TEST -8
SOUND

9th book	Unit – 8	Sound
10th book	Unit – 5	Acoustics

SOUND
(Physics)
9th book
Unit – 8 Sound

Introduction

- Sound is a form of energy which produces sensation of hearing in our ears. Some sounds are pleasant to hear and some others are not. But, all sounds are produced by vibrations of substances. These vibrations travel as disturbances in a medium and reach our ears as sound. Human ear can hear only a particular range of frequency of sound that too with a certain range of energy. We are not able to hear sound clearly if it is below certain intensity. The quality of sound also differs from one another. What are the reasons for all these? It is because sound has several qualities. In this lesson we are going to learn about production and propagation of sound along with its various other characteristics. We will also study about ultrasonic waves and their applications in our daily life.

Production of sound

- In your daily life you hear different sounds from different sources. But, have you ever thought how sound is produced? To understand the production of sound, let us do an activity.
- When you strike the tuning fork on the rubber pad, it starts vibrating. These vibrations cause the nearby molecules to vibrate. Thus, vibrations produce sound.

Propagation of Sound Waves

Sound needs a medium for propagation

- Sound needs a material medium like air, water, steel etc., for its propagation. It cannot travel through vacuum. This can be demonstrated by the Bell – Jar experiment.

- An electric bell and an airtight glass jar are taken. The electric bell is suspended inside the airtight jar. The jar is connected to a vacuum pump, as shown in Figure 8.1. If the bell is made to ring, we will be able to hear the sound of the bell. Now, when the jar is evacuated with the vacuum pump, the air in the jar is pumped out gradually and the sound becomes feebler and feebler. We will not hear any sound, if the air is fully removed (if the jar has vacuum).

Sound is a wave

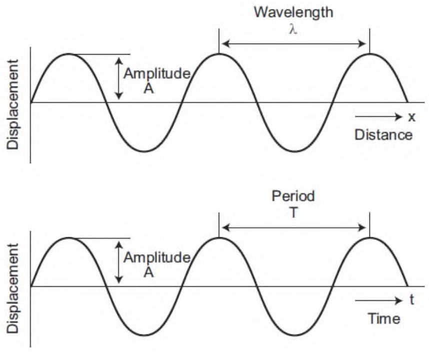
- Sound moves from the point of generation to the ear of the listener through a medium. When an object vibrates, it sets the particles of the medium around to vibrate. But, the vibrating particles do not travel all the way from the vibrating object to the ear. A particle of the medium in contact with the vibrating object is displaced from its equilibrium position. It then exerts a force on an adjacent particle. As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. This process continues in the medium till the sound reaches our ears. It is to be noted that only the disturbance created by a source of sound travels through the medium not the particles of the medium. All the particles of the medium restrict themselves with only a small to and fro motion called vibration which enables the disturbance to be carried forward. This disturbance which is carried forward in a medium is called wave.

Longitudinal nature of sound waves

- From the above activity you can see that in some parts of the coil, the turns are closer together. These are regions of compressions. In between these regions of compressions we have regions where the coil turns are far apart called rarefactions. As the coil oscillates, the compressions and rarefactions move along the coil. The waves that propagates with compressions and rarefactions are called longitudinal waves. In longitudinal waves the particles of the medium move to and fro along the direction of propagation of the wave. Sound also is a longitudinal wave. Sound can travel only when there are particles which can be compressed and rarefied. Compressions are the regions where particles are crowded together. Rarefactions are the regions of low pressure where particles are spread apart. A sound wave is an example of a longitudinal mechanical wave. Figure 8.2 represents the longitudinal nature of sound wave in the medium.

Characteristics of a Sound Wave

- A sound wave can be described completely by five characteristics namely amplitude, frequency, time period, wavelength and velocity or speed.



Amplitude (A)

- The maximum displacement of the particles of the medium from their original undisturbed positions, when a wave passes through the medium is called amplitude of the wave. If the vibration of a particle has large amplitude, the sound will be loud and if the vibration has small amplitude, the sound will be soft. Amplitude is denoted as A. Its SI unit is meter (m).

