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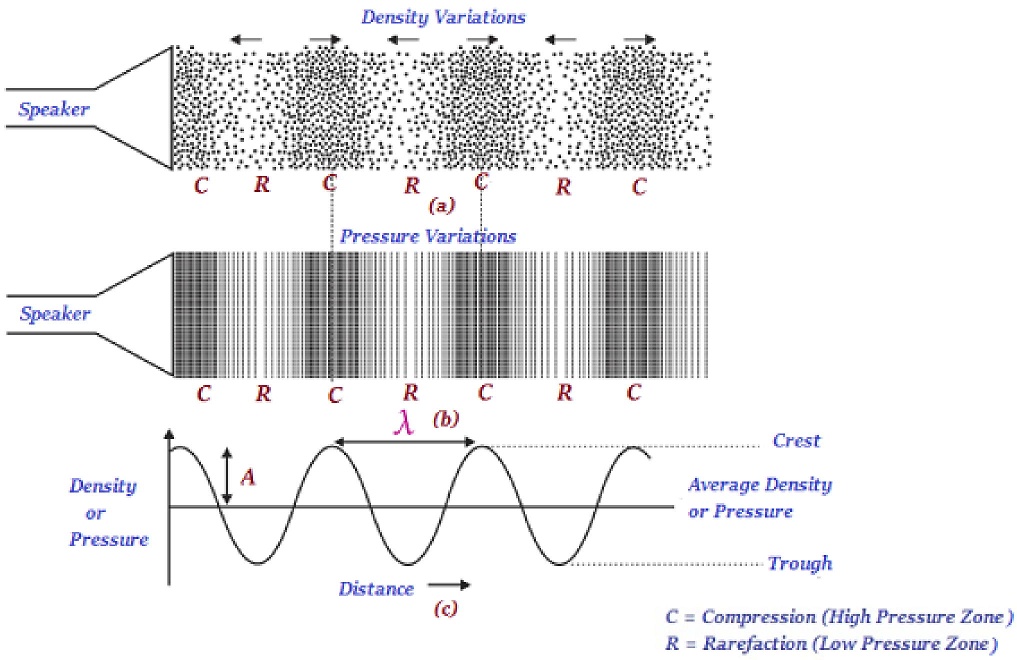
SOUND

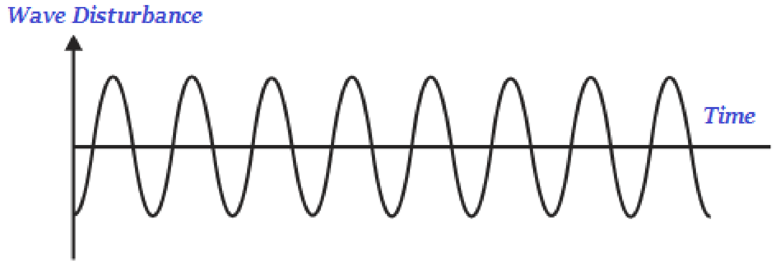
- Sound is a form of energy which produces a sensation of hearing in our ears. There are also other forms of energy like mechanical energy, light energy, etc.
- Sound is produced due to vibration of different objects.
- Sound waves are **longitudinal mechanical** waves.
- Sound waves are characterized by the motion of particles in the medium and are called mechanical waves.
- The sound of the human voice is produced due to vibrations in the vocal cords.
- The eardrum senses the vibrations of sound it sends the signals to the brain. This process is called hearing.
- The outer ear is called pinna; it collects the sound from the surroundings.
- The matter or substance through which sound is transmitted is called a medium. It can be solid, liquid or gas.
- Sound waves are typically characterized by the motion/vibration of particles in the medium and hence known as **mechanical waves**.
- Sound waves oscillate back and forth on their position; hence, they are known as **longitudinal waves**.

