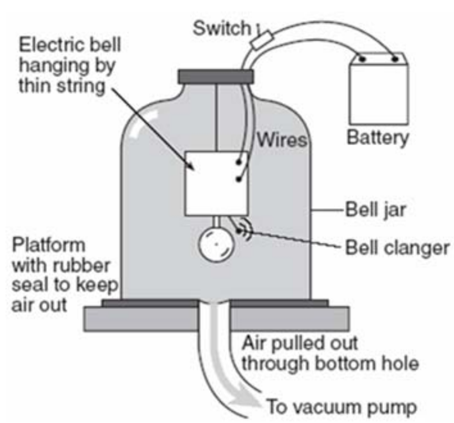


Question: How does the sound produced by vibrating object in a medium reach your ear?

Answer: When and vibrating object vibrates, it forces the neighboring particles of the medium to vibrate. These vibrating particles then force the particles adjacent to them to vibrate. In this way, vibration produced by an object are transferred from one particles to another till it reaches the ear.

Sound need Medium for Propagation (Travel)

- Sound is a mechanical wave and needs a material medium like air, water, steel etc. for its propagation.
- It cannot travel in vacuum. Which can be demonstrated by the following experiments.
- An electric bell is suspended in airtight bell jar connected with vacuum pump.
- When bell jar is full of air, we hear the sound but when air is pumped out from the bell jar by vacuum pump and we ring the bell, no sound is heard.
- So, medium is necessary for propagation of sound



Science – Class IX

Chapter 12: Sound (Physics)

Question: Explain how sound is produced by your school bell.

Answer: When the school bells vibrates, it forces the adjacent particles in air to vibrate. This disturbance gives rise to wave and then the bell moves forward, it pushes the air in front it. This creates a region of high pressure known as compression. When the bell moves backwards, it creates a region of low pressure know as rarefaction. As the bell continuous to move forward and backward, it produces a series of compression and rarefactions. This makes the sound of a bell propagate through air.

Question: Why sound waves are called mechanical waves?

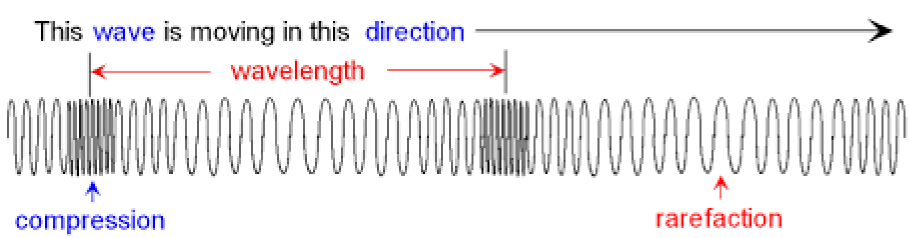
Answer: Sound waves force the medium particles to vibrate. Hence, these waves are known as mechanical waves. Sound wave propagate through medium because of the interaction of the particles present in that medium.

Question: Suppose you and your friend are on the moon. Will you be able to hear any sound produced by your friend?

Answer: Sounds needs a medium to propagate. Since the moon is devoid of any atmosphere you cannot hear any sound on the moon.

Sound Waves are Longitudinal Waves

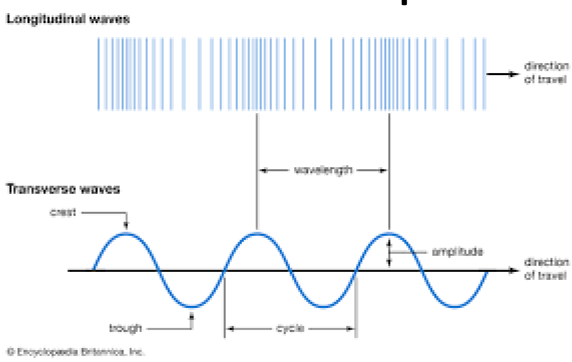
- A wave in which the particles of the medium vibrate back and forth in the same direction in which wave is moving is called a longitudinal wave.

