Sound

INTRODUCTION – SOUND

- Sound is a form of energy like heat energy, light energy, potential energy and kinetic energy. It causes a sensation of hearing in our ears.
- Sound cannot be created nor destroyed but can be changed from one form to another. E.g., when we clap, a sound is produced. Here, muscular energy is converted into sound energy. This is in accordance with the law of conservation of energy.

Similarly, in an electric bell, when connected to electricity starts producing sound. Here, again electrical energy is converted into sound energy.

PRODUCTION OF SOUND:

- Sound is produced due to the vibration of objects.
- The motion of materials or objects causes vibration.
- **Vibration** is a kind of rapid to and fro motion of an object about a central position. It is also referred to as oscillation.

For example, a stretched rubber band when plucked vibrates and produces sound.

Activity to show that vibrating bodies produces sound: – Strike the prongs of a tuning fork on a rubber pad and bring it near the ear. We can hear a sound. If a suspended table tennis ball is touched with the vibrating prong, the ball is pushed away repeatedly. This shows that the prong is vibrating and vibrating objects produces sound.
(A tuning fork is an instrument used in laboratories to perform sound related experiments).

Examples of how certain sounds are produced –
In every musical instrument, there is a vibrating part which produces sound. In case of musical instruments like flute, the air column vibrates to produce sound.

In stringed musical instruments like sitar, veena etc, there is a tightly stretched string which vibrates to produce sound.

In humans, sound is produced by the voice box or the Larynx. Vocal cords in the larynx vibrate and produce sound. We hear sound with our ears.
When a bird flaps its wings, a sound is produced.

PROPAGATION OF SOUND

- The travelling of sound is called **propagation of sound**.
- Sound is propagated by the to and fro motion of particles of the medium.
- When an object vibrates, it sets the particles of the medium around it vibrating. Each particle disturbs the particle. Thus, the disturbance is carried from the source to the listener.
- The disturbance produced by the vibrating body travels through the medium but the particles do not move forward themselves.

SOUND NEEDS A MEDIUM TO PROPAGATE:

- A medium is necessary for the propagation of sound waves.
- The matter or substance through which sound is transmitted is called a **medium**. The medium can be solid, liquid or gas.
- Sound cannot travel in vacuum. A true vacuum refers to the complete absence of matter. Sound waves can travel only through matter. So, sound needs a physical medium in order to travel anywhere.
- Wave that requires medium to propagate is called **Mechanical Wave**. For example – sound wave. Sound cannot travel in the absence of a medium.

Activity to show that sound needs a material medium for its propagation.
Suspend an electric bell in an air tight bell jar. Connect the bell jar to a vacuum pump. If the switch is pressed, we can hear the sound of the bell. If air is pumped out through the vacuum pump, we cannot hear the sound of the bell. This shows that sound needs a medium to travel and sound cannot travel in vacuum

SOUND PROPAGATES AS A WAVE:

- Sound propagates from one place to another in the form of waves, i.e. because of the disturbance of particles of the medium.
- **Wave** is a phenomenon or disturbance in which energy is transferred from one point to another without any direct contact between the points. So, sound is considered as a wave.
- Particles of medium only vibrate. They do not move from one point to another.

TYPES OF WAVES:

- On the basis of direction of propagation, waves can be divided into two types –- Longitudinal waves n transverse

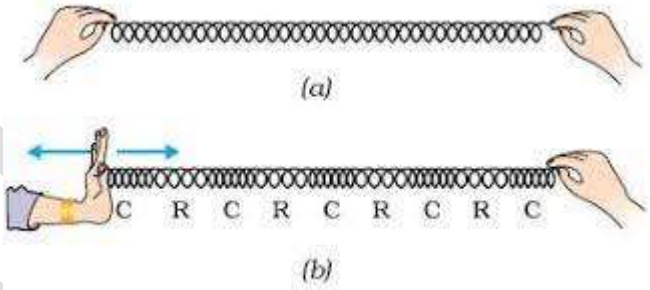
i)Longitudinal waves are waves in which particles of the medium do to and fro motion in the same direction in which the wave moves. E.g Sound waves

ii)Transverse waves are waves in which particles of the medium do to and fro motion in the direction perpendicular to the direction of movement of wave. E.g light waves.

