SOUND

Concepts Covered

- Production of Sound
- Propagation of Sound
- Wave Motion
- Speed of Sound in Different Media
- Characteristics of Sound
- Reflection of Sound
- Echo, Audible Range
- Ultrasound and SONAR
- Human Ear
- Noise and Noise pollution

Introduction

We hear a variety of sounds in our surroundings. The sound of an alarm clock, the barking of dogs, the voice of friends and teachers, sounds made by tabla and harmonium, humming of insects and mosquitoes and the ticking of a clock etc. are some of the common sounds we hear every day.

It is a form of energy that gives us the sensation of hearing. It is one of the modes of communication.
Can you recognize your friends by just listening to them, even without looking at them?

Yes, you can, because the sound (the voice) produced by each one of them has a different characteristic.
Like humans, even animals produce and hear sounds.
How is a sound produced? How does sound travel from one place to another?
Why do we hear different types of sounds? We shall study all these questions in this chapter.

Production of Sound Waves

- Sound is produced by vibrating bodies.
- A vibration is a rapid back-and-forth movement of a body about a mean position.
- A sound wave is produced because of a vibration. Thus, a sound is a vibration that is capable of being heard. We can also call every sound-producing object a vibrating body.

Sound Produced by Musical Instruments

What is music? We find certain sounds to be pleasant and we associate them with music. The sound that is harsh to the ear is called noise.
In a musical sound, there are a number of frequencies present in a definite ratio or in relation to each other.
Broadly, musical instruments are classified into three categories. These are:
(i) Stringed instruments
(ii) Wind instruments
(iii) Percussion instruments

Stringed Instruments [Tantu Vadya]

Stringed instruments have taut strings mounted over specially designed wooden panels which are partially hollow from inside where the air is trapped and it forms an air column. The air column increases the intensity of musical sound due to the resonance. When the strings are plucked or struck or played with a bow, they vibrate to produce a musical sound of some particular frequency.

The pitch of the sound of a musical instrument can be changed by altering its length.

DID YOU KNOW

The Moon has no atmosphere. The space above the atmosphere is also vacuum. If some explosion takes place on moon, sound of the explosion will not be propagated to the earth. So, the sound waves never reach the Earth.

Wind or Reed Instruments [Sushir Vadya]

Wind instruments make use of vibrating air columns. In these instruments, the air is blown either directly or through the reeds. Flute, Shehnai, Bagpipes, and Bugles are some examples of wind instruments.

Percussion or Membrane Instruments [Avanaddhu Vadya]

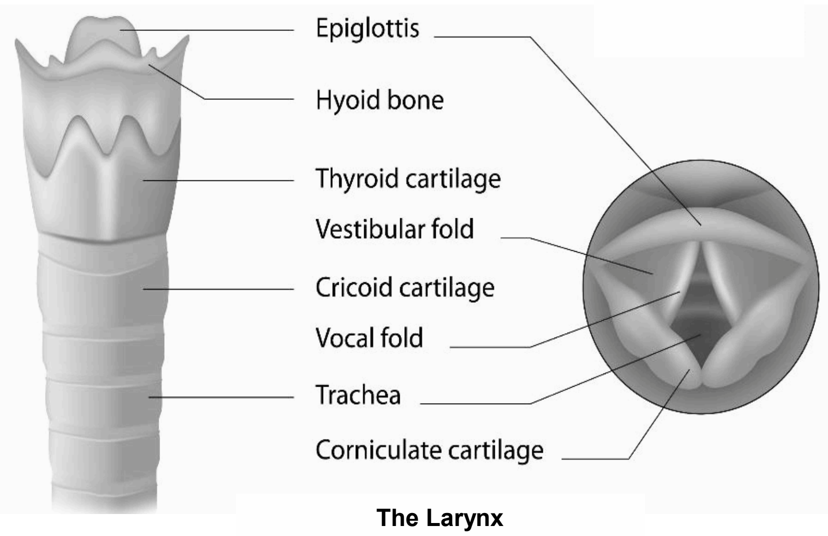
All percussion instruments have a taut skin over a hollow metal or wooden frame. When the skin is struck it produces musical sound. Dholak, Tabla, Mridangam, Drums, etc. are some of the examples of percussion instruments.

Production of Sound in Humans

In the human body larynx is the organ which is responsible for the production of voice. It is also called the voice box, which is located in the throat region of the human body. The different voice modulations produced by human beings cannot be generated, without the functioning of the larynx. Vocal folds in the larynx vibrate as the air reaches the larynx from the windpipe, to produce the sensation of voice.

From the diagram, it is clear that the larynx is a hollow tube, located at the top of the windpipe (trachea) in human beings. Air from the lungs passes through the windpipe to the larynx, and finally, through the mouth, to produce voice in human beings. Here, the larynx controls the amount of air, which passes from the windpipe to the mouth, generating voice modulations. This job is mainly done by vocal cords or vocal folds in the larynx.

They are nothing but soft tissues, which can be seen on either side of the given diagram. As the air reaches the larynx from the trachea, vocal cords start vibrating to produce sounds, which we hear as voices.



The Larynx

The amount of air allowed to pass through the larynx depends on the length of the vocal cords. This can easily be related to the different voices produced among males and females, adults and in children.

Check Your Concept - 1

(i) Sound is produced due to:
(A) vibrations of body (B) air in atmosphere
(C) random motion of body (D) none of these

(ii) Suppose a bell is ringing in a vacuum. Will you be able to hear the sound?

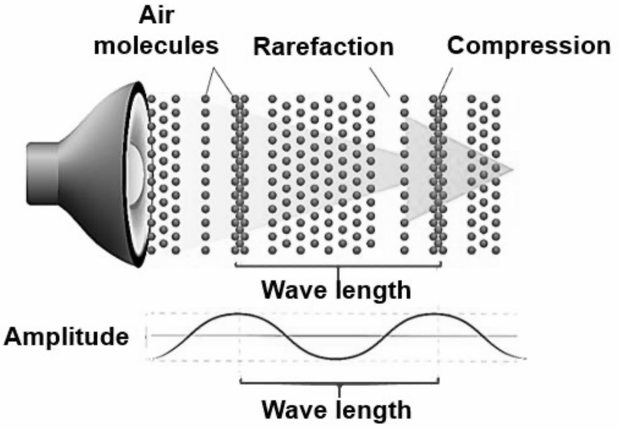
(iii) The voice box is also called as
(A) vocal cords (B) trachea
(C) larynx (D) mouth

Propagation of Sound Waves

Sound waves are longitudinal
We hear the sound when these waves reach our ears. To understand how this happens, let us take the example of a loudspeaker.

When a loudspeaker is switched on, a membrane in the loudspeaker moves backwards and forwards i.e. it vibrates. This causes the air molecules surrounding the loudspeaker to vibrate. If we imagine the air molecules to be like small balls, then sound wave travel through the air, it alternatively compresses (pushed close together) and relaxes (pulled away from each other).

The area where they come together is called compression.



Propagation of sound waves in air

The area where they move away from each other is called rarefaction.

As the sound wave propagates, the molecules themselves do not move from one point to another, they only vibrate about a mean position. It is the effect that propagates and reaches our ears.

Sound needs a medium to travel

Like all mechanical waves, sound too requires a medium to propagate. Sound cannot travel through a vacuum. This can be easily demonstrated by the famous bell jar experiment.

