**Q1. Define acoustics.**

**Ans: Acoustics:**

The study of sound is called acoustics.

## Physics of Sound

All sounds are produced by the vibrations of objects. Sound is a form of energy that travels in the form of waves from one place to another.

## For Your Information

Stethoscopes operate on the transmission of sound from the chest-piece, via air-filled hollow tubes, to the listener's ears. The chest-piece usually consists of a plastic disc called diaphragm. If the diaphragm is placed on the patient's body sounds vibrate the diaphragm, creating acoustic pressure waves which after multiple reflection travel up the tubing to the doctor's ears.

**Q2. Define sound. What is its nature?**

**Ans: Sound:**

Vibrations that travel through the air or another medium and can be heard when they reach a person's or animal's ear.

Sound is a form of energy, which produces hearing sensation in human ears.

**Nature of sound waves:**

Sound waves are longitudinal waves.

**Q3. Explain how sound is produced by vibrating sources and that sound waves require a material medium for their propagation.**

**Production of sound:**

Like other waves sound is also produced by vibrating bodies. Due to vibration of bodies the air around them also vibrates and the air vibration produces sensation of sound in our ear.

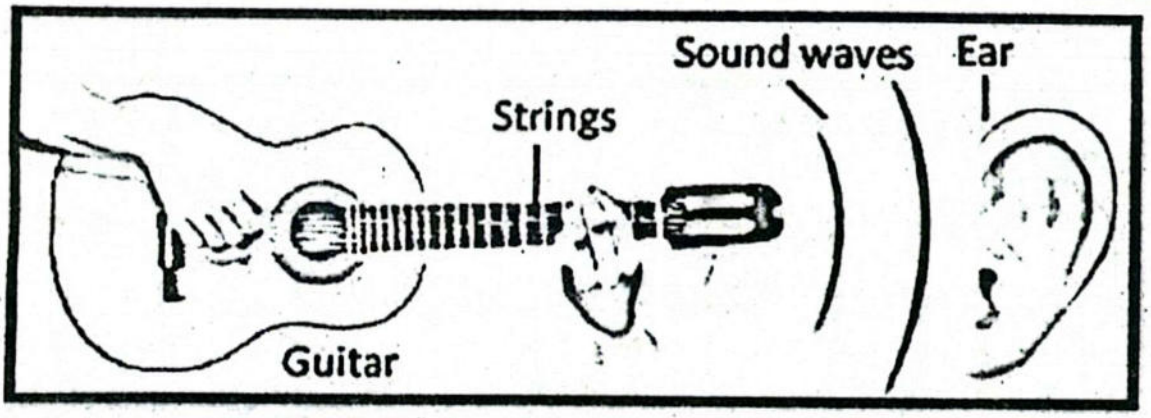
**Examples:**

i. In a guitar, sound is produced due to the vibrations of its strings.

ii. Our voice results from the vibrations of our vocal chords.

iii. Human heart beats and vibrations of other organs like lungs also produce sound waves.

iv. Doctors use stethoscope to hear this sound.

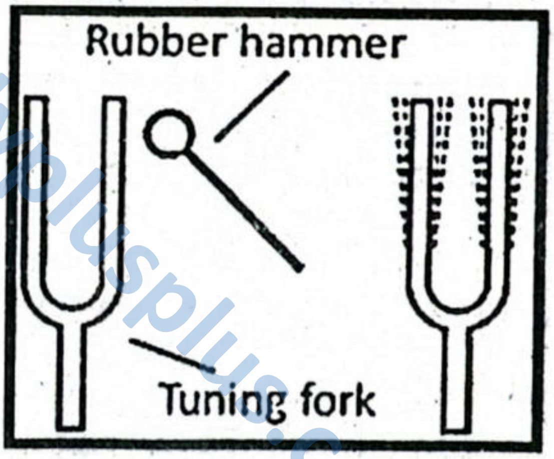



**Vibrations of guitar strings produce sound waves.**

## Sound is Produced by Vibrating Body:

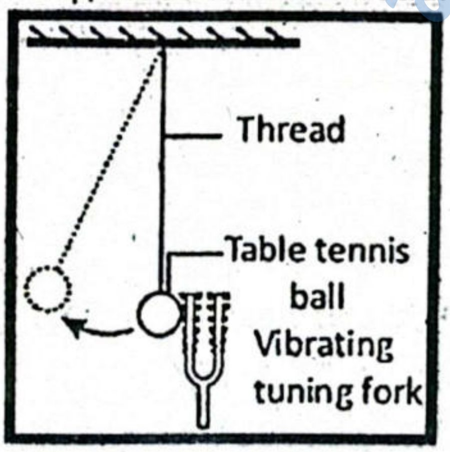
### Experiment:

In school laboratories, we use a device called tuning fork to produce a particular sound. If we strike the tuning fork against rubber hammer, the tuning fork will begin to vibrate.



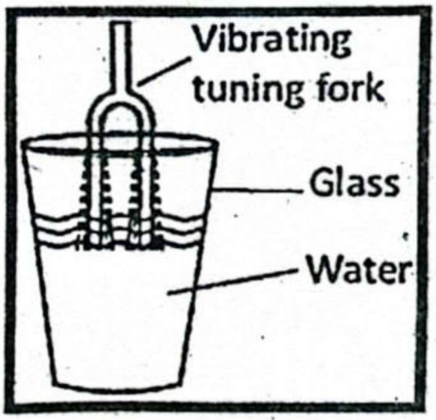

**Strike a rubber hammer on a tuning fork.**

We can hear the sound produced by tuning fork by bringing it near our ear. We can also feel the vibration by slightly touching one of the prongs of the vibrating tuning fork with a plastic ball suspended from a thread.




**Production of sound waves from a vibrating tuning fork**

Touch the ball gently with the prong of a vibrating tuning fork. The tuning fork will push the ball because of its vibration. Now if we dip the vibrating tuning fork into a glass of water, we will see a splash due to vibration of tuning fork.




**Conclusion:**

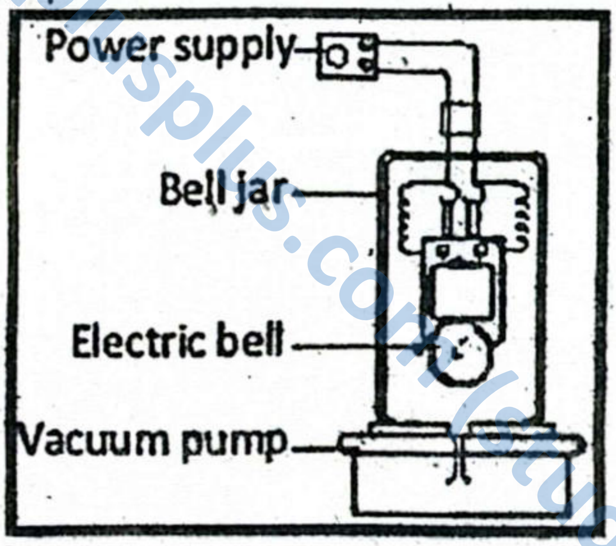
From this activity we can conclude that sound is produced by vibrating bodies.

**Q4. Sound requires material medium for its propagation justify your answer.**

**Ans: Sound Requires Material Medium for its Propagation:**

**Activity:** Unlike light waves which are electromagnetic in nature and can also pass through vacuum, sound waves require some material medium for their propagation.

This can be proved by bell jar apparatus. The bell jar is placed on the platform of a vacuum pump.




**Bell jar apparatus**

An electric bell is suspended in the bell jar with the help of two wires connected to a power supply. By setting ON the power supply, electric bell will begin to ring. We can hear the sound of the bell. Now start pumping out air from the jar by means of a vacuum pump. The sound of the bell starts becoming more and more feeble and eventually dies out, although bell is still ringing. When we put the air back into the jar we can hear the sound of the bell again.

**Conclusion:**

From this activity we conclude that sound waves can only travel/propagate in the presence of air (medium).

**Quick Quiz**

**Identify which part of these musical instruments vibrates to produce sound:**

(a) electric bell (b) loud speaker (c) piano (d) violin (e) flute

**Ans:** (a) **electric bell**

Armature and hammer vibrate in electric bell.

(b) **loud speaker**

Diaphragm vibrates in loud speaker.

(c) **piano**

Strings vibrate in piano.

(d) **violin**

Strings vibrate in violin.

(e) **flute**

When you blow a flute, air particles move towards the mouth piece of your flute, producing a whistling sound that vibrates constantly until you stop blowing the flute.

## Self Assessment

**1. Explain how sound is produced by a school bell.**

**Ans:** When the school bell vibrates, it forces the adjacent particles in air to vibrate. This disturbance gives rise to a wave and when the bell moves forward, it pushes the air in front of it. This creates a region of high pressures . When the bell moves backwards, it creates a region of low pressure. This makes the sound of a bell propagate through air.

