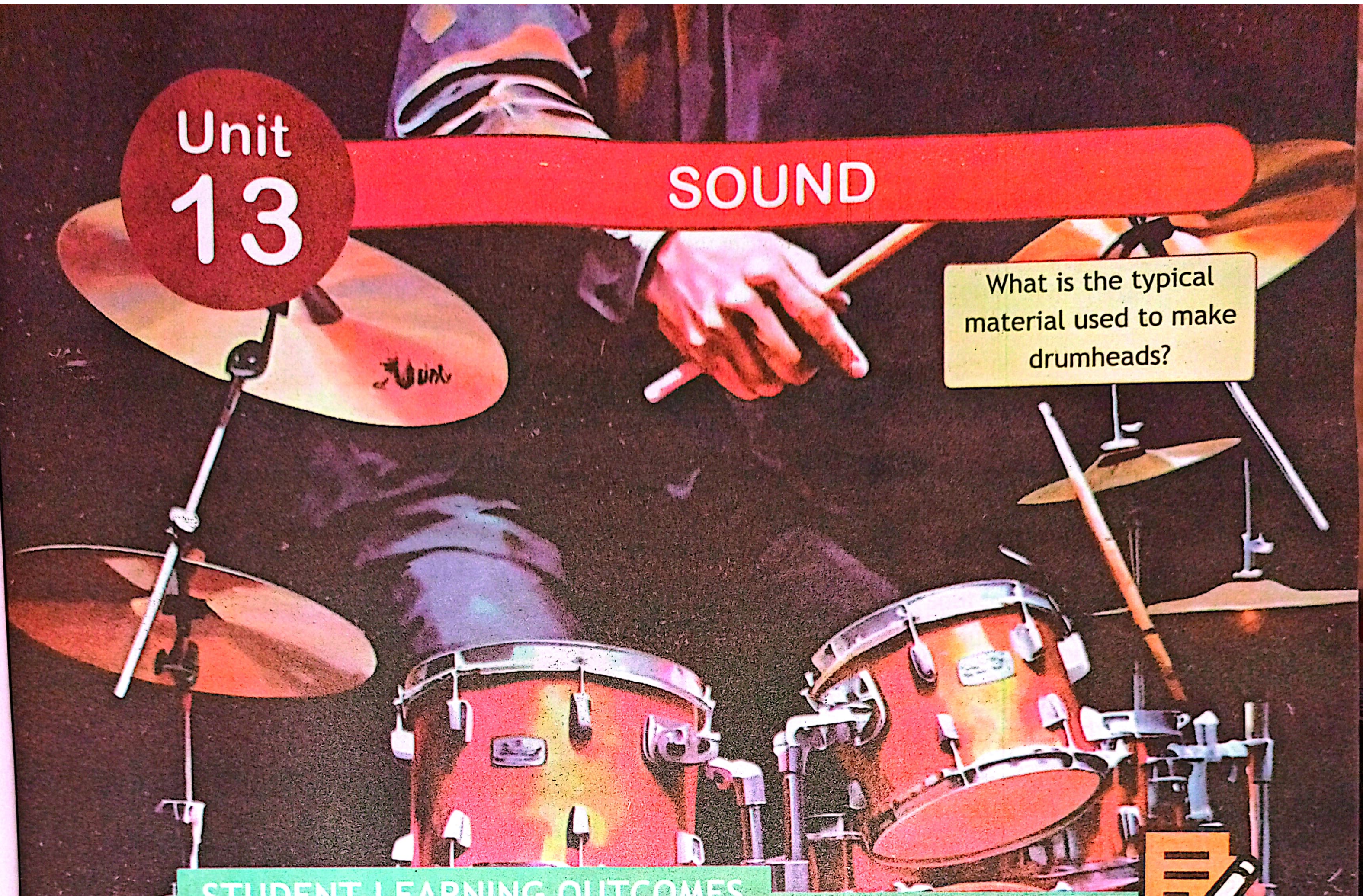
Unit 13 SOUND



What is the typical material used to make drumheads?

STUDENT LEARNING OUTCOMES

The students will:

- ✓ [SLO: P-10-D-12] Describe the production of sound.
- ✓ [SLO: P-10-D-13] Describe the longitudinal nature of sound waves.
- ✓ [SLO: P-10-D-14] State the approximate range of frequencies audible to humans as 20Hz to 20000Hz.
- ✓ [SLO: P-10-D-15] Justify why sound waves cannot travel in a vacuum.
- ✓ [SLO: P-10-D-16] Describe how changes in amplitude and frequency affect the loudness and pitch of sound waves.
- ✓ [SLO: P-10-D-17] Describe how different sound sources produce sound waves with different timbres.
- ✓ [SLO: P-10-D-18] Describe an echo as the reflection of sound waves.
- ✓ [SLO: P-10-D-19] Justify simple experiments to show the reflection of sound waves.
- ✓ [SLO: P-10-D-20] Illustrate a method involving a measurement of distance and time for determining the speed of sound in air.
- ✓ [SLO: P-10-D-21] State that the speed of sound in air is approximately 330 - 350m/s.
- ✓ [SLO: P-10-D-22] Describe that, in general, sound travels faster in solids than in liquids and faster in liquids than in gasses.
- ✓ [SLO: P-10-D-23] Define ultrasound as sound with a frequency higher than 20 kHz.
- ✓ [SLO: P-10-D-24] Illustrate and analyze the uses of Ultrasound [in cleaning, prenatal and other medical scanning, and in sonar.
- ✓ [SLO: P-10-D-25] Illustrate the use of infrasound.
- ✓ [SLO: P-10-D-26] Analzye the effects of noise pollution on the environment.

- ✓ [SLO: P-10-D-27] Justify the importance of acoustic protection.
- ✓ [SLO: P-10-D-28] Describe how knowledge of the properties of sound waves is applied in the design of buildings with respect to acoustics.
- ✓ [SLO: P-10-D-29] Explain the use of soft materials to reduce echo sounding.
- ✓ [SLO: P-10-D-30] Explain, with examples, how sound can reflect, refract and diffract.
- ✓ [SLO: P-10-D-31] Explain how sound is converted by the eardrum and nerves into electrical signals that are then interpreted by the brain.

Sound is a mechanical wave that originates from the vibration of particles in a medium such as air, water, or solids. These vibrations create longitudinal waves, where particles oscillate parallel to the direction of wave propagation, causing regions of compression and rarefaction. The properties of sound waves, including frequency, amplitude, and speed, determine the characteristics of the sound, such as pitch and loudness. Sound waves require a medium to travel, and their behavior can be influenced by reflection, refraction, diffraction, and interference.

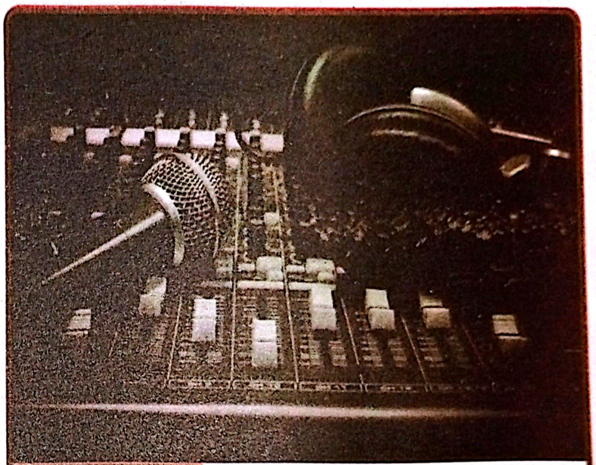


FIGURE 13.1 Sound Devices

Sound is essential for communication, entertainment, and various technological applications, making its study important in diverse fields.

13.1 SOURCE OF SOUND

That object which is basically the cause of vibration is called Source of Sound. For Example; Our clapping hands, chirping birds, Musical instruments etc. as shown in figure 13.2.

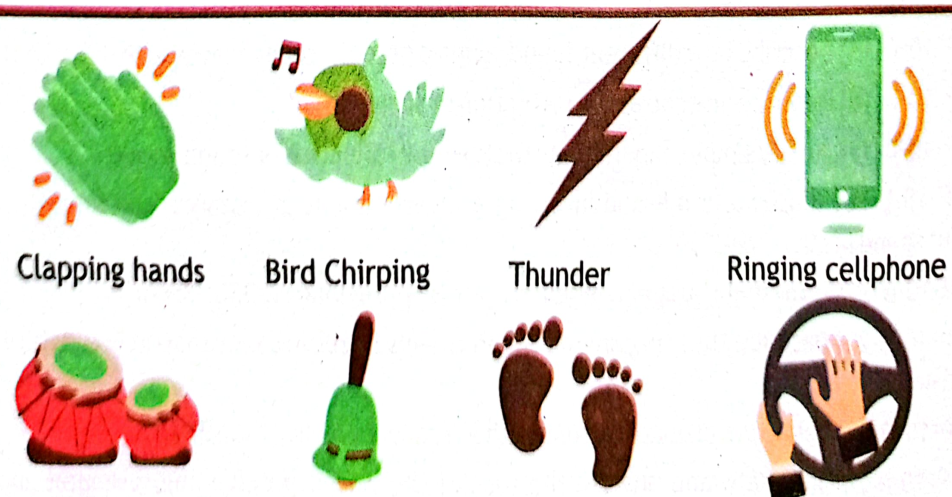
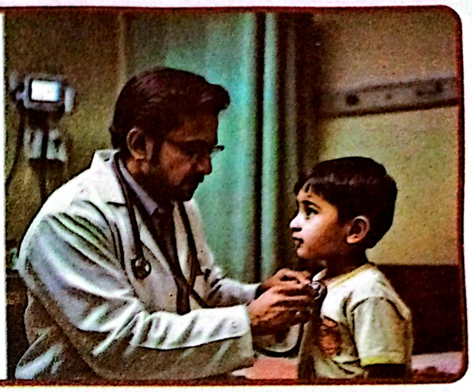


FIGURE 13.2 Sources of Sound

POINT TO PONDER

A stethoscope works by transmitting sound from the chest-piece to the listener's ears through air-filled hollow tubes. The chest-piece typically has a plastic disc known as the diaphragm. The diaphragm picks up vibrations from physiological noises.