The Speed of Sound Depends upon the following factors:

(1) If the temperature remains constant, the change in pressure has no effect on the velocity of sound in a gas.
(2) Sound travels faster on a hot summer day than on a cold winter day i.e., the velocity of sound varies directly as the square root of the temperature of the gas.
(3) Velocity of sound increases by $0.61 ms^{-1}$ for every one-degree centigrade rise of temperature.
(4) Velocity of sound in a gas is inversely proportional to the square root of the density of the gas.

Notes:
(1) Sound travels four times faster in hydrogen than in oxygen.
(2) Sound travels faster in moist air than in dry air.

Speed of sound is less than the speed of light and so,
(1) Lightning and thunder are produced together, but the flash of lightning is seen well before the thunder is heard.
(2) If a gun is fired at some distance, the flash of light is seen well before the sound is heard.

Wave Motion

Introduction

When a pebble is thrown in a pond of still water, circular ripples called waves or pulses move outward on the surface of the water. These waves are in the form of disturbances that travel outwards and no portion of the medium (water in this case) is transported from one part to another part of the medium. The particles of the medium simply vibrate about their mean positions.

Definition

A wave motion is a means of transferring energy from one point to another without any actual transportation of matter between these points.

Classification of Waves

Depending on the medium required to travel, waves can be classified as:
(1) Mechanical waves

(2) Non-Mechanical or Electromagnetic waves

Mechanical Waves

Those waves which need a material medium (like solid, liquid, or gas) for their propagation, are called mechanical waves or elastic waves.
A mechanical wave cannot travel through a vacuum.

Examples of mechanical waves

(i) Sound waves in air.
(ii) Water waves
(iii) Waves produced in a stretched string.
(iv) Waves produced in spring.

Electromagnetic Waves

Those waves which do not need a material medium (like solid, liquid, or gas) for their propagation and can travel even through a vacuum, are called electromagnetic waves.

Examples of electromagnetic waves

(i) Radio waves
(ii) Infrared waves
(iii) Visible (light) waves

Depending upon the direction of vibration of medium particles, waves are classified as:

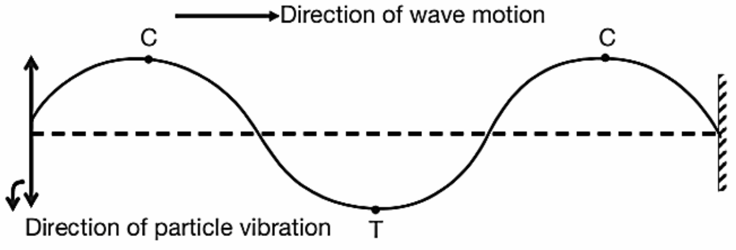
(1) Transverse waves
(2) Longitudinal waves

Transverse Waves

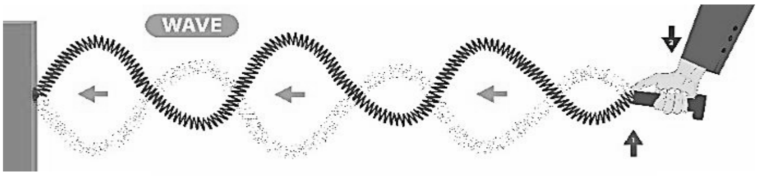
A wave motion in which an individual particle of the medium vibrates in a direction at right angles to the direction of propagation of the wave is called transverse wave motion.

In the case of waves formed over the surface of the water, the individual particles of water oscillate in a direction at right angles to the direction of propagation of the wave as shown in the adjacent figure.

Similarly, if a heavy rope with one of its ends tied to a hook in the wall is stretched along its length and is given an upward and downward jerk at the free end, a wave is seen to travel along the length of the room as shown in the adjacent figure. Every part of the rope vibrates up and down while the wave train travels along the length of the rope.



Transverse wave in string



Transverse Waves in Spring

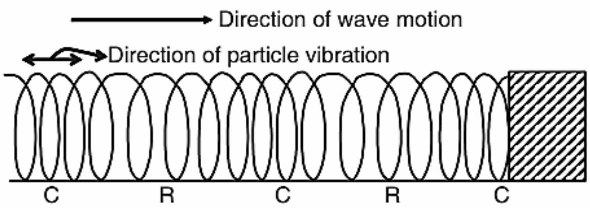
Longitudinal Waves

A wave motion in which the particles of the medium vibrate about their mean position along the direction of propagation of the wave is called longitudinal wave motion. For example, sound waves in air (340 m/s).

When a longitudinal wave travels in a medium, then the particles of the medium vibrate back and forth in the same direction in which the waves travel.

At any instant, there are points in space where pressure or density is maximum, called compression (C) and there are points where pressure or density is minimum called rarefaction (R).

These compressions and rarefactions occur one after the other. From compression to a rarefaction the pressure or density continually varies from a maximum to a minimum.
The figure shows the propagation of a longitudinal wave.

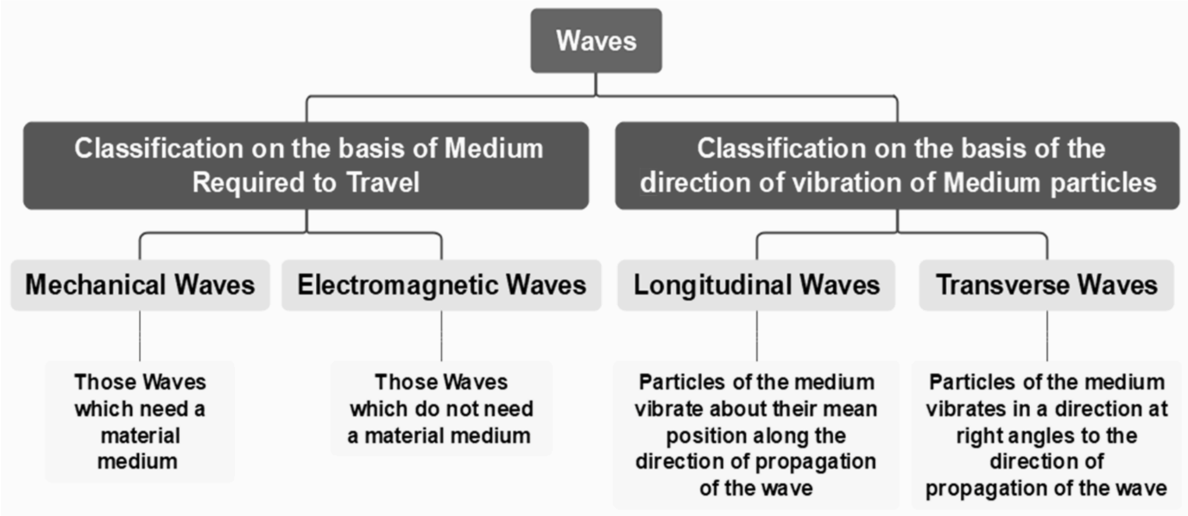


Compressions and Rarefactions in Spring(Longitudinal wave)

DID you KNOW

Dogs hear nearly twice as many frequencies as humans. They can also hear sounds four times further away so, what human ears can hear from 20 feet away our dogs can hear from 80 feet away.

Mind Map



Characteristics of a Wave

Sound waves can be described by its

(i) Wavelength
(ii) Frequency
(iii) Time period
(iv) Amplitude
(v) Speed

(i) Wavelength

The distance between two consecutive compressions (C) or rarefactions (R), or two consecutive crests or troughs, is called the wavelength. Wavelength is the minimum distance in which a sound wave repeats itself.

In other words, it is the combined length of compression and an adjacent rarefaction. It is represented by the Greek letter lambda (λ). Its SI unit is meter (m).