Frequency (n)

- The number of vibrations (complete waves or cycles) produced in one second is called frequency of the wave. It is denoted as n. The SI unit of frequency is s–1 (or) hertz (Hz). Human ear can hear sound of frequency from 20 Hz to 20,000 Hz. Sound with frequency less than 20 Hz is called infrasonic sound. Sound with frequency greater than 20,000 Hz is called ultrasonic sound. Human beings cannot hear infrasonic and ultrasonic sounds.

Time period (T)

- The time required to produce one complete vibration (wave or cycle) is called time period of the wave. It is denoted as T. The SI unit of time period is second (s). Frequency and time period are reciprocal to each other.

Wavelength (λ)

- The minimum distance in which a sound wave repeats itself is called its wavelength. In a sound wave, the distance between the centers of two consecutive compressions or two consecutive rarefactions is also called wavelength. The wavelength is usually denoted as λ (Greek letter, lambda). The SI unit of wavelength is metre (m).

Velocity or speed (v)

- The distance travelled by the sound wave in one second is called velocity of the sound. The SI unit of velocity of sound is m s–1.

Distinguishing different Sounds

- Sounds can be distinguished from one another in terms of the following three different factors.

1. Loudness
2. Pitch
3. Timbre (or quality)

1. Loudness and Intensity

- Loudness is a quantity by virtue of which a sound can be distinguished from another one, both having the same frequency. Loudness or softness of sound depends on the amplitude of the wave. If we strike a table lightly, we hear a soft sound because we produce a sound wave of less amplitude. If we hit the table hard we hear a louder sound. Loud sound can travel a longer distance as loudness is associated with higher energy. A sound wave spreads out from its source. As it move away from the source its amplitude decreases and thus its loudness decreases. Figure 8.4 shows the wave shapes of a soft and loud sound of the same frequency.

- The loudness of a sound depends on the intensity of sound wave. Intensity is defined as the amount of energy crossing per unit area per unit time perpendicular to the direction of propagation of the wave.

- The intensity of sound heard at a place depends on the following five factors.

    i. Amplitude of the source.
    ii. Distance of the observer from the source.
    iii. Surface area of the source.
    iv. Density of the medium.
    v. Frequency of the source.

- The unit of intensity of sound is decibel (dB). It is named in honour of the Scottish-born scientist Alexander Graham Bell who invented telephone.

2. Pitch

- Pitch is one of the characteristics of sound by which we can distinguish whether a sound is shrill or base. High pitch sound is shrill and low pitch sound is flat. Two music sounds produced by the same instrument with same amplitude, will differ when their vibrations are of different frequencies. Figure 8.6 consists of two waves representing low pitch and high pitch sounds.

3. Timbre or Quality

- Timbre is the characteristic which distinguishes two sounds of same loudness and pitch emitted by two different instruments. A sound of single frequency is called a tone and a collection of tones is called a note. Timbre is then a general term for the distinguishable characteristics of a tone.

Speed of Sound

- The speed of sound is defined as the distance travelled by a sound wave per unit time as it propagates through an elastic medium.

$$\text{speed (v)} = \frac{Distance}{Time}$$

- If the distance traveled by one wave is taken as one wavelength (λ), and the time taken for this propagation is one time period (T), then

$$\text{speed (V)} = \frac{one\ wavelengh\ (\gamma)}{one\ time\ period\ (T)} \quad \text{(or)} \quad v = \frac{\gamma}{T}$$

As, $T = \frac{1}{n}$, the speed (v) of sound is also written as, v = n λ.
The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

Speed of sound in different media

- Sound propagates through a medium at a finite speed. The sound of thunder is heard a little later than the flash of light is seen. So, we can make out that sound travels with a speed which is much less than the speed of light. The speed of sound depends on the properties of the medium through which it travels.

- The speed of sound is less in gaseous medium compared to solid medium. In any medium the speed of sound increases if we increase the temperature of the medium. For example the speed of sound in air is 330 m s–1 at 0 °C and 340 m s–1 at 25 °C. The speed of sound at a particular temperature in various media is listed in Table 8.1.

