Sound

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1. Introduction

The five basic senses of human beings are *sight, touch, taste, smell and hearing.*
After sight, sound is the most important among our senses.
It keeps us informed about our surroundings.
Sound is a form of energy just like heat and light.
We hear sounds from various sources of moving vehicles of televisions, people in our surroundings, machine and so on.
Sound is a form of energy which produces a sensation of hearing in our ears.
What is sound exactly? What are the characteristics of sound?
What is the mechanism of creating and propagating sound?
We will find the answers to these questions while we study this chapter.

2. Production of Sound

Sound is produced when a body vibrates, *i.e.* sound is produced by vibrating bodies. The following experiments demonstrate this fact. See Article NCERT Activities 1.

3. Wave

The movement of the disturbance through a medium due to the repeated periodic motion of the particles of the medium about their mean position is known as a wave.
Wave motion is a type of motion in which energy is transferred from one region to another without the actual movement of molecules of the medium from one region to other.

4. Medium

A substance or matter through which mechanical wave is transmitted is called medium.

e.g. solid, liquid, gas etc.

Mechanical wave: A mechanical wave is a periodic disturbance which requires material medium (solid, liquid, gas) for its propagation.

Examples: Sound waves, water waves, seismic wave (known as waves produced by earthquake), waves produced in a stretched string, waves produced in a slinky.

Electromagnetic waves (EM wave): Those waves which do not required any material medium like solid, liquid or gas for their propagation. They are called electromagnetic waves.

e.g., light waves, radio waves.

Do You Know

Sound wave travel in air at very low speed of 3-32 m/s at $20°C$. But light waves travel at a very high speed of $3\times10^{8} m/s$ in air.

5. Propagation of Sound

A vibrating body produces sound. Now we shall study, how the sound travels from one dace to another place.

When a body or an object vibrates, then the particles of the medium around the object are set into vibration.

These particles do not move their equilibrium position but simply vibrate about their equilibrium positions. A particle of the medium in contact with the vibrating object is displaced from its equilibrium position and away from the vibrating object. This displaced particle exerts \ force on the adjacent particle and come back to its equilibrium position.

However, the adjacent particle on which the force is exerted is displaced (from its equilibrium edition) away from the vibrating object.

This process continues in the medium till the disturbance created by the vibrating object or sound wave) reaches our ear. This is how, a sound wave propagates in a medium.

Remember: Particles do not move from their equilibrium positions but simply vibrate about their equilibrium positions.

6. Classification of Wave Motion

On the basis of the relative directions of the propagation of the wave with respect to direction the periodic changes in the medium (such as displacement, pressure etc.) the waves are Ossified into following two groups:

1. Transverse waves

2. Longitudinal waves

7. Graphical Representation of Longitudinal Waves

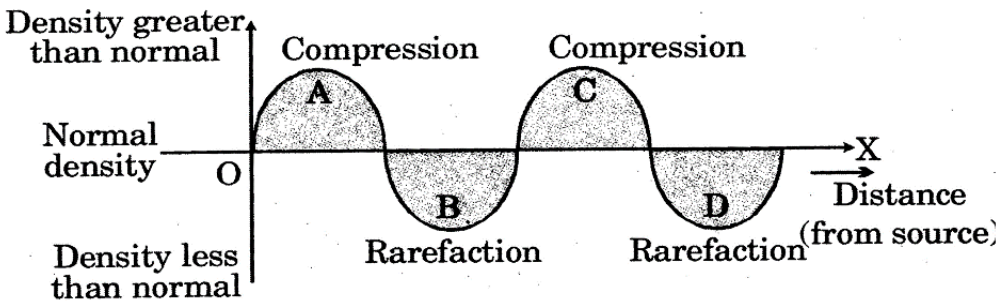


Fig. 7.1.

Density—Distance Graph

Do You Know

A sound wave is considered as the propagation of pressure or density variations in the medium.