- **Sound waves are longitudinal**

Sound travels as a longitudinal wave through a material medium.
The particles of sound wave do not move from one place to another. They just oscillate back n forth about their position of rest. The disturbance is carried forward. Hence, sound waves are longitudinal waves.

Longitudinal waves can be shown through a sling key.
Hold one end of the sling key n fix the other end to the wall nail. Now, stretch sling key by pulling the hand, after a while push the stretched sling key towards the wall. You'll observe that the coils come closer at some regions whereas it moves apart at other regions forming regions of compressions n rarefactions.



COMPRESSION AND RAREFACTION

- Sound travels as successive compressions and rarefactions in the medium. A vibrating object producing a series of compressions (C) and rarefaction (R)
- When a vibrating object moves forward, it pushes and compresses the air in front of it forming a region of high pressure called compression (C). Compressions are the regions of high pressure and density where the particles are crowded and are represented by the upper portion or peak of the curve called **crest**.
- When the vibrating object moves backward, it forms a region of low pressure called rarefaction (R). Rarefactions are the regions of low pressure and density where the particles are spread out and are represented by the lower portion of the curve called **trough or valleys**.

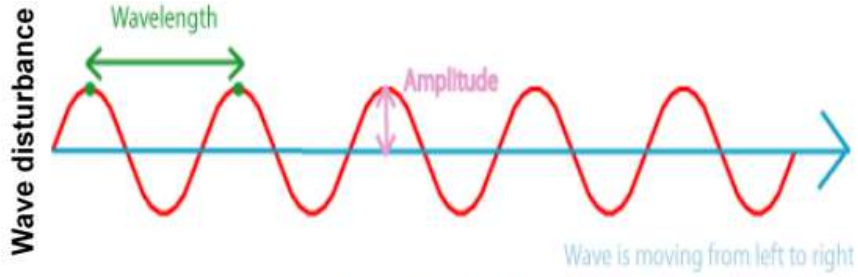
CHARACTERISTICS OF SOUND WAVES:

Sound waves have 4 characteristics

1. Amplitude

2. Wavelength
3. Frequency
4. Speed

- As the sound wave propagates in a medium, the density as well as the pressure of the medium at a given time varies with distance above and below the average value.
- Increase in density is not the same throughout compression. Maximum increase in density is seen at the centre of compression.

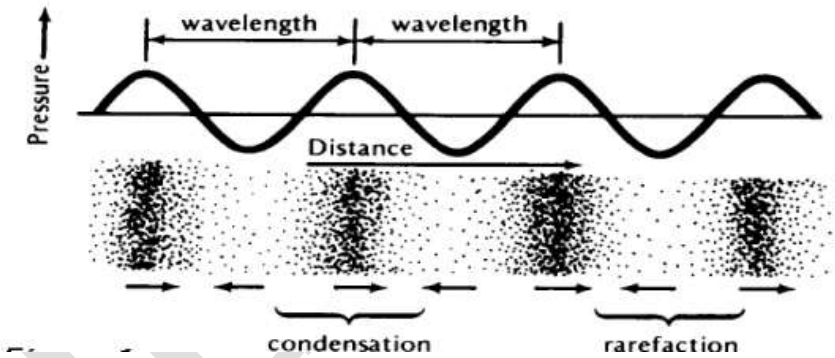


Wavelength and Amplitude

(i) Amplitude– The amplitude of sound wave is the height of the crest or tough. The amplitude is how high the crests are. In a sound wave, the maximum displacement associated with the particle constituting a wave is called its amplitude. It is represented by "A'. SI unit is metre.