These vibrations create acoustic pressure waves, which travel up the tubing to the listener's ears after multiple reflections.

13.1.1 HOW SOUND IS PRODUCED?

Production of sound totally depends upon vibration of object. Vibrating source transforms energy, due to vibration and it compels to the surrounding medium to vibrate through which sound wave travels. The surrounding medium particles obey to and fro motion. Basically sound waves are such waves which produce sensation of listening when strike with ear drum. Production of pressure waves are the main cause of vibration, later on it collides with our auditory system resultantly we are able to listen sound. Sounds surround us from machines and vehicles to birds and conversations. Experiments show that vibrations are essential for sound production, such as: blowing across a bottle, Plucking a stretched rubber band, flapping cardboard or bird wings and striking a bell or drumhead.

Let's perform a very simple and short duration experiment to show the vibration is necessary for production of sound. Few things are required in this experiment like Tuning fork, rubber- pad, Glass and water only. First of all take glass which is filled with full of water. Secondly hit tuning fork on rubber pad and touch one prong of vibrating tuning fork very gently with surface of water as shown in figure; 13.3(a). In third step, vibrating tuning fork will be dipped vertically into glass of water as shown in figure; 13.3 (b).

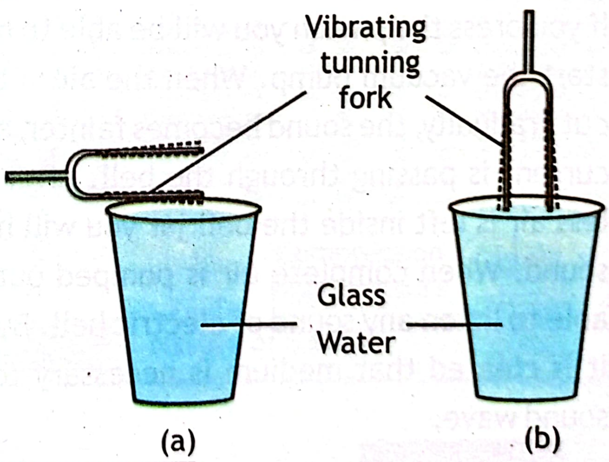


FIGURE 13.3 Production of sound

In both of the above positions of vibrating tuning fork, sound can be observed due to vibration of tuning fork with particles of medium (water molecules). This experiment can be performed with empty glass and sound of vibration of tuning fork can also be heard, but in both cases sound impact will be different because in empty glass air exists so sound impact is smaller as compare to presence of water.

INFORMATION

Bats can hear frequencies up to 120,000 Hz. Other animals cannot hear such high-pitched sounds. Mice can hear frequencies up to 100,000 Hz, dogs up to 35,000 Hz, and cats up to 25,000 Hz. Humans hear sounds only upto about 20,000 Hz, but children can usually hear higher-frequency sounds than adults

13.1.2 MEDIUM FOR PROPAGATION OF SOUND

As we know that sound waves are mechanical longitudinal in nature so for propagation of sound waves from one point to another point medium is required. Without the existence of medium these waves may be produced by vibrating objects but cannot travel from one place to another place. For example; in class room if air does not exit, students will be able to listen all lecture points are delivered by teacher. Let's discuss a very simple experiment for understanding the importance of medium for propagation of sound waves.

Let's take an electric bell and an airtight glass bell jar. The electric bell is suspended inside the airtight bell jar. The bell jar is connected to a vacuum pump, as shown in figure13.4.

If you press the switch you will be able to hear the bell. Now start the vacuum pump. When the air in the jar is pumped out gradually, the sound becomes fainter, although the same current is passing through the bell. After some time when less air is left inside the bell jar you will hear a very feeble sound. When complete air is pumped out, you will not be able to listen any sound of electric bell. By this experiment; it is cleared that medium is necessary for propagation of sound wave.

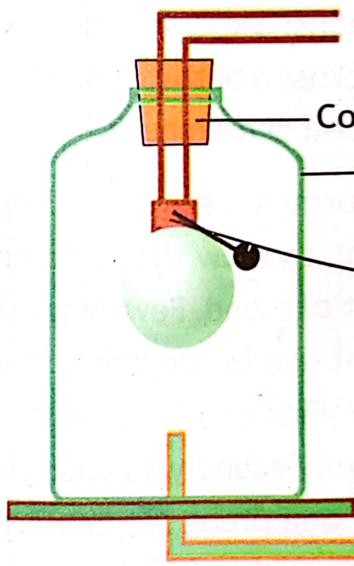


FIGURE 13.4 Propagation of Sound

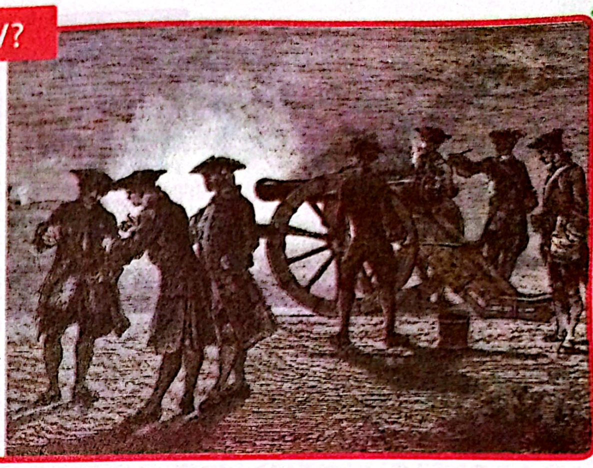
MINI LAB

Make a String Telephone:

Cut a length of string and thread it through the hole in each cup. Tie a paper clip on the end of each string, on the inside of the cup. Find a friend, walk apart until the string is tight then talk through the inside of your cup while they listen on their cup.

DO YOU KNOW?

The speed of sound in air was first accurately measured in 1738 by members of the French Academy. They used two cannons positioned on hills about 29 kilometers apart. By measuring the time interval between seeing the flash of a cannon and hearing its "boom," they were able to calculate the speed of sound. To minimize errors from wind and observer reaction times, they fired the cannons alternately. From their observations, they deduced that sound travels at approximately 332 meters per second at 0°C.



13.2 NATURE OF SOUND WAVES

Sound waves are mechanical longitudinal on nature. These waves are also called pressure wave. When any object (source of sound) vibrates, this vibration causes the vibration of molecules of medium (air, fluid etc.). Ultimately this initiated vibration is converted into a chain of vibrations after transferring its energy into molecules of medium till sound wave travels through medium.

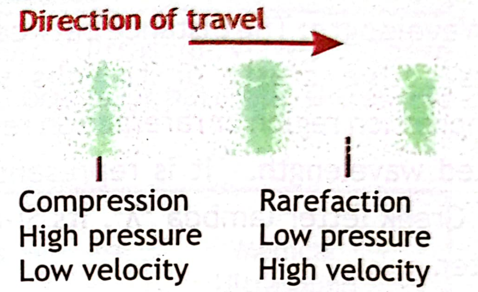


FIGURE 13.5 Travelling of Sound

Actually when any object vibrates, its vibration shows existence of kinetic energy. This kinetic energy is transmitted to the medium's molecules. These medium's molecules transfer acquired kinetic energy to next molecules of medium. Due to kinetic energy these molecules start vibrational movement in forward direction as shown in figure 13.5. By this way vibrational energy produced by sound source is transferred from one point to another point.

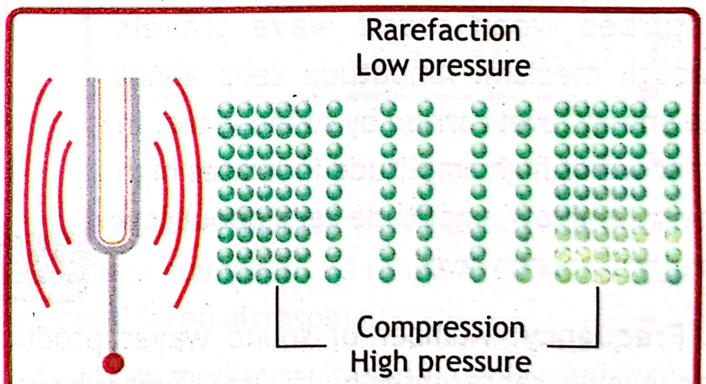


FIGURE 13.6 Nature of Sound

13.2.1 COMPRESSION AND RAREFACTION

Sound waves are the combination of compressions & rarefactions. Compression is that high pressure portion within sound wave, where molecules of medium acquire low velocity, which is produced due to vibrational kinetic energy of sound source. Here molecules of medium have very short distance between them. Rarefaction is that low pressure portion within sound wave, where molecules of medium acquire high velocity within a sound wave which is produced due to vibrational kinetic energy of sound source. Here molecules of medium have comparatively large distance between them as shown in figure 13.6.

PROJECT: MAKING SPEAKER

Materials Needed: Plastic or paper cup, Copper wire (1 meter), Small magnet, Tape, 3.5 mm audio jack with exposed wires, Scissor.

Instructions: Make a Coil and Wrap 1 meter of copper wire around a pen to make a coil. Leave 6 inches of wire free on each end. Attach Coil and Magnet, Tape the coil to the bottom of the cup. Place the magnet inside the coil at the bottom of the cup. Connect the Wires i.e. twist the ends of the copper wire to the wires of the audio jack.

Test the Speaker: Plug the audio jack into a phone or computer and play music.

13.2.2 RELATED TERMS OF SOUND WAVES

A. Wavelength: The distance between two consecutive crests or troughs within compression region or rarefaction region is called wavelength. It is represented by the Greek letter lambda 'λ'. Its SI-unit is meter.

B. Amplitude: It is the maximum displacement covered by particle disturbed when sound wave travels through medium. Amplitude tells about the energy level carried by sound wave. In other words high amplitude indicates high energy and low amplitude tells about low energy of sound wave.