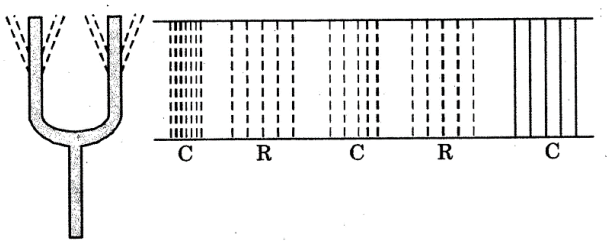


Fig. 7.2

8. Difference between Longitudinal and Transverse Wave

Longitudinal wave	Transverse wave
1. The particles of the medium vibrate to and fro in the same direction in which the wave is moving.	**1.** The particles of the medium vibrate up and down perpendicular to the direction in which the wave is moving.
2. It consists of regions of compressions and rarefactions.	**2.** It consist of crests and troughs.
3. It can propagate in all types of media (solid, liquid & gases).	**3.** It can propagate only in solid and at the surface of liquids.
4. The pressure and density are maximum at compressions and minimum at rarefactions.	**4.** There is no pressure or density variation.
5. It is represented by density-distance graph. For example sound wave. Waves formed in a slinky when pulled and pushed.	**5.** It is represented by displacement distance graph. **For example:** **(a)** Ripples produced on the water surface in a pond. **(b)** Vibration on of stretched wire in musical instruments.

9. Characteristics of a Sound Wave

(a) During a wave motion, the disturbance (or energy) moves from one region to another but the molecules of the medium only oscillate about their mean position.

(b) The speed of the wave depends on properties of the medium.

(c) For wave motion in a medium, the medium should have elastic delete inertia and less frictional forces.

We will now describe various terms related to sound wave-

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

Oscillation: The change in density or pressure from maximum value to minimum value md again to maximum value makes one oscillation.

Wavelength: The distance between two successive regions of high pressure or high density (or compressions) or the distance between two successive regions of low pressure or low density (or rarefactions) is known as wavelength of sound wave. It is denoted by λ (read as lambda).

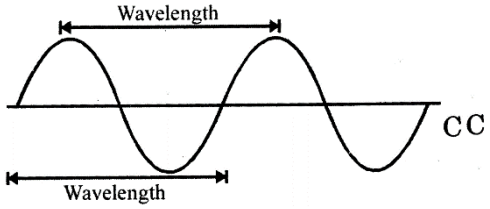


Fig. 9.1

S.I. unit of wavelength is metre (m).
C.G.S. unit of wavelength is cm.
Distance between a compression and the adjoining rarefaction = $\lambda / 2$
Frequency: *The frequency of a wave is defined as the number of waves produced per second.*
It is denoted by v (road as Neu).
Other symbols of frequency are *f* and n.
S.I. unit of frequency is Hz (Hertz).
1 hertz = one oscillation completed by a vibrating body or a vibrating particle in one second.
Time period: Time taken by a vibrating body or a vibrating particle to complete one oscillation is known as time period. It is denoted by T.
S.I. unit of Time period is second (s).

- **Relation between frequency & Time Period**

Let T = time period of a vibrating body
Then number of oscillations completed in T sec. = 1

$\therefore$ number of oscillations completed in $1\,\text{sec.} = \frac{1}{T}$

But number of oscillations completed in 1 sec. = frequency (v)

$\therefore \quad v = \frac{1}{T}$

Thus $\quad Frequency = \frac{1}{Time\ period}$

(5) Amplitude: The maximum displacement of the particles of a medium from their mean Positions during the propagation of a wave i3 called the amplitude of the wave.
The amplitude of a wave is denoted by A.
S.I. unit of amplitude is metre (m).
Remember: Greater the amplitude of a wave, greater is the energy carried by the wave.

