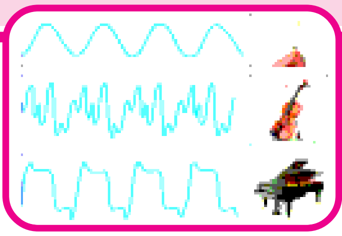
Chapter 10

SOUND



In class 8 we have learnt about sounds produced by vibrating bodies and also learnt how sound is transmitted through a medium and received by our ears. In this chapter we will study about nature of sound, its production, propagation and characteristics.

Every day we hear sounds from various sources like birds, bells, machines, vehicles, television and Radio etc. Our ears help us to hear the sounds produced at a distance.

- How does sound reach our ears from the source of its production?
- Does it travel by itself or is there any force bringing it to our ears?
- What is sound? Is it a force or an energy?
- Why don't we hear sounds when our ears are closed?

Let us find out.

Activity-1

Sound is a form of energy

Take a tin can and remove both ends to make a hollow cylinder as shown in figure 1. Take a balloon and stretch it over the can. Rap a rubber band around the balloon. Take a small piece of mirror and stick it on the balloon. Take a laser light and let it fall on the mirror. After reflection the light spot is seen on the wall as shown in figure. Now shout directly into the open end of the can and observe the dancing light.

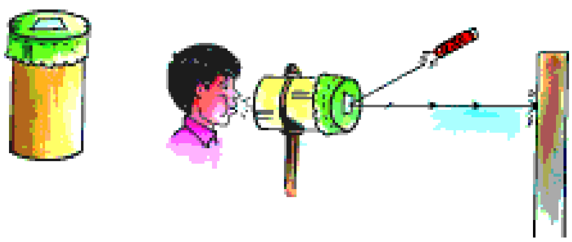


Fig-1 Observing vibrations of light

- Why is the light ray dancing, after sound is made in the tin?
- What do you infer from this?
- Can we say that sound is a form of mechanical energy?

Like the stretched rubber sheet in the above activity, sound produced at a distance travels through air and reaches our ears to produce a sensation of hearing in our ears.

Do you know?

Glimpses of history of sound

From the very early times the question "How sound travels through air", attracted the attention of philosophers. Pythagoras (around 570 B.C), a Greek scholar and traveler, explained that sound travels in air due to the **to and fro motion** of the air particles, which act upon the ear and produce the sensation of sound. Galileo (1564-1642) and Bacon (1561-1625) agreed with the above theory but it was Newton who first explained the phenomenon of propagation of sound through air.

Production of sound

Activity-2

Observing the vibration of tuning fork

Take a tuning fork and strike one of its prongs gently with a rubber hammer and bring it near your ear.

- Do you hear any sound?

Touch one of the prongs of the tuning fork with your finger. What do you feel? Share your feeling with your friends.

- Do you see any vibrations in the tuning fork?

To see vibrations, attach a small piece of steel wire to one of its prongs as shown in figure 2. While it is vibrating, try to draw a straight line on a piece of smoked glass as quick as possible with it. Keep the end of the wire in such a way that it just touches the glass. A line is formed in the form of wave as shown in figure 2. Repeat the experiment when the fork is not vibrating and observe the difference in the line

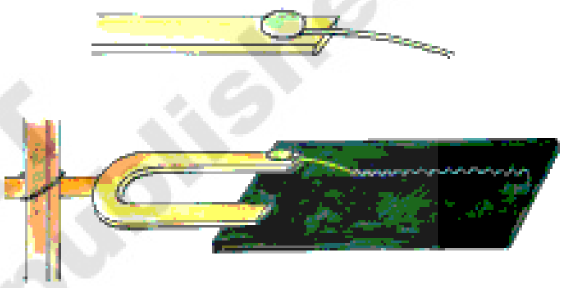


Fig - 2

- What do you conclude from the above activity?
- Can you produce sound without vibration in the body?

In above activity we have produced vibrations in tuning fork by striking it with a hammer. We observe that vibrating tuning fork produces sound. Thus sound is produced by vibrating bodies.

- Give some examples of vibrating bodies which produce sound.
- What part of our body vibrates when we speak?
- Do all vibrating bodies necessarily produce sound?

Do you know?

A tuning fork is an acoustic resonator; it is a steel bar, bent into a U- shape (Prongs), with a handle at the bend. It resonates at a specific constant pitch when set into vibration by striking it with a rubber hammer. The pitch of the tuning fork depends on the length of the prongs. It is mainly used as a standard of pitch to tune other musical instruments.

The device first invented in 1711 by a British musician John Shore.

How does sound travel?

We know that sound is a form of energy. It travels through the air and reaches our ears to give the sensation of sound.

If energy transfer takes place during sound propagation, then in which form, does it travel in air?

There may be two possible ways by which transfer of energy from the source of sound to our ears takes places. One is that the source of sound produces disturbances in air and they strike our ears. The other explanation is that some particles are shot off from the source of sound and they reach our ears.

If the second explanation is correct, vibrating body would gradually lose its weight as particles are continuously shot off from it, This certainly never happens, because it would lead to vanishing of the object. Thus we can conclude that 'sound travels through disturbances in the form of waves', can be taken as a correct explanation.

- If sound travels in the form of a wave then what is the pattern?

Propagation of Sound

We know that sound is produced by vibrating objects. The matter or the substance through which sound is transmitted is called the medium.