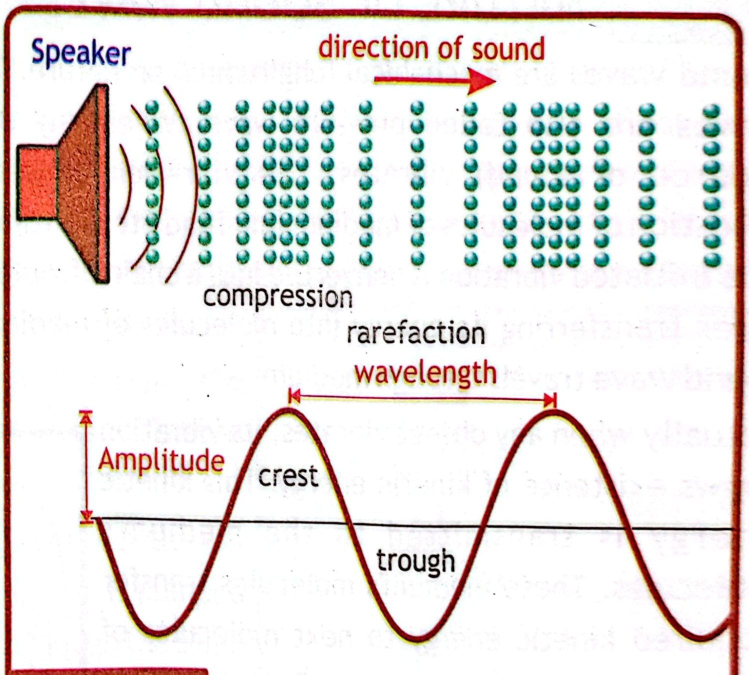


FIGURE 13.7 Properties of Sound Wave

C. Frequency: Number of sound waves produced in one second is called frequency. It is symbolically represented by 'f'. Its SI-unit is hertz. One hertz means one sound wave is produced in one second.

D. Time Period: Time taken by a wave to complete one cycle is called time period. It is symbolically represented by 'T'. It SI-unit is second.

13.2.3 TYPES OF SOUND WAVES

Sound waves have different names which are taken as its types. All types of sound waves are basically referenced dependent. For example; Unpleasant or pleasant effect of sound, Soft or hard sound, Musical sound or sound etc. In general sound waves can be categorized as Rhythmic and non-Rhythmic sound waves as shown in figure 13.8.

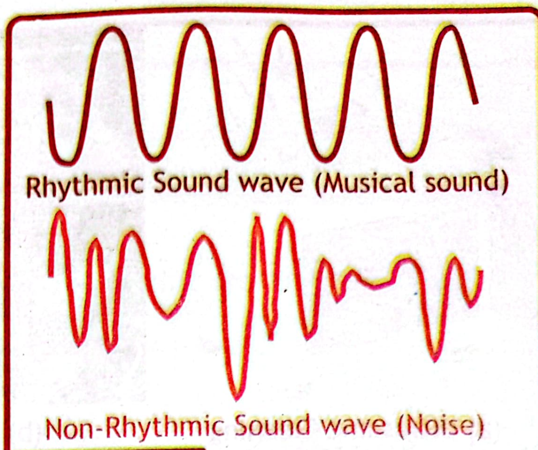


FIGURE 13.8 Types of Sound

Human ear has limitation of detection of sound waves. The audible range is in between 20 hertz to 20000 hertz. If wave has frequency less than 20 hertz, it be not audible to our ear, these waves are called "Infrasonic waves". These are used to detect map-rock, underground petroleum formation, earthquakes etc. Interesting point is that there are so many animals which usually use infrasonic waves for communication across impressive distances for examples; Whales, Elephants, Giraffes etc. Human ear can listen sound having frequencies greater than 20 hertz and less than 20000 hertz (figure 13.9).

Such waves which have frequency greater than 20,000 hertz is called "Ultrasonic waves". These waves are mostly used in medical field for examination of internal organs of patients. Ultrasonic waves are also used to navigation purposes and so on.

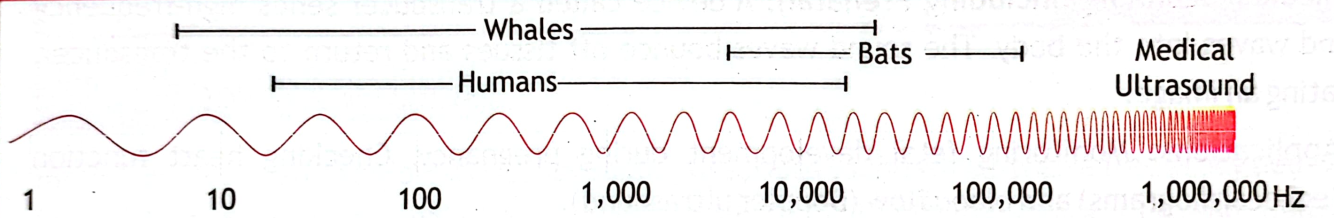


FIGURE 13.9 Frequency of Sound

13.3 ULTRASOUND

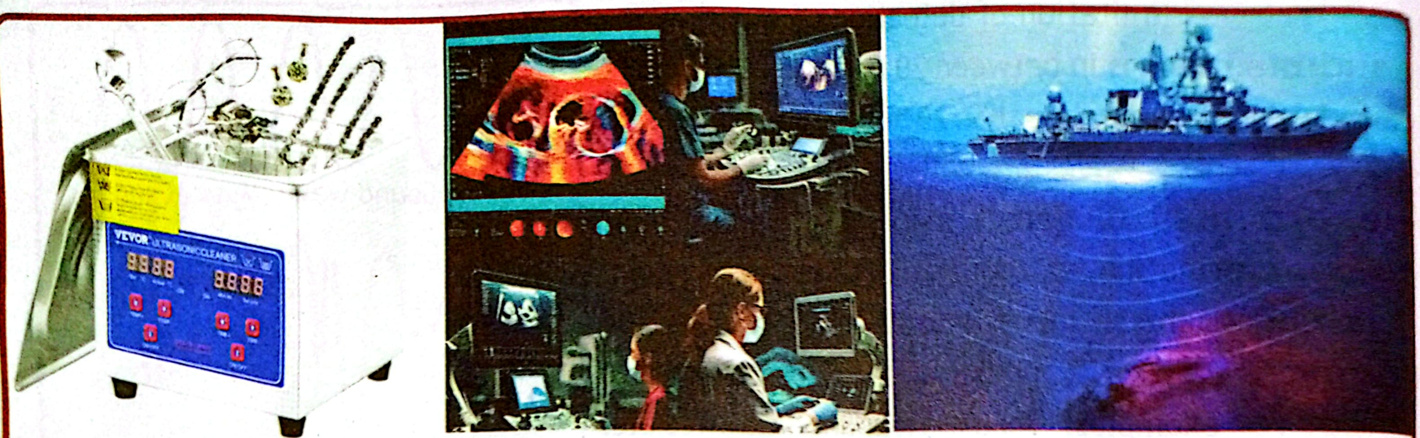
Ultrasound refers to sound waves that have frequencies above the upper limit of human hearing, which is around 20 kilohertz (kHz). Humans can typically hear sounds in the range of 20 Hz to 20 kHz. Sounds with frequencies higher than this range are considered ultrasonic.

Ultrasound has a wide range of applications in various fields. In medicine, it is commonly used for diagnostic imaging, such as in prenatal ultrasound scans to monitor the development of a fetus. Ultrasound waves can penetrate bodily tissues and produce images of internal structures without the need for invasive procedures. In industrial settings, ultrasound is used for nondestructive testing of materials, detecting flaws, and cleaning delicate objects. It is also employed in applications like sonar, which uses sound waves to detect objects underwater.

13.3.1 USES OF ULTRASOUND

A. Cleaning: High-frequency sound waves create tiny bubbles in a liquid. These bubbles implode, producing small shock waves that clean surfaces.

- **Applications:** Cleaning jewelry, electronic parts, and surgical tools.



(a) Ultrasonic Cleaning (b) Medical Scanning (c) Sonar

FIGURE 13.10 Applications of ultrasound

- **Advantages:** Non-damaging, reaches small and hard-to-clean areas, often only needs water or mild detergents.

B. Medical Scanning (Including Prenatal): A device called a transducer sends high-frequency sound waves into the body. The sound waves bounce off tissues and return to the transducer, creating an image.

- **Applications:** Monitoring fetal development during pregnancy. Checking heart function (echocardiograms) and blood flow (Doppler ultrasound).
- **Advantages:** Non-invasive, safe (no harmful radiation), provides real-time images.

C. Sonar (Sound Navigation and Ranging): A sonar device sends out sound pulses underwater. The pulses hit objects and return as echoes. The time it takes for the echoes to return is used to calculate distance.

- **Applications:** Mapping the ocean floor, finding underwater objects like shipwrecks, and measuring water depth.

13.3.2 CALCULATING DEPTH OR DISTANCE

Ultrasound can be used for measuring depth or distance , it involves sending sound pulses from a ship to the ocean floor and measuring the time it takes for the echoes to return. The depth is calculated using the formula:

$$\text{Depth or Distance } (d) = \frac{v \times t}{2} \quad \text{(13.1)}$$

for example, If the sound takes 2 seconds to return and the speed of sound in water is 1500 m/s

$$d = \frac{1500 \times 2}{2} \qquad \text{or} \qquad d = 1500\, m/s$$

Example 13.1

A ship sends sound wave in Pacific Ocean and it takes 14.7 s to return to the ship. Find depth of Pacific Ocean.

GIVEN:

Speed of sound in water 'v' = 1500 m/s

Time taken by sound to return 't' = 14.7 s

REQUIRED:

Depth of Pacific Ocean 'd' = ?