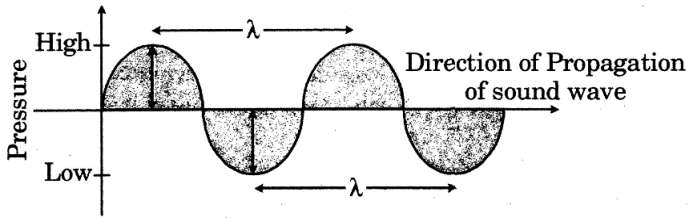


Fig. 9.2

(6) Pitch or shrillness: Pitch is the characteristics of a sound that depends on the frequency received by a human ear.
High pitch sound has high frequency

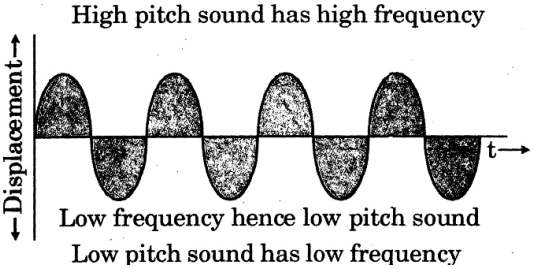


Fig. 9.3

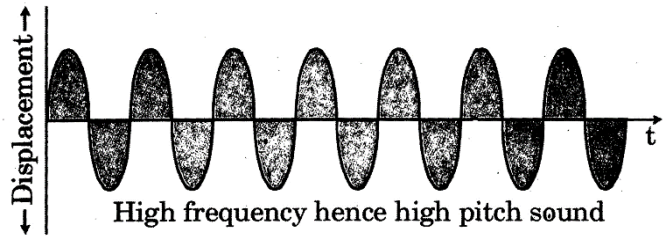


Fig. 9.4

Note-High and low pitched sounds are called trable and bass respectively

(7) Loudness: It is the sensation produced in the ear which enables is to dusting as between a loud and a faint sound. Loudness or softness of a sound depends on the amplitude of the vibrating body producing the sound. Loudness is a subjective quantity.

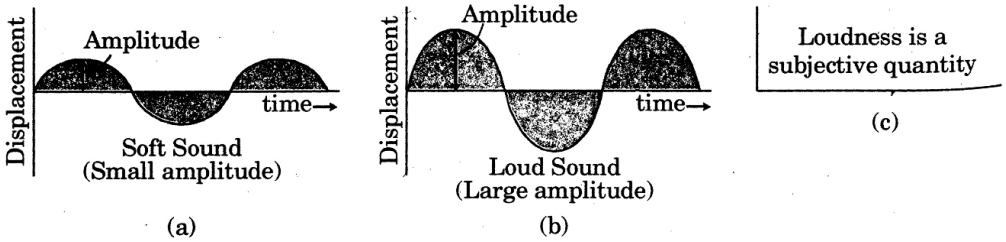


Fig. 9.5

(8) Timbre or Quality: It is a characteristic of a sound which enables us to distinguish between the sound of same loudness and pitch.

The quality of two sounds of same loudness and pitch produced by two different sources are distinguishable because of different waveforms produced by them.

(9) Intensity: The sound energy transferred per unit time through a unit area placed perpendicular to the direction of the propagation of sound.

$$Intensity\ of\ sound = \frac{Sound\ aenergy}{Time \times area} = \frac{\Pr ove}{Area}$$

S.I. unit of intensity of sound is

Joule $s^{-1}m^{-2} = watt\, m^{-2}$ $(\because Js^{-1} = 1W)$

Intensity of a sound is an objective physical quality. It does not depend on the response of our ears.

10. Relation between wave speed, frequency and wavelength

Let us consider a mechanical wave passing through a medium.

Wave velocity $(v) = \frac{\lambda}{T}$

$$v = \frac{1}{T} \times \lambda \qquad \left\{\because v = \frac{1}{T}\right\}$$

$$v = v \times \lambda$$

Wave velocity = Frequency × Wavelength

11. Factors affecting the loudness of sound:

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

2. Surface area of the vibrating body: The greater the surface area of the vibrating body, the greater is the loudness of sound.

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.

Greater the density of the medium louder is the sound.

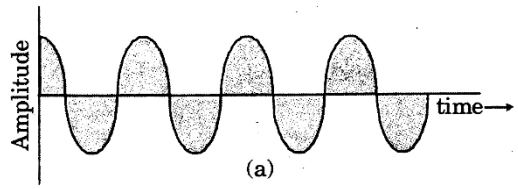
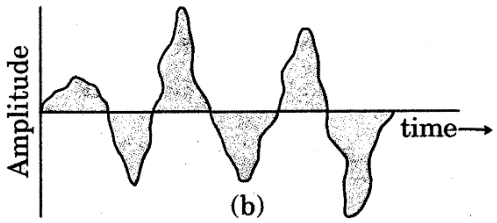
5. Presence of resonant bodies: The loudness of sound is increased due to the presence of other resonant bodies near the source of sound.