***OR (Second Answer)***

When the school bell vibrates, it forces the adjacent particles in air to vibrate. This disturbance gives rise to a wave and when the bell moves forward, it pushes the air in front of it. This creates a region of high pressures known as compression. When the bell moves backwards, it creates a region of low pressure know as rarefaction. As the bell continues to move forward and backward, it produces a series of compressions and rarefactions. This makes the sound of a bell propagate through air.

**2. Why are sound waves called mechanical waves?**

**Ans:** Mechanical waves is a periodic disturbance which required material medium (solid, liquid, gas) for its propagation. For example-sound wave in air. That 's why sound waves are known as mechanical waves.

**3. Suppose you and your friend are on the moon. Will you be able to hear any sound produced by your friend?**

**Ans:** No, we will not be able to hear any sound because moon has no atmosphere, it is vacuum on surface of moon, and sound need any medium.

## For Your Information

Thin-walled glass goblets can vibrate when hit by sound waves. This is due to a phenomenon of sound known as resonance. Some singers can produce a loud note of particular frequency such that it vibrates the glass so much that it shatters.

## Interesting Information

Some people use silent whistle to call dogs whose frequency lies between 20,000 Hz to 25,000 Hz. It is silent for human but not for dogs because the audible frequency range for dogs is much higher.

## For Your Information

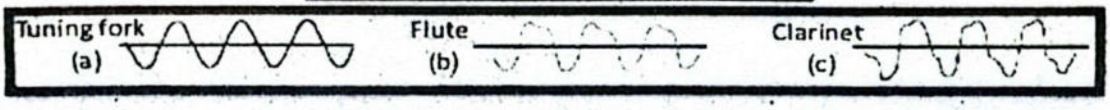



**Fig: Sound waveforms produced by (a) a tuning fork, (b) a flute, and (c) a clarinet, all at approximately the same frequency. Pressure is plotted vertically, time horizontally**

**Q5. List characteristics of sound.**

**Ans: Characteristics of Sound:**

- **i.** Loudness
- **ii.** Pitch
- **iii.** Quality
- **iv.** Intensity

**Q6. Define the term loudness.**

**Ans: Loudness:**

Loudness is the characteristic of sound by which loud and faint sounds can be distinguished.

When we talk to our friends, our voice is low, but when we address a public gathering our voice is loud.

**Q7. Describe the importance of quality in daily life?**

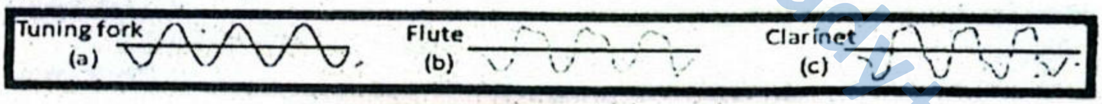
**Ans: Quality (Timbre):**

*The characteristic of sound by which we can distinguish between two sounds of same loudness and pitch is called quality.*

**Importance:**

While standing outside a room, we can distinguish between the notes of a piano and a flute being played inside the room. This is due to the difference in the quality of these notes.

Fig. shows the Waveform of the sound produced by a tuning fork, flute and clarinet. The loudness and the pitch of these three sounds are the same but their waveforms are different. So their quality is different and they can be distinguished from each other.






## Physics Insight

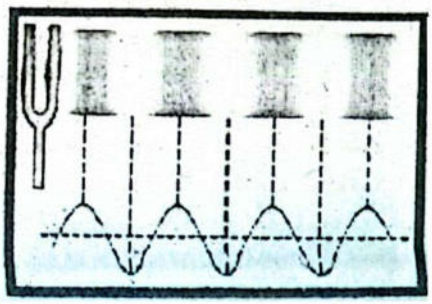


Illustration of longitudinal wave formed by vibrating tuning fork in the air. Compressions are places where air pressure is slightly higher than the surrounding air pressure due to high density of air particles. While rarefactions are the regions correspond to low air pressure due to low density of air particles.

## Quick Quiz

**1. Why the voice of women is more shrill than that of men?**

**Ans:** The shrill is of a sound depends upon its frequency and pitch, the higher the pitch the shriller the sound.

As the sounds produced by their vocal chords is naturally higher than men. So the sounds produced from the voices of women are shriller than men.

**2. Which property of sound wave determines its**

**(a) loudness (b) pitch?**

**Ans: (a) loudness:**

Amplitude and frequency determines its loudness.

**(b) pitch:**

Frequency determines the pitch of sound.

**3. What would happen to the loudness of sound with increase in its frequency?**

**Ans:** Loudness of sound will be increased by increasing frequency.

$$\text{Loudness} \propto \text{Amplitude} \propto \text{Frequency}$$

The amplitude has got bigger because the sound is louder.

The frequency has increased (there are more complete waves in the same time)

**Q8. What do you mean by the term intensity of sound?**

**Ans: Intensity:**

*Sound energy passing per second through a unit area held perpendicular to the direction of propagation of sound waves is called intensity of sound.*

Intensity is a physical quantity and can be measured accurately.

**Unit of intensity of sound:**

The unit of intensity of sound is watt per square metre ($Wm^{-2}$).

## Do You Know?

Frequency of tuning fork depends on the mass of its prongs. The greater the mass, the lower the frequency of vibration which means the lower the pitch.

## For Your Information

A sound wave with a frequency of 3500 Hz and an intensity of 80 dB sounds about twice as loud to us as a sound of 125 Hz and 80 dB. It is because our ears are more sensitive to the 3500 Hz sound than to the 125 Hz. Therefore intensity by itself does not mean loudness. Loudness is how our ears detect and our brain perceive the intensity of sound waves.

## Table 11.1

| Source of Sound | Intensity ($Wm^{-2}$) | Intensity level (dB) |
|---|---|---|
| Nearby jet airplane | $10^{3}$ | 150 |
| Jackhammer/Fast Train | $10^{1}$ | 130 |
| Siren | $10^{0}$ | 120 |
| Lawn Mover | $10^{-2}$ | 100 |
| Vacuum Cleaner | $10^{-5}$ | 70 |
| Mosquito buzzing | $10^{-8}$ | 40 |
| Whisper | $10^{-9}$ | 30 |
| Resulting of leaves | $10^{-11}$ | 10 |
| Faintest audible sound i.e. Threshold | $10^{-12}$ | 0 |

## For Your Information

| Logarithmic scale | Linear Scale |
|---|---|
| Decibels (dB) | Amplitude (m) |
| 0 | 1 |
| 20 | 10 |
| 40 | 100 |
| 60 | 1,000 |
| 80 | 10,000 |
| 100 | 100,000 |
| 120 | 1,000,000 |

The decibel scale is a logarithmic measure of the amplitude of sound waves. In a logarithmic scale, equal intervals correspond to multiplying by 10 instead of adding equal amounts.

**Example 11.1: Calculate the intensity levels of the (a) faintest audible sound (b) rustling of leaves.**

**Solution:** (a) Intensity level of faintest audible sound can be calculated by substituting $I = I_0 = 10^{-12}\ Wm^{-2}$ in Eq. (11.5).

Therefore, Intensity level of faintest audible sound = $10 \log \frac{I}{I_o}$

$= 10 \log \frac{I}{I_o} = 0$ dB

(b) As the intensity of the rustle of leaves is $I = 10^{-11}\ Wm^{-2}$. Therefore,
Intensity level due to rustling of leaves = $10 \log 10^{-11}/10^{-12} = 10 \log 10 = 10$ dB

## Interesting Information

**Rumble:**

A blue whale's 180 dB rumble is the loudest animal sound ever recorded. Whale sounds also appear to be part of a highly evolved communication system.

Some whales are thought to communicate over hundreds and may be thousands of kilometres. This is possible, in part, because sound waves travel five times faster in water than in air. In addition, the temperature characteristics of ocean water — decrease in temperature with depth — create a unique sound phenomenon.

**Do You Know?**

Elephants use low frequency sound waves to communicate with one another. Their large ears enable them to detect these low frequency sound waves, which have relatively long wavelengths. Elephants can effectively communicate in this way, even when they are separated by many kilometres.

**Q9. Describe how reflection of sound may produce echo.**

**Ans: Reflection (Echo) of Sound:**

*When sound is incident on the surface of a medium it bounces back into the first medium. This phenomenon is called echo or reflection of sound.*

**Explanation:**

The sensation of sound persists in our brain for about $0.1\ s$. To hear a clear echo, the time interval between our sound and the reflected sound must be at least 0.1s.

If we consider speed of sound to be 340 $ms^{-1}$ at a normal temperature in air, we will hear the echo after 0.1s.