SOLUTION:

Speed of sound is given by: $d = \frac{v \times t}{2}$

putting values $d = \frac{1500\,ms^{-1} \times 14.7\,s}{2}$

Therefore $d = 11{,}025\,m = 11.025\,km$ — ANSWER

The depth of Pacific Ocean is 11,025m (Approx).

13.4 INFRASOUND

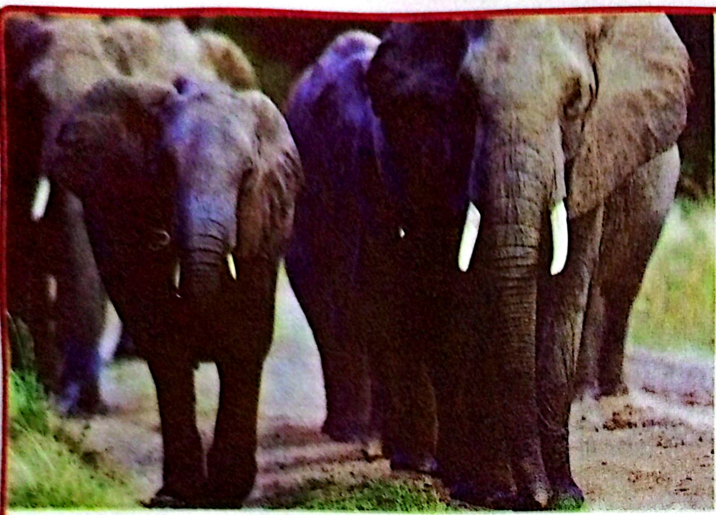
Infrasound referred to as low frequency sound, describes sound waves with a frequency below the lower limit of human audibility (generally less than 20Hz).Infrasonics find the following applications in daily life.

13.4.1: COMMUNICATION BY ANIMALS

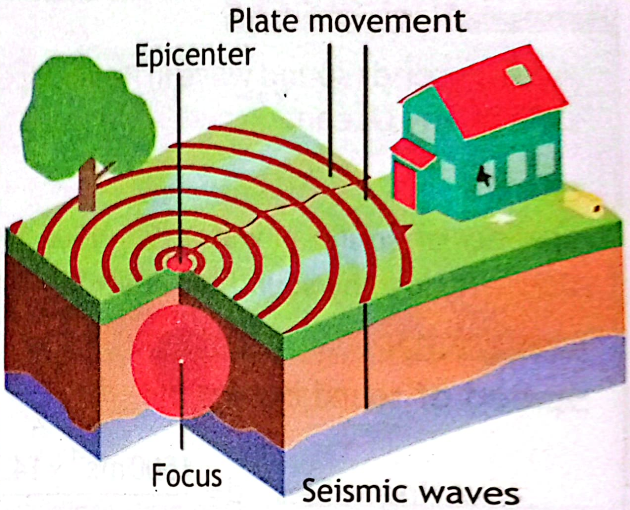
Giraffes were once believed to be silent creatures. However, it was later found that they actually make murmuring sounds at a very low frequency, making it hard for humans to hear. Typically, larger animals produce sounds in lower frequencies, while smaller animals produce higher frequencies. These sounds can travel far through the air and ground, and the ability to hear them depends on the size and structure of the animal's ears.

For example, elephants utilize infrasound to convey messages to each other across vast distances. The infrasound they produce can only be detected using complicated devices. They communicate warnings about potential threats and coordinate their movements. This form of communication enables them to stay connected over long distances and in areas with limited visibility, such as dense vegetation.

This remarkable ability to transmit messages across vast distances not only highlights the intelligence and social complexity of elephants but also underscores their remarkable adaptability to their natural habitats. By harnessing the power of infrasound, these magnificent creatures have developed a sophisticated means of communication that enables them to navigate and thrive in even the most challenging of environments.



(a) Communication by Elephants



(b) Seismic Activity

FIGURE 13.11 Applications of Infrasonic

13.4.2 SEISMIC ACTIVITY

Infrasound is generated by natural events like earthquakes, volcanic eruptions, and explosions Specialized instruments called infrasound sensors detect these low-frequency sound waves Monitoring seismic activity to predict earthquakes and volcanic eruptions. Studying and understanding the behavior of natural disasters. It provides early warnings for natural disasters It also helps in understanding the Earth's internal processes. For example infrasound sensors placed around a volcano can detect low-frequency rumblings that indicate an imminent eruption allowing timely evacuation of nearby populations.

SCIENCE TIDBITS

Infrasound can travel incredibly long distances without losing much of its energy. This means that infrasound waves produced by natural events, such as volcanic eruptions or earthquakes, can be detected thousands of kilometers away from their source. For instance, the infrasound waves generated by the eruption of Krakatoa in 1883 were recorded all around the world, circling the globe multiple times.

This long-range propagation makes infrasound a powerful tool for monitoring and studying geological and atmospheric phenomena on a global scale.

13.5 CHARACTERISTICS OF SOUND WAVE

There are basically three main characteristics of sound wave, pitch, loudness and quality.

13.5.1 PITCH

That characteristic of sound wave by which we can differentiate between grave and shrill voices. It is not a physical quantity that's why it cannot be measured directly. Basically it is the characteristic regarding perception of frequency, which also depends upon wavelength and speed of sound too. It cannot be detected directly and only can be analyzed on the basis of frequency of sound wave.

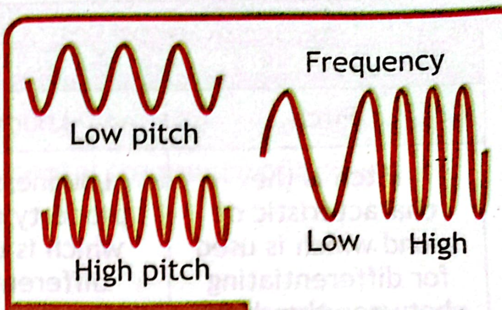


FIGURE 13.12 Pitch of sound

Pitch describes about number of vibrations produced by vocal chord in unit interval of time (one second). That's why pitch has direct relation with frequency of sound wave.

$$\text{Pitch of sound wave} \propto \text{Frequency of sound wave}$$

Low pitch of sound waves means less frequency while high pitch tells about high frequency. For example; A bird produces high-pitched sound whereas roaring of a lion is a low-pitched sound, the voice of a woman has a higher pitch than that of a man and so on.

13.5.2 LOUDNESS

It is that characteristic of sound wave by which we can differentiate between loud and faint sound. It is also not a physical quantity that's why it cannot be measured directly. Loudness can be measured on the basis of "Amplitude of sound wave".

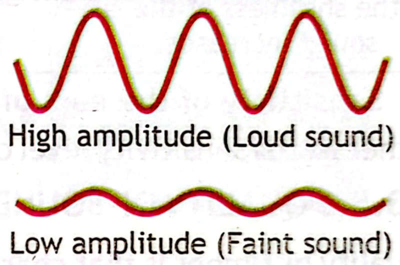


FIGURE 13.13 Loudness of sound

$$\text{Loudness of sound wave} \propto (\text{Amplitude of sound wave})^2$$

Basically loudness of sound wave is the sensation to test the strongest level of sound wave. Amplitude of the wave is the best parameter to check the strongest level of sound wave. Loudness level can be studied in term of 'decibel'.

There are basically 4-factors which directly affect the loudness of sound.

A. Vibrational amplitude of source of sound: Vibrational amplitude has direct relation with loudness of sound. It means that greater the vibration amplitude of vibrating object (Source of sound) will cause the production of high loudness.

B. Surface area of source of sound: Surface area is directly proportional to relation with loudness of sound. It means that greater the surface area of source of sound will produce of high loudness.

C. Distance from source of sound: Distance of listener form source of sound has inverse relation with loudness of sound wave. It means that short distance listener will feel more impact of loudness as compare to long distance listener.

TABLE 13.1 COMPARATIVE SKETCH OF LOUDNESS & PITCH OF SOUND WAVE	
Pitch	Loudness
Pitch is the characteristic of sound which is used for differentiating between the shrill and flat sound.	Loudness is the property of sound which is used for differentiating between the loud and faint sound
Pitch is independent of the energy received by the ear in unit time interval.	Loudness is dependent upon the energy received by the ear in unit time interval
Pitch is dependent on the change in the frequency. As the frequency increases, the shrillness of the sound increases.	Loudness is independent of the change in frequency

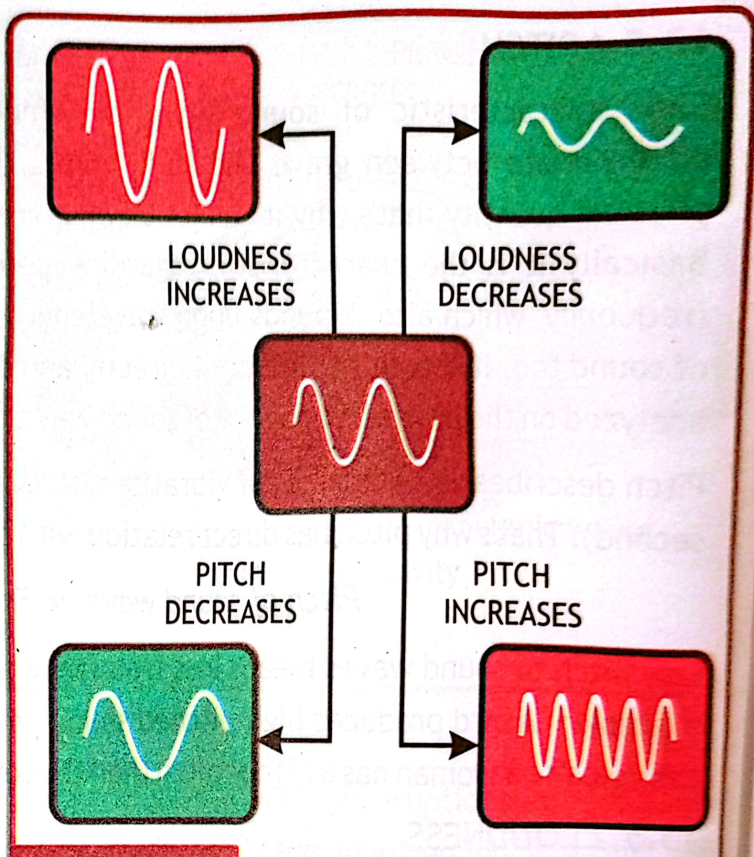


FIGURE 13.14 Pitch of waves

D. Sensitivity of the ears of listener: More sensitive ears can feel more effect of loudness. In other words Sensitivity level of ears has direct relation with loudness of sound wave.