State	Medium	Speed in m s-1
solids	Aluminum	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass	3980
Liquids	Water	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	340
	Oxygen	316
	Sulphur dioxide	213

Sound travels about 5 times faster in water than in air. Since the speed of sound in sea water is very large (being about 1530 m s-1 which is more than 5500 km / h-1), two whales in the sea which are even hundreds of kilometres away can talk to each other very easily through the sea water.

Reflection of Sound

- Sound bounces off a surface of solid or a liquid medium like a rubber ball that bounces off from a wall. An obstacle of large size which may be polished or rough is needed for the reflection of sound waves. The laws of reflection are:
- The angle in which the sound is incident is equal to the angle in which it is reflected.

- Direction of incident sound, the reflected sound and the normal are in the same plane.

Uses of multiple reflections of sound

Musical instruments

- Megaphones, loud speakers, horns, musical instruments such as nathaswaram, shehnai and trumpets are all designed to send sound in a particular direction without spreading it in all directions. In these instruments, a tube followed by a conical opening reflects sound successively to guide most of the sound waves from the source in the forward direction towards the audience.

Stethoscope

- Stethoscope is a medical instrument used for listening to sounds produced in the body. In stethoscopes, these sounds reach doctor's ears by multiple reflections that happen in the connecting tube.

Echo

- When we shout or clap near a suitable reflecting surface such as a tall building or a mountain, we will hear the same sound again a little later. This sound which we hear is called an echo. The sensation of sound persists in our brain for about 0.1s.

- Hence, to hear a distinct echo the time interval between the original sound and the reflected sound must be at least 0.1s. Let us consider the speed of sound to be 340 m s–1 at 25° C. The sound must go to the obstacle and return to the ear of the listener on reflection after 0.1 s. The total distance covered by the sound from the point of generation to the reflecting surface and back should be at least 340 m s–1 × 0.1 s = 34 m.

- Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance i.e. 17 m. This distance will change with the temperature of air. Echoes may be heard more than once due to successive or multiple reflections. The roaring of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds at different heights and the land.

Reverberation

- A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation. In an auditorium or big hall excessive reverberation is highly undesirable. To reduce reverberation, the roof and walls of the auditorium are generally covered with sound absorbing materials like compressed fiber board, flannel cloths, rough plaster and draperies. The seat materials are also selected on the basis of their sound absorbing properties. There is a separate branch in physics called acoustics which takes these aspects of sound in to account while designing auditoria, opera halls, theaters etc.

Ultrasonic Sound or Ultrasound

- Ultrasonic sound is the term used for sound waves with frequencies greater than 20,000 Hz. These waves cannot be heard by the human ear, but the audible frequency range for other animals includes ultrasound frequencies. For example, dogs can hear ultrasonic sound. Ultrasonic whistles are used in cars to alert deer to oncoming traffic so that they will not leap across the road in front of cars.

- An important use of ultrasound is in examining inner parts of the body. The ultrasonic waves allow different tissues such as organs and bones to be 'seen' or distinguished by bouncing of ultrasonic waves by the objects examined. The waves are detected, analysed and stored in a computer. An echogram is an image obtained by the use of reflected ultrasonic waves. It is used as a medical diagnostic tool. Ultrasonic sound is having application in marine surveying also.

Applications of ultrasonic waves

- Ultrasounds can be used in cleaning technology. Minute foreign particles can be removed from objects placed in a liquid bath through which ultrasound is passed.

- Ultrasounds can also be used to detect cracks and flaws in metal blocks.

- Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called 'echo cardiography'.

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

SONAR

- SONAR stands for sound Navigation and Ranging. Sonar is a device that uses ultrasonic waves to measure the distance, direction and speed of underwater objects. Sonar consists of a transmitter and a detector and is installed at the bottom of boats and ships.

- The transmitter produces and transmits ultrasonic waves. These waves travel through water and after striking the object on the seabed, get reflected back and are sensed by the detector. The detector converts the ultrasonic waves into electrical signals which are appropriately interpreted. The distance of the object that reflected the sound wave can be calculated by knowing the speed of sound in water and the time interval between transmission and reception of the ultrasound.
- Let the time interval between transmission and reception of ultrasound signal be 't'. Then, the speed of sound through sea water is $2d / t = v$

- This method is called echo-ranging. Sonar technique is used to determine the depth of the sea and to locate underwater hills, valleys, submarine, icebergs etc.