Propagation of Sound

- The substance or object through which sound is transmitted is known as **medium**.
- Sound moves through a medium from the point of the generation to the listener; the sound medium could be solid, liquid, or gas.
- However, sound cannot travel through a vacuum medium.
- The particles of gas, liquid, or solid do not travel all the way from the vibrating object to the ear, but rather when the object vibrates, it sets the particles of the medium around it vibrating and so on and so forth.
- In other words, the particles of the medium do not travel/move forward, but rather the disturbance is carried forward through one vibrating particle to another.
- When vibrating particles move forward, they push and compress the air in front of it and create a region of high pressure known as **compression.**

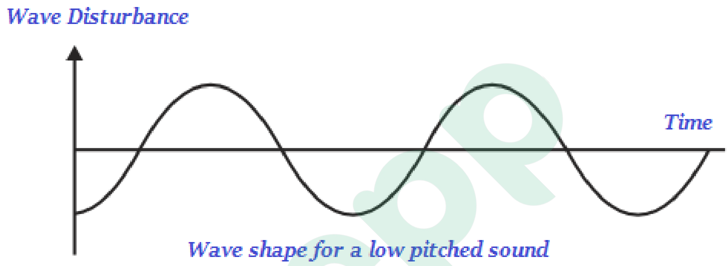


- Further, when the vibrating particles move backwards, it creates a region of low pressure known as **rarefaction** R.
- As the particles move back and forth rapidly, a series of compressions (high pressure zone) and rarefactions (low pressure zone) is created in the air; likewise, the sound wave propagates through the medium.
- As shown in the image given above, the lower portion valley of the curve is known as **trough** and the upper portion peak is known as **crest**.
- The distance between two consecutive compressions or two consecutive rarefactions is known as the **wavelength**.
- Wavelength is usually represented by the Greek letter lambda (**λ**) and its SI unit is meter mm.
- The number of the compressions or rarefactions that counted per unit time is known as **frequency** of the sound wave.
- Frequency of the sound wave is commonly represented by **v** Greekletter, nu.
- The SI unit of frequency of the sound wave is hertz Hz.
- The sensation of a frequency that we sense/listen is usually referred as the **pitch** of a sound.
- The faster the vibration of the sound source, the higher is the frequency and so the higher is the pitch.



Wave shape for a high pitched sound

- Likewise, a high pitch sound has more number of compressions and rarefactions passing the fixed point per unit time.
- The lower the vibration of the sound source, the lesser is the frequency and so the lesser is the pitch



Wave shape for a low pitched sound

- Likewise, a lower pitch sound has less number of compressions and rarefactions passing the fixed point per unit time.
- The magnitude of the maximum disturbance in the given medium on either side of the mean value is known as the **amplitude** of the sound wave.
- Amplitude is commonly represented by the letter **A**.
- The softness or loudness of a sound is fundamentally determined by its amplitude.
- A sound of single frequency is known as **tone**.
- The sound, which is created by mixing of several harmonious frequencies, is known as **note**.

Characteristics of a Sound Wave

Frequency

- The distance between two consecutive compressions or two consecutive rarefactions is called the wavelength. Its SI unit is metre.
- The number of such oscillations per unit time is the frequency of the sound wave. SI unit is hertz.
- 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 taken by two consecutive compressions or rarefactions to cross a fixed point is called

the time period of the wave. SI unit is second.

- Frequency and time period are reciprocal to each other.
- Relationship between frequency and time period is:

$$\nu = \frac{1}{T}.$$

- The sensation of frequency commonly referred as the pitch of a sound. Objects of different sizes and conditions vibrate at different frequencies to produce sounds of different pitch.
- A sound of single frequency is called a tone.
- When sound waves move from one medium to another medium its wavelength and speed changes but frequency remains unchanged.

Amplitude

- Magnitude of the maximum disturbance in the medium on either side of the mean value is called the amplitude of the wave.
- The loudness or softness of a sound is determined basically by its amplitude. 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.
- The amplitude of the sound wave depends upon the force with which an object is made to vibrate. If we strike a table lightly, we hear a soft sound because we produce a sound wave of less energy (amplitude).
- Sound wave source moves away from the source its amplitude as well as its loudness decreases. Louder sound can travel a larger distance as it is associated with higher energy.