13.5.3 QUALITY OF SOUND OR TIMBRE

Quality or timber is that characteristic of sound which helps our ear to distinguish between such two sound waves, which have same loudness and pitch. Timbre is that term which helps us to study dynamic characteristics as well as harmonic contact of sound waves.

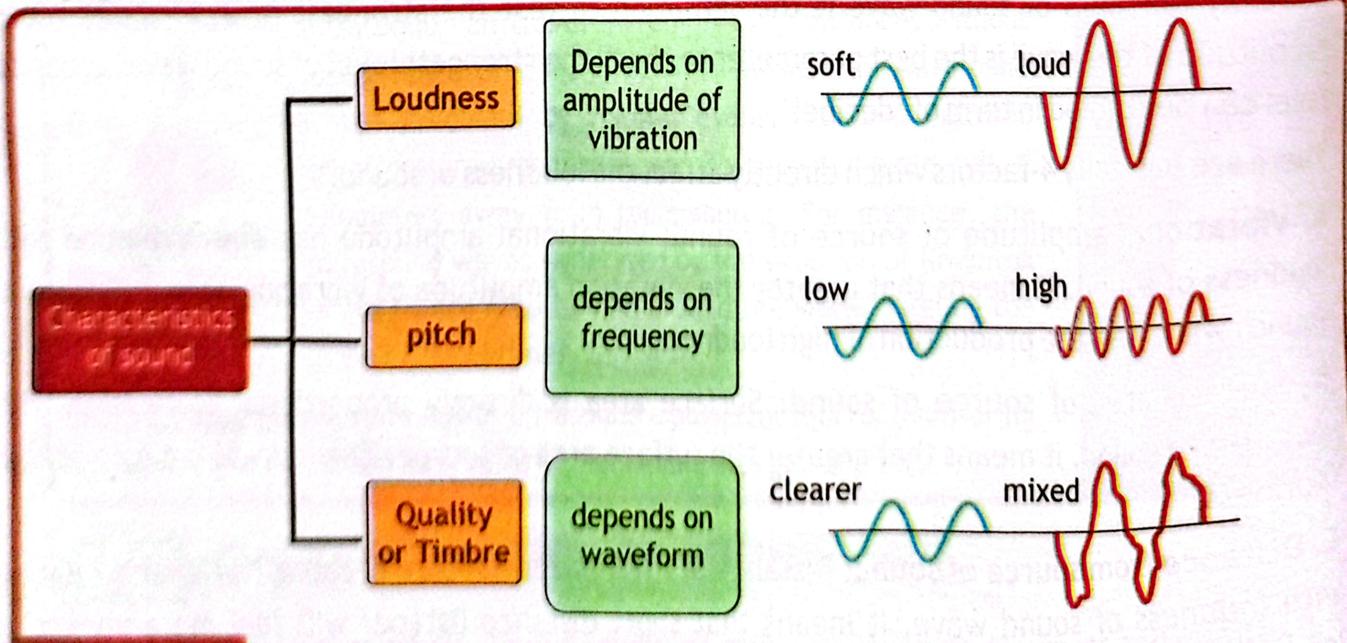


FIGURE 13.15 Pitch of waves

The word harmonic contact describes that during traveling of sound waves from one point to another point, the way adopted by molecules of medium for transmitting vibrational energy. The quality of sound depends upon relative intensities of overtones. The word over tones means an overtone is any harmonic with frequency greater than the fundamental frequency of a sound.

13.6 ANALYZING SOUND WAVES

Sound waves are vibrations that travel through the air (or other mediums) and reach our ears. These vibrations are usually produced by an object, like a guitar string, vocal cords, or a speaker, while Timbre (pronounced "tam-ber") as the quality or color of a sound that makes it unique. It's what allows us to distinguish between different instruments or voices, even if they are playing the same note. For analyzing sound wave oscilloscope is used.

Oscilloscope is a device that allows us to see sound waves. It displays a sound wave as a trace (a line) on a screen, whereas Waveform explains that different sound sources produce different waveforms on an oscilloscope. These shapes can help us understand the timbre of the sound.

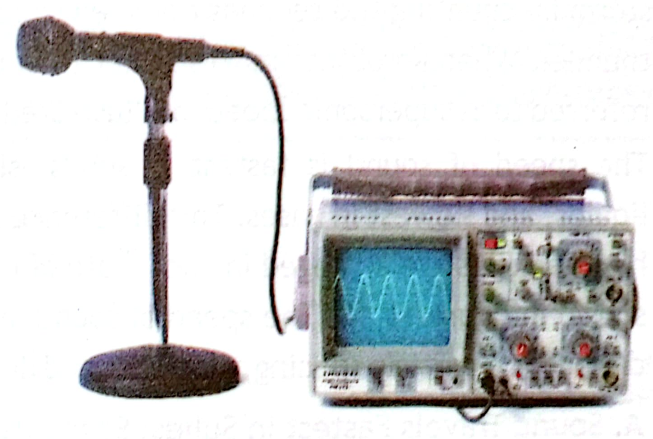


FIGURE 13.16 Oscilloscope

Some waves start with a pure tone, like that from a tuning fork. On an oscilloscope, this produces a smooth, regular sine wave called Pure Tones and Sine Waves.

This type of sound has a simple timbre, while compare this to a more complex sound, like a note from a piano or a violin, which produces a more complex waveform on an oscilloscope called Complex Waves. These sounds have richer timbres because they include multiple frequencies and overtones.

For examples string instruments explain how plucking a string on a guitar produces a sound wave with a specific shape. The oscilloscope trace will show the fundamental frequency and various overtones, resulting in a unique waveform, also wind instruments like blowing into a flute creates vibrations in the air column inside the instrument. This produces a different waveform, visible on the oscilloscope, and gives the flute its distinctive timbre.

13.7 SPEED OF SOUND

The speed of sound can be defined as: **The distance covered by sound wave per unit time is called speed of sound.** Mathematically:

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad \text{or} \quad v = \frac{d}{t} \qquad (13.2)$$

The speed of sound in air is generally between 330 m/s and 350 m/s, depending on t temperature. One key factor that influences the speed of sound is temperature. When the ai warmer, sound travels faster because the air particles have more energy and move more rapid In contrast, in colder air, the particles move more slowly, and the speed of sound decreases. F example, on a cold winter day, sound might travel closer to 330 m/s (1188 km/h), while on a hot summer day, it could reach up to 350 m/s (1260 km/h).

FIGURE 13.17 Supersonic Speed

For example, during a thunderstorm, you often see lightning before hearing thunder. This is because light travels almost instantly, while sound takes longer due to its comparatively slower speed. The difference in their speeds allows us to estimate the distance of the storm by counting the seconds between seeing lightning and hearing thunder. When an object moves faster than the speed of sound, it is referred to as supersonic speed, as illustrated in figure 13.17.

The speed of sound is fastest in solids, slower in liquids, and slowest in gases. This difference is due to how particles are arranged in each state of matter as shown in figure 13.18. The speed of sound in general depends on particle spacing, elasticity and density.

FIGURE 13.18 Speed of Sound in different medium

A. Sound Travels Fastest in Solids: Sound travels the fastest in solids because the particles in solids are tightly packed and held together by strong forces. When a sound wave moves through a solid, the vibrations transfer efficiently from one partic the next due to their close proximity. For example, if you place your ear on a metal rod an one end, you will hear the sound almost instantly. In metals like steel, sound can travel at sp of over 5000 m/s, much faster than in air or water.

B. Sound Travels Faster in Liquids: In liquids, particles are less tightly packed than solids they are still closer together than in gases. This allows sound waves to travel faster in liquids in gases, though not as fast as in solids. For instance, sound travels in water at approximately m/s, which is about four times faster than in air. This is why marine animals, such as dolphin whales, rely on sound for communication over long distances in water.

C. Sound Travels Slowest in Gases: In gases, the particles are widely spaced, making it hard vibrations to transfer from one particle to another. This is why sound travels slowest in gases a speed of around 340 m/s in air at room temperature. The large gaps between particles more delay in the transfer of sound energy.

Example 13.2

A boy at night heard sound of thunder with a gap of about 3.0 seconds when he saw lightning. How far away is the lightning, taking speed of sound as 343 m/s?

GIVEN:
Speed of sound 'v' = 343 m/s
Time taken 't' = 3.0 s

REQUIRED:
Distance of lightning 'd' = ?