Electrocardiogram (ECG)

- The electrocardiogram (ECG) is one of the simplest and oldest cardiac investigations available. It can provide a wealth of useful information and remains an essential part of the assessment of cardiac patients. In ECG, the sound variation produced by heart is converted into electric signals. Thus, an ECG is simply a representation of the electrical activity of the heart muscle as it changes with time. Usually it is printed on paper for easy analysis. The sum of this electrical activity, when amplified and recorded for just a few seconds is known as an ECG.

Structure of Human Ear

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

- 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 ear is eardrum or tympanic membrane. When a compression of the medium reaches the eardrum the pressure on the outside of the membrane increases and forces the eardrum inward. Similarly, the eardrum moves outward when a rarefaction reaches it. In this way the eardrum vibrates. The vibrations are amplified several times by three bones (the hammer, anvil and stirrup) in the middle ear. The middle ear transmits the amplified pressure variations received from the sound wave to the inner ear. In the inner ear, the pressure variations are turned into electrical signals by the cochlea. These electrical signals are sent to the brain via the auditory nerve and the brain interrupts them as sound.

Points to Remember
• Sound is produced due to vibration. • Sound cannot travel through vacuum. • Sound travels as a longitudinal wave through a material medium. • Sound travels as successive compressions and rarefactions in the medium. • In sound propagation, it is the energy of the sound that travels and not the particles of the medium. • The speed (v), frequency (n), and wavelength (λ), of sound are related by the equation, $v = n\lambda$. • The law of reflection of sound: (i) The angle of incidence, the angle of reflection and normal drawn at the point of incidence all lie in the same plane (ii) The angle of incidence (i) and the angle of reflection (r) are always equal. • The speed of sound depends primarily on the nature and the temperature of the transmitting medium. • For hearing distinct echo sound, the time interval between the original sound and the reflected sound must be at least 0.1 s. • The persistence of hearing sound in an auditorium is the result of repeated reflections of sound and is called reverberation. • The amount of sound energy passing each second through unit area is called the intensity of sound. • The audible range of hearing for average human being is in the frequency range of 20 Hz to 20000 Hz • Sound waves with frequencies below audible range are termed as 'Infrasonics' and those above audible range are termed as 'Ultrasonics'. • The SONAR technique is used to determine the depth of the sea and to locate under water hills, valleys, submarines, icebergs, etc.

10th standard

Unit – 5 ACOUSTICS

INTRODUCTION

- Sound plays a major role in our lives. We communicate with each other mainly through sound. In our daily life, we hear a variety of sounds produced by different sources like humans, animals, vehicle horns, etc. Hence, it becomes inevitable to understand how sound is produced, how it is propagated and how you hear the sound from various sources. It is sometimes misinterpreted that acoustics only deals with musical instruments and design of auditoria and concert halls. But, acoustics is a branch of physics that deals with production, transmission, reception, control, and effects of sound. You have studied about propagation and properties of sound waves in IX standard. In this lesson we will study about reflection of sound waves, Echo and Doppler effect.

SOUND WAVES

- When you think about sound, the questions that arise in your minds are: How is sound produced? How does sound reach our ears from various sources? What is sound? Is it a force or energy? Let us answer all these questions.
- By touching a ringing bell or a musical instrument while it is producing music, you can conclude that sound is produced by vibrations. The vibrating bodies produce energy in the form of waves, which are nothing but sound waves

- Suppose you and your friend are on theMoon. Will you be able to hear any sound produced by your friend? As the Moon doesnot have air, you will not be able to hear anysound produced by your friend. Hence, you understand that the sound produced due to the vibration of different bodies needs a material medium like air, water, steel, etc, forits propagation. Hence, sound can propagate through a gaseous medium or a liquid medium or a solid medium.