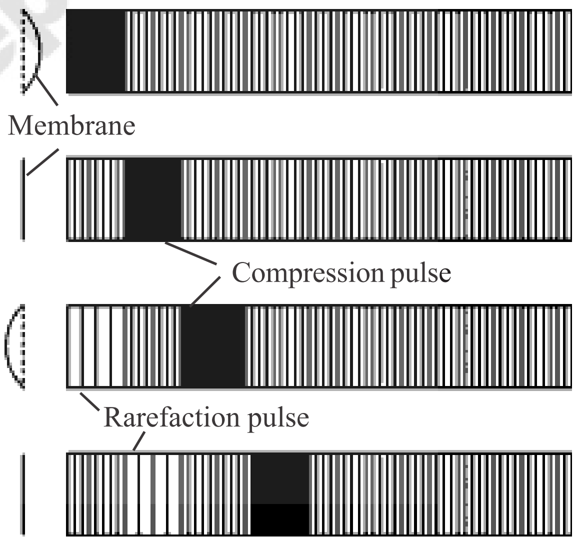


Fig-3

When a source of sound vibrates it creates a disturbance in the medium near it. This means that the condition of the medium near the source becomes different from its normal condition. The disturbance could be in the form of compression of the medium close to the source. This disturbance then travels in the medium. Let us see how it travels.

Consider a vibrating membrane of musical instrument like a drum or tabla. As it moves back and forth, it produces a sound. Figure 3 shows the membrane at different instants and the condition of the air near it at those instants.

As the membrane moves forward (towards the right in Figure), it pushes the particles of air in the layer in front of it. So, the particles of air in the layer get closer to each other. Hence the density of air increases locally and this layer of air pushes and compresses the layer next to it, which then compresses the next layer, and so on. In this way the disturbance moves forward. We call this type of disturbance as compression pulse. The particles of the medium do not travel with the compression pulse they only oscillate about a mean position. It is the disturbance which travels in the forward direction.

What happens when the membrane moves back (to the left)? It drags back the layer of air near it, decreasing the density of air there. The particles of air in the next layer on the right move in to fill this less dense area. As a result, its own density reduces. In the same way, the density of air in successive layers on the right decrease one after the other. We say that a rarefaction pulse moves to the right.

As the membrane moves back and forth repeatedly, compression and rarefaction pulses are produced, one after the other. These two types of pulses travel one behind the other, carrying the disturbance with it. This is how sound travels in air.

Think and Discuss

Do compressions and rarefactions in sound wave travel in same directions or in opposite directions ? Explain.

Types of waves

Activity-3

Demonstrating types of wave propagation

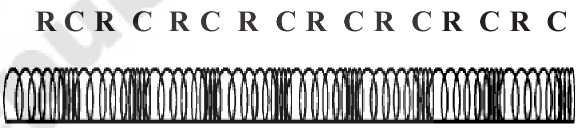


Fig-4 Compressions and rarefactions in a slinky

1. Take a slinky, it is a spring – shaped toy which can be extended or compressed very easily. It is very flexible and can be put into many shapes easily. You can send continuous waves on a slinky. Lay it down on a table or the floor as shown in the figure 4 and ask a friend to hold one end. Pull the other end to stretch the slinky, and then move it to and fro along its length.

   You will see alternate compressions and rarefactions of the coil. This is similar to the pattern of varying density produced in a medium when sound passes through it.

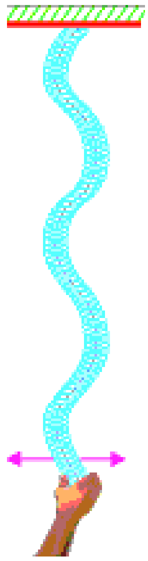


Fig-5 Transvers waves in a slinky

2. Hang a slinky from a fixed support. Hold it gently at the lower end and quickly move your hand sideways and back. What do you observe? This will cause a hump on the slinky near the lower end.

   This hump travels upwards on the slinky as shown in figure 5. What is travelling upwards? The part of the slinky that was at the bottom in the beginning is still at the bottom. Similarly no other part of the slinky has moved up. Only the disturbance has moved up. Hence we may say that a wave has travelled up through the slinky.

We have discussed two examples of wave propagation in a slinky. In the first case the vibrations are along the direction of wave motion and in the second case the vibrations are perpendicular to the direction of wave motion.

If the particles of the medium vibrate along the direction of wave, the wave is called a longitudinal wave.

If the particles of the medium vibrate perpendicular to the direction of wave, then the wave is called a transverse wave.

Longitudinal wave involves change in the density of the medium, whereas transverse wave involves change in the 'shape' of the medium.

- What do you say about sound waves in air by the above activity?
- Are they longitudinal or transverse?

Sound waves are longitudinal

As we have seen, when a sound wave passes through air, the layers in the medium are alternately pushed and pulled. Thus the particles of the medium move to and fro along the direction of propagation. Therefore sound waves in air are longitudinal.

Characteristics of the sound wave

Four quantities play an important role in describing the nature of a wave. These quantities are its wave length, amplitude, frequency and wave speed. They are called characteristics of the wave. Let us learn about these characteristics in the context of the sound wave.

Let us consider a sound wave produced by a source such as a tuning fork. Figure 6 shows the variation in the density of air near the source at a particular time and the variation in the density of air with distance is also shown by a graph in Figure 6. Since the pressure of air is proportional to density at a given temperature, the plot of density verses distance will also have the same shape.

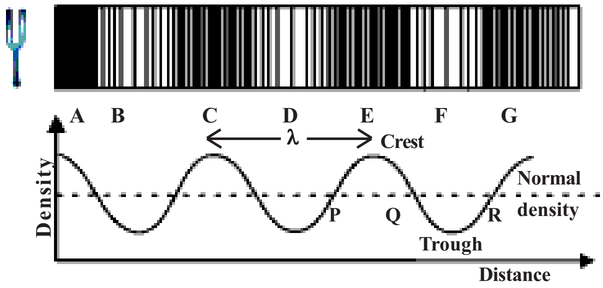


Fig-6

It can be seen from the graph that in portions like PQ, the density is more than the normal density, represents a compression. In portions like QR, the density is less than the normal, represents a rarefaction.