SOLUTION:
Speed of sound is given by: $v = \frac{d}{t}$ or $d = v \times t$

putting values $d = 343\,ms^{-1} \times 3.0\,s$

or $d = 1029\,m = 1.029\,km$

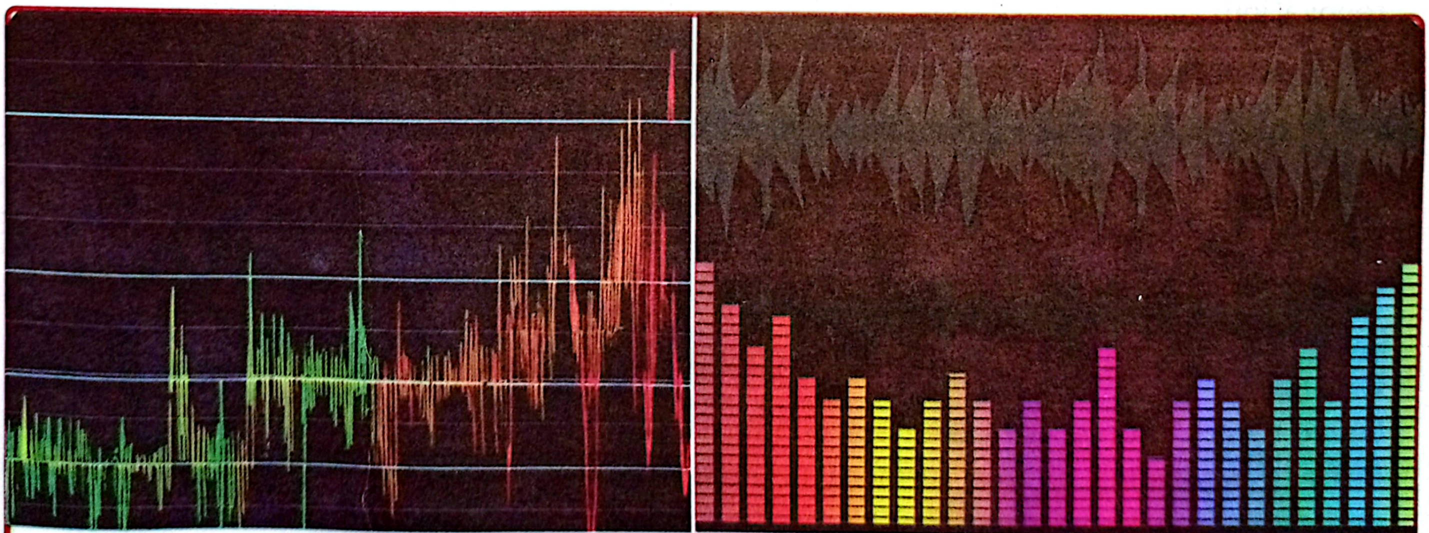
Therefore $d = 1.029\,km = 1\,km$ — **ANSWER**

Therefore the clouds are at about 1 km distance.

13.8 NOISE

In general; the term noise means unpleasant sound waves experienced by listener. But in physics noise has following characteristics; these sound waves have;

- Non-Rhythmic behavior
- Irregular time intervals for completion of vibrations
- Variable energy states
- Irregular intensities



(a) Noise (b) Musical Sound

FIGURE 13.19 Difference between noise and musical sound

Basically; sound waves can be studied in two manners as 'periodic sound waves' and 'non-periodic sound waves'. Human ears structures are designed for periodic sound waves. It means that our

Industrial buildings Construction sites Transportation Public places

FIGURE 13.20 Pitch of waves

ears feel pleasant effect for those sound waves which have regular periodic vibrations, energi frequencies and even intensities levels.

The range of periodic sound waves is about 15 hertz to 4000 hertz. While beyond this ra periodic sound waves are converted into non-periodic waves which give very unpleased effec listener. Beyond this range receiving sound signals are painful.

Noise is also one of the main causes for creating psychological and physical stress in daily routi Noise also provides negative impact on concentration level to perform any a daily life activity. all are mostly affected by environmental noise sources for examples.

- **Industrial buildings;** factories and machineries, air-conditioning systems.
- **Construction sites;** site formation (e.g. excavation), piling, road work, demoli renovation.
- **Transportation;** aircrafts, trains, road vehicles, vessels.
- **Public places;** open markets, streets, parks.

Noise pollution can be reduced by use of earplugs, turning off appliances when not in planting more trees, lowering the volume, regular maintenance of vehicles and machines et controlling noise we can control negative health effects that noise pollution has on everyone

13.9 REFLECTION, REFRACTION AND DIFFRACTION OF SOUND

Sound waves interact with their surroundings in different ways. They can reflect, refract diffract depending on the surfaces or materials they encounter. These behaviors he understand how sound travels and why we hear it in various situations.

13.9.1 REFLECTION

Sound can reflect when it hits a surface and bounces back, just like light reflecting from a n Reflection of sound waves is used to find the depth of ocean as shown in figure 13.21 (a example, when you clap your hands in a large room with tiled walls, the sound seems to "bo

DO YOU KNOW?

If you heard the sound of thunder, you are safe now, how?

It is because thunder has occurre a bit earlier and you heard the sound later because sound travels at much lower speed than light. But still it is instructed to find some covered space and stays there during thunder.

around the room. Similarly, in a small space like a bathroom, you might notice your voice sounds louder due to sound waves reflecting off the walls.

13.9.2 REFRACTION

Sound waves change direction as they pass through different materials or layers of air with varying temperatures. This causes the sound to bend as its speed changes. For example, distant sounds are clearer at night when cooler ground air and warmer upper air cause sound waves to bend towards the ground as shown in figure 13.21 (b). Sound waves bend when they move through water layers that have different temperatures and densities. This bending impacts how submarines and marine animals, like whales, communicate underwater.

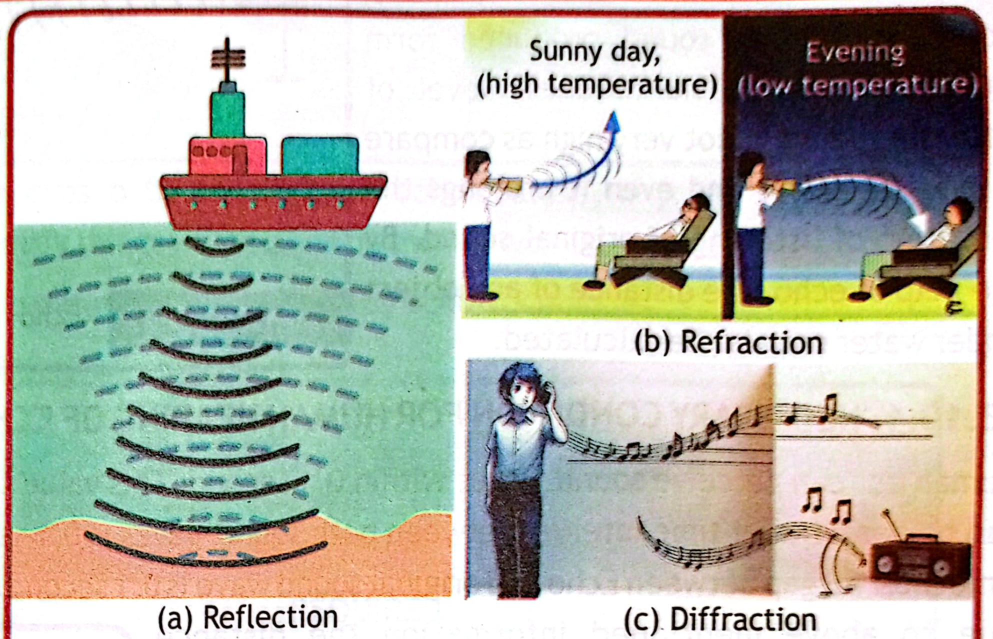


FIGURE 13.21 Sound waves in reflection, refraction and diffraction.

13.9.3 DIFFRACTION

Sound waves bend around obstacles or spread out after passing through small openings. his allows sound to spread into areas where there is no direct line of sight. For example, you can hear music playing from another room, even if the door is slightly closed, because the sound waves bend and spread as shown in figure 13.21 (c). Similarly, when someone calls your name from behind a corner, you can still hear them because the sound waves diffract around the wall.

13.10 ECHO

Basically the term echo is such behavior of sound wave by which it comes back to the listener after striking with any obstacle due to Wave-reflection phenomenon. Like other waves, Sound waves also bounce back from any nature of hard surface (obstacle) like a bouncing of rubber ball from the surface of earth or wall.

So in general we can say that ECHO is distinct sound wave which obeys reflection phenomenon. When sound wave is generated from sound source its reflection from any surface (obstacle) produces another wave which is separately heard from the original sound produced form source of sound. The hardness level of reflecting sound is not very high as compare to original sound and even it prolongs the sensation of listening of original sound. By the help of echo, the distance of any object under water can also be calculated.

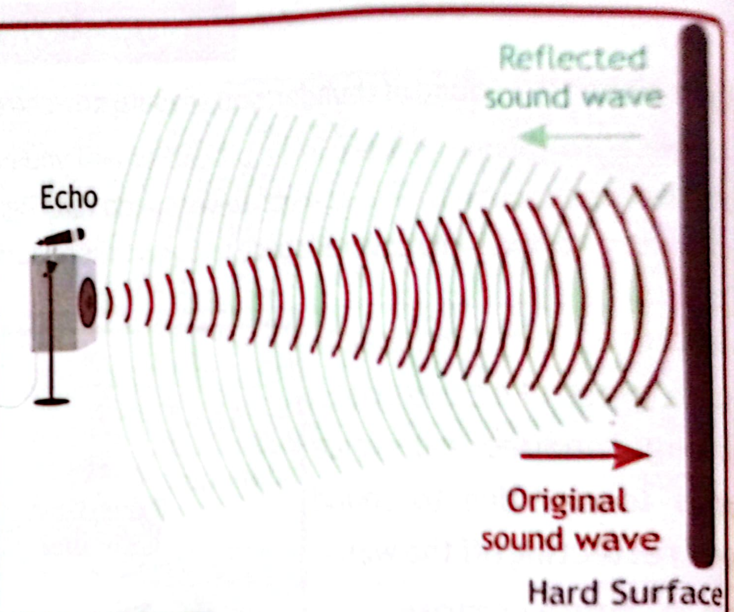


FIGURE 13.22 Echo

13.10.1. NECESSARY CONDITION FOR HUMAN HEARING OF ECHO

Human ear can perceive sound waves within 0.1 second. This value shows that two sound waves can be perceived if time interval between both sound waves is 0.1 second. So it is clear that the time interval gap between Echo and original sound wave is 0.1 second.