Longitudinal Waves

- Sound waves are longitudinal waves that can travel through any medium (solids,liquids, gases) with a speed that dependson the properties of the medium. As soundtravels through a medium, the particles of the medium vibrate along the direction of propagation of the wave. This displacement involves the longitudinal displacements of the individual molecules from their mean positions. This results in a series of high and low pressure regions called compressions and rarefactions.

Categories of sound waves based on their frequencies

- (i) Audible waves – These are sound waves with a frequency ranging between 20 Hz and 20,000 Hz. These are generated by vibrating bodies such as vocal cords, stretched strings etc.

- (ii) Infrasonic waves – These are sound waves with a frequency below 20 Hz that cannot be heard by the human ear. e.g., waves produced
during earth quake, ocean waves, sound produced by whales, etc.

- (iii) Ultrasonic waves – These are sound waves with a frequency greater than 20 kHz, Human ear cannot detect these waves, but certain creatures like mosquito, dogs, bats,dolphins can detect these waves. e.g., waves produced by bats.

Difference between the sound and light waves

s.no	sound	light
1	Medium is required for the propagation.	Medium is not required for the propagation.
2	Sound waves are longitudinal.	Light waves are transverse.
3	Wavelength ranges from 1.65 cm to 1.65 m.	Wavelength ranges from 4 × 10–7 m to 7 × 10–7 m.
4	Sound waves travel in air with a speed of about 340 ms–1 at NTP	Light waves travel in air with a speed of 3 × 108 ms–1.

Velocity of sound waves

- When you talk about the velocity associated with any wave, there are two velocities, namely particle velocity and wave velocity. SI unit of velocity is ms-1.

Particle velocity:

- The velocity with which the particles of the medium vibrate in order to transfer the energyin the form of a wave is called particle velocity. Wave velocity:

- The velocity with which the wave travels through the medium is called wave velocity. In other words, the distance travelled by a sound wave in unit time is called the velocity of a sound wave.

∴ Velocity =Distance/Time taken

- If the distance travelled by one wave istaken as one wavelength (λ) and, the time taken for this propagation is one time period (T), then, the expression for velocity can be written as

$$\therefore V = \lambda / T \quad (5.1)$$

- Therefore, velocity can be defined as the distance travelled per second by a sound wave. Since, Frequency (n) =1 / T, equation can be written as

$$V = n\lambda \qquad (5.2)$$

- Velocity of a sound wave is maximum in solids because they are more elastic in nature than liquids and gases. Since, gases are least elastic in nature, the velocity of sound is the least in a gaseous medium.

So, vS > vL > vG

Effect of density:

- The velocity of sound in a gas is inversely proportional to the square root of the density of the gas. Hence, the velocity decreases as the density of the gas increases.

v / √1d

Effect of temperature:

- The velocity of sound in a gas is directly proportional to the square root of its temperature. The velocity of sound in a gas increases with the increase in temperature. $V \propto \sqrt{T}$. Velocity at temperature T is given by the following equation:

vT = (vo + 0.61 T) ms–1

- Here, vo is the velocity of sound in the gas at 0° C. For air, vo = 331 ms–1. Hence, the velocity of sound changes by 0.61 ms–1 when the temperature changes by one degree celsius.

Effect of relative humidity:

- When humidity increases, the speed of sound increases. That is why you can hear sound from long distances clearly during rainy seasons. Speed of sound waves in different media are given in table

s.no	Nature of the medium	Name of the medium	Speed of sound (in ms–1)

1	Solid	Copper	5010
2		Iron	5950
3		Aluminium	6420
4	Liquid	Kerosene	1324
5		Water	1493
6		Sea water	1533
7	Gas	Air	331
8		Air	343

Factors affecting velocity of sound

- In the case of solids, the elastic properties and the density of the solids affect the velocity of sound waves. Elastic property of solids is characterized by their elastic moduli. The speed of sound is directly proportional to the square root of the elastic modulus and inversely proportional to the square root of the density. Thus the velocity of sound in solids decreases as the density increases whereas the velocity of sound increases when the elasticity of the material increases. In the case of gases, the following factors affect the velocity of sound waves.