Thus the compressions are the regions where density as well as pressure is high. Rarefactions are the regions where the density as well as pressure is low. In above density vs. distance graph, the peak of the graph is called crest and valley of the graph is called trough.

1. Wave length

At any given instant, the density of air is different at different places along the direction in which sound is moving. For a source like a tuning fork, the distance between the consecutive position of maximum density (compressions) (like C and E in the above figure 6) or minimum density (rarefactions) like B and E as shown in figure 6 remain the same. So these values get repeated after a fixed distance. This distance is called the wave length of the wave. It is denoted by the Greek letter λ (read as 'lambda'). We can define wavelength as follows.

The distance between two consecutive compressions or two consecutive rarefaction is called the wave length of a sound wave.

Being a length, wavelength is measured in meters. SI unit of wave length is meter (m).

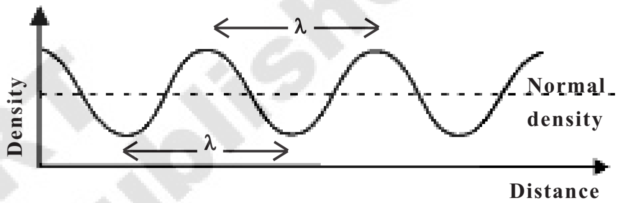


Fig-7

2. Amplitude

The amplitude of a sound wave in air can be described in terms of the density of air or pressure of air or the displacement of the layers of air. You know that when sound travels in air, the layers of air move to and fro, causing compressions and rarefactions. As a result, the density and pressure of air at a place varies. Its value increases from the normal to reach a maximum and then reduces to a minimum.

The amplitude of density of medium is the maximum variation in the density when sound wave passes through it. Similarly we can define amplitude of pressure and displacement of the particle of a medium when sound travels through it.

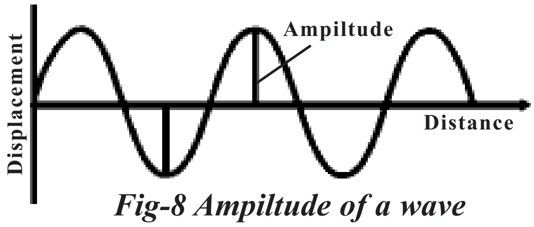


Fig-8 Ampiltude of a wave

Thus the maximum disturbance of particles in the medium on either side of mean position is called amplitude of wave. It is usually represented by a letter A. The units of amplitude depend on which terms the amplitude is being described. Because if sound wave is moving through air we describe amplitude in terms of density and pressure. If sound wave is moving in solids, we describe amplitude in terms of displacement of particles from their mean positions.

Terms of describing amplitude	Units of amplitude
Density	Kg/m^3
Pressure	Pascal
Displacement	Metre.

3. Time period and frequency

We know that when sound is propagating through a medium the density of medium oscillates between a maximum value and minimum value.

"The time taken to complete one oscillation of the density of the medium is called the time period of the sound wave". It is represented by the symbol (T). Its SI unit is second (s).

Frequency is a quantity that is closely related to time period. We can define that the frequency of sound wave as follows.

"The number of oscillations of the density of the medium at a place per unit time is called the frequency of the sound wave".

We usually use the Greek letter υ (read as 'nu') to denote frequency.

Relation between frequency and time period

Let us find the relationship between frequency and time period.

Let the time taken for υ oscillations = 1s

The time taken for one oscillation=(1/υ) s

But the time taken for one oscillation is called the time period (T) and the number of oscillations per second is called the frequency (υ).

Hence Frequency and time period are related as $T = 1/\upsilon$ or $\upsilon = 1/T$

The SI unit of frequency is hertz (Hz). It is named after Heinrich Rudolph Hertz.

Heinrich Rudolph Hertz was born on 22 February 1857 in Hamburg, Germany and educated at the University of Berlin.He was the first to conclusively prove the existence of electromagnetic waves. He laid the foundation for future development of radio, telephone, telegraph and even television. He also discovered the photoelectric effect which was later explained by Albert Einstein. The SI unit of frequency was named Hertz in his honour.

Larger units of frequency

Kilo Hertz (KHz)	10^3 Hz
Mega Hertz (MHz)	10^6 Hz
Giga Hertz (GHz)	10^9 Hz
Tera Hertz (THz)	10^{12}Hz

Example-1

Find the time period of the wave whose frequency is 500Hz?

Solution

from $T = 1/\upsilon$ $=1/500$ s

$=0.002$ s

Think and discuss

- Does the frequency of sound waves depend on the medium in which it travels? How?
- The frequency of source of sound is 10Hz. How many times does it vibrate in one minute?
- Gently strike a hanging bell (temple bell) and try to listen to the sound produced by it with a stethoscope keeping it both at bottom portion and top portion of the bell. Is the pitch and loudness of the sound same at the two portions ? Why ?

4. Speed of Sound wave

The distance by which a point on the wave, such as a compressions or rarefaction, travels in unit time is called speed of sound wave.

Let the distance travelled by a wave in T seconds = λ metres

The distance travelled by a wave in 1second = λ/T metres

Thus by definition, speed of sound wave $v = \lambda/T$ ———————— (1)

We know that frequency $\upsilon = 1/T$ —(2)

From equation (1) & (2) we get $v = \upsilon\lambda$

Speed of a sound wave = frequency x wave length.