For example: Sound appears to be much louder inside a hall than in open air. It is because the walls, roof, floor etc. reflect the sound so the loudness is increased.

6. Motion of the medium: If wind is blowing in the direction of propagation of sound, loudness is increased. On the other hand if wind is blowing in a direction opposite to the direction propagation of sound loudness is decreased.

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

12. Difference between Musical sound and Noise

Musical sound	Noise
It produces pleasing effect to our ears and mind. The frequency of musical sound in high. It produce regular wave form.  Sound produced by musical instruments	It produce unpleasing effect to our ears and mind. The frequency of noise is low. It produces an irregular waveform.  Sound produced by machines in a factory. Moving train etc.

13. Speed of Sound

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

Factors on which work done depends

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

Hence speed of sound in solid is greater than the speed of sound in liquids and the speed of sound in liquids is greater than the speed of sourid in gases.

2. Effect of density: Speed of sound $\frac{1}{density\ of\ the\ medium}$

The density of oxygen is 16 times the density of hydrogen. We will find the speed of sound in hydrogen is more (approx. 4 times) than the speed of sound in oxygen.

3. Effect of humidity: The presence of water vapour in the air reduces the density of air.

Density of moist air < Density of dry air so 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.

4. Effect of Wind: (i) If the wind blows in the same direction in which the sound travels, the velocity of sound increases, *i.e.* velocity of sound = velocity of sound in still air + velocity of wind $v = v_s + v_w$

(ii) If the wind blows in the opposite direction in which the sound travels, the velocity of sound decreases.

velocity of sound = velocity of sound in still air - velocity of wind $v = v_s - v_w$

5. Effect of temperature: The speed of sound in a medium depends on the temperature of the medium. As the temperature of the medium increases, the particles of the medium collides more frequently and disturbance move faster.

Hence sound travels fast as the temperature of the medium increases.

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

State	Substance	Speed in m/s
Solid	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

14. Shockwaves 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 air craft, rockets move with supersonic speed.

When an object moves through the air with supersonic speed, then the sound wave produced by them are piled up in the form of a cone-shaped wave known as shockwave of highly compressed air.

The shock wave carries a huge amount of energy. The shock wave produced a loud sound called sonic boom as it travels through the air.

The harmful effects of sonic booms are:

Shockwaves can shatter glass and window panes of the houses and even damage buildings.

The supersonic air craft are very noisy. Their sonic booms harm the environment.

One sonic boom produces sounds of more than 130 decibels. It is enough to cause pain, headache and even damage the delicate tissues of the inner ear.

15. Echo

Echo is a repetition of sound due to the reflection of original sound by a large and hard obstacle, (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:

$$Speed = \frac{Distance\ travelled}{Time\ taken}$$

Speed of sound = 344 m/s (at $22°C$ in air)

Time taken $= \frac{1}{10} s$ (persistence of hearing)

(time gap between the original sound and its echo)

$$\text{Distance travelled} = \text{speed} \times \text{time taken}$$

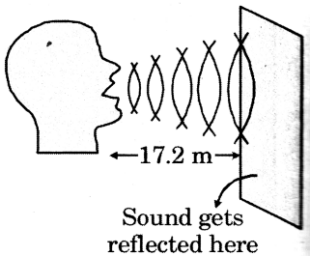
$$= 344 \times \frac{1}{10} = 34.4m$$

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 m which is 34.4 - 2 = 17.2 m.

Conclusion is that the minimum distance from a sound reflecting surface (like wall etc.) to hear an echo is 17.2 m. Echoes may be head more than once due to successive or multiple reflections. The rolling of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds and the land.

Condition for the formation of Echoes:



(1) The minimum distance between the source of sound and the reflector should be at least 17.2 m.

(2) The size of the reflector must be large compared to the wavelength of the incident sound.

(3) The intensity or loudness of the sound should be sufficient.