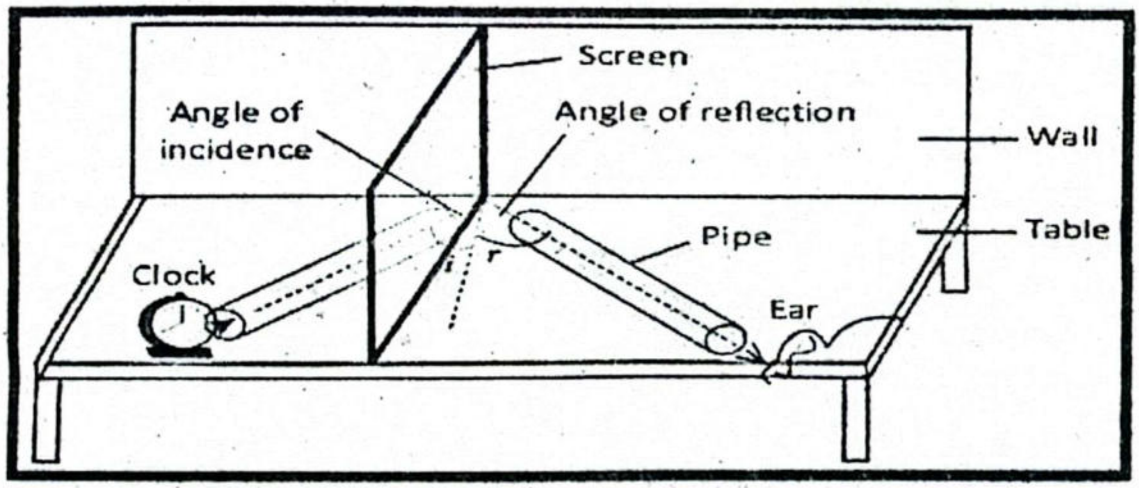
The total distance covered by the sound from the point of generation to the reflecting surface and back should be at least 340 $ms^{-1} \times 0.1s = 34.0$ m. Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance, that is, 17 m. Echoes may be heard more than once due to successive or multiple reflections.

**Q10. When we clap or shout near a reflecting surface such as a tall building or a mountain, we will hear the same sound again a little later. What causes this?**

**Ans:** This sound which we hear is called an echo and is a result of reflection of sound from the surface.

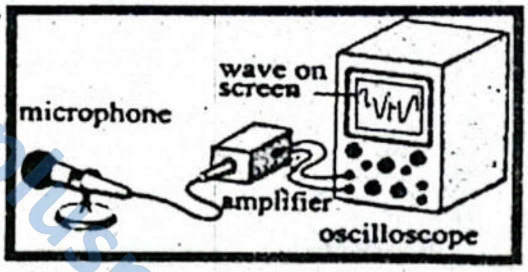
**Activity 11.3:** Take two identical plastic pipes of suitable length, as shown in Fig. 11.10 (We can make the pipes using chart paper).

- Arrange the pipes on a table near a wall.
- Place a clock near the open end of one of the pipes and try to hear the sound of the clock through the other pipe.
- Adjust the position of the pipes so that you can hear the sound of the clock clearly.
- Now, measure the angles of incidence and reflection and see the relationship between the angles.
- Lift the pipe on the right vertically to a small height and observe what happens.




**Reflection of sound**

**For Your Information**




By using an oscilloscope, you can "see" sound waves.

**Table 11.2**

| Speed of sound in various media | |
|---|---|
| **Medium** | **Speed ($ms^{-1}$)** |
| **Gases** | |
| Air (0°C) | 331 |
| Air (25°C) | 346 |
| Air (100°C) | 386 |
| Hydrogen (0°C) | 1290 |
| Oxygen (0°C) | 317 |
| Helium (0°C) | 972 |
| **Liquids at 25°C** | |
| Distilled water | 1498 |
| Sea water | 1531 |
| **Solids 25°C** | |
| Woods | 2000 |
| Aluminum | 6420 |
| Brass | 4700 |
| Nickel | 6040 |
| Iron | 5950 |
| Steel | 5960 |
| Flint Glass | 3980 |

**Q11. State the speed of sound in different mediums.**

**Ans: Speed of Sound:**

In general, the speed of sound in a liquid is $five\ times$ that in gases; the speed of sound in solid is about $fifteen\ times$ that in gases. The speed of sound in air is affected by changes in some physical conditions such as temperature, pressure and humidity etc.

**Speed of sound in air:**

The speed of sound in air is 343 $ms^{-1}$ at one atmosphere of pressure and room temperature (21°C). The speed varies with temperature and humidity. The speed of sound in solids and liquids is faster than in air.

**Formula to find the speed of sound:**

Following relation can be used to find the speed of sound.

$$v = f\lambda$$

Where $v$ is the speed, $f$ is the frequency and $\lambda$ is the wavelength of sound wave.

**Example 11.2: Calculate the frequency of a sound wave of speed 340 $ms^{-1}$ and wavelength 0.5 m.**

**Solution:** Given that;

Speed of waves = v = 340 $ms^{-1}$

Wavelength = $\lambda$ = 0.5 m

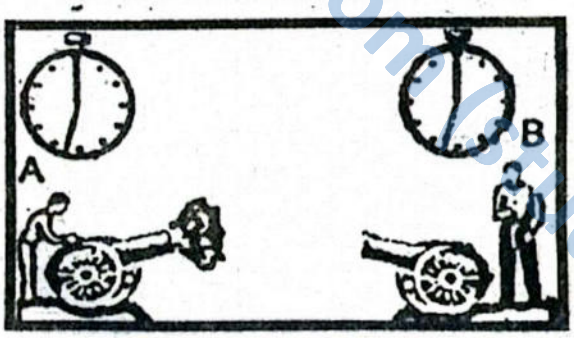
Frequency = $f$ = ?

Using the formula = $f = \frac{v}{\lambda}$

Putting the values $f$ = 340/0.5 = 680 Hz



**Do You Know?**



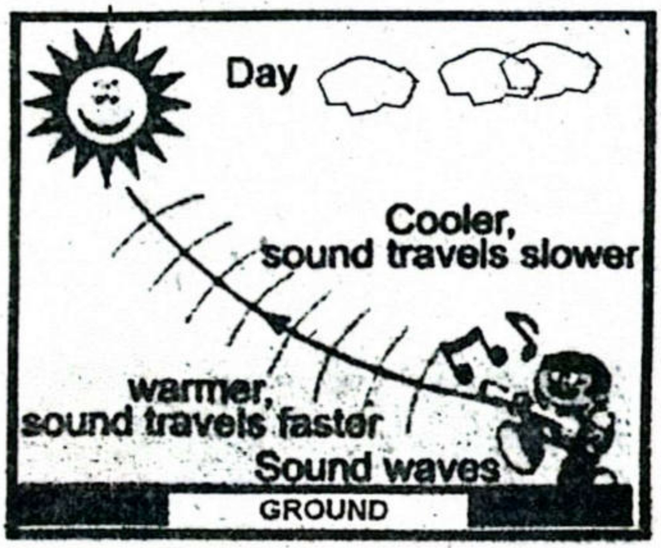

The speed of sound in air was first accurately measured in 1738 by members of the French Academy. Two cannons were set up on two hills approximately 29 km apart. By measuring the time interval between the flash of a cannon and the "boom", the speed of sound was calculated. Two cannons were fired alternatively to minimize errors due to the wind and to delayed reactions in the observers. From their observations, they deduced that sound travels at about 336 ms-1 at 0 °C.

**Example 11.3: Flash of lightening is seen 1.5 seconds earlier than the thunder. How far away is the cloud in which the flash has occurred? (speed of sound = 332 $ms^{-1}$).**

**Solution:** Given that, time $t$ = 1.5 s, speed of sound $v$ = 332 $ms^{-1}$.

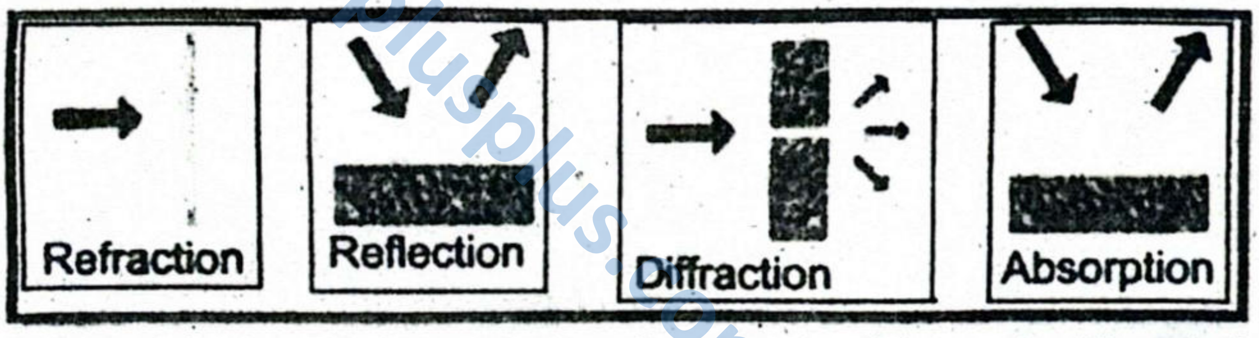
Therefore, distance of the cloud s = $vt$ = 1.5 s × 332 $ms^{-1}$ = 498 m.