The speed of a sound wave depends on the properties such as the temperature and nature of the medium in which it is travelling. But the speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

In common speech, speed of sound refers to the speed of sound waves in air. However speed of sound varies from substance to substance. Sound travels faster in liquids and nonporous solids than it does in air. It travels about 4.3 times faster in water (1484 m/s) and nearly 15 times as fast in iron (5120 m/s) than in air at 20^0 C. In dry air at 20^0 C the speed of sound is 343.2 m/s. this is 1236 km/hr or about 1km in 3s.

Think and discuss

- During a thunderstrom if you note a 3 second delay between the flash of lightning and sound of thunder. What is the approximate distance of thunderstrom from you.

Example-2

1. In a certain gas, a source produces 40.000 compression and 40.000 rarefaction pulses in 1 sec. When the second compression pulse is produced; the

first is 1cm away from the source. Calculate the wave speed.

Solution

We know frequency is equal to number of compression or rarefaction pulses travelled per second, hence frequency (υ) = 40,000 Hz

Wave length (λ) = distance between two consecutive compression or rarefaction pulses.

λ = 1cm

From $v = \upsilon \lambda$ = 40.000Hz x 1cm = 40.000cm/s = 400m/s

Do you know?

Sonic boom

When a body moves with a speed which is greater than the speed of sound in air, it is said to be travelling at supersonic speed. Jet fighters, bullets etc., often travel at supersonic speeds.

When a sound producing source moves with a speed higher than that of sound, it produces shock waves in air. These waves carry a large amount of energy. They produce a very sharp and loud sound called the sonic boom.

The sonic boom produced by supersonic aircraft is accompanied by waves that have enough energy to shatter glass and even damage buildings.

Characteristics of a musical sound

In the previous class we learnt that all sounds can be roughly classified as musical sounds and noises. The sounds which produce pleasing effect on the ear are called musical sounds while the sounds which produce unpleasant effect are called noises.

There are three characteristics by which we can distinguish a musical note from other.

They are 1. Pitch 2. Loudness 3. Quality

1. Pitch

- Sound of mosquito is shrill while sound of lion is growl.
- Female voice is shriller than male voice.

From the above examples, what property of sound differentiates them?

Pitch is the characteristic of sound which distinguishes between a shrill sound and a growling sound. Actually pitch of sound is the sensation conveyed to our brain by the sound waves falling on our ears which depends directly on the frequency of the incident sound waves. The greater the frequency of a musical note, higher is the pitch.

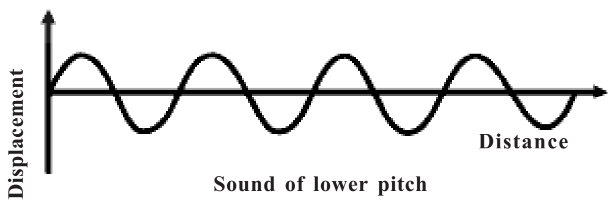


Fig-9(a)

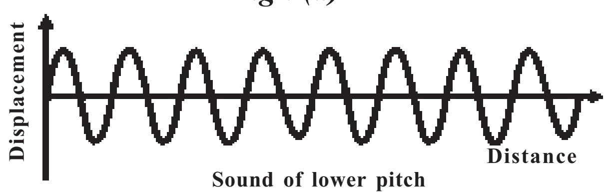


Fig-9(b)

In musical terms, the pitch of the note determines the position of the note on the musical scale which is denoted as

Note:	C (sa)	D (re)	E (ga)	F (ma)	G (pa)	A (dha)	B (ni)	C^1 (sa)^1
Frequency (Hz)	256	288	320	341.3	384	426.7	480	512

The tuning fork set is prepared based on the above frequencies.

2. Loudness

If we strike a school bell lightly, we hear a soft sound. If we hit the same bell hard we hear a loud sound. Can you guess the reasons for this change? The reason for this change in intensity of sound is due to the another characteristic of sound called loudness.

Loudness of sound is defined as the degree of the sensation produced on the ear.

The loudness or softness of a sound is determined basically by its amplitude. The amplitude of the sound wave depends upon the 'force' with which the objects are made to vibrate.

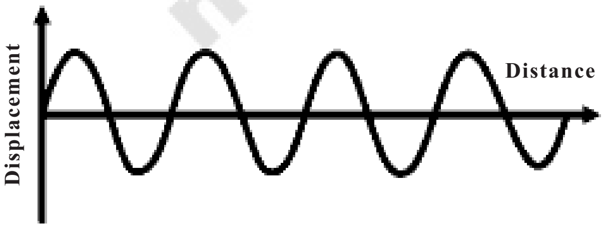


Fig-10(a) Louder sound

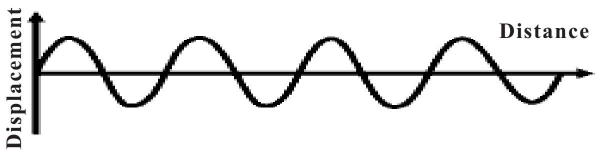


Fig-10(b) Soft Sound

In the above figures 10(a) and 10(b) the variation of wave disturbance with time is shown as a graph for two sounds with different amplitudes.

The amplitude of the sound wave in figure10(a) is greater than the amplitude of sound wave in figure10(b). So the graph in figure 10(a) represents a louder sound and the graph in figure 10(b) represents a soft sound.

The loudness of the sound is measured in decibels (dB). It signifies the sound pressure level. Human ears pickup sounds from 10 dB to 180 dB. The loudness of sound is considered normal, if it is between 50 dB to 60dB.

A normal human being can tolerate loudness of 80 dB. The sound above 80 dB is painful and causes various health problems. The decibel level of a jet engine taking off is 120 dB.