Amplitude depends upon the force with which an object vibrates . E.g., When we hit a table hard, a loud sound is produced due to its larger amplitude. Similarly, if we hit the table slowly, the sound produced is low as its amplitude is small. Thus, loudness as well as soft sound is determined by its amplitude.

(ii) Wavelength–



The wavelength is the distance between 2 consecutive compressions or 2 consecutive rarefaction is called wavelength n is represented as λ (lambda). Its SI unit is metre.
Wavelength can also be considered as the distance over which graph/wave is repeated.

(iii)Frequency– The number of vibrations completed by a particle in one second is the frequency of the sound wave.

Frequency = Number of Oscillations / Total Time

$V = 1/T$

We can calculate the frequency of sound by calculating the number of compressions or rarefaction in one second. It is represented by a Greek letter (Greek letter nu). SI unit is Hertz.
SI unit is named after **Heinrich Rudolph Hertz** who laid foundation 4 future development of radio, telephone, telegraph n TV

(iv) Time period– The time taken by the particle of the medium for completing one oscillation/vibration is called the time period. It is represented by the symbol "T". SI unit is second. Time period of a sound wave is the time between 2 successive compressions or 2 successive rarefactions

(v) Velocity of sound wave– It is the distance travelled by a wave in one second. Speed is represented by V. Speed with which compression and rarefactions move ahead is called velocity. The speed of sound is more in solids, less in liquids and least in gases.

RELATIONSHIP BETWEEN SPEED V, FREQUENCY AND WAVELENGTH OF SOUND

Wave Velocity= Distance covered/ time taken

= Wavelength/time taken

$v = \lambda/T$ .....(1)

As v =1/T, eq(1), connecting V and in terms of frequency can be written as

$V = v\lambda$.....(2)

(Or)

Wave velocity= Frequency x wavelength

The velocity of sound remains almost same for all frequencies in a given medium under the same physical conditions.

DEPENDENCE OF SPEED OF SOUND:

(i) Nature of the medium: Speed of sound depends on the nature of the medium(material) through which it travels. Speed of sound is different in different mediums

The speed of sound is more in solids, less in liquids and least in gases.

For example- velocity of sound in Iron is 5130m/s

At room temperature, the speed of sound in air is 344m/s, in water, it is 1500m/s; in solids, it is 5130m/s.

(ii) Temperature of medium:

The speed of sound also depends on the temperature of the medium. If the temperature of the medium is more, the speed of sound is more

E.g., Speed of sound at 0^oC is 332m/s

Speed of sound at 20^oC is 344m/s

iii)Humidity of medium:

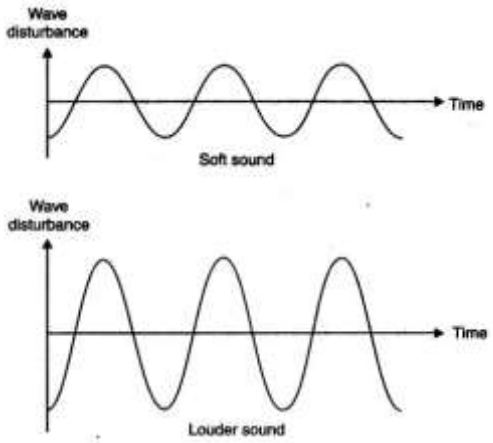
Speed of sound increases with increase in humidity.

E.g., In rainy seasons, humidity is high and therefore speed of sound is more

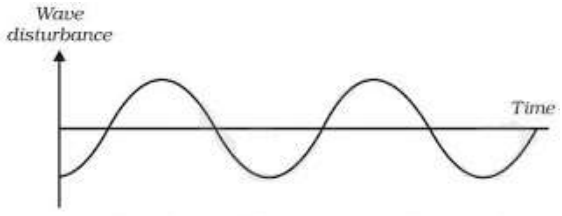
CHARACTERISTICS OF SOUND AS WE HEAR IT

(i) Loudness: Loudness of sound is the measure of sound energy reaching the ear per second. Loudness or softness of a sound wave is the sensation that depends upon its amplitude.