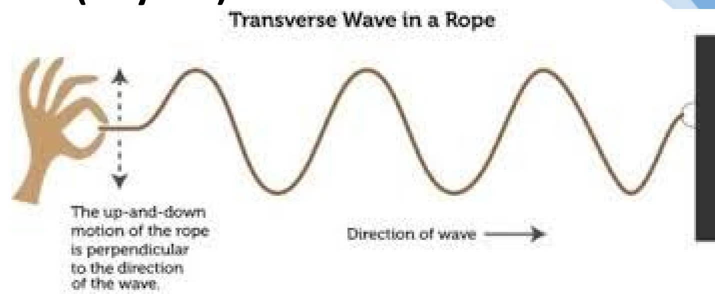


- In these waves the individual particles of the medium move in a direction parallel to the direction of propagation of the disturbance.
- Sound waves are longitudinal waves.

Transverse Wave

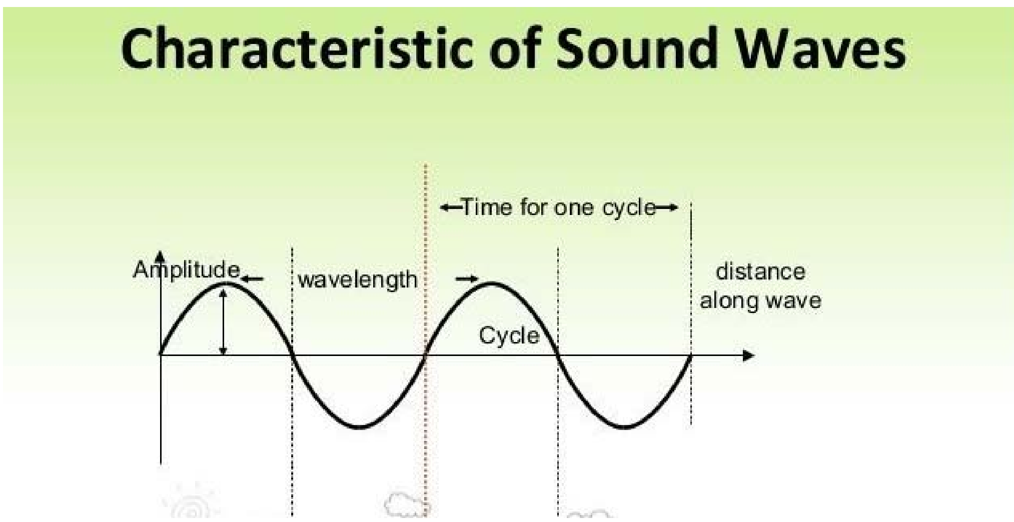
In transverse wave particles oscillate up and down about their mean position as the wave travels. Particles of medium move in a direction perpendicular to the direction of wave propagation. Light is a transverse wave.





Characteristics of Sound Wave

- The characteristics of sound waves are: wavelength, frequency, amplitude, time period and velocity.



- ***Wavelength:*** The distance between two consecutive compression (C) or two consecutive rarefactions (R) is called the wavelength. It is represented by ƛ (lambda). Its SI unit is metre (m).
- ***Frequency:*** The change in density from the maximum value to the minimum value, again to the maximum value, makes one complete oscillation. The number of oscillations per unit time is frequency of sound wave. Number of compression or rarefaction passed on one second is called frequency. It is represented by v (nu). Its SI unit is hertz (Hz). 1 Hz = 1 vibration per second. 1 kHz = 1000 Hz.
- ***Time period:*** Time taken to complete one vibration is called time period. Time required to pass two consecutive compressions or rarefaction through a point is called time period. It is denoted by T. SI unit is second (s). $v = 1/T$
- **Amplitude:** The magnitude of the maximum disturbance in the medium on either side of the mean value si called the amplitude of the wave. It is denoted by A and its SI unit is metre(m).