Therefore people working near the airbase need to protect their ears by using ear plugs. Otherwise it may lead to hearing loss. Listening to very loud music through earphones of MP3 player or mobile phones also leads to hearing loss because loudness of sound means high energy is delivered to our ears. Hence we should be very careful when listening to music through ear phones.

3. Quality

You might have noticed different sounds produced by different instruments such as violin, piano, flute, etc. To distinguish between two sounds, we need to learn about the quality of sound.

The quality of sound is the characteristic which enables us to distinguish between musical notes emitted by different musical instruments or voices even though they have the same pitch and loudness. It is because different wave forms are produced by different musical instruments. Hence the quality of a note depends on its wave form.

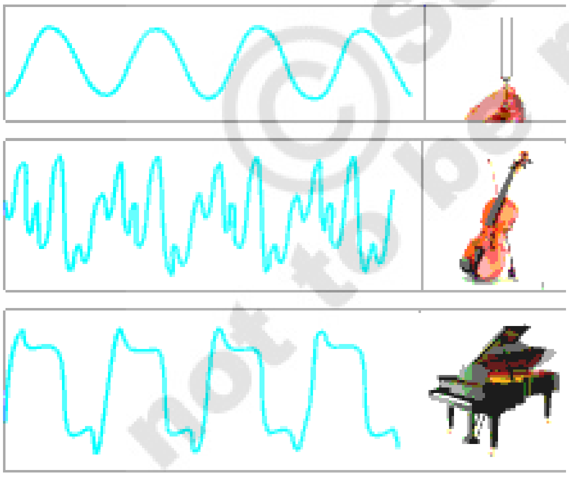


Fig-11

figure 11 shows graphical representation of sound wave produced by a tuning fork, a violin and a piano playing the same note (fundamental frequency = 440Hz) with equal loudness.

Think and discuss

- Two girls are playing on identical stringed instruments. The strings of the both instruments are adjusted to give notes of same pitch. Will the quality of two notes be same? Justify your answer.
- What change, would you expect in the characteristic of a musical sound when we increase its frequency one instance and amplitude in another instance?

Reflection of sound

Does sound get reflected at the surface of a solid? Let us find out?

Activity-4

Listening to reflected sound

Take two long, identical tubes and place them on a table near a wall. Ask your friend to speak softly into one tube while you use the other tube to listen. Adjust the tube until you hear the best sound. You will find that you hear your friend's voice best when the tubes make equal angles with a normal to the wall as shown in figure 12. Why?

Reflection of sound follows the same laws as the reflection of light when sound is reflected. i.e., the directions in which the sound is incident and reflected make equal angles with the normal to the reflecting surface.

- What happens if you lift your tube slightly above the table?
- Are able to listen to the sound? If not why?

You will not be able to hear your friend's voice clearly. Think about the planes of the tube carrying incident sound and reflected sound. What will happens to these planes if we lift one of the pipes? If you lift one of the pipes then the pipe carrying incident sound, the pipe carrying reflected sound will not be in the same plane. Hence we cannot hear a clear sound.

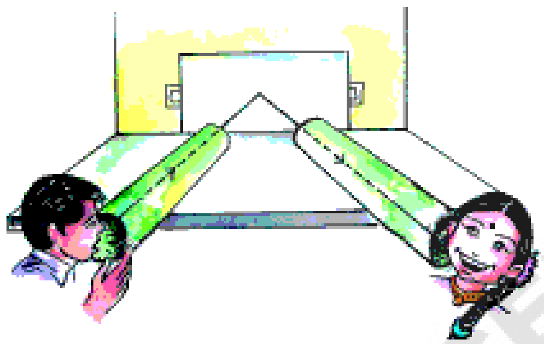


Fig-12

Repeat the experiment by placing flat objects of different materials (steel and plastic trays, a card board, a tray draped with cloth, etc) against the wall and observe changes in sounds.

- Do hard surfaces reflect sound better than soft ones?

As you have seen in the second part of the activity, the reflection of sound is dependent on the reflecting surface. Generally, hard surfaces reflect sound better than soft surfaces. But unlike light, which is reflected well only from highly polished surfaces, sound reflects quite well from rough surfaces as well. For example, an un-plastered brick wall will reflect sound quite well.

Think and discuss

- What could be the reason for better reflection of sound by rough surfaces than polished surfaces?

Echo

If we shout or clap standing at a suitable distance from a reflecting object such as a tall building or a mountain, we will hear the same sound again a little later. This sound which we hear is called an echo. The sensation of sound persists in our brain for about 0.1s. This is called persistence of sound. To hear a distinct echo, the time interval between the original sound and the reflected sound must be at least 0.1s. This means that if a sound produced by a source is reflected in less than 0.1 sec., the echo would not be heard. For sound to reflect after 0.1 sec., what should be the minimum distance between the source and the obstacle?

Let us now derive a formula for finding out speed of sound if we hear an echo.

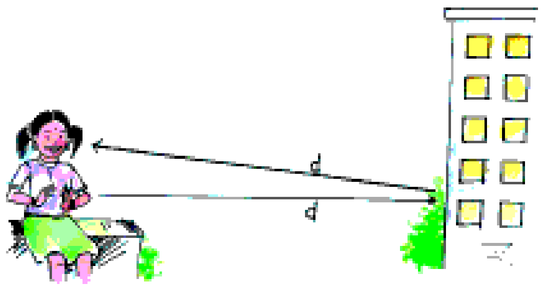


Fig-13

Let the distance travelled by sound from source to obstacle = d

Then distance travelled by sound from obstacle to source = d

Thus, total distance travelled by sound wave = 2d

Let echo time be ‘t’ Sec

Speed = total distance travelled/echo time
= 2d/t

Do you know?