REFLECTION OF SOUND

- When you speak in an empty room, you hear a soft repetition of your voice. This is nothing but the reflection of the sound waves that you produce. Let us discuss about the reflection of sound in detail through the following activity.When sound waves travel in a given medium and strike the surface of another medium, they can be bounced back into the first medium. This phenomenon is known as reflection. In simple the reflection and refraction of sound is actually similar to the reflection of light. Thus, the bouncing of sound waves from the interface between two media is termed as the reflection of sound. The waves that strike the interface are termed as the incident wave and the waves that bounce back are termed as the reflected waves.

Laws of reflection

- Like light waves, sound waves also obey some fundamental laws of reflection.

The following two laws of reflection are applicable to sound waves as well.

- The incident wave, the normal to the reflecting surface and the reflected wave at the point of incidence lie in the same plane.

- The angle of incidence ∠i is equal to the angle of reflection ∠r.

- The sound waves that travel towards the reflecting surface are called the incident waves. The sound wavesbouncing back from the reflecting surface are called reflected waves.

For all practical purposes, the point of incidence and the point of reflection is the same point on the reflecting surface.

- A perpendicular line drawn at the point of incidence is called the normal. The angle which the incident sound wave makes with the normal is called the angle of incidence, ' i ' . The angle which the reflected wave makes with the normal is called the angle of reflection, ' r ' .

Reflection at the boundary of a denser medium

- A longitudinal wave travels in a medium in the form of compressions and rarefactions. Suppose a compression travelling in air from left to right reaches a rigid wall. The compression exerts a force F on the rigid wall. In turn, the wall exerts an equal and opposite reaction R = – F on the air molecules.

- This results in a compression near the rigid wall Thus, a compression travelling towards the rigid wall is reflected back as a compression. That is the direction of compression is reversed

Reflection at the boundary of a rarer medium

- Consider a wave travelling in a solid medium striking on the interface between the solid and the air. The compression exerts a force F on the surface of the rarer medium. As a rarer medium has smaller resistance for any deformation, the surface of separation is pushed backwards. As the particles of the rarer medium are free to move, a rarefaction is produced at the interface.Thus, a compression is reflected as a rarefaction and a rarefaction travels from right to left.

More to know:
What is meant by rarer and denser medium?
The medium in which the velocity of sound increases compared to other medium is called rarer medium. (Water is rarer compared to air for sound).The medium in which the velocity of sound decreases compared to other medium is called denser medium. (Air is densercompared to water for sound)

Reflection of sound in plane and curved surfaces

- When sound waves are reflected from aplane surface, the reflected waves travel in adirection, according to the law of reflection.The intensity of the reflected wave is neither decreased nor increased. But, when the sound waves are reflected from the curved surfaces,the intensity of the reflected waves is changed.When reflected from a convex surface, the reflected waves are diverged out and the intensity is decreased. When sound is reflected from a concave surface, the reflected waves are converged and focused at a point. So the intensity of reflected waves is concentrated at a point. Parabolic surfaces are used when it is required to focus the sound at a particular point.

- Hence, many halls are designed with parabolic reflecting surfaces. In elliptical surfaces, sound from one focus will always be reflected to the other focus, no matter where it strikes the wall.

- This principle is used in designing whispering halls. In a whispering hall, the speech of a person standing in one focus can be heard clearly by a listener standing at the other focus.

Whispering Gallery One of the famous whispering galleries is in St. Paul ' s cathedral church in London. It is built with elliptically shaped walls. When a person is talking at one focus, his voice can be heard distinctly at the other focus. It is due to the multiple reflections of sound waves from the curved walls.

ECHOES

- An echo is the sound reproduced due to the reflection of the original sound from various rigid surfaces such as walls, ceilings, surfaces of mountains, etc.

- If you shout or clap near a mountain or near a reflecting surface, like a building you can hear the same sound again. The sound, which you hear is called an echo. It is dueto the reflection of sound. One does not experience any echo sound in a small room.This does not mean that sound is not reflected in a small room. This is because smaller rooms do not satisfy the basic conditions for hearing an echo.