Speed

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

  Speed = distance/time
- The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.
- Amount of sound energy passing each second through unit area is called the intensity of sound.
- The speed of sound decreases when we go from solid to gaseous state. Speed of the sound maximum in solid state and minimum in gaseous state.
- The speed of the sound remains unchanged by the increase or decrease of pressure.
- The speed of sound in a medium depends on temperature of the medium. In any medium as we increase the temperature the speed of sound increases.
- Speed of sound is more in humid air than dry air because density of humid air is less than dry air.
- The speed of sound depends on the properties of the medium through which it travels.
- 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.
- Sound travels about 5 times faster in water than in air. Since the speed of sound in sea water

is very large.

Speed of Sound in Different Medium

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

Sonic Boom

- When the **speed of any object exceeds the speed of sound** it is said to be travelling at **supersonic speed**.
- Bullets, jet aircrafts etc. often travel at supersonic speeds.
- When a sound, producing source moves with a speed higher than that of sound, it produces shock waves in air. These shock waves carry a large amount of energy. The air pressure variation associated with this type of shock waves produces a very sharp and loud sound called the "sonic boom".
- The shock waves produced by a supersonic aircraft have enough energy to shatter window glass and even damage buildings.

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.

Echo

- When we will hear the same sound again a little later due to the reflection of sound wave, it is called echo.
- To hear a distinct echo the time interval between the original sound and the reflected one must be at **least 0.1s.**
- The total distance covered by the sound from the point of generation to the reflecting surface and back should be at least 340 ms^{-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.

Reverberation

- The repeated reflection that results in this persistence of sound is called 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.

Uses of Multiple Reflection of Sound

- Megaphones or loudhailers, horns, musical instruments such as trumpets and shehnais are all designed to send sound in a particular direction without spreading it in all directions.
- Stethoscope is a medical instrument used for listening to sounds produced within the body, mainly in the heart or lungs.
- The ceilings of concert halls conference halls and cinema halls are curved so that sound after reflection reaches all corners of the hall.

Range of Hearing

- The audible range of hearing for average human beings is in the frequency range of 20 Hz – 20 kHz.
- Sounds of frequencies below 20 Hz are called infrasonic sound or infrasound.
- Frequencies higher than 20 kHz are called ultrasonic sound or ultrasound.

Infrasonic Sound

- Sounds of frequencies below 20 Hz are called infrasonic sound or infrasound.
- Rhinoceroses communicate using infrasound of frequency as low as 5 Hz.
- Whales and elephants produce sound in the infrasound range.
- Earthquakes produce low-frequency infrasound before the main shock waves begin which possibly alert the animals.

Ultrasonic Sound

- Ultrasonic sound is the term used for sound waves with frequencies greater than 20,000Hz.
- 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.

Applications of Ultrasound

- Ultrasounds can 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 echocardiography.
- Ultrasound scanner is an instrument which uses ultrasonic waves for getting images of internal organs of the human body.
- Ultrasound may be employed to break small stones formed in the kidneys into fine grains.
- 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.
- Porpoises use ultrasound for navigation and location of food in the dark.

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.

Frequency of a Vibration

- The vibration motion is known as **oscillatory motion**.
- The number of oscillations per second is known the **frequency** of oscillation and the frequency is expressed in **hertz** *Hz*.
- Amplitude and frequency are the two significant features of any sound.
- The loudness of sound depends on its amplitude; if amplitude is higher, then the sound is louder and if the amplitude is lesser, then the sound is feeble.
- The loudness of sound is expressed in a unit and it is expressed in **decibel** *dB*.
- The following table illustrates the loudness of sound generated from various sources –

Source of Sound	Loudness of Sound
Normal breathing	10 dB
Soft whisper at5mat5m	30 dB

Normal conversation	60 dB
Busy traffic	70 dB
Average factory	80 dB

- The frequency determines the pitch or shrillness of the sound; therefore, if the frequency of vibration is higher, then the sound has a higher pitch and shrillness is higher and vice versa.
- The frequencies of sound less than about 20 vibrations per second i.e., 20Hz cannot be perceived by the human ear.
- The frequencies of sound higher than about 20,000 vibrations per second i.e., 20kHz cannot be perceived by the human ear.
- For a human ear, the range of audible frequencies roughly range between 20 and 20,000 Hz.
- Some of the animals can hear the sounds of frequencies higher than 20,000 Hz, e.g. dogs.

Structure of Human Ear

- 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.