(ii) Frequency

It tells us how frequently an event occurs. The number of complete waves (or oscillations) produced in one second is called the frequency of the wave. It is the number of vibrations that occur per second.

The frequency of a wave is fixed and does not change even when it passes through different substances.
It is denoted by 'f'.

Its SI unit is **hertz (symbol Hz)** named in honour of **Heinrich Rudolf Hertz** who discovered the photoelectric effect.
1 hertz is equal to 1 vibration per second.
$1\ \text{kHz} = 1000\ \text{Hz}$.

(iii) Time Period

The time taken by two consecutive compressions or rarefactions to cross a fixed point is called the time period of the wave. In other words, the time required to produce one complete wave (or oscillation) is called time period of the wave. It is denoted by the symbol T. Its SI unit is second (s).
The time period of a wave is the reciprocal of its frequency, i.e.,

$T = \frac{1}{f}$ or Time period $= \frac{1}{\text{Frequency}}$ or Frequency $= \frac{1}{\text{Time period}}$

(iv) Amplitude

The maximum displacement of the particles of the medium from their original mean positions on passing a wave is called the amplitude of the wave. It is used to describe the size of the wave. It is usually denoted by the letter A. Its SI unit is metre (m). The amplitude of a wave is the same as the amplitude of the vibrating body producing the wave.

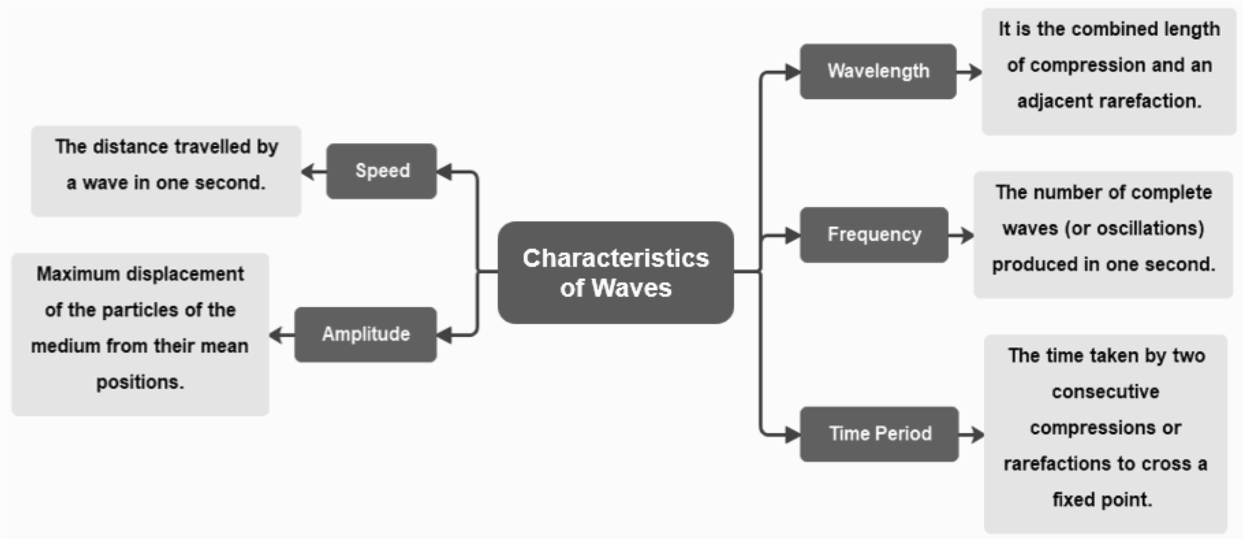
(v) Speed

The distance travelled by a wave in one second is called speed of the wave or velocity of the wave. Under the same physical conditions, the speed of sound remains the same for all frequencies. It is represented by the letter v. Its SI unit is metre per second (m/s or ms^{-1}).

DID you KNOW

Do you know what is louder than a car horn? The cry of a human baby, which is about 115 decibels.

Mind Map



Examples:

(1) A boy heard a sound of frequency $100\ \mathrm{Hz}$ at a distance of $500\ \mathrm{m}$ from the source of sound. What is the time period of oscillating particles of the medium?

Solution: Here, $f = 100\ \mathrm{Hz}$

Using, $T = \frac{1}{f} = \frac{1}{100} = 0.01\ \mathrm{s}$

(2) The sound from a mosquito is produced when it vibrates its wings at an average rate of 500 vibrations per seconds, what is the time period of the vibrations?

Solution: Total vibrations = 500 and Time taken = 1 second

Time taken to complete one vibration = $\frac{1}{500}$ = 0.002 seconds.

So, time period = **0.002 seconds.**

Check Your Concept - 2

(i) Sound cannot propagate in:
(A) Solid (B) Liquid
(C) Vacuum (D) Air

(ii) The correct relation between frequency and time period of a sound wave is
(A) $f = T$ (B) $f = \frac{1}{T}$
(C) $f = T^2$ (D) $v = \sqrt{T}$

(iii) Time period of oscillation is 20 seconds. What is its frequency?

Relationship between Speed, Frequency and Wavelength of a Wave

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

Suppose distance travelled by a wave is λ (wavelength), in time T, then speed is given by,

$$v = \frac{\lambda}{T}$$

We know that, $f = \frac{1}{T}$

Therefore, $v = \lambda \cdot f$ or $v = f\lambda$

or Speed (velocity) = Frequency × Wavelength

Examples:

(1) A bat can hear a sound of frequency $100\ \mathrm{kHz}$. Find the wavelength of the sound wave in air corresponding to this frequency. Given, the speed of sound in air $= 344\ \mathrm{ms}^{-1}$.

Solution: Here, $v = 100\ \mathrm{kHz} = 100 \times 10^3\ \mathrm{Hz} = 10^5\ \mathrm{Hz}$

$v = 344\ \mathrm{ms}^{-1}$

Using, $v = f\lambda$,

we get $\lambda = \frac{v}{f} = \frac{344\ \mathrm{ms}^{-1}}{10^5\ \mathrm{Hz}(\ \mathrm{s}^{-1})} = 344 \times 10^{-5}\ \mathrm{m} = \mathbf{3.44 \times 10^{-3}\ m.}$

(2) The water waves are produced at a frequency of 40 Hz. If the wavelength of these waves is 2.5 cm, calculate the speed of the waves.

Solution: Here, Frequency, $f = 40\ \text{Hz}(\text{or } s^{-1})$

Wavelength, $\lambda = 2.5\ \text{cm} = 0.025\ \text{m}$

Using, $v = f\lambda$, we get

$v = 40\ s^{-1} \times 0.025\ \text{m} = \mathbf{1\ ms^{-1}}$.

Check Your Concept - 3

(i) In a hospital an ultrasonic scanner is used to locate tumours in a tissue. The operating frequency of the scanner is 4.2 MHz the speed of sound in a tissue is 1.7 kms^{-1}. The wavelength of sound in the tissue is approximately. **[NSO 2013]**

(A) 4×10^{-4} m (B) 2×10^{-4} m

(C) 8×10^{-6} m (D) 2×10^{-6} m

(ii) Ships use sound waves to find the vertical distance to the seabed. A pulse of sound waves is sent out and the echoes are detected. A ship emits a pulse of waves lasting 0.50 s. The waves have a frequency of 3600 Hz. How many complete wavelengths does the pulse contain? **[NSO 2012]**

(A) 1800 (B) 3600

(C) 7200 (D) 1800

Speed of Sound and Light in different Mediums

We know that sound can travel through media like solid, liquid and gas (air). It travels at maximum velocity in solids then in liquids and minimum in gases.

