3 Sound

We interact with the world around us mainly through sight and hearing. Sound plays a very important part in our existence. We recognise many living and nonliving things around us through the sounds they produce. We also use sound to communicate with each other. In this chapter we will discuss how sound is produced, how it travels and what distinguishes one sound from another.

SOURCES OF SOUND

Sound is produced by vibrations. Vibration means the rapid back and forth movement of any object or particle. Every source of sound vibrates when it produces sound.

ACTIVITY Choose a source of sound, such as the speaker of an audio system or a brass bell. Touch it gently when it is producing sound. You will feel the vibrations at once. If you turn off the audio system, the vibrations will stop and so also will the sound. If you press on the vibrating bell from both sides, it will gradually stop vibrating and its sound will die out. You can easily feel this happening. You can experiment with other things too, for example, an electrical buzzer, a guitar string or a television.

Fig. 3.1 Sound is produced by vibrations.

The Human Voice

The sound that we are most familiar with is that of the human voice. What is the source of this sound? When we speak, sound is produced by an organ called the larynx or voice box. This is a broad part of the trachea (wind pipe), where the trachea meets the pharynx. Inside it are two folds of tissue called vocal cords. These vibrate and produce sound when exhaled air passes through the larynx. The nature of the sound changes with the tightness of the vocal cords. When

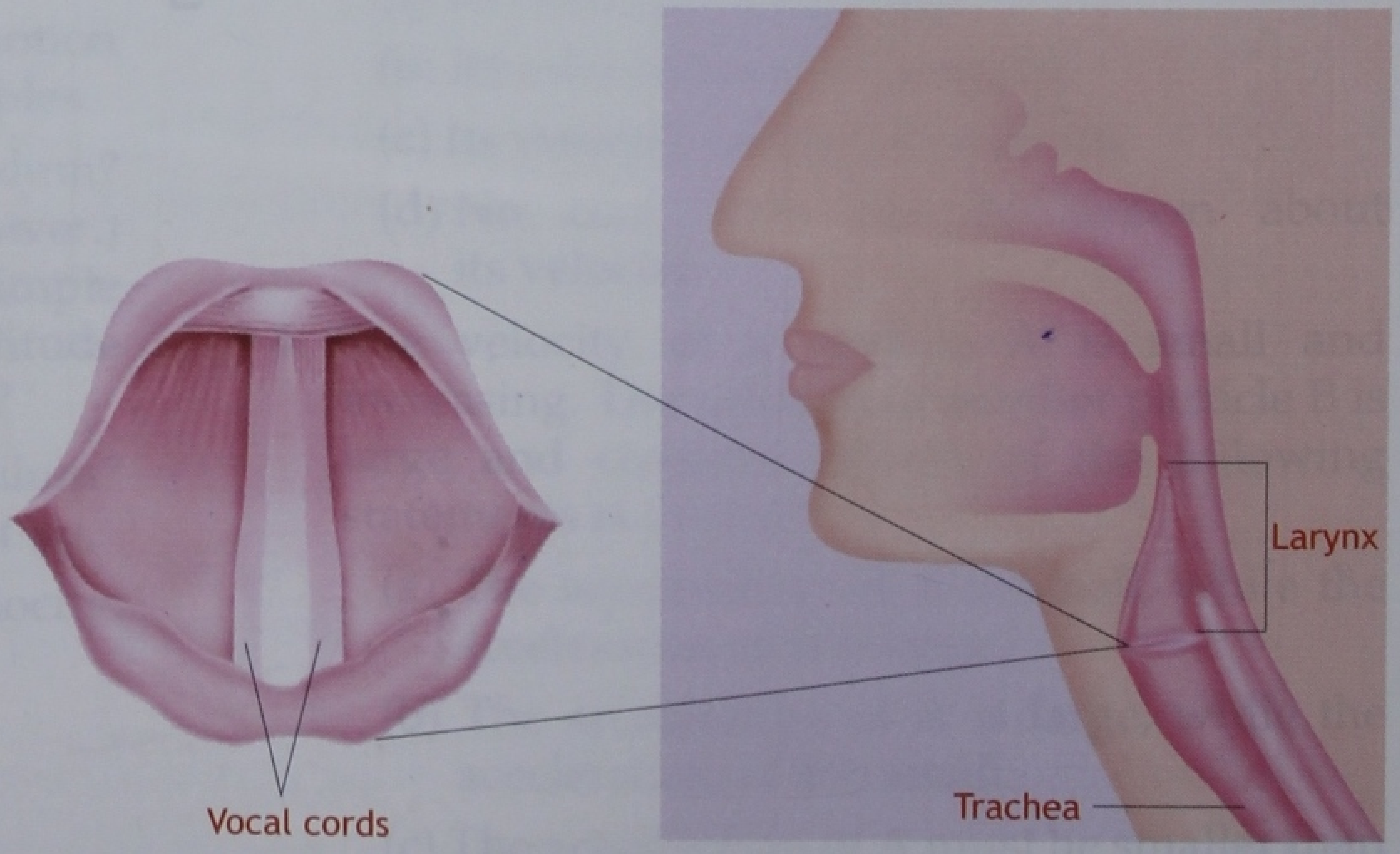


Fig. 3.2 Human larynx

they are tight, the sound is shrill. When they are loose, the sound is bass. The nature of the sound is also determined by the length of the vocal cords. Women and children sound shriller than men because they have shorter vocal cords than men. The sound produced by the larynx is modified into speech by the tongue, teeth and lips.