Whispering Gallery: We can experience extraordinary sound effects in the form of echoes at Gol Gumbaz, Bijapur (Karnataka).

16. Reverberation

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

Reverberation Time: The time interval for which the original sound appears to be prolonged.

In other words, the time interval during which the audible sound persist after the production of original sound is called reverberation time.

In an auditorium or a big hall, excessive reverberation is highly undesirable. The sound gets jumbled. So during construction of large halls or auditorium, following measures are taken to reduce reverberation.

(1) The large plane surface of the walls and roofs are covered with sound absorbing material like compressed fireboard, rough plaster etc.

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

(3) Heavy curtains are kept at the entrance, exist and doors.

(4) Sound absorbing panels are kept near the stage.

Do You Know

1. Acoustic means the scientific study of sound.

2. The soft and porous material are bad reflectors of sound. The soft and porous materials are actually good obsorbers of sound.

17. Use of Multiple Reflection of Sound

(1) Megaphone: It is device used to address public meetings. It is a horn shaped. When we speak through megaphone sound waves are reflected by the megaphone. These reflected sound waves are directed towards the people (or audience) without much spreading.

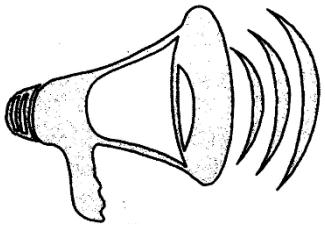


Fig. 17.1

(2) Sound Boards: Sound Boards are curved surfaces (concave) which are used in a big hall to direct the sound wave towards the people sitting in a hall. The speaker is (source of sound) placed at the focus of the sound board as in fig.

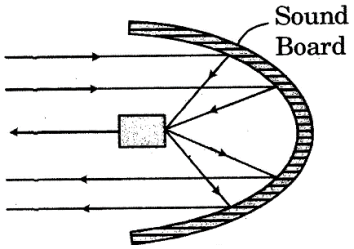


Fig. 17.2

Sound waves from the speaker are reflected by the sound board and these reflected waves are directed towards the people.

(3) Stethoscope: If is a device used by doctors to listen the sound produced by heart & lungs. The sound produced by heart beat & lungs of a patient reaches the ears of a doctor due to multiple reflection of sound.

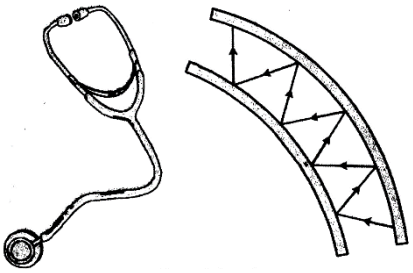


Fig. 17.3

(4) Ceilings of concert halls are curved: The ceilings of concert halls and auditoriums are made curved. This is done so that the sound reaches all the parts of the hall after reflecting from he ceiling. Moreover these ceilings are made up of sound absorbing materials to reduce the reverberation.

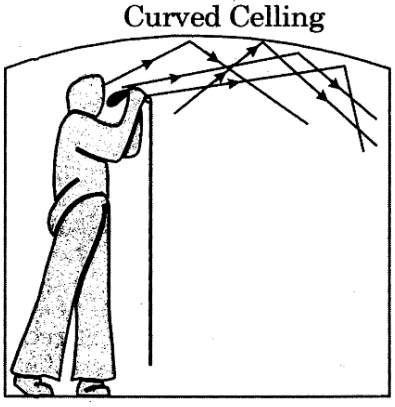


Fig. 17.4

18. Range of Hearing (Audible Range)

The waves having frequency less than 20 Hz and greater than 20,000 Hz can not be heared by human ear. Childrens under the age of five and some animal, such as dogs can hear up to 25 Khz (1 kHz =1000 Hz).

Hearing Aid: It is an battery operated electronic device for the people who are suffering from hearing loss. It receives sound through a microphone which converts the sound waves to electrical signals. These electrical signals are than amplified with the help of audio amplifier.

These amplified electrical signals send to the speaker of the hearing aid. Finally the speaker converts the amplified electrical signals to sound. This sound spends to the ear for clean hearing of the patients.