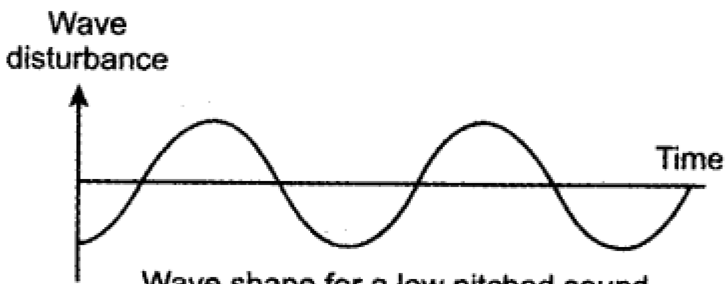
Science – Class IX

Chapter 12: Sound (Physics)

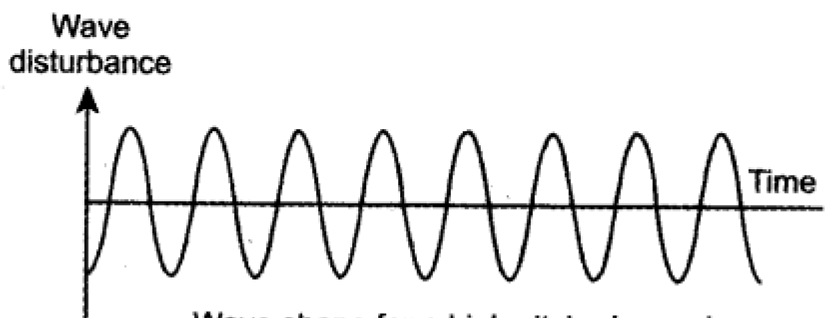
Pitch:

The sensation of a frequency is commonly referred to as the **pitch** of a **sound**. A high **pitch sound** corresponds to a high frequency **sound** wave and a low **pitch sound** corresponds to a low frequency **sound** wave.

High pitch sound has larger number of compressions and rarefactions passing a fixed point per unit time.



Wave shape for a low pitched sound



Wave shape for a high pitched sound

Loudness:

Loudness refers to how loud or soft a **sound** seems to a listener. The **loudness of sound** is determined, in turn, by the intensity, or amount of energy, in **sound** waves. The unit of intensity is the decibel (dB). As decibel levels get higher, **sound** waves have greater intensity and **sounds** are louder.

Quality or Timber of Sound:

In music, **timbre** is the perceived **sound quality** of a musical note, **sound** or tone. ... In simple terms, **timbre** is what makes a particular musical **sound** have a different **sound** from another, even when they have the same pitch and loudness.

Sound of single (same) frequency is called tone while a mixture of different frequencies is called note.

Noise is unpleasant to hear while music is pleasant to hear and it is of good quality.

Science – Class IX

Chapter 12: Sound (Physics)

Question: Which wave property determines (a) loudness (b) pitch?

Answer:

(a) The loudness of sound depends on its amplitude. If the amplitude of a sound is high large, then the sound produced will be also loud.
(b) The pitch of sound depends on its frequency. A sound will be considered a high pitched sound if its frequency is high.

Velocity

The distance travelled by a wave in one second is called velocity of the wave. Its SI unit is m/s.

Velocity = Distance travelled / Time taken

V = ƛ / T (ƛ is the wavelength of the waves travelled in one time period T)

V= ƛ ν (Because ν = 1/T)

Velocity = Wavelength x Frequency (This is the wave equation).