The roaring of thunder is due to the successive reflections of the sound from a number of reflection surfaces, such as the clouds and the land.

Think and discuss

- Why is an echo weaker than the original sound ?

Example-3

An echo is heard after 0.8s, when a boy fires a cracker, 132m away from a tall building. Calculate the speed of sound?

Solution

Echo time (t) = 0.8s

Total distance travelled by sound wave

2d = 2x132 m = 264m

From, speed of sound V =2d/t

V = 264m/0.8s = 330 m/s

Reverberation

A reverberation is perceived when the reflected sound wave reaches your ear in less than 0.1s after the original sound wave. Since the original sound and reflected sound waves tend to combine, we get to hear one, prolonged sound wave.

In an auditorium or big hall excessive reverberation is highly undesirable. To reduce reverberation, the roof and walls of the auditorium are generally covered with sound – absorbent materials like compressed fiber board, rough plaster or draperies. The seat materials are also selected on the basis of their sound absorbing properties.

Think and discuss

- In a closed box if you say hello, the sound heard will be Hellooooo….. What does it mean?

Relation between Echo and Reverberation

Reverberation is quite different from an echo. A reflected sound, arriving at the position of listener more than 0.1s after the direct sound is called an echo. A reflection of sound, arriving at the listener in less than 0.1s after the direct sound is called reverberation.

Uses of multiple reflection of sound

1. A megaphone and a horn

Megaphones, horns, musical instruments such as trumpets, shehanai and loud speakers are all designed to send sound in a particular direction without spreading it in all directions, as shown in fig 14.

In these instruments, a tube followed by a conical opening reflects sound successively to guide most of the sound waves from the source in the forward direction towards the audience

Fig-14

Think and discuss

- What is the advantage of having conical openings in Horns, megaphones etc ?

2. Stethoscope

Stethoscope is a medical instrument used for listening to sounds produced within the body, chiefly in the heart or lungs. In stethoscopes the sound of the patient's heartbeat reaches the doctor's ears by multiple reflection and amplifying the sound as shown in figure 15.

Fig-15

3. Designing of concert halls and cinema halls

Generally the ceilings of concert halls, conference halls and cinema halls are designed such that sound after reflection reaches all corners of the hall, as shown in figure 16. In some halls a curved sealing is arranged in such a way that the sound after reflecting from the ceiling spreads evenly across the hall.

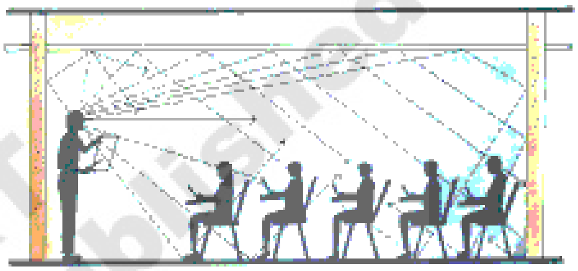


Fig-16

Think and discuss

- Why do we put cushions on the chairs, carpet on the floor, straw materials on the walls in cinema halls?

Range of hearing

The human ears are able to hear sound in a frequency range of about 20 Hz to 20,000 Hz. The above range of frequencies is thus written as 20 Hz- 20 KHz. We cannot hear sounds of frequencies less than 20 Hz or more than 20 KHz. These limits vary from person to person and with age. Children can hear sounds of somewhat higher frequencies, say up to 30 KHz. With age, our ability to hear high-frequency sound diminishes. For the elders, the upper limit often falls to 10-12 KHz. However, we take 20-20,000 Hz as the audible range for an average person.

Even in the audible range, the human ear is not equally sensitive to all frequencies,. It is the most sensitive to frequencies around 2,000-3,000 Hz, where it can hear even a very low-intensity sound.

Sound of frequency less than 20 Hz is known as infrasonic sound or infrasound. Sound of frequency greater than 20 KHz is known as ultrasonic sound or ultrasound.

Do you know?

Different animals have different ranges of audible frequencies. A dog can hear sounds of frequencies up to about 50 KHz and a bat, up to about 100 KHz. Dolphins can hear sounds of even higher frequencies. These animals can also produce ultrasonic waves and communicate using them. Bats use ultrasonic waves to navigate, as we shall see a little later. Animals such as elephants and whales produce sounds of frequencies less than 20 KHz . Scientists have found that elephants grieve over their dead by producing infrasonic sounds. Some fishes can hear sounds, of frequencies as low as 1-25 Hz. Rhinoceroses communicate using infrasonic sounds of frequency around 5 Hz.

Applications of ultrasound

Ultra sounds are high frequency sound waves. They are able to travel along a well defined path in gaseous and liquid media. Ultra sounds are used extensively in industries and for medical purposes.

Industrial applications of ultrasonic waves

1. Drilling holes or making cuts of desired shape

Holes can also be drilled using ultrasonic vibrations produced in a metallic rod, called a horn, This acts like a hammer, hammering the plate about a hundred thousand times per second.

The shape of the hole is the same as that of the tip of the horn. . Ultrasonic cutting and drilling are very effective for fragile materials like glass, for which ordinary methods might not succeed.

2. Ultrasonic cleaning

We normally clean dirty clothes, plates or other large objects by dipping them in a detergent solution and then rubbing and washing. Parts located in hard-to-reach places, cannot be easily cleaned by this method.

Ultrasonics help in cleaning such objects which are placed in a cleaning solution and ultrasonic waves are sent into the solution. This causes high-frequency vibrations in the solution. These vibrations knocks off all dirt and grease particles from the objects, which are then removed using ordinary water.

3. Ultrasonic detection of defects in metals

Metallic components are used in buildings, bridges, machines, scientific equipment, and so on.