Due to above mentioned information the distance between source of sound and reflecting surface can be calculated as: Distance travelled by sound 'D' = 2d

Time taken by echo 't' = 0.1 s

If the speed of sound is 'v', then

$$v = \frac{D}{t} \quad \text{or} \quad D = v \times t$$

putting values: $2d = v \times 0.1$ or $d = v \times \frac{0.1}{2}$

Therefore, $d = \frac{v}{20}$ — 13.3

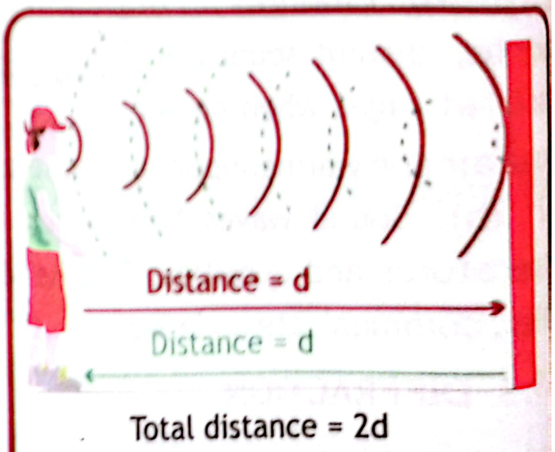


FIGURE 13.23 Human Echo

This result tells that minimum required distance for production of echo is 1/20th value of speed of sound. For example, if speed of sound in air is 340 m/s then for producing echo the least distance should be 17 m.

13.10.2 APPLICATIONS OF ECHO

There are so many applications of echo are common in daily life; by the help of echo

- Speed of sound can be determined
- Usage in obstetric ultrasonography and so on

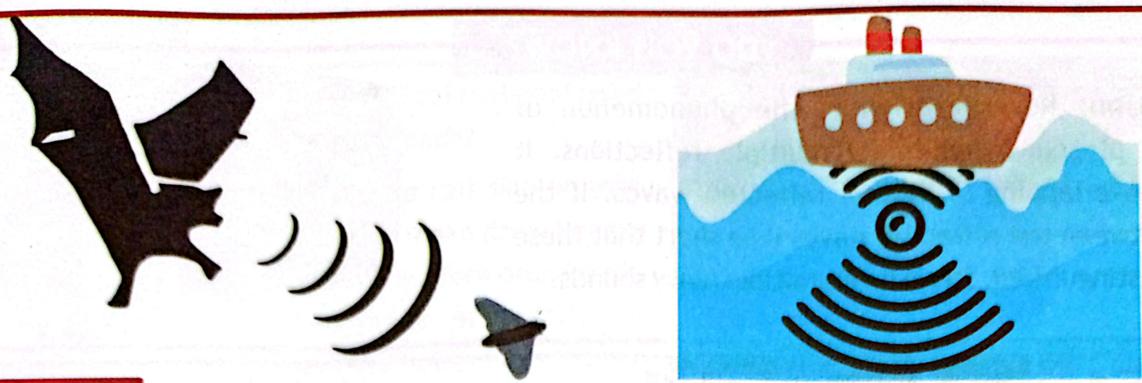


FIGURE 13.24 Applications of Echo

- Bats cannot see from their eyes o by the help of echolocation they can reach their destinations and even can identify things which come on their ways.
- Depth of sea or presence of submarines can be located by echo-techniques.

Example 13.3

A teacher took students to a nearby hill for performing Echo experiment. Abdullah shouted and the teacher and all other students heard his echo after 1.2 s, using a stop watch. If speed of sound is 346 m/s, how far will the cliff be from him?

GIVEN:
Time taken for echo 'Δt' = 1.2 s
Speed of sound in air 'v' = 346 m/s

REQUIRED:
Distance of cliff d = ?

SOLUTION:
Using the equation for echo: $d = \frac{v \times \Delta t}{2}$ putting values $d = \frac{(346\,m/s) \times (1.2\,s)}{2}$

Therefore $d = 207.6\,m$ — ANSWER

So, the cliff is 207.6 m away from him.

13.11 ACOUSTICS

It is that branch of physics which deals with study of sound; its characteristics, production, transmission, effects and so on. There are so many types of acoustic like; Environmental Noise, Musical Acoustics, Ultra-sounds, Infra-sounds, Vibration and Dynamics.

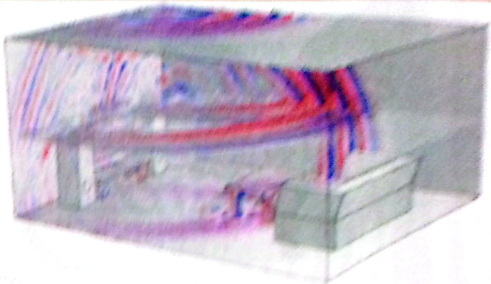
Environmental noise is defined as undesirable or destructive open-air sound created by human activity, such as noise emitted by means of road traffic transport, industrial activity, rail traffic, and air traffic.

13.11.1 ACOUSTIC PROTECTION

The technique or method used to absorb undesirable sounds by soft and porous surface is called

DO YOU KNOW?

Reverberation: Reverberation is the phenomenon of overlapping of sound caused by multiple reflections. It causes the overlapping of several reflected waves. If the time gap between the reflected waves is so short that these cannot be distinguished. So we hear multiple noisy sounds.



(a) Acoustic protection

(b) Traffic Noise

FIGURE 13.25 Acoustic

acoustic protection. Reflection of sound is more prominent if the surface is rigid and smooth, and less if the surface is soft and irregular. Soft porous materials, such as draperies and rugs absorb large amount of sound energy and thus quiet echoes and softening noises. Thus by using such materials in noisy places, we can reduce the level of noise pollution. However, if the surface of "classrooms or public halls are too absorbent, the sound level may be low for the audience.

13.11.2 IMPORTANCE OF ACOUSTIC PROTECTION

Acoustic protection is crucial for several key reasons:

A. Health and Well-being:

- **Hearing Protection:** Prevents hearing loss from prolonged noise exposure.
- **Mental Health:** Reduces stress, anxiety, and sleep disorders by minimizing noise pollution.

B. Productivity and Performance:

- **Workplace Efficiency:** Enhances concentration, reduces errors, and prevents accidents by limiting distractions.
- **Learning Environments:** Improves students' ability to focus and retain information.

C. Environmental and Community Impact:

UNIT OPENER?

What is the typical material used to make drumheads?

Animal skins like calf skin or goat skin are used to make drum heads. Although some modern drumheads are often made of plastic or synthetic materials, but traditional drumheads were made from animal skin.

- **Wildlife Preservation:** Protects animals that rely on sound for communication and navigation.
- **Quality of Life:** Ensures quieter, more pleasant living environments for communities.

D. Legal and Regulatory Compliance:

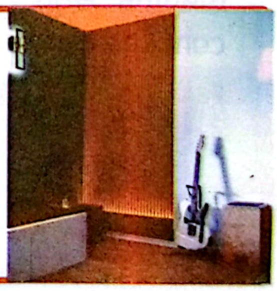
- **Occupational Safety:** Helps organizations meet noise exposure regulations.
- **Building Standards:** Ensures buildings provide adequate noise control as per codes.

E. Technological and Industrial Development:

- **Innovation:** Drives the creation of new materials and quieter machinery, benefiting various industries.

DO YOU KNOW?

Without acoustic protection, people can suffer hearing loss and increased stress levels. Productivity in workplaces and learning environments may drop due to constant noise distractions. Additionally, excessive noise can disrupt community peace and harm wildlife.



13.11.3 APPLYING ACOUSTICS IN BUILDING DESIGN

Understanding sound wave properties is crucial for designing buildings with good acoustics

A. Sound Absorption: Materials like carpets, acoustic panels, and curtains are used to absorb sound and reduce echoes.

B. Sound Reflection: Design of walls and ceiling are made in such a way that it reflects sound where needed, materials like glass and concrete are used for such purpose.

C. Sound Transmission: We Use thick walls, double-glazed windows, and insulated doors to prevent sound from traveling between spaces. Mostly Dense Materials or Heavy materials like concrete block are used.

D. Sound Diffusion: For acoustic protection we install elements that scatter sound evenly, like irregular surfaces or special panels.

E. Resonance Control: The size and design of the room are taken in consideration to avoi amplification of certain sounds. Also Bass Traps are used in these studios to control low-frequenc sounds.

F. Noise Control: Gaps are properly sealed to ensure that doors and windows are well-sealed t block noise. Also barrier walls, fences, and landscaping are used to reduce outside noise.

G. Vibration Control: For damping we use rubber mounts and floating floors to reduce vibration And isolate noisy equipment to prevent vibrations from spreading.

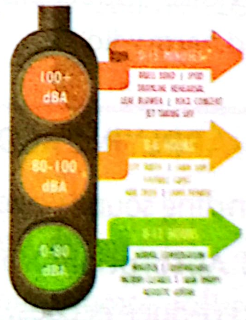
Practical examples are Concert halls in which combine absorbing, reflecting, and diffusin materials for clear sound. In offices we use absorbing materials to reduce noise and increas productivity. In homes incorporate soundproofing are used for privacy and quiet. Using soun wave properties helps design buildings that sound good and are comfortable.

Soft materials are used on walls of classrooms and public buildings in order to reduce echo, whic have following benefits.

- **Sound Absorption:** Soft materials like carpets, curtains, and acoustic panels absorb soun waves, reducing reflections and echoes. It ensures students can hear and understand th teacher effectively, leading to better learning outcomes.
- **Reducing Reverberation Time:** Soft materials shorten the time it takes for sound to decay making speech and other sounds clearer. It creates an environment conducive to concentration and productivity in spaces like libraries and lecture halls. A quieter environment reduces stress and fatigue, enhancing comfort in places like hospitals and auditoriums.

DO YOU KNOW?

The sound pressure level needed for the human ear to recover from NITTS, the effective quiet level, is approximately 55 dB. This is probably the safe noise exposure level to prevent NIHL from a single exposure, with 55-60 dB time-weighted average being the actual safe noise exposure level for a day.



13.12 HUMAN HEARING SYSTEM

In physics, the process of converting sound into electrical signals that are interpreted by the brain involves several steps that can be described through the principles of wave mechanics, mechanical vibrations, and signal transduction.