Conditions necessary for hearing echo

1. The persistence of hearing for human ears is 0.1 second. This means that you can hear two sound waves clearly, if the time interval between the two sounds is at least 0.1 s. Thus, the minimum time gap
between the original sound and an echo must be 0.1 s.

2. The above criterion can be satisfied only when the distance between the source of sound and the reflecting surface would satisfy the following equation:

Velocity = distance travelled by sound / time taken

$$V = 2d/t$$

$$d = vt/2$$

Since, t = 0.1 second, then $d = v \times 0.1/2 = v/20$

- Thus the minimum distance required to hear an echo is 1/20th part of the magnitude of the velocity of sound in air. If you consider the velocity of sound as 344 ms^{-1},the minimum distance required to hear an echo is 17.2 m.

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Applications of echo

- Some animals communicate with each other over long distances and also locate objects by sending the sound signals and receiving the echo as reflected from the targets.

- The principle of echo is used in obstetric ultrasonography, which is used to create real-time visual images of the developing Embryo or fetus in the mothers uterus.This is a safe testing tool, as it does not useany harmful radiations.

- Echo is used to determine the velocity of sound waves in any medium.

Measuring velocity of sound by echo method Apparatus required:

- A source of sound pulses, a measuring tape, a sound receiver, and a stop watch.

Procedure:

1. Measure the distance ‘d’ between the source of sound pulse and the reflecting surface using the measuring tape.

2. The receiver is also placed adjacent to the source. A sound pulse is emitted by the source.

3. The stopwatch is used to note the time interval between the instant at which the sound pulse is sent and the instant at which the echo is received by the receiver. Note the time interval as ‘t’.

4. Repeat the experiment for three or four times. The average time taken for the given number of pulses is calculated.

Calculation of speed of sound:

- The sound pulse emitted by the source travels a total distance of 2d while travelling from the source to the wall and then back to the receiver. The time taken for this has been observed to be ‘ t ’ . Hence, the speed of soundwave is given by:

Speed of sound =distance travelled/time taken = 2d/t.

APPLICATIONS REFLECTION OF SOUND

Sound board

- These are basically curved surfaces (concave), which are used in auditoria and halls to improve the quality of sound. This board is placed such that the speaker is at the focus of the concave surface. The sound of the speaker is reflected towards the audience thus improving the quality of sound heard by the audience.

Ear trumpet

- Ear trumpet is a hearing aid, which is useful by people who have difficulty in hearing.In this device, one end is wide and the other end is narrow. The sound from the sources fall into the wide end and are reflected by its walls into the narrow part of the device. This helps in concentrating the sound and the sound enters the ear drum with more intensity. This enables a person to hear the sound better.

Mega phone

- A megaphone is a horn-shaped device used to address a small gathering of people. Its one end is wide and the other end is narrow. When a person speaks at the narrow end, the sound of his speech is concentrated by the multiple reflections from the walls of the tube. Thus, his voice can be heard loudly over a long distance.

DOPPLER EFFECT

- The whistle of a fast moving train appears to increase in pitch as it approaches a stationary listener and it appears to decreaseas the train moves away from the listener.

- This apparent change in frequency was first observed and explained by Christian Doppler (1803-1853), an Austrian Mathematician and Physicist. He observed that the frequency of the sound as received by a listener is different from the original frequency produced by the source whenever there is a relative motion between the source and the listener.

- This is known as Doppler effect This relative motion could be due to various possibilities as follows:

(i) The listener moves towards or away from a stationary source
(ii) The source moves towards or away from a stationary listener
(iii) Both source and listener move towards or away from one other
(iv) The medium moves when both source and listener are at rest

- For simplicity of calculation, it is assumed that the medium is at rest. That is the velocityof the medium is zero. Let S and L be the source and the listener moving with velocities vS and vL respectively.

- Consider the case of source and listener moving towards each other (Figure 5.7). As the distance between them decreases, the apparent frequency will be more than the actual source frequency.