Question: Distinguish between loudness and intensity of sound

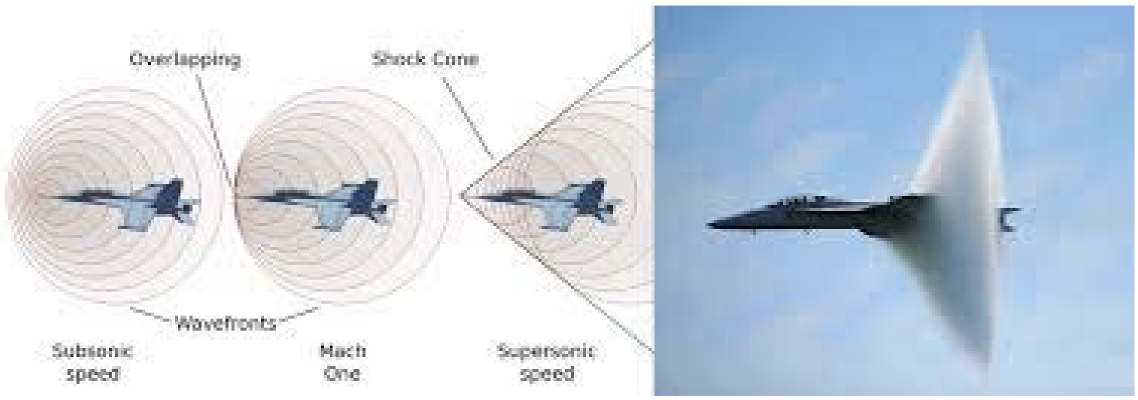
Answer: Intensity of a sound wave is defined as the amount of sound energy passing through a unit area per second. Loudness is the measure of the response of the ear to the sound. The loudness of a sound is defined by its amplitude. The amplitude of a sound decide its intensity, which in turn is perceived by the ear as loudness.

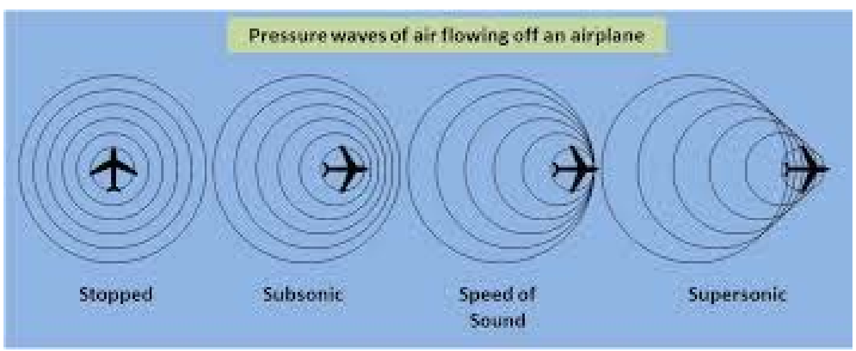
Speed of Sound in different media

- Speed of sound depends on the nature of material through which it travels. It is slowest in gases, faster in liquids and fastest in solids.
- Speed of sound increases with rise in temperature
- Speed of sound increases as humidity of air increases
- Speed of light is faster than speed of sound. Therefore, sound of thunder is heard a little later than the flash of light is seen.
- In air, speed of sound is 344 m/s at 22 °C

Sonic Boom

- When the speed of any object exceeds the speed of sound it is said to be travelling at supersonic speed. Some aircrafts, bullets rockets etc. have ‘supersonic speed’.
- It produces shock waves in air which carry a large amount of energy.
- Sonic boom is explosive noise caused by shock waves. It emits tremendous sound energy which can shatter the glass panes of windows.





Reflection of Sound

- Like light, sound also bounces back when it falls on a hard surface. It is called reflection of sound
- The laws of reflection of sound is same as laws of reflection of light.
- The incident sound wave, the reflected sound wave and normal at the point of incidence lie in the same plane
- Angle of reflection of sound is always equal to the angle of incidence of sound

Science – Class IX

Chapter 12: Sound (Physics)

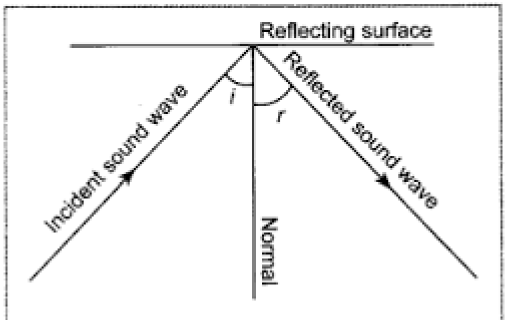
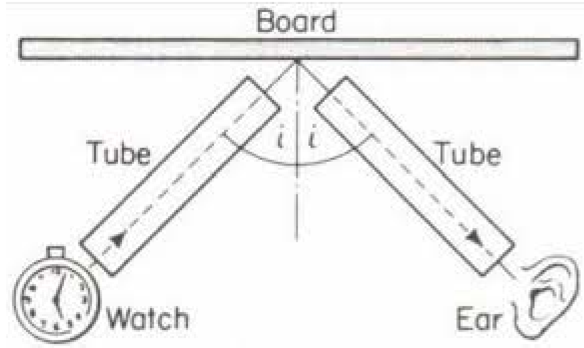