## For Your Information




Variation of sound with temperature.

## Physics Insight




Sound displays all the properties of waves when it interacts with materials and boundaries.

**Q12. What is the difference between musical sound and noise.**

**Ans: Musical sound:**

Such sounds which are pleasant to our ears are called musical sounds. In musical programmes, we hear sound produced by musical instruments such as flute, harmonium, violin, drum etc.

**Noise:**

Sound which has jarring and unpleasant effect on our ears is called noise. Noise corresponds to irregular and sudden vibrations produced by some sounds.

Some sounds produce unpleasant effects on our ears such as sound of machinery, the slamming of a door, and sounds of traffic in big cities.

**11.15. How can you find the speed of sound by echo method? What factors can affect the accuracy of this method?**

**Ans: Measuring Speed of Sound by Echo Method:**

**Apparatus:**

Measuring tape, stopwatch, flat wall that can produce a good echo.

**Procedure:**

i. Use the tape to measure a distance of 50 metres from the wall.

ii. Now clap your hands in front of the wall at a distance of 50 metres and check if you can clearly hear an echo from the well. Make sure the echo is not coming from any other wall in the area. The time taken by the sound to travel 100 metres is the time difference between the clap and the echo.

iii. Now restart the clapping and start the stopwatch at the first clap. Count the number of claps, and stop the clapping and the stopwatch when you hear the echo of the 10th clap (say).

iv. Now find the average time for 10 claps. After calculating the time interval t between claps and using the formula $s = vt$, we can calculate the speed of the sound.

**Q13. How can noise pollution effect the human health.**

**OR**

**Describe that some sounds are injurious to health.**

**Ans: Noise Pollution:**

Noise pollution has become a major issue of concern in big cities. Noise is an undesirable sound that is harmful for health of human and other species. Transportation equipment and heavy machinery are the main sources of noise pollution. For example, noise of machinery in industrial areas, loud vehicle horns, hooters and alarms.

Noise has negative effects on human health as it can cause conditions such as hearing loss, sleep disturbances, aggression, hypertension, high stress levels. Noise can also cause accidents by interfering with communication and warning signals.

**Q14. What do you understand by safe level of noise?**

**Ans: Safe level of noise:**

A safe level of noise depends on two factors: the level (volume) of the noise; and the period of exposure to the noise.

The level of noise recommended in most countries is usually 85-90 dB over an eight-hour workday.

Noise pollution can be reduced to acceptable level by replacing the noisy machinery with environment friendly machinery and equipments, putting sound-reducing barriers, or using hearing protection devices.

**Activity 11.4:** Develop an action plan to help you address any problem(s) with noise in your workplace considering the following points:

1. Describe the problem(s).
2. What are the sources of the problem(s)?
3. Who are the people being affected?
4. Your suggestions for the solution.

**Solution:**

1. Noise problem in the factory area.

Noise pollution is annoying, disruptive to your emotional state, and sometimes even bad for your health. Noise pollution can also affect animals and the environment. *The effects can be auditory and non- auditory.* The auditory effect may be fatigue and deafness, while the non-auditory effect may be physiological and psychological changes in human beings. Preventing these can do a lot to help your mental and physical condition.

2. i. Old machinery in the factory.
ii. Loud sound of hammering.
iii. Sound of electric equipment.

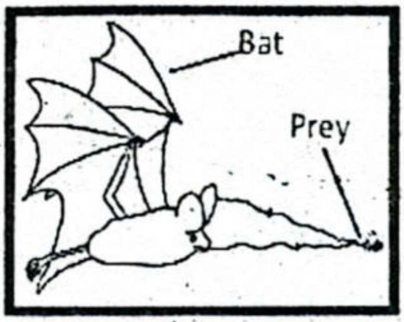
3. Workers and labourers of the factory are more effected.

4. **Suggestion:**

- controlling resonance – e.g. altering the mass and/or stiffness of the panel or changing a machine's running speed to detune it from the natural frequency of the panel;
- control of stiffness – e.g. the use of resilient layers/treatments and the addition of coupling devices;
- vibration isolation – e.g. the use of isolating springs to reduce the transmission of vibration to building structures or to larger machines or machine parts; and
- increase in damping – i.e., a process whereby vibrational energy is converted into heat through some form of frictional mechanism (e.g. constrained or unconstrained layer damping techniques).

**For Your Information**

The phrase "blind as a bat" is a false statement. Bats have some vision using light, but when placed in pitch-black rooms crisscrossed with fine wires, they can easily fly around and unerringly locate tiny flying insects for food. We usually assume that vision requires light but both bats and dolphins have the ability to "see" using sound waves. Research in science and technology has developed "eyes" that enable humans also to see using sound waves.




**For Your Information**

Pilots wear special headphones that reduce the roar of an airplane engine to a quiet hum.

## Tidbits

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.

**Q15. Define ultrasound or ultrasonic.**

**Ans: 11.7 Ultrasound:**

*Sounds of frequency higher than 20,000 Hz which are inaudible to normal human ear are called ultrasound or ultrasonic.*

**Q16. Why ultrasound are very useful for detecting very small objects.**

**Ans: Detection of very small objects by ultrasound:**

Ultrasonic waves carry more energy and higher frequency than audible sound waves. Therefore, according to the wave equation $v = f\lambda$, the wavelength of ultrasonic waves is very small and is very useful for detecting very small objects.

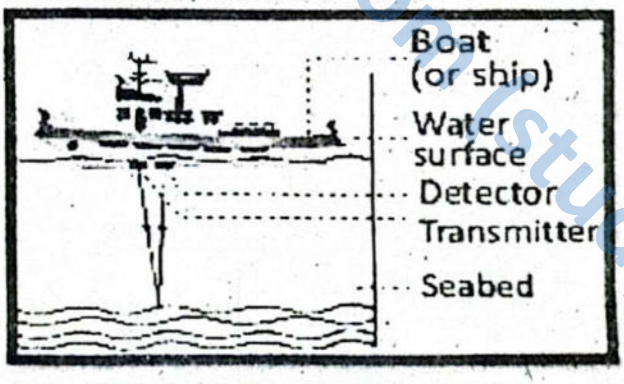
**Q17. How ultrasounds are used to measure the underwater depths?**

**OR**

**What do you mean by the term SONAR?**

- **Sonar:**

Ultrasound is used to locate underwater depths or is used for locating objects lying deep on the ocean floor, etc. The technique is called *SONAR, (sound navigation and ranging).* The sound waves are sent from a transmitter, and a receiver collects the reflected sound (Fig). The time-lapse is calculated, knowing the speed of sound in water, the distance of the object from the ocean surface can be estimated.




**Ultrasonics are used to measure the depth of water by echo method**

- SONAR ranging is also used to see the shape and the size of the object.

**Q18. How can you find a clue of the existence of the cracks by using ultrasound?**

**Ans: Clue of the existence of the cracks:**

Cracks appear in the interior of moving parts of high speed heavy machines such as turbines, *engines of ships* and airplanes due to excessive use. These cracks are not visible from outside but they can be very dangerous. Such cracks can be detected by ultrasonic.

A powerful beam of ultrasound is made to pass through these defective parts. While passing, these waves are reflected by the surface of these cracks and flaws. The comparison of the ultrasonic waves reflected from cracks and from the surfaces of these parts can give a clue of the existence of the cracks.

# Summary

- Sound is produced by a vibrating body. It travels in the medium from one place to another in the form of compressional waves.
- Loudness is a feature of sound by which a loud and a faint sound can be distinguished. It depends upon the amplitude, surface area and distance from the vibrating body.
- Sound energy flowing per second through unit area held perpendicular to the direction of sound waves is called the intensity of sound, bel is unit of .the intensity level of sound, where 1 bel = 10 decibel.
- Pitch of the sound is the characteristics of sound by which a shrill sound can be distinguished from a grave one. It depends upon the frequency.
- The characteristics of sound by which two sound waves of same loudness and pitch are distinguished from each other is called the quality of sound.
- The sounds with jarring effect on our ears are called noise and the sounds having pleasant effect on our ears are called musical sounds.
- Noise pollution has become a major issue of concern in some big cities. Any form of sound which disturbs the normal functioning of any natural ecosystem or some human community is the cause of noise pollution.
- Noise pollution can be reduced to acceptable level by replacing the rusty noisy machinery with environment friendly machinery and equipments, putting sound-reducing barriers, or using hearing protection devices.
- The technique or method used to reduce the loss of sound energy by soft and porous surfaces is called acoustic protection. This can be done by using rigid, smooth and non-porous materials.
- Audible frequency range lies between 20 Hz to 20,000 Hz.
- Sound waves of frequency higher than 20,000 Hz are called *ultrasound* while sound waves of frequency lower than 20 Hz are called *infrasound*.
- Ultrasound is used in many fields of science and technology such as medical, engineering, agriculture. In medical field ultrasound is used to diagnose and treat different ailments. Ultrasound is also used to locate underwater depths or for locating objects lying deep on the ocean floor. The technique is called *SONAR*, short for *sound navigation and ranging*.