$^{s}V_{\text{solid}} > {}^{s}V_{\text{liquid}} > {}^{s}V_{\text{gas}}$

It is noted that light travels maximum in gases/vacuum, then in liquids and minimum in solids.

$^{l}V_{\text{gas}} > {}^{l}V_{\text{liquid}} > {}^{l}V_{\text{solid}}$

$s \rightarrow$ stands for sound and $l \rightarrow$ stands for light

It also depends on

1. Temperature 2. Pressure

Speed of Sound

Sound waves travel at different speeds in different substances. The speed of sound varies with various factors such as temperature, nature of the material, physical state of the substances, etc. For example, the speed of sound in air is about 330 m/s at 0°C and 346 m/s at room temperature. From the table, we can see that sound waves travel the fastest in solids and the slowest in gases.

State	Medium	Speed in m/s
Solids	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass	3980

State	Medium	Speed in m/s
Liquids	Sea Water	1531
	Distilled Water	1498
	Ethanol	1207
	Methanol	1103

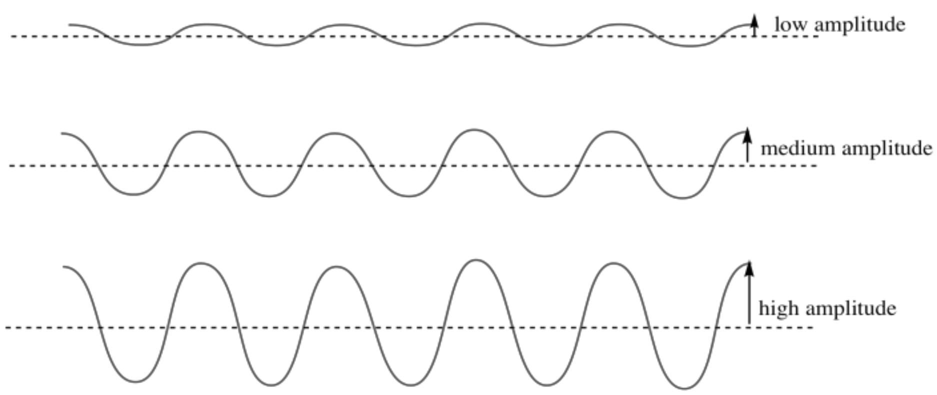
State	Medium	Speed in m/s
Gases	Hydrogen	1284
	Helium	965
	Air	340
	Oxygen	316

Characteristics of Sound

A sound wave has four characteristics which are loudness, pitch, quality (or timbre), and intensity.

(i) Loudness

It is the measure of sound energy reaching our ears per second. The greater the sound energy reaching our ears per second, the louder the sound will appear to be. If the sound waves have a small amplitude, then the sound will be faint or soft but if waves have a large amplitude, then the sound will be loud. The figure shown below shows the wave shapes of a loud and a soft sound of the same frequency.



Since the amplitude of a sound wave is equal to the amplitude of vibrations of the source producing the sound waves, the loudness of sound depends on the amplitude of vibrations of the source producing the sound waves.

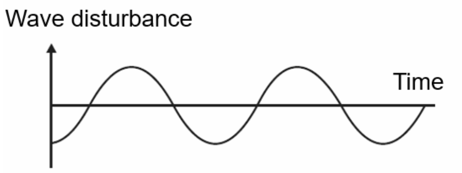
- Loud sound can travel a larger distance as it has higher energy.
- The loudness and amplitude of sound waves decrease as they move away from their source.
- The loudness of sound is measured in **decibels (dB)**.
- It depends on the sensitivity or the response of our ears.

(ii) Pitch or Shrillness

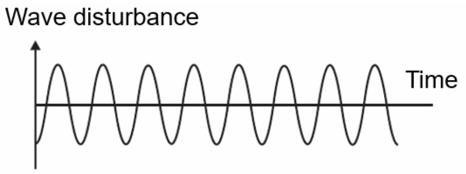
It is that characteristic of sound by which we can distinguish between different sounds of the same loudness. Due to this characteristic, we can distinguish between a man's voice and a woman's voice of the same loudness without seeing them.

The pitch of a sound depends on the frequency of vibration. The greater the frequency of a sound, the higher will be its pitch.

In other words, the faster the vibration of the source, the higher will be the frequency and hence, a higher pitch is produced, as shown in the figure. Thus, a high pitch sound corresponds to more number of compressions and rarefactions passing a fixed point per unit of time.
Objects of different sizes and conditions vibrate at different frequencies to produce sounds of different pitches.



Wave shaped for a low pitched sound



Wave shaped for a high pitched sound

(iii) Quality (or Timbre)

The quality or timbre of the sound is that characteristic of sound that enables us to distinguish one sound from another having the same pitch and loudness.

A pleasant sound is said to be of a rich quality.

- Sound of a single frequency is called a tone.
- Sound produced due to the mixture of several frequencies is called a note and is pleasant in listening too.
- Noise is unpleasant to the ears, and music is pleasant because it is of rich quality.

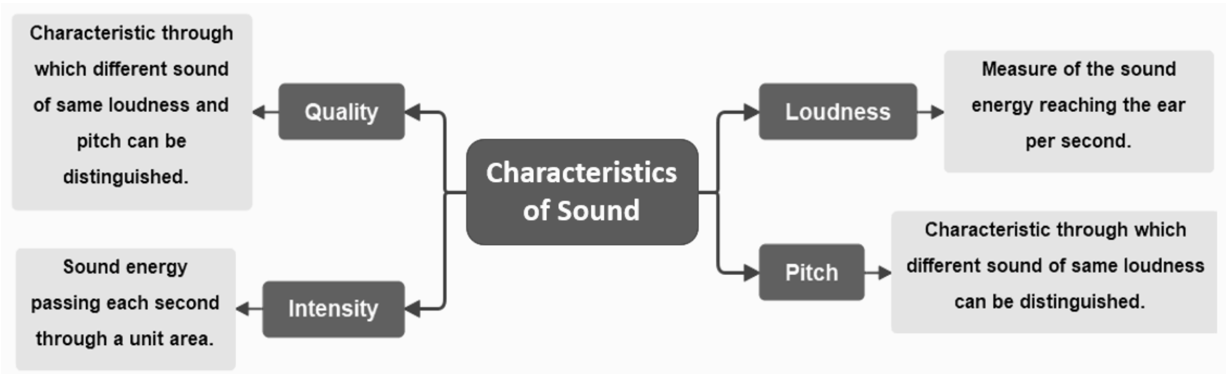
The sound produced by different musical instruments like flute, violin, sitar, tanpura, etc. and similarly sound produced by different singers, like Kumar Sanu, Mohammad Rafi, Udit Narayan, etc. can be distinguished from one another on the basis of their quality or timbre.

The quality of musical instruments depends on:
(a) The shape of the sound wave produced (b) Mixture of frequencies present.

(iv) Intensity

The amount of sound energy passing each second through a unit area is known as the intensity of sound. Loudness and intensity are not the same terms. Loudness is the measure of the response of the ears to the sound. Even when two sounds are of equal intensity, we may hear one as louder than the other, simply because our ears detect it in a better way.
The S.I. unit of intensity is watt per square metre (W/m^2).

Mind Map



Examples:

(1) State the factor that determines.
(i) pitch (ii) loudness (iii) timbre or quality

Answer: (i) Frequency of sound wave determines the pitch of sound.
(ii) Amplitude of the vibrating body determines the loudness of the sound.
(iii) The waveform produced by a vibrating body determines the timbre or quality of sound.