Fig. 1.2. Laws of reflection of sound



Echo

- The repetition of sound caused by the reflection of sound waves is called echo
- We can hear echo when these is a time gap of 0.1 second in original sound and echo (reflected sound).
- Echo is produced when sound reflected from a hard surface (i.e. brick wall, mountain etc). No echo is heard from soft surface which tends to absorb sound.

Minimum distance to hear an echo

Speed = Distance / Time

Here speed of sound in air = 344 m/s at 22 °C

Time = 0.1 Sec

Distance /0.1 Sec = 344

Distance = 34.4 m

So distance between reflecting surface and audience = 34.4/2 = 17.2 m (at 22 °C)

Reverberation

The persistence of sound in a big hall due to repeated reflection of sound from the walls, ceiling and floor of the hall is called reverberation.

If reverberation is too long, sound becomes blurred, distorted and confusing due to overlapping of different sound.

To reduce reverberation, the roof and walls of auditorium are generally covered with sound – absorbent materials like compressed fiberboard, rough plaster or draperies. The seat materials are selected on the basis of their sound absorbing properties.

Science – Class IX

Chapter 12: Sound (Physics)

Application of reflection of Sound

(i) Megaphones, loudspeakers, bulb horns and trumpets, shehnai etc are designed to send sound in a particular direction without spreading all round.

Megaphone

Bulb Hord

Loudspeaker

Trumpets

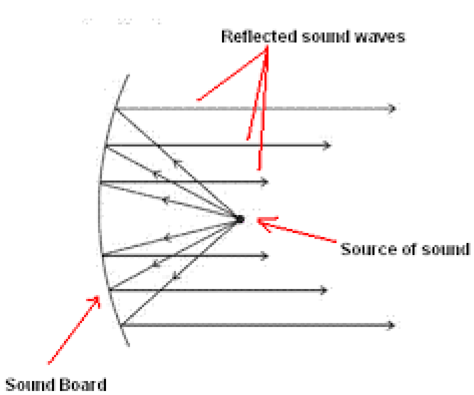
Shehnai

Stethoscope

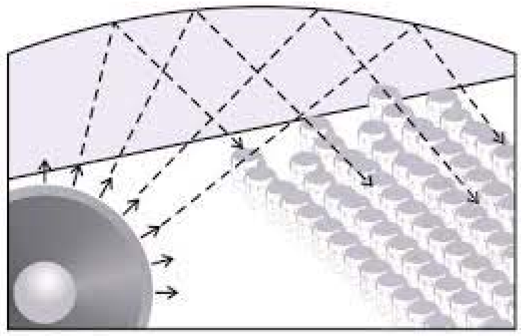
(ii) All the above instruments have funnel tube which reflects sound waves repeatedly towards audience. In this amplitude of sound waves ads up to increase loudness of sound.

(iii) **<u>Stethoscope:</u>** It is a medical instrument used for listening the sound produced in human body mainly in heart and lungs. The sound of the heartbeats reaches the doctor's ears by the multiple reflection of the sound waves in the rubber tube of stethoscope.

(iv) Sound Board: In big halls or auditoriums sound is absorbed by walls, ceiling, seats etc. So a curved board (sound board) is places behind the speakers so that his speech can be heard easily by audience. The sound board works on the multiple reflections of sound.



(v) The ceiling of concert halls are made curved, so that sound after reflection from ceiling, reaches all the parts of hall.