## Multiple Choice Questions (MCQs)

**Choose the correct answer from the following choices:**

***i.*** **Which is an example of a longitudinal wave?**

✓A. sound wave B. light wave

C. radio wave D. water wave

ii. **How does sound travel from its source to your ear?**
A. by changes in air pressure
B. by vibrations in wires or strings
C. by electromagnetic wave
D. by infrared waves

iii. **Which form of energy is sound?**
A. electrical B. mechanical
C. thermal D. chemical

iv. **Astronauts in space need to communicate with each other by radio links because**
A. sound waves travel very slowly in space
B. sound waves travel very fast in space
C. sound waves cannot travel in space
D. sound waves have low frequency in space

v. **The loudness of a sound is most closely related to its**
A. frequency B. period
C. wavelength D. amplitude

vi. **For a normal person, audible frequency range for sound wave lie between**
A. 10 Hz and 10 kHz B. 20 Hz and 20 kHz
C. 25 Hz and 25 kHz D. 30 Hz and 30 kHz

vii. **When the frequency of a sound wave is increased, which of the following will decrease?**
**i. Wavelength ii. Period iii. Amplitude**
A. i only B. iii only
C. i and ii only D. i and iii only

**Answers**

| | | | | |
|---|---|---|---|---|
| **i. A** | **ii. A** | **iii. B** | **iv. C** | **v. D** |
| **vi. B** | **vii. A** | | | |

# Review Questions

**11.1. What is the necessary condition for the production of sound?**

**Ans:** The necessary condition for the production of sound is vibration of a body.

**11.2. What is the effect of the medium on the speed of sound? In which medium sound travels more faster: air, solid or liquid? Justify your answer.**

**Ans: Effect of the medium:**

The speed of sound depends on two factors: elasticity and density. The more elastic a medium, the greater the speed. The more dense the medium the slower the speed of sound. For example steel is 6000 times more dense than air but 2,000,000 times more elastic than air, so sound travels 16 times faster in steel than in air.

**Comparison of the medium:**

Sound is actually the vibration of the molecules of the medium. Sound moves through the medium as a longitudinal wave. Sound travels faster in those mediums that are more dense (particles are closer to each other, and can transmit their energy to the other particles more easily. Therefore sound travels faster in solids, than liquids, and than air.

**Example:**

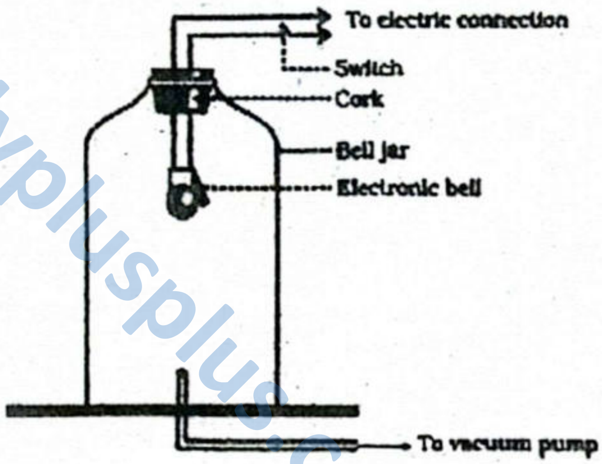
In steel sound's velocity is about 5000 m/s, in water 1400 m/s and in air 344 m/s.

**11.3. How can you prove the mechanical nature of sound by a simple experiment?**

**Ans: Mechanical nature of sound:**

Since a sound wave is a disturbance that is transported through a medium via the mechanism of particle-to-particle interaction, a sound wave is characterized as a mechanical wave.

**Experiment:**




**The sound produced by the bell cannot be heard since sound cannot travel through a vacuum.**

A ringing bell is placed in a jar and air inside the jar is evacuated. Once air is removed from the jar, the sound of the ringing bell can no longer be heard. The clapper is seen striking the bell; but the sound that it produces cannot be heard because there are no particles inside of the jar to transport the disturbance through the vacuum. Sound is a mechanical wave and cannot travel through a vacuum.

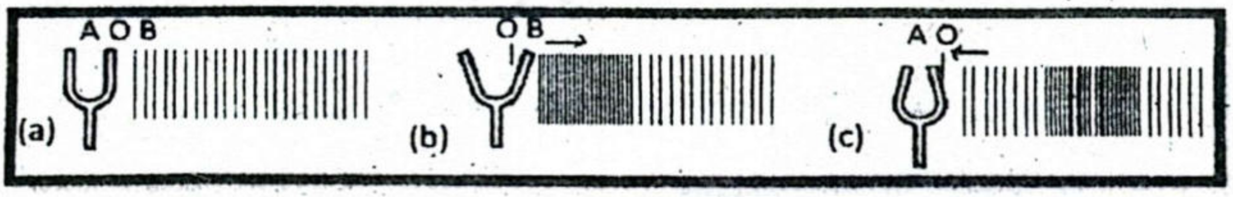
**11.4. What do you understand by the longitudinal wave? Describe the longitudinal nature of sound waves.**

**Ans: Longitudinal waves:**

In longitudinal waves the particles of the medium move back and forth along the direction of propagation of wave.

**Longitudinal Nature of Sound Waves:**

Propagation of sound waves produced by vibrating tuning fork can be understood by a vibrating tuning fork as shown in Fig. Before the vibration of tuning fork, density of air molecules on the right side is uniform (*a*). When the right prong of tuning fork moves from mean position O to B (*b*), it exerts some pressure on the adjacent layer of air molecules and produces a compression.




**Vibrations of tuning fork after striking with a rubber hammer**

This compressed air layer in turn compresses the layer next to it and so on. A moment later, the prong begins to move from B towards A $(c)$. Now the pressure in the adjacent layer decreases and a rarefaction is produced. This rarefaction is transfered to the air layer next to it and so on. As the tuning fork moves back and forth rapidly, a series of compressions and rarefactions are created in the air. In this way, sound wave propagates through the air.

**Conclusion:**

As in the direction of propagation of sound wave is along the direction of oscillating air molecules. This shows the longitudinal nature of sound waves. Distance between two consecutive compressions or rarefactions is the wavelength of sound wave.

***(OR Second Answer)***

Regardless of the source of the sound wave - whether it is a vibrating string or the vibrating tines of a tuning fork - sound waves traveling through air are longitudinal waves. And the essential characteristic of a longitudinal wave that distinguishes it from other types of waves is that the particles of the medium move in a direction parallel to the direction of energy transfer Since air molecules (the particles of the medium) are moving in a direction that is parallel to the direction that the wave moves, the sound wave is referred to as a longitudinal wave. The result of such longitudinal vibrations is the creation of **compressions** and **rarefactions** within the air.

**11.5. Sound is a form of wave. List at least three reasons to support the idea that sound is a wave.**

**Ans:**

**i.** Sound wave carries energy like other waves therefore sound is the form of wave.

**ii.** Sound wave obeys the property of reflection refraction; diffraction like other waves therefore sound is the form of wave.

**iii.** Sound wave obeys the property of interference like other waves therefore sound is the form of wave.

**11.6. We know that waves manifest phenomenon of reflection, diffraction and refraction. Does sound also manifest these characteristics?**

**Ans:** Like any wave, a sound wave doesn't just *stop* when it reaches the end of the medium or when it encounters an obstacle in its path. Rather, a sound wave will undergo certain behaviors when it encounters the end of the medium or an obstacle. Possible behaviors include *reflection* off the *obstacle*, *diffraction* around the obstacle, and transmission (accompanied by refraction) into the obstacle or new medium.

Therefore sound waves manifest phenomenon of reflection, diffraction and refraction.

**11.7. What is the difference between the loudness and intensity of sound? Derive the relationship between the two.**

**Ans:** Sound intensity is the amount of energy carried by sound whereas loudness is a measurement of the audible sound

**Loudness vs Sound Intensity:**

- Sound intensity is a property of the sound source but loudness depends on the sound source, the medium and the receiver as well.
- Sound intensity holds a small significance in problems involving human hearing system; but loudness is a very important property to consider in such problems.
- Sound intensity is measured in Watt per square meter whereas loudness is measured in Sones.

**Relationship between the loudness and intensity of sound:**

**Sound Intensity Level:**

This difference between the loudness of the faintest audible sound and the loudness of an unknown sound is called intensity level or sound level of the unknown sound.

The human ear responds to the intensities ranging from $10^{-12}$ $Wm^{-2}$ to more than 1 $Wm^{-2}$ (which is loud enough to be painful). Because the range is so wide intensities are scaled by factors of ten. The barely audible and the faintest intensity of sound i.e., $10^{-12}$ $Wm^{-2}$ is taken as reference intensity, called zero bel (a unit named after Alexander Graham Bell).