Reflection of Sound

When sound waves strike a surface, they return back into the same medium. This phenomenon is called as reflection of sound.

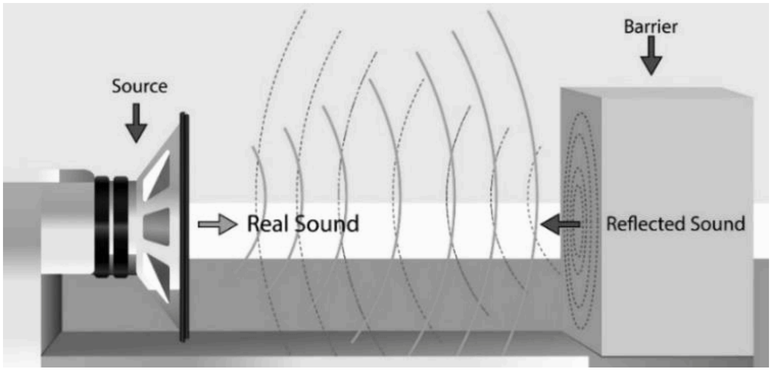
The reflection of sound waves is similar to that of light rays. The only difference is that sound waves being larger in wavelength, require bigger surfaces for reflection.

Laws of Reflection

(i) Angle of incidence is equal to the angle of reflection.
(ii) The incident wave, the reflected wave and the normal, all lie on the same plane.

Echo

Echo is based on the reflection of sound. An echo is defined as repetition of sound due to reflection. There are a number of tourist places where echo points are marked. If you speak something from there loudly, you will hear back your sound after sometime. This is called an echo. In some places, you might listen to a number of echoes one after the other. This is called as multiple echoes.



Production of Echo

There are certain conditions required for an echo to be heard. Before discussing these conditions, we will first talk about the term persistence of sound. The impact of any sound heard by us does not vanish immediately. But a person can't hear two sounds if the time delay between them is less than the minimum required.

It is found by scientists that if the time delay between the sounds is less than 1/10 sec, they are heard as a single sound. Thus, to hear and recognize two different sounds, the time delay must be at least 1/10th of a second. This forms the basis of an important condition required to hear an echo.

Now, let the distance between the observer & obstacle $= d$
Speed of sound (in the medium) $= v$
Time after which echo is heard = t

$\therefore\ t = \frac{2d}{v}$ or $d = \frac{vt}{2}$

Now speed of sound in air at $25\ °C = 344\ m/s$
For echo
$t \geq 0.1\ s$

$$\therefore\ \frac{2\ d}{v} = 0.1$$

$$d \geq \frac{0.1 \times v}{2} \Rightarrow d \geq \frac{0.1 \times 344}{2} \Rightarrow\ d\ \geq 17.2\ m$$

Therefore, a minimum distance between the observer & the obstacle for the echo to be heard clearly should be 17.2 m.

DID you KNOW

Light travels at 186,000 miles per second, whilst sound travels at 770 miles per hour.

Types of Echo

It is of three types:
(a) Instantaneous echo (b) Syllabic echo (c) Successive echo

(a) Instantaneous Echo: The echo of the sound of short duration (like clap, pistol shot) is called instantaneous echo. It is found that the sensation of any sound persists for $\frac{1}{10}$ to $\frac{1}{20}$ seconds in our ear, after it, the existing sound dies off. This time is called persistence of sound or persistence of hearing. It varies from person to person and also with the frequency of sound. We will use $\frac{1}{15}$ second as a typical interval needed to distinguish two sounds.

(b) Syllabic Echo: The echo of syllables of spoken words is called syllabic echo. This echo is clear when the sound of the last syllable of speech is reflected from an obstacle at least 22 m away so that sound takes at least $\left(\frac{2}{15}\right)^{th}$ second during which the last syllable is compactly spoken.

(c) Successive Echo: This echo is heard when sound is produced between two distant parallel rows of tall buildings or hills. Several echoes are heard successively due to the multiple reflections. This echo is heard only in the vast open field.

Relation between Speed of Sound, Time of hearing Echo and distance of Reflecting Body

If t is the time at which an echo is heard, d is the distance between the source of sound and the reflecting body and v is the speed of sound. The total distance travelled by the sound wave is $2d$.

Speed of sound, $\mathbf{v = \frac{2d}{t}}$ or $\mathbf{d = \frac{vt}{2}}$

(a) Calculation of Minimum distance to hear an Echo

Let d be the minimum distance required for hearing an echo when persistence of hearing is $\frac{1}{10}$ second.

The velocity of sound (at room temperature) is $340\ m/s$.

So, $d = \frac{vt}{2} = \frac{340}{2} \times \frac{1}{10} = \frac{34}{2}$

$d = 17$ metre (approx).

∴ 17 metre is the minimum distance of hearing an echo.

(b) Conditions for formation of an Echo

(i) The minimum distance between the source of sound and the reflecting body should be 17 metres.
(ii) The wavelength of the sound should be less than the height of the reflecting body.
(iii) The intensity of sound should be sufficient enough that it can be heard after reflection.

Examples:

(1) When a sound is reflected from a distant object, an echo is produced. Let the distance of the reflecting surface and the source of sound production remain the same. Do you hear an echo sound on a hotter day?

Solution: Let d = distance between the reflecting surface and the source of sound and v = speed of sound in air.

∴ The echo will be heard after time, t = $\frac{2d}{v}$

On a hotter day, the speed of sound increases with an increase in temperature.
Hence, the time after which an echo is heard decreases.
If the time taken by the reflected sound is less than 0.1 s after the production of the original sound, then echo is not heard.
However, if this time is greater than 0.1 s, then echo will be heard.

(2) A person clapped his hands near a cliff and heard the echo after $5\ s$. What is the distance of the cliff from the person if the speed of sound is $346\ m\ s^{-1}$?

Solution: Here $t = 5\ s, v = 346\ m\ s^{-1}$.

Time $= 2$ s since sound has to go, get reflected and come back the same distance

$\therefore\ S = \frac{tv}{2} = \frac{5 \times 346}{2} = \mathbf{865\ m}$

(3) A ship sends out an ultrasound that returns from the sea bed and is detected after $3.42\ s$. If the speed of ultrasound through seawater is $1531\ m\ s^{-1}$. What is the distance of the sea bed from the ship?

Solution: Here $v = 1531\ m\ s^{-1}; t = 3.42\ s; S =$ distance

Since $t = \frac{2S}{v}$

$\therefore\ S = \frac{vt}{2} = \frac{1531 \times 3.42}{2} = \mathbf{2618.01\ m}$

Check Your Concept - 4

(i) Echo can be heard clearly if the minimum distance between the source of sound and the reflecting surface is:
(A) 10 m (B) 12 m
(C) 15.2 m (D) 17.2 m

(ii) During summer, an echo is heard:
(A) Sooner than during winter (B) Later than during winter
(C) After same time as in winter (D) Rarely

(iii) A sound is played on a flute. A sound of same pitch is played on a trumpet, then the frequency and speed of two sound waves respectively at the same place are:
(A) Different, different (B) Same, same
(C) Different, same (D) Same, different

(iv) A boy dropped a stone in a well 45 m deep. If speed of sound is 340 ms^{-1}, then after how much time will he hear the splash? (Take g = 10 ms^{-2}).
(A) 1.13 s (B) 2.13 s
(C) 3.13 s (D) 4.13 s

Reverberation

The phenomenon of persistence of prolongation of sound after the source has stopped producing is called reverberation. The time for which sound persists until it becomes inaudible is called reverberation time.