Curved ceiling of conference hall

Range of Hearing

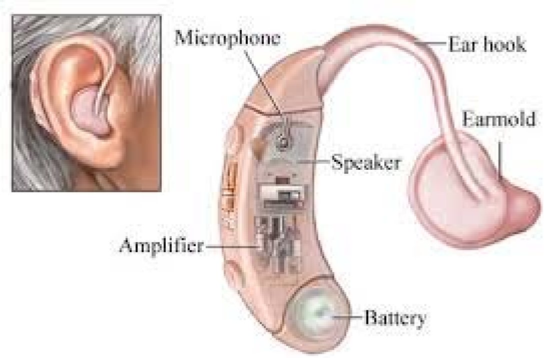
- Range of hearing in human is 20 Hz to 20,000 Hz. Children younger than 5 years and dogs can hear up to 25 kHz.
- The sound of frequencies lower than 20 Hz are known as 'infrasonic sounds'.
  - A vibrating simple pendulum produces infrasonic sound
  - Rhinoceroses communicate each other using frequencies as low as 5 Hz
  - Elephants and whales produces infrasonic waves
  - Earthquakes produces infrasonic waves (before shock waves) which some animals can hear and get disturbed.

- The sound of frequencies higher than 20 kHz are known as 'ultrasonic waves'.
  - Dogs, parpoises, dolphins, bats and rats can hear ultrasonic sounds
  - Bats and rats can produce ultrasonic sounds.

Hearing Aid

A hearing aid is a small electronic device that you wear in or behind your ear. It makes some sounds louder so that a person with hearing loss can listen, communicate, and participate more fully in daily activities. A hearing aid can help people hear more in both quiet and noisy situations. However, only about one out of five people who would benefit from a hearing aid actually uses one.

A hearing aid has three basic parts: a microphone, amplifier, and speaker. The hearing aid receives sound through a microphone, which converts the sound waves to electrical signals and sends them to an amplifier. The amplifier increases the power of the signals and then sends them to the ear through a speaker.



Application of Ultrasound

(i) It is used to detect cracks in metal block in industries without damaging them

(ii) It is used in industries to clean 'hard to reach' parts of objects such as spiral tubes, odd shaped machines etc

(iii) It is used to investigate the internal organs of human body such as liver, gall bladder, kidney, uterus and heart.

(iv) **Echocardiography:** These waves are used to reflect the action of heart and its image are formed. This technique is called echocardiography.

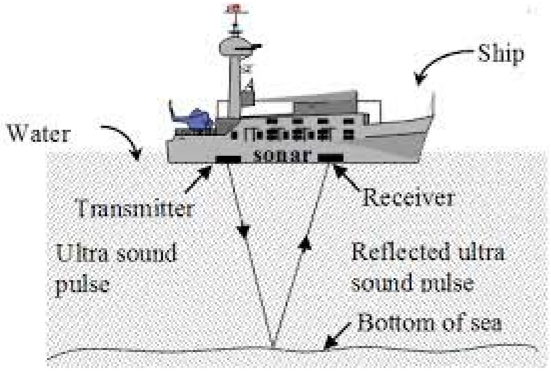
(v) **Ultrasonography:** The technique of obtaining pictures of internal organs of the body by using echoes of ultrasound waves is called ultrasonography.

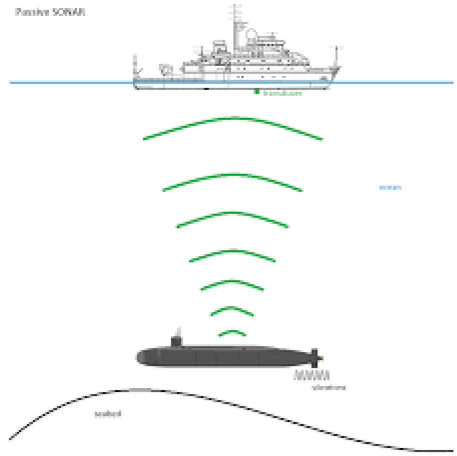
(vi) Ultrasound is used to split tiny stones in kidneys into fine grains.