The *loudness* ($L$) of a sound is directly proportional to the logarithm of *intensity* ($I$) i.e.

$L \propto \log I$

$L = K \log I$ .......... (i)

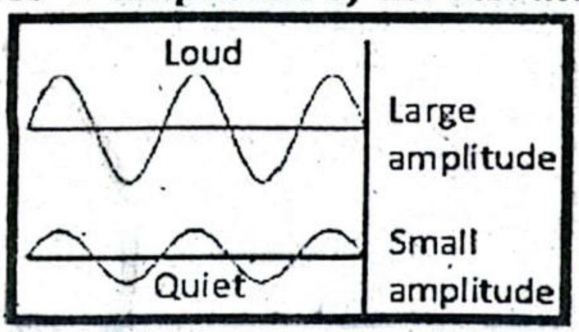
**11.8. On what factors does the loudness of sound depend?**

**Ans:** Loudness of a sound depends upon a number of factors.

**(a) Amplitude of the vibrating body:**

The loudness of the sound varies directly with the amplitude of the vibrating body. The sound produced by a sitar will be loud if we pluck its wires more violently. Similarly, when we beat a drum forcefully, the amplitude of its membrane increases and we hear a loud sound.

$$Loudness \propto Amplitude\ of\ the\ vibrating\ body$$




**Variation of loudness with amplitude**

**(b) Area of the vibrating body:**

The loudness of sound also depends upon the area of the vibrating body. For example, sound produced by a large drum is louder than that by small one because of its large vibrating area. If we strike a tuning fork on a rubber pad, a feeble sound will be heard. But if the vibrating tuning fork is placed vertically on the surface of a bench, we will hear a louder sound. From this we can conclude that the loudness increases with the area of the vibrating body and vice versa.

$$Loudness \propto Area\ of\ the\ vibrating\ body$$

**(c) Distance from the vibrating body:**

Loudness of sound also depends upon the distance of the vibrating body from the listener. It is caused by the decrease in amplitude due to increase in distance.

$$Loudness \propto \frac{1}{Distance\ from\ the\ vibrating\ body}$$

**Note:**

1. Loudness also depends upon the physical condition of the ears of the listener. A sound appears louder to a person with sensitive ears than to a man with defective ears.
2. However, there is a characteristic of sound which does not depend upon the sensitivity of the ear of the listener and it is called intensity of sound.

**11.9. What do you mean by the term intensity level of the sound? Name and define the unit of intensity level of sound.**

**Ans: Sound Intensity Level/Acoustic Intensity Level:**

Sound intensity level or acoustic intensity level is a logarithmic measure of the sound intensity, in comparison to a reference level.

The loudness *(L)* of a sound is directly proportional to the logarithm of intensity i.e.

$L \propto \log I$

$L = K \log I$ .......... (i)

Where K is a constant of proportionality. Let $L_o$ be the loudness of the faintest audible sound of intensity $I_o$ and $L$ be the loudness of an unknown sound of intensity I, then by Eq. (i), we can write

$L_o = K \log I_o$ .......... (ii)

Subtracting Eq. (i) from Eq. (ii), we get

$$L - L_o = K(\log I - \log I_o) = K \log \frac{I}{I_o}$$

**Intensity level:**

This difference, $(L - L_o)$, between the loudness L of an unknown sound and the loudness $L_o$ is called the intensity level of the unknown sound. Therefore, the intensity level of an unknown sound is given by

$$\text{Sound level} = K \log \frac{I}{I_o} \quad .......... \quad (iii)$$

$$\text{Sound level} = \log \frac{I}{I_o} \quad \text{(bel)} \quad .......... \quad (iv)$$

$$\text{Sound level} = 10 \log \frac{I}{I_o} \quad \text{(dB)} \quad .......... \quad (v)$$

**Unit:** The SI unit of intensity level or sound level is bel.

**Note:** bel is a very large unit of intensity level of a sound. Generally, a small unit called decibel (dB) is used. 1 bel is equal to 10 dB.

**Decibel:** *A logarithmical unit which measures the intensity or level of a signal.*

Decibel scale is a logarithmic scale which is based on the multiple of 10. A Decibel is equal to the ratio of physical quantities with respect to a reference level.

**Note:**

The barely audible and the faintest intensity of sound i.e., $\mathbf{10^{-12}\,Wm^{-2}}$ is taken as reference intensity, called zero bel (a unit named after Alexander Graham Bell).

**11.10. What are the units of loudness? Why do we use logarithmic scale to describe the range of the sound intensities we hear?**

**Ans: Units of loudness:**

Bel, Sone, Phon, Decibel.

Because the ear responds to sound pressure logarithmically, using a logarithmic scale corresponds to the way humans perceive loudness. Audio meters and sound measurement equipment are specifically designed to show audio levels in decibels. That is why we use logarithmic scale to describe the range of the sound intensities we hear.

***(OR Second Answer)***

The dynamic range of human hearing and sound intensity spans from $10^{-12}$ W/m$^2$ to 10 - 100 W/m$^2$. The highest sound intensity possible to hear is10,000,000,000,000 times as loud as the quietest!

This span makes the absolute value of the sound intensity impractical for normal use. A more convenient way to express the sound intensity is the relative logarithmic scale with reference to the lowest human hearable sound $10^{-12}$ W/m$^2$ (0 dB).

**11.11. What is difference between frequency and pitch? Describe their relationship graphically.**

**Ans: Pitch:**

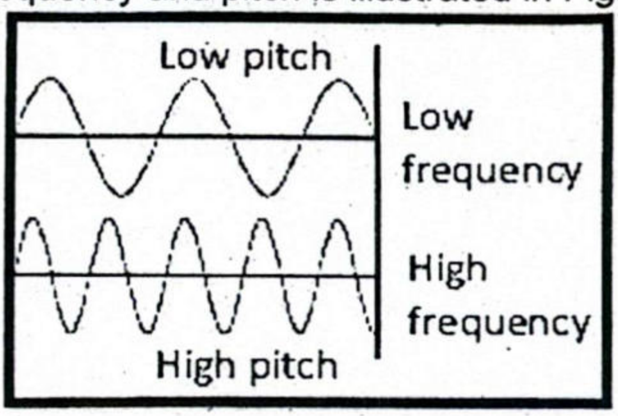
*Pitch is the characteristic of sound by which we can distinguish between a shrill and a grave sound.*

**Frequency ($f$):**

*The number of vibrations per cycle of a vibrating body in one second is called its frequency. It is reciprocal of time period i.e., $f = 1/T$*

**Relation between frequency and pitch:**

Pitch depends upon the frequency. A higher pitch means a higher frequency and vice versa. The frequency of the voice of ladies and children is higher than that of men. Therefore, the voice of ladies and children is shrill and of high pitch. The relationship between frequency and pitch is illustrated in Fig.




**Variation of pitch with frequency**

**11.12. Describe the effect of change in amplitude on loudness and the effect of change in frequency on pitch of sound.**

**Ans: Effect of change in amplitude on loudness:**

The loudness of the sound varies directly with the amplitude of the vibrating body. The sound produced by a sitar will be loud if we pluck its wires more violently. Similarly, when we beat a drum forcefully, the amplitude of its membrane increases and we hear a loud sound.

$$Loudness \propto Amplitude\ of\ the\ vibrating\ body$$

**Effect of change in frequency on pitch of sound:**

Pitch depends upon the frequency. A higher pitch means a higher frequency and vice versa. $Pitch \propto Frequency$

**11.13. If the pitch of sound is increased, what are the changes in the following?**

a. **the frequency** b. **the wavelength**
c. **the wave velocity** d. **the amplitude of the wave**

**Ans: a. the frequency**

If the pitch of the sound is increased its frequency is also increased.

$$Pitch \propto Frequency$$

**b. the wavelength**

If the pitch of the sound is increased its wavelength is decreased.

$$Pitch \propto \frac{1}{Wavelength}$$

**c. the wave velocity**

If the pitch of the sound is increased its wave velocity v is increased.

$$Pitch \propto Velocity$$

**d. the amplitude of the wave**

If the pitch of the sound is increased the amplitude of the wave does not change because pitch of the sound does not depend on the amplitudes.