OR

The repeated reflection that results in the persistence of sound in large hall is called reverberation. In the case of sharp sounds, reverberation time is counted from the instant of the production of sound. In the case of a continuous note, reverberation time is counted from the instant the source stops producing sound.

In an auditorium or a big hall, reverberation is undesirable. Therefore, to reduce reverberation, the roof and the walls of the hall are covered with sound-absorbing material for example - curtains are also used to absorb sound.

Applications of Reflection of Sound

(i) Megaphone or Speaking tube

When we have to call someone at a far-off distance (say 100 m), we cup our hands and call the person with the maximum sound we can produce. The hands prevent the sound energy from spreading in all directions. In the same way, people use horn-shaped metal tubes, commonly called megaphones. The loudspeakers have horn-shaped openings. In these devices, the sound energy is prevented from spreading out by successive reflections from the horn-shaped tubes.

Mega phone

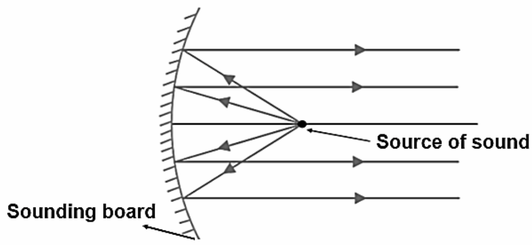
(ii) Stethoscope

It is an instrument used by doctors to listen to the sound produced within the body, empirically in the heart and lungs. In the stethoscope, the sound produced within the body of a patient is picked up by a sensitive diaphragm and then reaches the doctor's ears after multiple reflections.

Multiple reflection in the Stethoscope

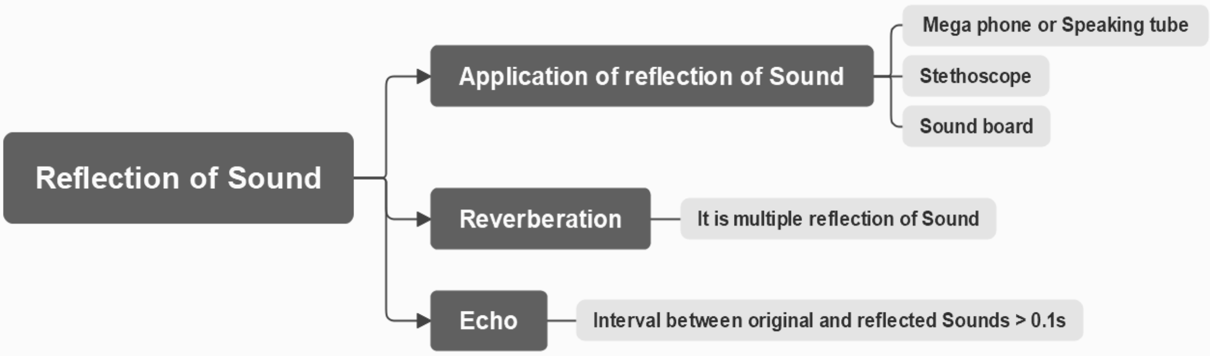
(iii) Soundboard

The soundwaves obey the laws of reflection on the plane as well as curved reflecting surfaces. To spread sound evenly in big halls or auditoriums, the speaker (S) is fixed at the principal focus of the concave reflector. This concave reflector is commonly called a sounding board. The soundwaves striking the soundboard get reflected parallel to the principal axis.



Ideal position of source of Sound

Mind Map



Audible and Inaudible Sounds

Infrasound < 20 Hz - 20000 Hz < Ultrasound **Audible range**

DID you KNOW

The loudest natural sound on earth is caused by an erupting volcano.

(a) Audible Wave: The human ear is sensitive to sound waves of frequency between 20 Hz to 20 kHz. This range is known as the audible range and the waves associated in this range are known as audible waves.
Example: Waves produced by vibrating sitar, guitar, organ pipes, flutes, shehnai etc.

(b) Ultrasonic Wave: A longitudinal wave whose frequency is above the upper limit of audible range i.e. 20 kHz, is called an ultrasonic wave. It is generated by very small sources.

(c) Infrasonic Wave: A longitudinal elastic wave whose frequency is below the audible range i.e. 20Hz, is called an infrasonic wave. It is generally generated by a large source.
Example: Earthquake

Ultrasound

Sound of very high frequency (greater than 20 kHz) is called ultrasound.

(a) Production: These are produced by an electronic oscillator using high-frequency vibrations of quartz crystal.

(b) Properties: Sound waves of all frequencies carry energy with them. With an increase in frequency vibration becomes faster and also energy contents and force increases.
When ultrasound travels in solid, liquid and gas it subjects the particles of matter to face large amount of force and energy.

Application of Ultrasound

Detecting Cracks in Metal Blocks

Metal blocks are used in building bridges, machines etc. Sometimes, these metal blocks look fine from outside but may have cracks inside. To detect it, ultrasound waves are passed. If there is no defect, these ultrasound waves pass through them and are detected by detectors but if there is a defect, these waves reflect back (and hence are not detected by detector).

Detecting Cracks in Metal Blocks

Echocardiography (ECG)

- It is used to check heart ailments in patients.
- Ultrasound waves are transmitted to the heart. These waves are reflected back thus, forming images of the heart. This is called echocardiography.

ECG

DID you KNOW

Detecting small cracks in a material using ultrasound is one of the methods in 'Non-destructive testing', since there is no harm caused to material in this test.

Ultrasound Scanners

Doctors use these ultrasound scanners to get an image of internal organs of the human body. These waves fall on organs and reflect back where there is a change in tissue density. This helps in finding image of different organs. They are also used to see foetus (unborn baby) during pregnancy.

Application of Ultrasound Scanners in Medical field

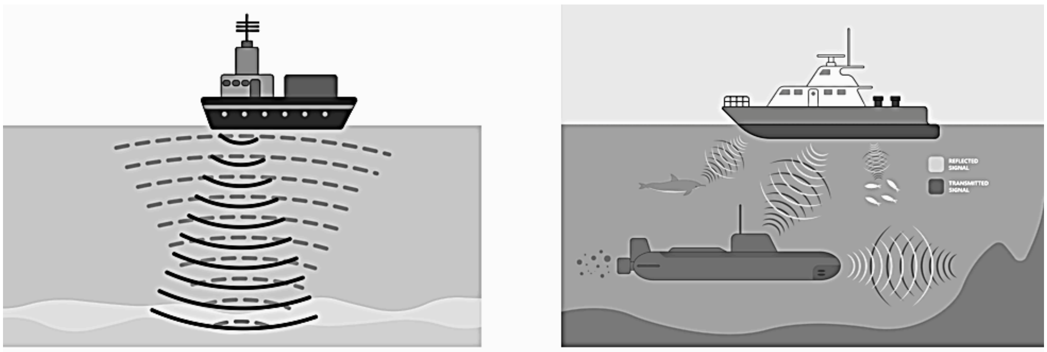
SONAR

The word 'SONAR' stands for 'Sound Navigation and Ranging'.

(a) Principle of SONAR

Sonar is an apparatus which is used to find the depth of a sea or to locate underwater things like shoals of fish, enemy submarines etc. Sonar works by sending short bursts of ultrasonic sound from a ship down into seawater and then picking up the echo produced by the reflection of ultrasonic sound from the underwater objects.

(b) Working of SONAR



Detecting underwater bodies using SONAR

A SONAR apparatus consists of two parts:
(i) A transmitter (for emitting ultrasonic waves).
(ii) A receiver (for detecting ultrasonic waves).