SONAR

- The word 'SONAR' stands for Sound Navigation and Ranging
- SONAR is a device which is used to find distance, direction and speed of underwater objects.
- SONAR consists of a transmitter and a receptor or detector and installed at the bottom of a ship.
- The transmitter produces and transmits ultrasonic waves.
- These waves travel through water and after striking the objects on the bottom of sea, are reflected back and received by detector

Chapter 12: Sound (Physics)





- These waves are converted into electric signals by detector
- The sonar device measure the time taken by the ultrasound waves from ship to bottom. Total distance travelled by the waves 2d = v x t, v = speed of sound through sea, t = time interval between transmission and reception. This is called echo ranging.
- The sonar is used to find depth of sea, to locate underwater hills, valleys, submarines, icebergs and sunken ships.
- Bats fly in the dark night by emitting high pitched ultrasound waves which are reflected from the obstacle or prey and returned to bat ear. The nature of reflection tells the bat where the obstacle or prey is and what it is like.

Science – Class IX

Chapter 12: Sound (Physics)

Structure of Human Ear

We are able to hear with help of an extremely sensitive device called the ear. It allows us to convert pressure variations in air with audible frequencies into electrical signals that travel to brain via the auditory nerve. The auditory aspects of human ear is discussed below.

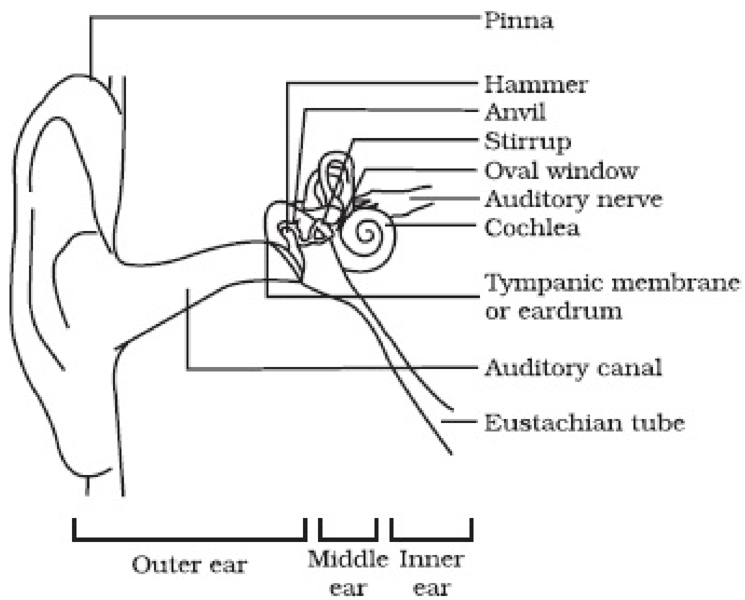


Fig. 12.19: *Auditory parts of human ear.*

Sound waves are collected by the pinna and then are directed through ear canal sound waves on striking the eardrum make it vibrate exactly the same way as the given sound emitting object.

The bones in the middle ear start vibrating when eardrum vibrates. It helps in magnifying the vibrations. When the magnified vibrations reach the cochlea in the inner ear, the fluid in it starts vibrating.

These vibrations are picked up by sensory receptors and are converted into electrical signals.

These electrical signals then travel to the brain which interprets sound.

Sound

Numerical Problems

1) A person has a hearing range from 20 Hz to 20 kHz. What are the typical wavelength of sound waves in air corresponding to these two frequencies. Take the speed of sound in air as 344 m/s.

2) Two children are at opposite ends of an aluminium rod. One strike the end of the rod with a stone. Find the ratio of times taken by the sound wave in air and in aluminium to reach the second child.

3) The frequency of a source of sound is 100 Hz. How many times does it vibrate in a minute?

4. A sound wave travels at a speed of 339 m/s if its wavelength is 1.5 cm, what is the frequency of the wave. Will it be audible?

5. A sonar device on a submarine sends out a signal and receives an echo 5 s later. Calculate the speed of sound in water if the distance of the object from the submarine is 3625 m.