- Let n and n' be the frequency of the sound produced by the source and the sound observed by the listener respectively. Then,the expression for the apparent frequency n' is

$$n' = (v + v L / v – vs)n$$

- Here, v is the velocity of sound waves in the given medium. Let us consider different possibilities of motions of the source and the listener. In all such cases, the expression for the apparent frequency

s.no	Position of source and listener	Note	Expression for apparent frequency
1	1.Both source and listener move 2.They move towards each other	a)Distance between source and listener decreases. b)Apparent frequency is more than actual frequency	$n' = (v+vL/v-vs)n$
2	1.Both source and listener move 2.They move away from each other	Distance between source and listener increases. b) Apparent frequency is less than actual frequency. c) vS and vL become opposite to that in case-1.	n'=v-(vL / v+vs)n
3	Both source and listener move They move one behind the other Source follows the listener	a)Apparent frequency depends on the velocities of the source and the listener. b) vS becomes opposite to that in case-2.	$n' =$ $(v – vL / v – vs)n$
4	Both source and listener move They move one behind the other Listener follows the source	a)Apparent frequency depends on the velocities of the source and the listener. b)vS and vL become opposite to that in case-3.	$n' = (v + Vl/v + vs)n$

5	Source at rest Listener moves towards the source	a)Distance between source and listener decreases. b)Apparent frequency is more than actual frequency. c) vS = 0 in case-1.	*n' =(v + vL/v) n*
6	Source at rest Listener moves away from the source	a)Distance between source and listener increases. b)Apparent frequency is less than actual frequency. c) vS = 0 in case-2.	*n' =(v – vL/v) n*
7	Listener at rest Source moves towards the listener	a)Distance between source and listener decreases. b)Apparent frequency is more than actual frequency. c) vL = 0 in case-1.	*n' =(v/v – vs)n*
8	Listener at rest Source moves away from the listener	a) Distance between source and listener increases. b) Apparent frequency is less than actual frequency. c) vL = 0 in case-2.	*n'=(v/v + vs)n*

- Suppose the medium (say wind) is moving with a velocity W in the direction of the propagation of sound. For this case, the velocity of sound, ' v ' should be replaced with (v + W). If the medium moves in a direction opposite to the propagation of sound, then ' v ' should be replaced with (v – W).

Conditions for no Doppler effect

- Under the following circumstances, there will be no Doppler effect and the apparent frequency as heard by the listener will be the same as the source frequency.

(i) When source (S) and listener (L) both areat rest.

(ii) When S and L move in such a way that distance between them remains constant.

(iii) When source S and L are moving in mutually perpendicular directions.

(iv) If the source is situated at the center of the circle along which the listener is moving.

Applications of Doppler effect

(a) To measure the speed of an automobile

- An electromagnetic wave is emitted by a source attached to a police car. The wave is reflected by a moving vehicle, which acts as a moving source. There is a shift in the frequency of the reflected wave. From the frequency shift, the speed of the car can be determined. This helps to track the over speeding vehicles

(b) Tracking a satellite

- The frequency of radio waves emitted bya satellite decreases as the satellite passes away from the Earth. By measuring the change in the frequency of the radio waves, the location

of the satellites is studied.

(c) RADAR (Radio Detection And Ranging)

- In RADAR, radio waves are sent, and the reflected waves are detected by the receiver of the RADAR station. From the frequency change, the speed and location of the aeroplanes and aircrafts are tracked.

(d) SONAR

- In SONAR, by measuring the change in the frequency between the sent signal and received signal, the speed of marine animals and submarines can be determined.

Points to Remember

Wave velocity is the velocity with which the wave travels through the medium.

Velocity of a sound wave is maximum in solids because they are more elastic in nature than liquids and gases. Since gases are least elastic in nature.

Infrasonic waves are sound wave with a frequency below 20 Hz. A human ear cannot hear these waves.

Ultrasonic waves are sound waves with frequency greater than 20 kHz, A human ear cannot detect these waves.

Reflection of sound waves obey the laws of reflection.

when a compression hits the boundary of a rarer medium, it is reflected as a rarefaction.

An echo is the sound reproduced due to the reflection of the original sound wave.

The minimum distance between the source and the reflecting surface should be 17.2 m to hear an echo clearly.

The apparent frequency is the frequency of the sound as heard by the listener.