A. Sound Waves Enter the Ear: Sound waves are vibrations in the air that travel into the ear canal and hit the eardrum.

B. Eardrum Vibration: The eardrum vibrates in response to these sound waves.

C. Ossicles Amplify Vibrations: These vibrations are passed to three tiny bones in the middle ear called the ossicles (malleus, incus, and stapes), which amplify the vibrations.

D. Vibrations Enter the Cochlea: The stapes (one of the ossicles) sends the vibrations into the cochlea, a fluid-filled spiral structure in the inner ear.

E. Fluid Waves in the Cochlea: The vibrations create waves in the fluid inside the cochlea.

F. Hair Cells Detect Vibrations: These fluid waves move the basilar membrane inside the cochlea, causing hair cells on the membrane to bend.

G. Conversion to Electrical Signals: When the hair cells bend, they generate electrical signals.

H. Electrical Signals Travel to the Brain: These electrical signals are sent through the auditory nerve to the brain.

I. Brain Interprets the Signals: The brain processes these signals and interprets them as sound, such as music or speech.

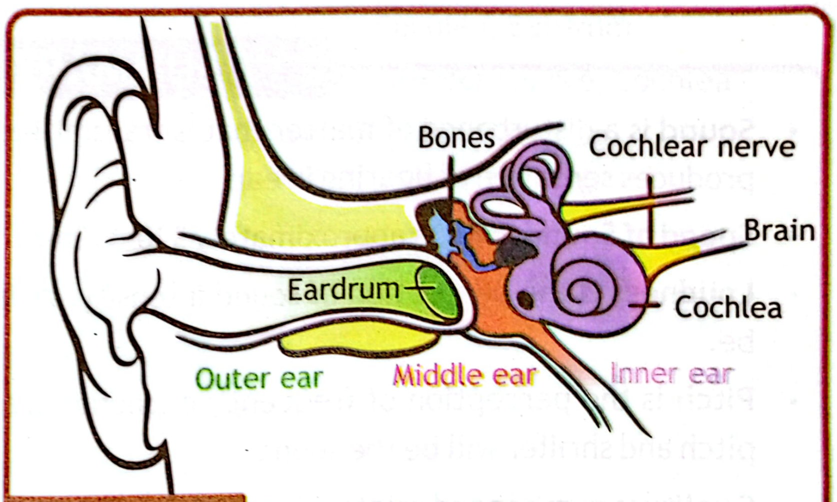


FIGURE 13.26 Human Hearing System

CAUTION

Continuous use of hands-free devices like earphones and headphones, especially at high volumes, can lead to noise-induced hearing loss (NIHL), tinnitus (ringing in the ears), ear infections from bacteria on dirty earphones, and temporary hearing fatigue. To protect your hearing, follow the 60/60 rule (no more than 60% volume for 60 minutes), use noise-canceling headphones, take regular breaks, opt for over-ear headphones, and get regular hearing checks. These measures help minimize the risk of hearing damage while using these devices.

EXERCISE

MULTIPLE CHOICE QUESTIONS

QI. Choose the best possible option in the following questions.

1. What are the three main parts of the human ear?
   A. Outer ear, Middle ear, Inner ear
   B. Inner ear, Cochlea, Eardrum
   C. Middle ear, Eardrum, Auditory nerve
   D. Outer ear, Auditory nerve, Cochlea
2. Sound produced by piano and violin gives ________ waveform on oscilloscope.
   A. Simple B. Harmonic C. Complex D. Symmetric
3. Which is NOT true for sound?
   A. Sound is produced by vibrating body
   B. Sound travels due to variation of pressure in air
   C. Sound transfer energy along with matter of medium
   D. Sound is compressional and longitudinal wave
4. Sound travels faster in:
   A. rubber B. air C. water D. steel
5. Speed of sound in air is 332 ms^{-1}. What is its speed in vacuum?
   A. Equal to 332 ms^{-1} B. Great than 332 ms^{-1} C. Less than 332 ms^{-1} D. Zero
6. The sound travels from water to an iron rod and then into air and back into water. The speed of sound will successively:
   A. increase, decrease, increase
   B. decrease, increase, decrease
   C. increase, increase, increase
   D. decrease, decrease, decrease
7. What will happen to speed of sound, if frequency is doubled? It will become:
   A. half B. double C. four times D. remain same
8. Infrasonic waves have frequency:
   A. greater than 20Hz B. less than 20Hz C. of 20 Hz D. of 20 kHz
9. For echo, the minimum distance of a person from obstacle is:
   A. 17 m B. 34 m C. 0.1 m D. any distance above 50 m
10. The property of waves which is directly related with loudness of sound is
    A. Frequency B. Wavelength C. Speed D. Amplitude

11. Sound entered in ear is amplified by:

A. Ossicles B. Cochlea C. Eardrum D. Brain

12. Silent whistle is used to train dog. When trainer blows the whistle, human beings do not hear it but dog do listen. Its possible frequency is:

A. > 20 Hz B. < 20 Hz C. < 20000 Hz D. > 20000 Hz

13. The pitch of sound depends upon:

A. frequency B. amplitude C. quality D. displacement

14. Two sound waves having same loudness and pitch can be distinguished by one of the characteristics of sound called:

A. loudness B. pitch C. quality D. intensity

15. The sensation of sound persists in our brain for about

A. 10 s B. 1 s C. 0.1 s D. 0.01 s

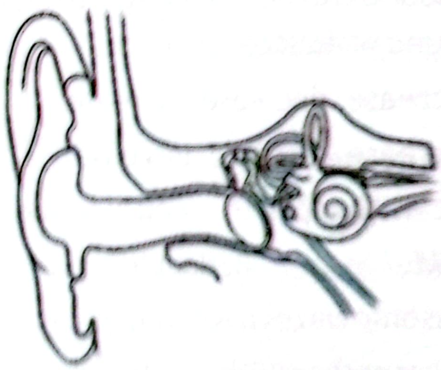
CONSTRUCTED RESPONSE QUESTIONS

QII. Follow the directions to respond to the following questions.

1. Mark the frequency region for Infrasound, Human Audible Frequency and Ultrasound.

0 Hz	10 Hz	20 Hz	1000 Hz	3500 Hz	13,000 Hz	20,000 Hz	40,000 Hz	55,000 Hz	80,000 Hz

2. Label the major parts of Human Hearing System.



SHORT RESPONSE QUESTIONS

QIII. Give a short response to the following questions.

1. Analyses the process of sound transmission from outer ear to brain.
2. What are common sources of harmful noise, assess their impact on human health?

3. How do animals use infrasound for communication? Compare this with human communication methods.
4. Evaluate the advantages and limitations of ultrasonic cleaning.
5. Why does sound travel faster in solids than liquids and gases?
6. How two plastic glasses with a string stretched between them could be better way to communicate than merely shouting through the air?
7. How can we distinguish between two sounds having same loudness?
8. During a match in cricket stadium, you see a batsman striking the ball but we hear stroke sound slightly later. Explain this time difference?
9. When a pendulum vibrates, we do not hear its sound. Why?
10. Two students are talking in the corridor of your school, you can hear them in your class room but you cannot see them. How?
11. What steps would you take to stop echo and reverberation effects in a large room?

LONG RESPONSE QUESTIONS

QIV. Give a detailed response to the following questions.

1. Explain the production of sound waves with examples.
2. Justify why sound waves cannot travel in a vacuum. Design an experiment that demonstrates this principle.
3. What is nature of sound waves? How is sound propagated? Explain.
4. Discuss how changes in amplitude and frequency affect the loudness and pitch of sound waves.
5. What is quality of sound? How do the shape and material of a sound source influence the waveform of the sound it produces.
6. Explain the speed of sound in different media. How does the speed of sound differ in solids, liquids, and gases? Explain why, and discuss real-world implications.
7. What is reflection of sound? Differentiate between echo and reverberation.
8. Explain the phenomenon of an echo as the reflection of sound waves. Design an experiment to measure the time delay of an echo, and discuss how this can be used to determine distances in various applications, such as sonar.
9. Differentiate between noise and music? Explain that how is noise nuisance?

10. Justify the importance of acoustic protection in environments such as schools a hospitals. How can design elements and materials contribute to creating sound-frien spaces?

11. Analyze the effects of noise pollution on the environment and human health. Wh strategies can be implemented to mitigate these effects, and how can communiti balance development with acoustic quality?

12. Humans can hear frequencies from approximately 20 Hz to 20,000 Hz. Analyze how soun outside this range (infrasound and ultrasound) are utilized in nature and technology. Wh are the implications of these frequencies for human hearing?

15. Explain how sound waves are converted into electrical signals by the eardrum and auditor nerves.

NUMERICAL RESPONSE QUESTIONS

QV. Solve the questions given below.

1. A tourist clapped his hands near a cliff and heard the echo after 5 s. What is the distance o the cliff from the student if the speed of the sound is taken as 344 m/s? **(Ans. 860 m)**

2. Speed of sound in seawater is 1500 m/s. If its wavelength is 45 cm, find the frequency o these sound waves. **(Ans. 3,333.3 Hz)**

3. A sound wave in seawater travels at speed of 1500 m/s, it is sent and detected back afte reflection from seabed in 8.5 s. Find the distance from surface to the bottom of the sea. **(Ans. 6,375 m)**

4. A physician counts 69 heartbeats in 1 min. Calculate the frequency and period of the heartbeats. **(Ans. 1.15 Hz, 0.8696 s)**

5 Find the range of wavelengths at speed 343 m/s for audible frequency range (20 Hz to 20 kHz). **(Ans. 17.15 m, 0.01715 m)**

6. During thunder storm, thunder sound is heard after 3 second of lightning flash. Find the distance of clouds from ground. (Speed of sound = 340 m/s). **(Ans. 1020 m)**

7. SONAR (sound navigation and ranging system) sends ultrasound signal towards sea bed. It is received back after 5.3 s. If speed of sound in sea water is 1550 m/s. Find the depth of sea there. **(Ans. 4107.5 m)**