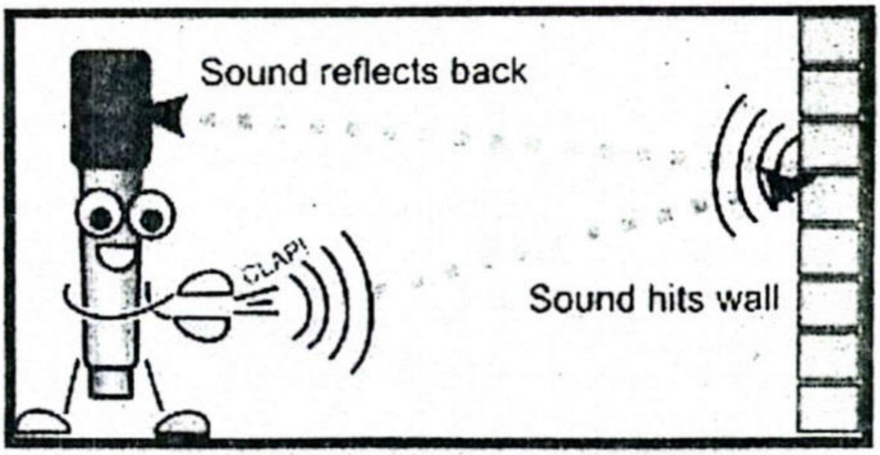
**11.14. If we clap or speak in front of a building while standing at a particular distance, we rehear our sound after sometime. Can we explain how does this happen?**

**Ans:** This is due to echo of sound. An echo (plural echoes) is a reflection of sound, arriving at the listener some time after the direct sound.

**Explanation:**

Sound is a waveform made from vibrating matter. The sound wave travels through matter—especially air—in a straight line. When the wave hits a different material, some of it is reflected, absorbed and transmitted through the material. In the case of a sound wave in air hitting a solid wall, most of the sound is reflected.

If the wall is relatively flat, perpendicular to the source of the sound, and far enough away (but not too far), then you can hear the reflected waveform or echo. If the sound comes back in about 0.1 second or longer, you can readily distinguish the echo.




**11.15. What is the audible frequency range for human ear? Does this range vary with the age of people? Explain.**

**Ans: Audible Frequency Range:**

*The range of the frequencies which a human ear can hear is called the audible frequency range.*

A normal human ear can hear a sound only if its frequency lies between 20Hz and 20,000 Hz. In other words, a human ear neither hears a sound of frequency less than 20 Hz nor a sound of frequency more than 20,000 Hz.

**Effect of age:**

Different people have different range of audibility. It also decreases with age. Young children can hear sounds of 20,000 Hz but old people cannot hear sounds even above 15,000 Hz.

**11.16. Explain that noise is a nuisance.**

**Ans: Noise nuisance (irritation):**

Noise pollution is the disturbing or excessive noise that may harm the activity or balance of human or animal life. The source of most outdoor noise worldwide is mainly caused by machines and transportation systems, motor vehicles, aircrafts, and trains.

**Effects of noise nuisance:**

Generally, problems caused by noise **nuisance** include stress related illnesses, speech interference, hearing loss, sleep disruption, and lost productivity (efficiency).

**11.17. Describe the importance of acoustic protection.**

**Ans: Acoustics:**

The technique or method used to absorb undesirable sounds by soft and porous surfaces is called acoustic protection.

**Importance/Advantages of Acoustics:**

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 material in noisy places we can reduce the level of noise pollution.

**Disadvantage of Acoustics:**

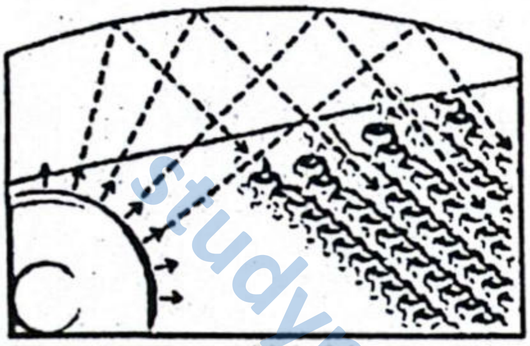
However, if the surface of classrooms or public halls are too absorbent, the sound level may be low for the audience.

## Reverberations:

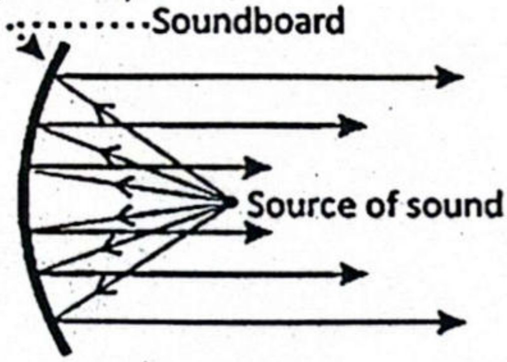
When sound reflects from the walls, ceiling, and floor of a room, the reflecting surfaces are too reflective and the sound becomes garbled (Confused). This is due to multiple reflections called reverberations.

In the design of lecture halls, auditorium, or theater halls, a balance must be achieved between reverberation and absorption. It is often advantageous to place reflective surfaces behind the stage to direct sound to the audience.

Generally the ceilings of lecture halls, conference halls and theatre halls are curved so that sound after reflection may reach all the corners of the hall (Fig 11.11). Sometimes curved sound boards are placed behind the stage so that sound after reflection distributed evenly across the hall (Fig. 11.12).



Curved ceiling of a conference hall

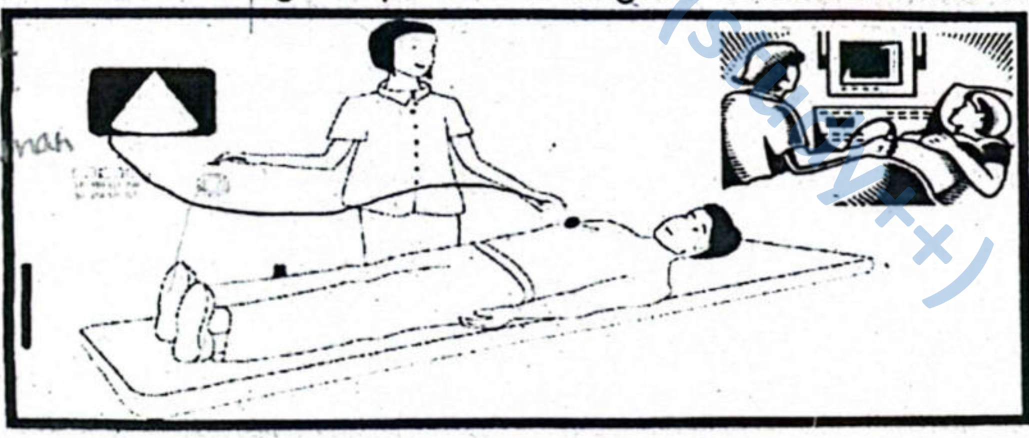



Soundboard used in a big hall

**11.18 What are the uses of ultrasound in medicine?**

**Ans: Uses of ultrasound in medicine:**

- Ultrasonic are utilized in medical and technical fields.
- In medical field, ultrasonic waves are used to diagnose and treat different ailments. For diagnosis of different diseases, ultrasonic waves are made to enter the human body through transmitters. These waves are reflected differently by different organs, tissues or tumors etc. The reflected waves are then amplified to form an image of the internal organs of the body on the screen. Such an image helps in detecting the defects in these organs.



Doctors are taking ultrasound test of a patient with an ultrasound machine.

- Powerful ultrasound is now being used to remove blood clots formed in the arteries.
- Ultrasound can also be used to get the pictures of thyroid gland for diagnosis purposes.
- Germs and bacteria in liquids can also be destroyed by using high intensity ultrasonic waves.

# Conceptual Questions

**11.1. Why two tin cans with a string stretched between them could be better way to communicate than merely shouting through the air?**

**Ans:** When two tin cans are attached with a stretched string then the string becomes a medium that transmit sound wave from one can to the other. String is a solid and it makes a batter medium of transmitting sound wave rather than air. When we shout in air then air carries sound with low speed than a stretched string.

**11.2. We can recognize persons speaking with the same loudness from their voice. How is this possible?**

**Ans:** We can recognize persons speaking with the same loudness from their voice because their quality of sound is different. Quality of sound is the characteristic by which we can distinguish between two sounds of same loudness and pitch. The waveforms of sound produced by persons are different. So their quality is different and they can be distinguished from each other.

**11.3. You can listen to your friend round a corner, but you cannot watch him/her. Why?**

**Ans:** Wavelength of sound waves is large and is comparable with the size of buildings and corners. So sound of our friend can be diffracted and easily heard by us. However, light rays have small wavelength and cannot be diffracted, which makes it impossible for us to see our friend round a corner.

**11.4. Why must the volume of a stereo in a room with wall-to-wall carpet be tuned higher than in a room with a wooden floor?**

**Ans:** In carpeted floor rooms, the volume of stereo will be higher due to less amount of reverberations. Volume of a stereo in a room with wall to wall carpet must be tuned higher than in a room with a wooden floor because reflection of sound (reverberations/after effects) is more prominent if the surface is smooth (carpeted), and less if the surface is irregular(wooden floor).

**11.5. A student says that the two terms *speed* and *frequency* of the wave refer to the same thing. What is your response?**

**Ans:** No, the statement of student is not correct. Speed is the distance traveled by the wave in unit time (one second).