6. An underwater device directs ultrasound of frequency 75 kHz towards water surface. What is the wavelength of sound in air above the water surface and what is its frequency? Speed of sound in air = 340 m/s.

7) When a wave travels from one medium to another, the wavelength changes but not frequency. The wavelength of sound disturbance 30 cm in air and of the wave velocity is 340 m/s. What will be the wavelength of this disturbance in Helium & water. The speed of sound in helium is 970 m/s and 1450 m/s in water.

8. Sound waves of wavelength λ travel from medium in which its velocity is V m/s into another medium in which its velocity is 3 V m/s. What is the wavelength of the sound λ in the second medium?

9. A sound wave travels at a speed of 340 m/s. If the wavelength of wave is 1.4 m, what is the frequency of wave?

10. An observer far away from a railway station hears the train starting. The sound arrives both from the steel rails and through air with a time difference of 3.5 s. How far is the railway station from the observer? The speed of sound in air and steel is 340 m/s & 5130 m/s respectively.

Science - Class IX
Chap 12 - Sound (Numerical)

1) A sound wave has a frequency of 2 kHz and wave length 35 cm. How long will it take to travel 1.5 km?

Soln: Given, frequency $\nu = 2\ kHz = 2000\ Hz$
Wavelength $\lambda = 35\ cm = 0.35\ m$

Velocity (Speed) V = wavelength × frequency

$V = \lambda \times \nu$

$= 0.35\ m \times 2000\ Hz$

$V = 700\ m/s.$

The time taken by the wave to travel a distance, d of 1.5 km is

$$T = \frac{d}{v} = \frac{1500}{700}$$

$T = 2.142$ sec

Thus sound will take 2.1 s to travel a distance of 1.5 km.

2) Calculate the wave length of sound wave whose frequency is 220 Hz and speed is 440 m/s in given medium.

Soln: Given, frequency $\nu = 220\ Hz$ Speed $v = 440\ m/s$
For a sound wave $v = \lambda \times \nu$

$$\lambda = \frac{v}{\nu} = \frac{440}{220} = 2\ m$$

Hence, wavelength of sound is 2 m.

3) A person is listening to a tone of 500 Hz sitting at distance of 450 m from the source of sound. What is the time interval between successive compression from the source?

Soln: Time interval between two successive compression is equal to the time period of the wave. This time period is reciprocal of frequency.

$$T = \frac{1}{\text{frequency}} = \frac{1}{\nu} = \frac{1}{500}$$

$T = 0.002$ s

4) A person clapped his hands near a cliff and heard the echo after 5 sec. What is the distance of the cliff from the person if the speed of sound, v is taken as 346 m/s^{-1}?

Soln: Speed $v = 346$ m/s.

Time taken to hear echo $t = 5$ sec

distance travelled by sound =

$= v \times t$

$2d = 346 \times 5 = 1730$ m

$d = \frac{1730}{2} = 865$ m

5) An echo returned in 3 sec. What is the distance of the reflecting surface from the source, given that the speed of sound is 342 m/s.

Soln: $v = 342$ m/s $\quad t = 3$ s $\quad 2d = 342 \times 3 = 1026$ m

$d = \frac{1026}{2}$ m $= 513$ m

6) A ship sends out ultrasound that returns from the seabed and detected after 3.42 s. If the speed of ultrasound through sea water is 1531 m/s, what is the distance of the seabed from the ship?

Soln: Given, $t = 3.42$ sec

$v = 1531$ m/s

Distance travelled by ultrasound

$= 2 \times$ depth of sea

$= 2 \times d$

$2d =$ speed of sound $\times$ time

$= v \times t$

$2d = 1531 \times 3.42 = 5236$ m

$d = 2618$ m

$d = 2.618$ km seabed from ship.

7) A submarine emits a sonar pulse, which returns from an underwater cliff in 1.02 s. If the speed of sound in salt water is 1531 m/s, how far away is the cliff?

Soln: $t = 1.02$ sec $v = 1531$ m/s

$2d = 1.02 \times 1531$

$= 1561.62$ m

$d = 780.31$ m.