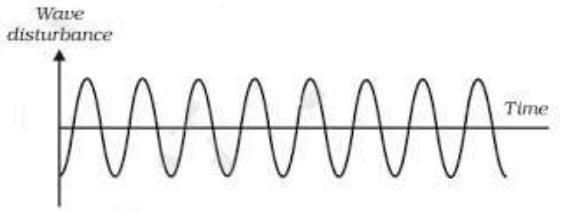
E.g., When we strike the top of a table with more force, it vibrates and produces a loud sound. But, when we strike the top of a table with lesser force, the vibrating table top produces soft sound waves. Louder sound has more amplitude.



(ii) Pitch: When a guitar n flute are played together then the sound emitted by the two musical instruments are different. The difference is due to one more characteristic of sound namely pitch.



Wave shape for a low pitched sound



Wave shape for a high pitched sound

Pitch is the sensation (brain's interpretation) of the frequency of an emitted sound. The pitch of sound (shrillness or flatness) depends on the frequency of vibration.
Faster the vibration of the source, higher is the frequency and higher the pitch and vice versa. Similarly, low pitch sound corresponds to low pitch.

- A high pitch sound is called a **shrill sound**(meowing of a cat, sound of guitar, girl's voice). High pitch has more compressions and rarefactions
- A low pitch sound is called a **hoarse sound/ heavy sound**(sound of a lion, boy's voice). Low pitch has less compressions and rarefactions

(iii) Quality or Timbre: Quality or timbre of sound wave is that characteristic which helps us in distinguishing between two sounds of same loudness and same pitch.

MUSIC AND NOISE:

- **Music** is the sound that is pleasant to hear/to the ears (e.g, sound coming out of musical instruments)
- **Noise** is the sound that is unpleasant to hear /the ears(E.g., Sound produced by vehicles)

TONE AND NOTE:

- A pure sound of single frequency is called **tone**.
- An impure sound produced by mixture of many frequencies is called a **note**. It is pleasant to hear.

SONIC BOOM:

Speed of sound in air is 333m/s, Speed of fastest runner= 12.5m/s
Many objects such as aircrafts, bullets, rocket planes travel at speeds greater than the speed of sound in air. Such objects are said to be travelling with supersonic speed.

- Objects moving with speed greater than speed of sound is said to have **supersonic speed**.
- Supersonic aircraft produces shock waves in air due to its very high speed. The air pressure variation associated with shock waves produces a very sharp and loud sound called "**sonic boom".**
    - Sonic boom is the loud sound due to shock waves generated by objects moving with supersonic speed. Shock waves have lot of energy, they can damage buildings and break glasses.

LIGHT TRAVELS FASTER THAN SOUND:

Speed of light in air = $3x\ 10^8$ m/s

- Man hears sound of thunder only after he sees the flash of lightning. **This is because** light travels at a very great speed as compared to the speed of sound, we see the flash before the sound.
- Similarly, **the flash of a gunshot reaches us before the sound of the gun shot. This is because** light travels at a very great speed as compared to the speed of sound, we see the flash before the sound.

REFLECTION OF SOUND:

Just like light, sound gets reflected at the surface of a solid or liquid.

- The bouncing back of sound when it strikes the surface of a solid or liquid is called **reflection of sound.**
- Hard surfaces(like mountain, wall, metals) are good reflectors of sound while soft surfaces(like cloth, paper etc) are bad reflectors of sound.

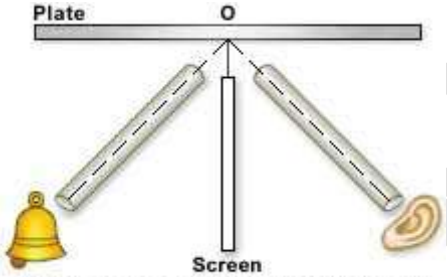
Laws of reflection of sound:

Sound follows the same laws of reflection as light does.
There are two laws of reflection of sound:

(i) The incident sound wave, the reflected sound wave, and the normal at the point of incidence all lie in the same plane.