19. Infrasonies or Infrasound

The waves of frequency less than 20 Hz are known as infrasonic waves. The frequency of in Fra sonic wave is greater than 0 and less than 20 Hz.

Examples : Vibration of the earth's surface during the earthquake, elephants, rhinoceroses and whales etc. These waves are not audible to a human ear.

20. Ultrasonics or Ultrasound

The waves of frequency greater than 20,000 Hz are known as ultrasonic waves or ultrasound.

These waves are not audible to a human ear but they can be heard by animals and birds.

Due to its very high frequency, ultrasound has a much greater penetrating power than ordinary sound.

21. Echolocation

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

The ultrasonic waves produced by the bats after reflection from the obstacle like building guide them to remain away from the obstacle during their flights. Hence they can fly during night without hitting the obstacles. Bats also catch their prey during night with the help of ultrasonic waves.

The ultrasonic waves produced by a bat spread-out. These waves after reflecting from a prey say an insect reach the bat. Hence bat can easily locate its prey.

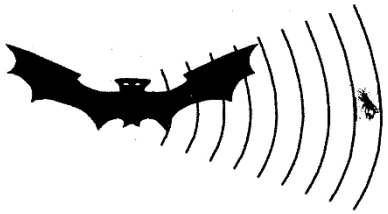


Fig. 21.1

Chapter at a Glance

- Sound is a form of energy which produces the sensation of hearing in our ears.
- Sound is produced by vibrating bodies.
- Wave or wave motion carries energy from one place to another place of the medium.
- Mechanical wave is a periodic disturbance which requires material medium (i.e. solid, liquid or gas) for its propagation.
- Sound wave is a mechanical wave.
- Sound wave is longitudinal in nature.
- Sound needs material medium for it propagation.
- Sound cannot travel through vacuum.
- Sound travels through a medium in the form of compressions, and rarefactions.
- Compression is a region (of a medium) of high pressure or high density.
- Rarefaction is a region (of a medium) of low pressure or low density.

- The maximum displacement of a vibrating body or particle of medium from its mean position is known as amplitude.
- The SJ. unit of amplitude is metre (m).
- The distance between two successive compressions or two successive rarefactions is known as the wavelength of a sound wave.
- The S.I. unit of wavelength is metre (m).
- Time taken by an oscillating body to complete one vibration is known as time period (T).
- Number of oscillations made by a vibrating body in one second is known as frequency (u or f).

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

- Unit of frequency is s^{-1} or Hz.
- Pitch or shrillness is a characteristic of a sound that depends on the frequency received by a human ear.
- High pitch sound has high frequency.
- Low pitch sound has low frequency.
- Loudness of a sound is the characteristic of a sound that depends upon the amplitude of the vibrating body producing sound.
- Loudness is a subjecting quantity and depends on the sensitivity of the human ear.
- A loud sound for a person may be feeble sound for another person.
- Timbre or quality is a characteristic of sound that enables us to distinguish between two sounds of same pitch and same loudness.
- Intensity of a sound is defined as the sound energy transferred per unit time per unit area placed perpendicular to the direction of sound.
- Intensity of sound is an objective physical quantity and can be measured.
- In S.I., unit of intensity of sound is $Js^{-1}m^{-2}$ or Wm^{-2}
- The relationship between speed of wave, wavelength and frequency is $\upsilon = \nu\lambda$
- Echo is a repetition of sound due to the reflection of original sound by a large and hard obstacle.
- When echoes due to multiple reflection of sound follow so closely behind the original sound that the original sound appears to be prolonged even when the source of source stops to produced sound, then the effect is known as reverberation.
- Reverberation time is the time interval for which the audible sound persists after the production of original sound.
- The audible range of frequency is 20 Hz to 20,000 Hz (or 20 kHz).
- Infrasonic waves are the waves of frequencies less than 20 Hz.
- Ultrasonic waves (or ultrasound) are the waves of frequencies greater than 20,000 Hz (or 20 kHz).
- Human ears cannot hear infrasonic and ultrasonic waves but animals and birds can hear these waves.
- Human ear is a hearing device. It consists of three parts - the external ear, the middle ear and the inner ear.