Now suppose a SONAR device is attached to the bottom of a ship and we want to measure the depth of the sea (below the ship). To do this, the transmitter of sonar is made to emit a pulse of ultrasonic sound with a very high frequency of about 50,000 hertz. This pulse of ultrasonic sound travels down in the seawater towards the bottom of the sea. When the ultrasonic sound pulse strikes the bottom of the sea, it is reflected back to the ship in the form of an echo.

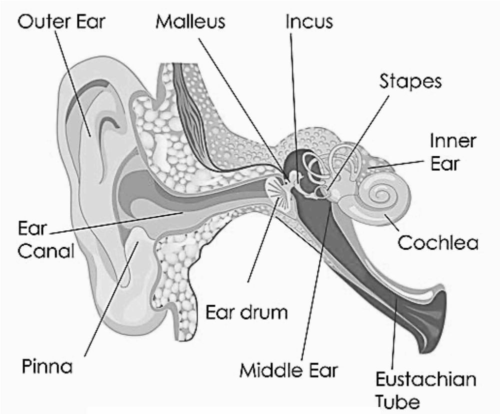
$$\textbf{Depth of sea} = \frac{\textbf{Velocity of sound in sea water} \times \textbf{time recorded by the recorder}}{\textbf{2}} \Rightarrow \mathbf{d} = \frac{\mathbf{v \times t}}{\mathbf{2}}$$

This echo produces an electrical signal in the receiver part of the sonar device. The sonar device measures the time taken by the ultrasonic sound pulse to travel from the ship to the bottom of the sea and back to the ship. Half of this time gives the time taken by the ultrasonic sound to travel from the ship to the bottom of the sea.

Human Ear

The ear is the sense organ which helps us in hearing sound. So, we hear through our ears.

- The shape of the outer part of the ear is like a funnel and is called Pinna. It is attached to about 2 to 3 centimeter long passage called Ear Canal.
- At the end of ear canal a thin, elastic and circular membrane called an eardrum is stretched tightly.
- There are three small and delicate bones called hammer, anvil and stirrup in the middle part of the ear which are linked to one another.
- One end of hammer touches the eardrum and its other end is connected to the second bone anvil.
  The other end of anvil is connected to the third bone called stirrup. And the free end of stirrup touches the membrane over the oval window.

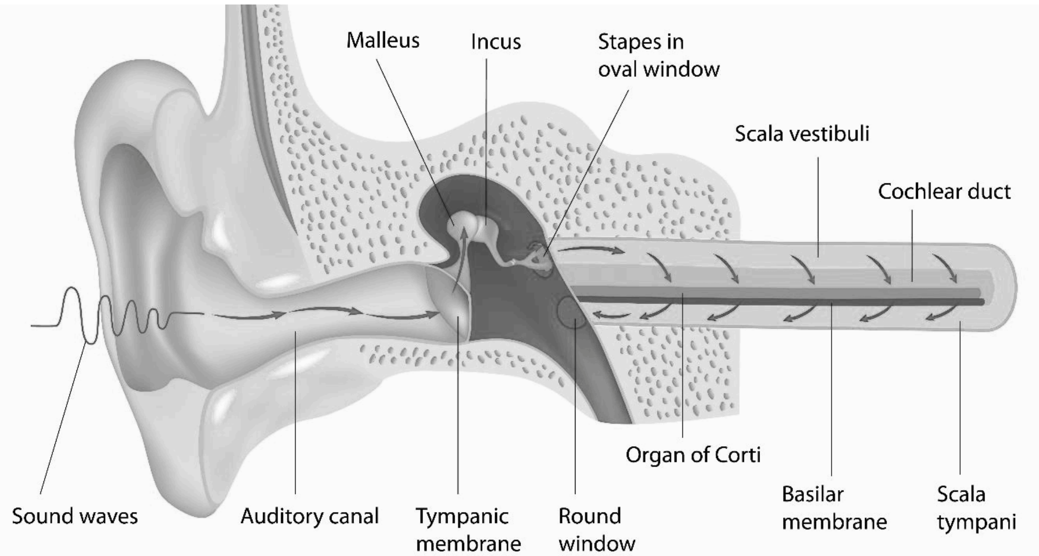


Human Ear

- The inner part of the ear has a coiled tube called cochlea.
  One end of cochlea is connected to the middle part of the ear through the elastic membrane over the oval window. Cochlea is filled with liquid. The liquid present in cochlea contains nerve cells which are sensitive to sound. The other end of cochlea is connected to auditory nerve which goes into the brain. The three tiny bones in the middle part of the ear act as a system of levers and amplify sound vibrations coming from the eardrum before passing them on to the inner part of the ear.

Working of Ear

The sound waves are collected by the pinna of outer part of the ear. These sound waves pass through the ear canal and fall on the ear drum. When the sound waves fall on the eardrum, the eardrum starts vibrating back and forth rapidly. The vibrating eardrum causes a small bone (hammer) to vibrate. From the hammer, vibrations are passed on to the second bone (anvil) and then to the third bone (stirrup). The vibrating stirrup strikes on the membrane of oval window and passes the amplified vibrations to the liquid cochlea. Due to this, liquid in cochlea begins to vibrate. The vibrating liquid of cochlea sets up electrical impulses in the nerve cells present in it. These electrical impulses are carried by the auditory nerve to the brain. The brain interprets these electrical impulses as sound and we get the sensation of hearing. We should not put anything inside ear because they can tear eardrum. The tearing of an eardrum can make a person deaf. Our ears are very delicate organs.



Check Your Concept - 5

(i) The audible range of hearing is:
(A) > 20 Hz (B) < 20 Hz
(C) > 20000 Hz (D) 50 kHz

(ii) Pitch of sound is determined by its
(A) frequency (B) speed
(C) amplitude (D) loudness

(iii) Sonali heard the sound of a thunderbolt 10 second after she saw a flash of lightning. How far is she from the place where lightning occurs? (speed of sound = 330 m/s)

Noise Pollution

The disturbance produced in the environment by undesirable, loud and harsh sound from various sources is called noise pollution. Noise pollution is a recent phenomenon of the twentieth century. Increasing dependence of man on various kinds of machines at home or workplace of factories etc. has contributed to a lot noise pollution.

Noise Pollution

Noise pollution is determined by the following factors:
1. Loudness of the sound.
2. Duration of noise at a particular place.

Harmful effects of Noise Pollution

The harmful effects of noise pollution are as follows:
1. Noise in the surroundings interfere with speech and conversation with another person.
2. A long exposure to noise pollution may result in the loss of hearing or deafness.
3. Noise pollution reduces concentration and results in loss of work efficiency.
4. Noise causes anger, tension and interferes with the sleep pattern of individuals.
5. Noise produces headaches, irritability and nervous tension.
6. Noise can cause loss of night vision as well as colour blindness.

Prevention and Control of Noise

In modern society, we cannot eliminate noise, but can lower down its level to bearable limits by taking following measures:
1. Machines should be designed in such a way that they produce minimum noise.
2. All automobiles, electric generators, etc. should be provided with improved and modified silencers.
3. Heavy vehicles should not be allowed in residential areas.
4. Use of loudspeakers for various social or religious functions should be banned.
5. Factories should be relocated far away from the residential areas.
6. At homes, the television, the radio, and the power music system should be played at a lower volume.