(ii) The angle of incident sound wave is equal to the angle of reflection of sound wave. But, only important here is that the sound wave needs rough or polished and large obstacle is very much necessary.

EXPERIMENT TO VERIFY LAW OF REFLECTION:



Reflection of sound from a plane surface

- We require 2 identical pipes made up of chart paper,a clock, table and a scale and protractor.
- Take two pipes of the same length and arrange them on a table near a wall or metal plate. Keep a clock near the open end of one pipe and try to hear the sound of the clock through the other pipe by adjusting the position of the pipe.
- Now measure the angles of incidence and reflection. Then lift the second pipe and try to hear the sound.

It will be seen that the angle of incidence is equal to the angle of reflection. The incident ray, the reflected ray and normal all lie in the same plane

USE OF REFLECTION OF SOUND:-

Reflection of sound is used in many devices. For example; megaphone, loudspeaker, bulb horn, stethoscope, hearing aid, sound board etc.

1. Loudspeaker, Megaphone, bulb horn:

Megaphones, horns, musical instruments like trumpets, shehnais etc. are deigned to send sound by multiple reflection in a particular direction without spreading in all directions

2. Stethoscope: –

Doctors listen to sounds from the human body through a stethoscope. The sound of heartbeat reaches the doctor's ears by multiple reflection.

3. Soundboard –

Generally the ceilings of cinema halls and auditoriums are curved so that sound after multiple reflections reaches all parts of the hall.

ECHO:

- If we shout or clap near a reflecting surface like tall building or a mountain, we hear the same sound again. This sound which we hear is called echo.
- Repetition of sound caused by the reflection of sound wave is called an **Echo**. An echo is heard when sound is reflected from a hard surface such as the cliff of mountain.

- To hear an echo clearly,the time interval between the original sound and reflected one(echo) must be atleast 0.1sec. This is because the sensation of any sound remains in our ears only for 0.1 sec.
- Since, sound covers 344 m in air in 1 second.Thus in 0.1 second, sound would cover a distance of 344 m x 0.1 = 34.4 m
- Thus, to hear an echo sound the reflecting surface must be at a distance of 17.2 m, so that sound has to cover a distance which is more than 17.2 m x 2 = 34.4 m; before reaching the ears.
- So, if reflecting surface is at a distance of more than 17.2 m, the sound would reach to our brain after 0.1 second and we would be able to hear the echo of sound.

CONDITIONS TO EXPERIENCE THE SOUND OF AN ECHO:

There are two conditions to experience the echo of sound –

(a) Sound must come back to the person after 0.1 second.

(b) For above condition, the reflecting surface must be at a minimum distance of 17.2m. It also depends on temperature.

REVERBERATION:

Echoes may be heard more than once due to repeated or multiple reflections of sound from several reflecting surfaces.

Persistence of sound wave for a long time because of repeated(multiple) reflections of sound is called **reverberation**.

Usually, this happens in big halls. Sound becomes too blurred and distorted to be heard in big concert halls because of reverberation. This can often lead to annoyance.

Reverberation can be prevented by stopping the reflection of sound. This could be done by

- using soft sound absorbent materials, such as curtains, plant fibre, compressed fireboard, carpets, etc. are used in the auditorium.
- These materials absorb undesired reflected sound and reduce reverberation.

TYPES OF SOUND BASED ON FREQUENCY:

Range of sound

Humans cannot hear sounds of all frequencies. The human ear can hear the sound between frequencies of 20 Hz to 20,000 Hz. Thus, audible range or range of hearing for an average human being is between 20 Hz to 20,000 Hz. However, children under 5 years of age can hear the sound upto 25000 Hz.