If there are cracks or holes inside the metal used, the strength of the structure or component is reduced and it can fail. Such defects are not visible from the outside. Ultrasonic waves can be used to detect such defects.

Medical applications of ultrasound

1. Imaging of organs

Ultrasonic waves have given doctors powerful and safe tools for imaging human organs. Echocardiography is a technique in which ultrasonic waves, reflected from various parts of the heart, form an image of the heart.

Ultrasonography is routinely used to show doctors, the images of a patient's organs such as the liver, gall bladder, uterus, etc. It helps doctors to detect abnormalities such as stones in the gall bladder, tumors, etc.

It is also used to monitor the growth of a foetus inside the mother's womb.

Ultrasonography is safer than older X-ray imaging technique. Repeated X-rays can harm tissues, especially those of a foetus.

Fig-17 Image of Ultrasound scanning

2. Surgical use of ultrasound

The ability of ultrasonic waves to cause molecules of materials to vibrate vigorously and thus cause certain materials to break into tiny pieces (emulsify) is employed in ultrasound surgery. Cataract removal is a very common example.

Ultrasound is also employed to break small stones that form in the kidneys into fine grains. These grains get flushed out with urine. This method has eliminated the need to perform surgery.

Think and discuss

- What is the benefit of using ultrasound over light waves in the above applications?

SONAR

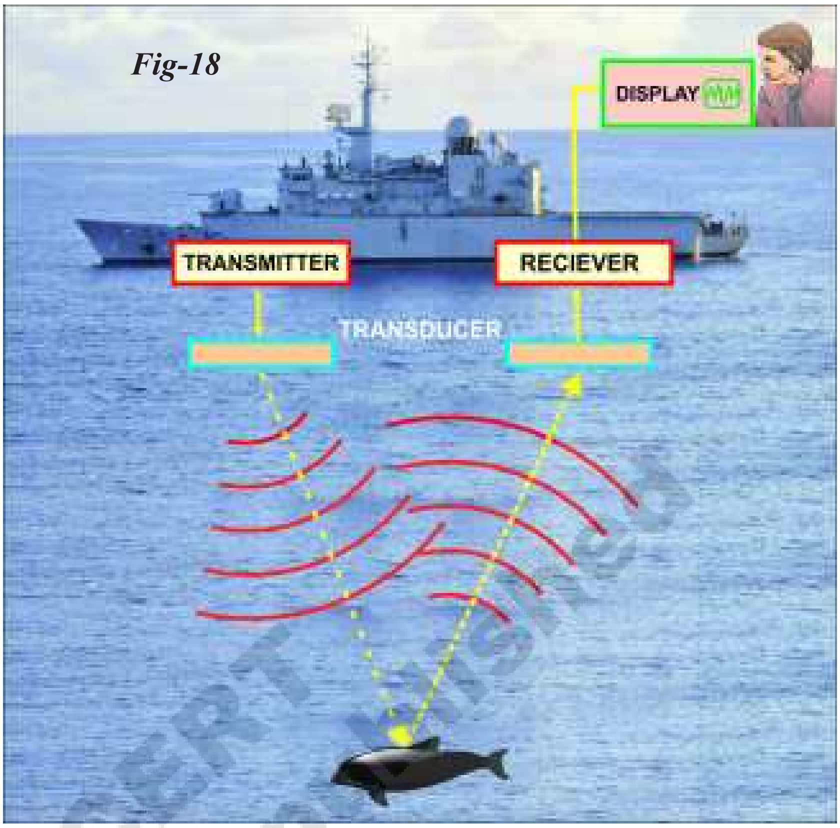
Do you know how we can measure the depth of the sea? Let us find out.

SONAR stands for Sonographic Navigation And Ranging. This is a method for detecting and finding the distance of objects under water by means of reflected ultrasonic waves. The device used in this method is also called SONAR.

- How does a SONAR system work?

SONAR system consists of a transmitter and a detector which are installed in the "Observation Centre" on board of a ship. From the observation centre on board a ship, ultrasonic waves of high frequencies, say 1,000 KHz, are sent in all directions under the water through transmitter. These waves travel in straight lines till they hit an object such as a submarine, a sunken ship, a school of fish, etc. The waves are then reflected, and are received back by the receiver at the observation centre. The direction from which a reflected wave comes to the observation centre tells the direction in which the object is located. From the time between sending the ultrasonic wave and receiving its echo, and the speed of sound in sea water, the distance of the object from the observation centre is calculated. Reflections from various angles can be utilized to determine the shape and size of the object.

Fig-18



Let **d** be the distance between the sonar and an underwater object, **t** be time between sending an ultrasonic wave and receiving its echo from the object and **u** is the speed of sound in water.

The total distance covered by the wave from the sonar to the object and back is **2d.**

Using s = ut,

$$\text{Or } 2d = ut$$

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

This method of finding distances is also called echo ranging. Marine geologists use this method to determine the depth of the sea and to locate underwater hills and valleys.

Example 4

A research team sends a sonar signal to confirm the depth of a sea. They heard an echo after 6s.Find the depth of the sea. If the speed of sound in sea water is 1500 m/s?

Solution

Let the depth of the sea = d m

Then Total distance

travelled by sonar signal (s) = 2d

Speed of sound in sea water (u) = 1500 m/s

Total time taken (t) = 6s

From, s = ut,

2d = 1500 m/s x 6s

d = 9000/2 m =4.5 km

Key words

Mechanical energy, tuning fork, longitudinal wave, transverse wave, compression, rarefaction, crest, trough, density of mediam, pressure, wavelength, amplitude, frequency, pitch, loudness, quality of sound, echo, reverberation, infrasonic, sonic, ultrasonic and SONAR.