Frequency is the number of vibrations in the medium in unit time (one second). Speed of a wave is how fast the wave is moving in a medium while the frequency of wave is the number of cycle per unit of time. So these two things are not same. Also frequency does not depend on the nature of medium, but speed of wave is different in different media.

**11.6. Two people are listening to the same music at the same distance. They disagree on its loudness, Explain how this could happen.**

**Ans:** This is due to difference in the hearing sense of two persons. A sound appears louder to a person with sensitive ears than to a man with defective ears.

**11.7. Is there any difference between echo and reflection of sound? Explain.**

**Ans:** No. there is no difference between echo and reflection. Echo can be defined as, when sound is incident on the surface of a medium it bounces back into the first medium. This phenomenon is also called reflection of sound.

**11.8. Will two separate 50dB sounds together constitute a100dB sound? Explain**

**Ans:** No, two separate 50dB sounds together do not constitute a 100dB sound because dB is an exponential scale (logarithmic scale). Each ten dB increase in sound makes the sound ten times louder. An increase of 50dB makes the sound $\mathbf{10^4}$ times louder.

Hence it will not make 100dB but twice as loud is an increase of 10Log (2) = 3.01dB. So 53.01dB is twice as loud as 50dB.

**11.9. Why ultrasound is useful in medical field?**

**Ans:** Ultrasound wavelength are shorter as compared to normal sound waves. Because of this the ultrasound waves are reflected back by obstacles in their path rather than bending round them and move forward. This quality of ultrasound makes it useful in many different fields including medical field.

The ultrasound techniques score over the x-ray techniques for obtaining images of internal organ in that these are safer.

Active use of ultrasound in medical field includes destruction of brain tumors and kidney stones.



# Numerical Problems

**11.1. A normal conversation involves sound intensities of about $3.0\times10^{-6}$ $Wm^{-2}$. What is the decibel level for this intensity? What is the intensity of the sound for 100 dB? Ans. (64.8 dB, 0.01 $Wm^{-2}$)**

**Solution:** Intensity of sound = $I = 3.0\times10^{-6}Wm^{-2}$

Here faintest sound intensity $I_o = 10^{-12}Wm^{-2}$ (1 Bell=10 dB)

Intensity level = ?

Intensity level $= 10\log\frac{I}{I_o}$ dB ......(i)

Intensity level$=10\log\frac{3.0\times10^{-6}}{10^{-12}}$

Intensity level$=10\log 3.0\times10^{6}$

We know log (mn) = log m + log n

Intensity level$=10(\log 3+\log10^{6})$

Intensity level$=10(0.48+6\times\log10)$

Intensity level$=10(0.48+6\times1)$

Intensity level=64.8 dB

**(ii)** ***When Sound level = 100 dB***

Intensity of sound = I = ?

Sound level $=10\log\frac{I}{I_o}$ dB ... (i)

$$100 \text{ dB} = 10 \log \frac{I}{10^{-12}} \text{ dB}$$
$$10 = \log \frac{I}{10^{-12}}$$
$$10 = \log I - \log 10^{-12}$$
$$10 = \log I + 12 \log 10$$
$$10 = \log I + 12(1)$$
$$10 - 12 = \log I$$
$$\text{Log } I = -2$$
Taking antilog on both sides
$$I = \text{antilog}(-2)$$
$$I = 0.01 \text{ Wm}^{-2}$$

**11.2. If at Anarkali bazar Lahore, the sound level is 80 dB, what will be the intensity level of sound there? Ans. ($10^{-4}$ Wm$^{-2}$)**

**Solution:** Sound level = 80 dB

Intensity level of sound = ?

Intensity level/sound level = $10 \log \frac{I}{I_o}$ dB ......(i)

(Where $I_o = 10^{-12} Wm^{-2}$)

From (i)
$$80 \text{ dB} = 10 \log \frac{I}{10^{-12}} \text{ dB}$$
$$8 = \log \frac{I}{10^{-12}}$$
$$8 = \log I - \log 10^{-12}$$
$$8 = \log I + 12 \log 10$$
$$8 = \log I + 12(1)$$
$$8 - 12 = \log I$$
$$\log I = -4$$
Taking antilog on both sides
$$I = \text{antilog}(-4)$$
$$I = 0.0001 \text{ Wm}^{-2}$$
$$I = 10^{-4} \text{ Wm}^{-2}$$

**11.3. At a particular temperature, the speed of sound in air is 330 ms$^{-1}$. If the wavelength of a note is 5 cm, calculate the frequency of the sound wave. Is this frequency lies in the audible range of the human ear? Ans. ($6.6 \times 10^3$ Hz, Yes)**

**Solution:** The speed of sound = v = 330 $ms^{-1}$

Wavelength = $\lambda$ = 5 cm = $\frac{5}{100}$ = 0.05 m

Frequency = $f$ =?
$$f = \frac{v}{\lambda}$$
$$f = \frac{330}{0.5} = 6.6 \times 10^3 \text{Hz}$$
Yes this frequency lies audible range of human ear. (20 $Hz$ to 20,000 $Hz$)

**11.4. A doctor counts 72 heartbeats in 1 min. Calculate the frequency and period of the heartbeats.** **Ans. (1.2 Hz, 0.83 s)**

**Solution:** Number of heartbeats = n = 72

Time = t = 1 min.=60 sec.

Frequency = f = ?

Time period =T =?

$$f = \frac{number\ of\ heartbeats}{time}$$

$$f = \frac{72}{60} = 1.2\ Hz$$

Since, $T = \frac{1}{f}$

$$T = \frac{1}{1.2} = 0.83 \text{ sec.}$$

**11.5. A marine survey ship sends a sound wave straight to the sea bed. It receives an echo 1.5 s later. The speed of sound in sea water is 1500 $ms^{-1}$. Find the depth of the sea at this position.** **Ans. (1125 m)**

**Solution:** Speed of sound = v = 1500 $ms^{-1}$

Time = t = 1.5 s

Depth = d = ?

d = vt .......(i)

For echo sound waves travel the total distance d + d = 2d

Put in (i) 2d = vt

2d = (1500)×(1.5)

$d = \frac{2250}{2}$

d = 1125 m

**11.6. A student clapped his hands near a cliff and heard the echo after 5s. What is the distance of the cliff from the student if the speed of the sound, v is taken as 346 $ms^{-1}$?** **Ans. (865 m)**

**Solution:** Time = t = 5 sec.

Speed of sound = v = 346 $ms^{-1}$

Distance = d = ?

Since, d = vt ....... (i)

For echo sound waves travel the total distance d + d = 2 d

Put in (i) 2d = 346×5

2d = 1730

$d = \frac{1730}{2}$

d = 865 m

**1.7. A ship sends out ultrasound that returns from the seabed and is detected after 3.42s. If the speed of ultrasound through seawater is 1531 $ms^{-1}$, what is the distance of the seabed from the ship?** **Ans. (2618 m)**

**Solution:** Time = t = 3.42 Sec.

Speed of sound = v = 1531 $ms^{-1}$

Distance = d = ?

Since, d = vt ......(i)

Ultra – sound travels the total distance d + d = 2 d

Put in (i) we get:

$2d = (1531)\times(3.42)$

$d = \frac{5236.02}{2}$

$d = 2618$ m

**11.8. The highest frequency sound humans can hear is about 20,000 Hz. What is the wavelength of sound in air at this frequency at a temperature of 20°C? What is the wavelength of the lowest sounds we can hear of about 20 Hz? Assume the speed of sound in air at 20°C is 343 $ms^{-1}$. Ans. ($1.7 \times 10^{-2}$ m, 17.2 m)**

**Solution:** Highest frequency = $f_m$ = 20,000 Hz

Lowest frequency = $f_L$ = 20 Hz

Speed of sound = v = 343 $ms^{-1}$

Wavelength of highest sound = $\lambda_L$ = ?

Wavelength of minimum sound = $\lambda_m$ = ?

Since, $= f\lambda = v$ ........ (i)

Since, $\lambda_L = \frac{v}{f_m}$

$\lambda_L = \frac{343}{20000}$

$\lambda_L = 0.017 = 1.7 \times 10^{-3}$ m

Now, $\lambda_m = \frac{v}{f_L}$

$\lambda_m = \frac{343}{20}$

$\lambda_m = 17.2$ m

**11.9. A sound wave has a frequency of 2 kHz and wavelength 35 cm. How long will it take to travel 1.5 km? Ans. (2.1 s)**

**Solution:** Frequency = f = 2 kHz = 2 × 1000 = 2000 Hz

Wavelength $\lambda = 35\text{ cm} = \frac{35}{100} = 0.35$ m

Distance = d =1.5Km= 1.5 × 1000 =1500 m

Time = t = ?

Since, $v = f\lambda$

$v = (2000) \times (0.35)$

$v = 700\ ms^{-1}$

Again by using the relation $d = v\,t$

$t = \frac{d}{v}$

$t = \frac{1500}{700} = 2.1$ sec.