Musical Instruments

Musical instruments are another very familiar source of sound. They can be divided into three broad groups on the basis of the way sound is produced by them. Let us see what these groups are.

Vibrating strings

In a large number of musical instruments, sound is produced by vibrating strings. The strings are made of animal gut, nylon or metal and are stretched over a hollow structure, which is usually made of wood. Sound is produced by plucking or bowing the strings. The hollow wooden structure makes the sound louder and more melodious.

Instruments in which sound is produced by vibrating strings are callled string instruments. Sitar, sarod, santoor, veena and sarangi are traditional Indian string instruments. Piano, harp, cello, fiddle, violin and guitar are traditionally western instruments, though many of them are very popular in India as well. The larynx, which helps us make sounds, also works like a string instrument.

Fig. 3.3 String instruments

Vibrating air columns

In the second group of musical instruments, sound is produced by the vibrations of a column of air trapped in a 'pipe'. These are called wind instruments. When the pipe is made of wood, as in the flute, shahnai and clarinet, the instrument is called a woodwind instrument. When the pipe is metallic, as in the bugle, trumpet, trombone and saxophone, the instrument may be called a horn or brass. A band playing metallic wind instruments is often called a brass band.

Fig. 3.4 Wind instruments

ACTIVITY The whistles used by policemen and sports referees also produce sound with the help of a vibrating column of air. With a little practice, you can use the cap of a pen or a small bottle (like the vials used by homoeopaths) as a whistle. Hold the cap vertically, with the open end just touching your lips, and blow. You could also experiment with drinking straws. Cut the straws to different lengths and blow into them. You will notice that shorter straws make sharper (shriller) sounds.

Vibrating membranes

In instruments like drums, tablas, bongos and mridangams, sound is produced by vibrating membranes (skins). The skin or leather is stretched across a hollow, barrel-shaped or bowl-shaped body made of wood, metal or clay. The skin is struck by the hand or a stick.

Instruments which produce a sound when they are struck or shaken are called percussion instruments. These include not only drums, tablas, etc., but also cymbals, rattles, tambourines and xylophones.

Fig. 3.5 Percussion instruments

ACTIVITY Make drums of different sizes by stretching pieces of balloons across the mouths of cans, tins, and cardboard boxes and tubes. Strike them with a pencil or stick. You will notice that smaller drums sound sharper or shriller.

Fig. 3.6

PROPERTIES OF A SOUND

The sounds that we hear around us vary widely in nature. They may be loud or soft, shrill (sharp) or bass (dull), pleasant or unpleasant, and so on. Let us discuss these properties of a sound in some detail.

Loudness

The loudness of a sound is also called its intensity. It depends on the power of the source and the distance of the listener from the source. To take a familiar example, a powerful source of sound, such as a loudspeaker, produces a loud sound. However, the loudness of the sound decreases as we move away from the speaker.

What determines the power of a source of sound? Something called the amplitude of its vibrations. The maximum displacement of a

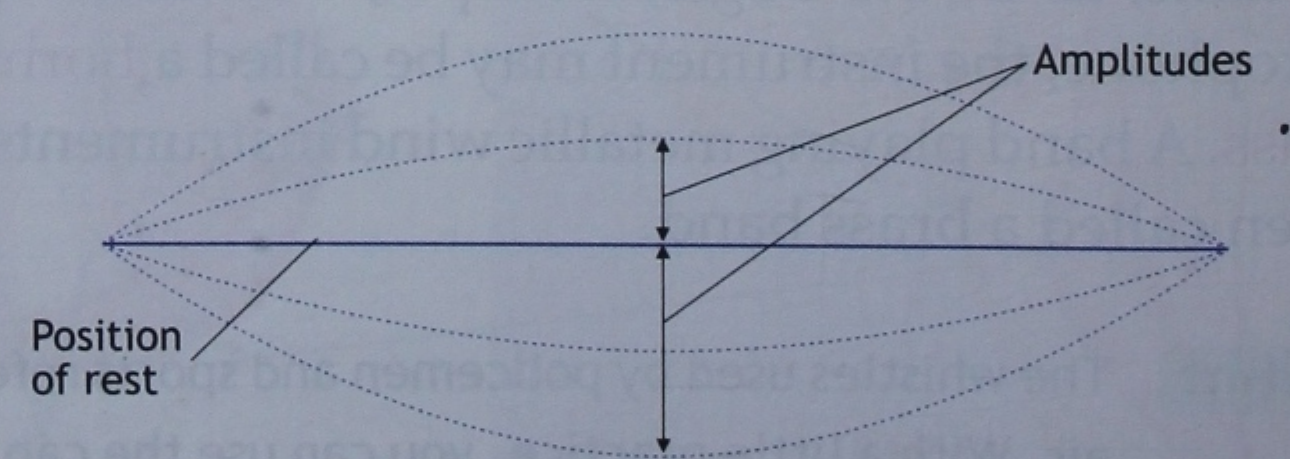


Fig. 3.7 The greater the amplitude the louder is the sound.