FILL IN THE BLANKS

(1) A rapid back and forth movement of a body about a central position is called a ______.
(2) Sound waves travel in air through ______ and ______.
(3) When we touch a source of sound, we can feel the ______.
(4) Sound is produced when a body is in a state of ____________.
(5) A sound of frequency less than 20 Hz is called ____ sound.
(6) The ______ collects sound waves and directs them to the ear tube.
(7) Compression and rarefaction is formed in ___________.
(8) Time taken by an object to complete one oscillation is called ______.
(9) Loudness is determined by the ______ of vibration.
(10) The unit of frequency is ______.

TRUE OR FALSE

(1) All human beings can hear sounds of frequencies up to 60,000 Hz.
(2) The sound in a sitar is produced by plucking its strings.
(3) Sound cannot travel through vacuum.
(4) Sound does not need a medium for its propagation.
(5) The loudness is expressed in a unit called decibel.
(6) Loud sounds have high frequencies.
(7) Sound travels faster in air, slower in iron.
(8) Light travels much faster than sound.
(9) Man cannot hear the sound of bats.
(10) The time taken to complete one oscillation is called frequency.

OBJECTIVE TYPE QUESTIONS

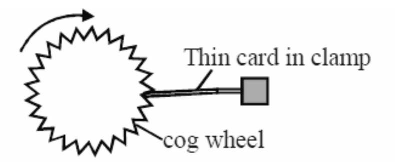
(1) A boy stands between two vertical walls. After making a loud clap, he hears two echoes at an interval of 1 s. If the distance between the two walls is 1000m, what is his distance from the nearest wall?
(A) 425m (B) 215m **[NSO 2014]**
(C) 265 m (D) 365m

(2) Which of the following statement is/are correct? **[NSO 2012]**
(i)The distance between two consecutive compressions is called frequency of sound wave.
(ii) Sound propagates as pressure variations.
(iii) Compressions are narrower in a high-pitched sound.
(A) (i) only (B) (ii) only
(C) (iii) only (D) (ii) and (ii)

(3) Large amplitude of sound vibrations will produce:
(A) Loud sound (B) Weak sound
(C) Slow sound (D) Shreak.

(4) A sonic 'tape measure' is used to measure the length of a room. It measures a time interval of 0.06 s between transmitting a sound pulse and receiving the echo. The speed of sound in air is 300m/s. How far is the reflecting wall from the tape measure? **[NSO 2011]**
(A) 5.5m (B) 9.9m
(C) 11m (D) 20m

(5) A piece of thin card is held against the teeth of a cog wheel. When the wheel is turned at high speed, a note is heard. How can the pitch of the note be raised? **[NSO 2012]**



(A) By pressing the card against the teeth with a greater force.
(B) By turning the wheel more quickly.
(C) By using a thicker card.
(D) By using a wheel with fewer teeth.

(6) The properties of ultrasound that make it useful are
(A) high power and high speed
(B) good directionality and high power
(C) high speed and frequency
(D) good directionality and ability to move around objects

(7) In a sound wave, the direction of propagation is:
(A) in the direction of the vibrations of the vibrating body
(B) opposite to the direction of vibrations of vibrating body
(C) perpendicular to the direction of vibrations of the vibrating body
(D) at an angle of 60° to the direction of vibrations of the vibrating body

(8) The frequency of ultrasonic waves lies in the same range as that of radio frequency waves. However
(A) the ultrasonic waves are mechanical and longitudinal in nature.
(B) the ultrasonic waves are transverse and electromagnetic.
(C) the ultrasonic waves are longitudinal and electromagnetic in nature.
(D) nature of both is similar.

(9) When longitudinal wave propagates through a medium then the physical quantities propagating in the direction of wave are:
(A) Energy
(B) Energy. Momentum and mass
(C) Energy and mass
(D) Energy and momentum

(10) Which of the following statement is correct?
(A) In air the waves of light and sound are longitudinal.
(B) In air the waves of light and sound are transverse.
(C) In air the sound waves are transverse and the light waves are longitudinal.
(D) In air the sound waves are longitudinal and the light waves are transverse.

(11) Infrasonic frequency range is:
(A) below 20 Hz
(B) 20 Hz to 20 kHz
(C) above 20 kHz
(D) no limit

(12) Hertz stands for
(A) second
(B) $second^{-1}$
(C) metre
(D) $metre^{-1}$

(13) Time period of a sound wave having the wavelength 0.2 m and frequency 10Hz will be:
(A) 2 s
(B) 0.2 s
(C) 0.1 s
(D) 0.02 s

(14) A sound wave passes from a medium A to a medium B. The velocity of sound B is greater than that in A. Assume that there is no absorption or reflection of the boundary. As the wave moves across the boundary, the ______. **[NSO 2012]**
(A) Frequency of sound will increase
(B) Wavelength of sound will increase
(C) Wavelength of sound will decrease
(D) intensity of sound will increase

(15) The speeds of sound in air and sea-water are given to be 340m/s and 1440m/s. resp. A ship sends a strong signal straight down and detects its echo after 1.5 secs. The depth of sea at that point is: **[Delhi/ NTSE Stage-I/2013]**
(A) 2.16 kms
(B) 1.08 kms
(C) 0.51 kms
(D) 0.255 kms

(16) When we say 'sound travels in a medium', we mean
(A) the particles of the medium travel
(B) the source travels
(C) the disturbance travels
(D) the medium travels

(17) A thunder clap is heard 5.5 second after the lightning flash. The distance of the flash is: (speed of sound in air is 340 m/s)
(A) 1780 m
(B) 1870 m
(C) 300 m
(D) 3560 m

(18) A source produces 50 crests and 50 troughs in 0.5 s. What is the frequency of the wave?
(A) 100 Hz
(B) 150 Hz
(C) 50 Hz
(D) 125 Hz

(19) The wavelength of sound in air is 5 cm. Its frequency is (Take velocity of sound = 330 m/s):
(A) 6.6 kilo cycles per second
(B) 660 cycles per second
(C) 6.6 mega cycles per second
(D) 6×10^9 cycles per second

Answer Key

CHECK YOUR CONCEPT

(1)	**(i)** (A) Vibrations	**(ii)** No	**(iii)** (C) larynx
(2)	**(i)** (C) Vacuum	**(ii)** (B) f = 1/T	**(iii)** 0.05 Hz.
(3)	**(i)** (A) 4×10^{-4} m	**(ii)** (A) 1800	
(4)	**(i)** (D) 17.2 m	**(ii)** (A) Sooner than during winter	
	(iii) (B) Same, same	**(iv)** (C) 3.13 s	
(5)	**(i)** (A) > 20 Hz	**(ii)** (A) frequency	**(iii)** 3300 m or 3.3 km

FILL IN THE BLANKS

(1) Vibration
(2) Compressions and Rarefaction
(3) Vibrations
(4) Vibrations
(5) Infrasonic
(6) Pinna
(7) Longitudinal wave
(8) time period
(9) amplitude
(10) hertz

TRUE OR FALSE

(1) False
(2) True
(3) True
(4) False
(5) True
(6) False
(7) False
(8) True
(9) True
(10) False

OBJECTIVE TYPE QUESTIONS

(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
(A)	(D)	(A)	(C)	(B)	(B)	(B)	(C)	(A)	(D)
(11)	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**	**(19)**	**(20)**
(A)	(B)	(C)	(B)	(B)	(C)	(B)	(A)	(A)	(C)

VERY SHORT ANSWER TYPE QUESTIONS

(2) 1/6

LONG ANSWER TYPE QUESTIONS

(2) 1.65 km
(3) 0.0025 s
(4) 330 m/s
(6) 0.9 s
(8) 1.2 s, 0.83 Hz
(9) 477 Hz