Sound beyond audible range of human being: Infrasound and Ultrasound

(i) Infrasonic Sound or Infrasound

Sound, below the frequency of 20Hz is called infrasonic or infrasound. Infrasound is produced because of very slow vibration. For example; simple pendulum produces sound below 20Hz. Human being cannot hear infrasound as their ears are not adapted to hear the sound of such range.

Many animals such as whale, elephant, rhinoceros, etc. can produce and hear sound having frequencies below 20 Hz.

(ii) Ultrasound or Ultrasonic Sound

Ultrasound or ultrasonic sound:- Sound, above the frequency of 20000 Hz is called ultrasound. Humans cannot hear the ultrasonic sound. However, many animals such as dogs, cat, bat, monkey, deer, etc. can hear ultrasound. Human children can also hear to ultrasound. Earthquakes, volcanic eruptions also produce ultrasound

Audible sound- bends at the edges while ultrasound doesn't bend at the edges.

USE OF ULTRASOUND

Ultrasound is sound waves of high frequency. Because of high frequency, ultrasound is associated with more energy and can penetrate upto a large extent. This characteristic of ultrasound makes it very useful for many purposes. Some of its uses are given here:

1. Detection of any deformities(flaws, cracks) in metal blocks or sheets.

2. Ultrasound is generally used to clean parts located in hard to reach places like spiral tubes.

3. Ultrasound is used by bats to find their prey. Bats produce high-pitched ultrasonic squeaks. These high-pitched squeaks are reflected by objects such as preys and returned to the bat's ear. This allows a bat to know the distance of his prey.
4. Some moths can hear ultrasound and this helps them in escaping from their predators.
5. Dolphins use ultrasound to find fish and to detect sharks that may attack them.
6. Ultrasound may be employed to break stones formed in the kidneys into fine grains.
7. Ultrasound scanner is used to detect problems of the internal organs.
8. Ultrasonography is the process of getting the pictures of parts of the body by using multiple reflection.
9. Echocardiography- is the use of ultrasound to detect activities of heart.
10. Ultrasonography is used to study the development of foetus during pregnancy to detect any abnormalities.

SONAR–

- Sonar stands for Sound Navigation And Ranging.
- The SONAR technique is used to determine the depth of sea and to locate under water hills, valleys, icebergs, submarines , sunken ships etc.
- A beam of ultrasonic sound is produced and transmitted by the transducer (it is a device that produces ultrasonic sound) of the SONAR, which travels through sea water. Ultrasound is reflected by seawater. The echo produced by the reflection of this ultrasonic sound is detected and recorded by the detector, which is converted into electrical signals. Using the time taken for echo to come back, we can find the depth of sea.
- The distance (d) of the under-water object is calculated from the time (t) taken by the echo to return with speed (v) is given by $2d = v \times t$. This method of measuring distance is also known as 'echo-ranging'.
- Echo ranging is the process of finding distances using process of ultrasound.

HUMAN EAR

Structure of Human Ear:

The human ear can be divided into three main parts, viz. external ear, middle ear and internal ear.

Outer Ear: The outer ear is outside the body and is also called pinna. It extends into the ear canal. Ear canal is filled with air.

Middle Ear: The middle ear is composed of the ear drum or tympanum(it is an elastic membrane, circular in shape) and the bone ossicles. There are three bone ossicles, namely, the hammer, the anvil and the strirrup.

Internal/inner Ear: The internal ear is composed of a cochlea and three semi-circular canals. The cochlea is filled with liquid. The cochlea makes the hearing apparatus and the auditory nerve from it goes to the brain. Eardrum is the intersection of the outer and middle ear. Oval window is the intersection of middle and inner ear.

Working of Human Ear: The outer ear called pinna collects the sound waves. The sound waves passes through the ear canal to a thin membrane called eardrum. The eardrum vibrates. The vibrations are amplified by the three bones of the middle ear called hammer, anvil and stirrup. The middle ear then transmits the sound waves to the inner ear. In the inner ear the sound waves are converted into electrical signals by the cochlea and sent to the brain through the auditory nerves. The brain then interprets the signals as sound.