What we have learnt

- Sound is a form of mechanical energy which produces sensation of hearing.
- A tuning fork is an acoustic resonator, which resonates at constant pitch when set into vibration.
- If the particles of the medium move to and fro along the direction of propagation of the wave, the waves are called longitudinal waves.
- Sound waves are longitudinal.
- The region of high density of particles in the medium during propagation of sound is called compression and low density regions are called rarefaction.
- The distance between two consecutive compressions or rarefactions is called wavelength.
- The maximum variation in density or pressure from the mean value is called amplitude or the maximum disturbance of particles of a medium from their mean position is called amplitude.
- The time taken to complete one oscillation of density in the medium is called time period of sound wave.
- The number of oscillations of the density of the medium at a place per unit time is called frequency.
- The distance by which a point of on the wave, such as a compression or rarefaction travels per unit time is called speed of sound.
- Pitch is a characteristic of sound which distinguishes between a shrill sound and a deep, low sound.
- Loudness of sound is defined as the degree of sensation produced in the ear.

- The quality of sound is the characteristic which enables us to distinguish between musical notes emitted by different musical instruments.
- A reflection of sound, arriving at the listener in more than 0.1s after direct sound is called an echo.
- A reflection of sound, arriving at the listener in less than 0.1s after direct sound is called reverberation.
- Sound of frequency between 20Hz – 20KHz is called sonic or audible limit.
- Sound of frequency less than 20Hz is known as infrasonic sounds.
- Sound of frequency higher than 20KHz is known as ultrasonic sounds.
- SONAR stands for Sound Navigation and Ranging.

Improve your learning

I. Pick the correct answer

1. When we say sound travels in a medium (AS_1) (   )

   A) The medium travels

   B) The particles of the medium travel

   C) The source travels

   D) The disturbance travels

2. A sound wave consists of (AS_1) (   )

   A) number of compression pulses only

   B) number of rarefaction pulses only

   C) number of compression and rarefaction pulses one after the other

   D) vacuum only

3. Hertz stands for oscillations per (AS_1) (   )

   A) second   B) minute   C)hour   D) milli second

4. When we increase the loudness of sound of a TV, the property of sound that changes is
A) amplitude B) frequency C) wavelength D) speed (AS$_1$)

5. The characteristic of the sound that describes how the brain interprets the frequency of sound is called (AS$_1$) (   )

A) Pitch B) loudness C) quality D) sound

6. In a stethoscope, sound of heart beats travel through stethoscopes tube (AS$_1$) (   )

A) By bending along the tube B) In a straight line

C) Undergoing multiple reflections D) all of the above

7. Explain the following terms a) amplitude b) wavelength c) frequency (AS$_1$)

8. Deduce the relation between wavelength, frequency and speed of sound (AS$_1$)

9. How are multiple reflections of sound helpful to doctors and engineers? (AS$_7$)

10. Name two quantities that vary periodically at a place in air as a sound wave travels through it. (AS$_1$)

11. Which has larger frequency – infrasonic sound or ultrasonic sound? (AS$_7$ (AS$_2$)

12. The grandparents and parents of two-year old girl are playing with her in a room. A sound source produces a 28-kHz sound. Who in the room is most likely to hear the sound? (AS$_2$, AS$_7$)

13. Does the sound follow same laws of reflection as light does? (AS$_1$)

14. Why is soft furnishing avoided in concert halls? (AS$_7$)

15. Two sources A and B vibrate with the same amplitude. They produce sounds of frequencies 1kHz and 30kHz respectively. Which of the two waves will have larger power? (AS$_1$)

16. What do you understand by a sound wave? (AS$_1$)

17. Define the wavelength of a sound wave. How is it related to the frequency and the wave speed? (AS$_1$)

18. Explain how echoes are used by bats to judge the distance of an obstacle in front of them. (AS$_1$)

19. With the help of a diagram describe how compression and rarefaction pulses are produced in air near a source of sound. (AS_5)

20. How do echoes in a normal room affect the quality of the sounds that we hear? (AS_7)

21. Explain the working and applications of SONAR. (AS_1)

22. Find the period of a source of a sound wave whose frequency is 400Hz. (AS_1)

23. A sound wave travels at a speed of 340 m/s. If its wavelength is 2cm, what is the frequency of the wave? Will it be in the audible range? (AS_1)

24. Given that sound travels in air at 340 m/s, find the wavelength of the waves in air produced by a 20kHz sound source. If the same source is put in a water tank, what would be the wavelength of the sound waves in water? Speed of sound in water = 1,480 m/s. (AS_7)

25. A man is lying on the floor of a large, empty hemispherical hall, in such a way that his head is at the centre of the hall. He shouts "Hello!" and hears the echo of his voice after 0.2 s. What is the radius of the hall? (AS_7) (Speed of sound in air = 340 m/s)

26. "We know that sound is a form of energy. So, the large amount of energy produced due the sound pollution in cosmopolitan cities can be used to our day to day needs of energy. It also helps us to protect bio diversity in urban areas". Do you agree with this statement? Explain. (AS_7)

27. How do you appreciate efforts of a musician to produce melodious sound using a musical instrument by simultaneously controlling frequency and amplitude of the sounds produced by it. (AS_6)

28. You might have observed that sometimes your pet dog starts barking though no one is seen near in its surroundings or no disturbance heard nearby. Does this observation raise any doubts in your mind about the peculiar behavior of dog after your understanding about 'range of hearing the sound'. If yes, write them. (AS_2)

Project work **(AS_4)**

Find out the information about names of animals and their photographs from internet, which communicate using infra-sonic or ultra-sonic sound and prepare a scrap book.