body during its vibrations is called the amplitude (of its vibrations). The greater the amplitude the louder is the sound. A powerful source of sound has a large amplitude, while a low-power source has a small amplitude.

ACTIVITY You can explore the relation between amplitude and loudness with the help of the drums you made in the preceding activity. When you strike a drum hard, the skin vibrates with greater amplitude and the sound is loud. When you strike it gently, the skin vibrates with a smaller amplitude and the sound is softer.

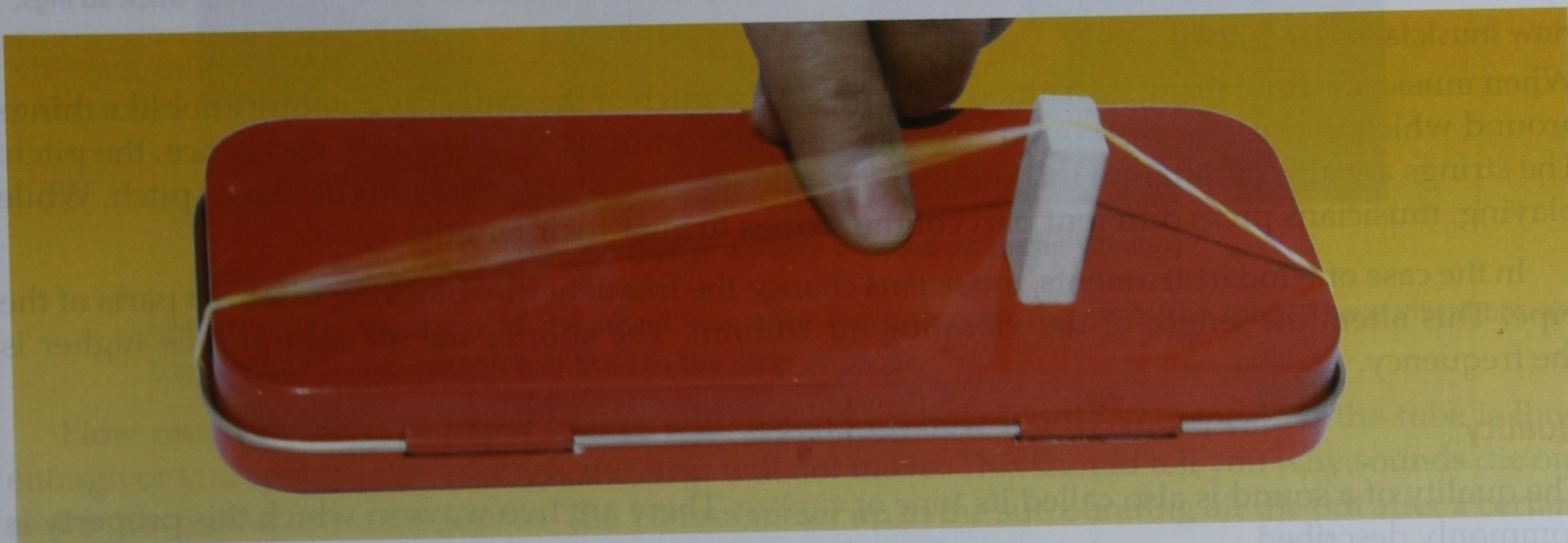


Fig. 3.8

Alternatively, you can make a string instrument by stretching a rubber band across a pencil box, as shown in Figure 3.8. When you pluck the string gently, the amplitude of the vibrations will be small and the sound will be soft. When you pluck harder, the amplitude will be greater and the sound louder.

Why does a sound become softer and finally die out as we move away from its source? We will discuss this in the section on the propagation of sound.

Pitch

The sharpness or dullness of a sound is called its pitch. Sharp or shrill sounds have a high pitch, while dull or heavy sounds have a low pitch. Thus, a child's voice is of high pitch, while the sound of a large drum is of low pitch. Again, male voices on the average have a lower pitch than female voices. We should be careful not to confuse between loudness and pitch. The examples given in Table 3.1 should make the distinction clear.

Table 3.1

Source	Loudness	Pitch
Large drum	High	Low
Siren	High	High
Sound of a mosquito	Low	High
Sound of a refrigerator	Low	Low

What is the relation between the vibrations of a source of sound and the pitch of the sound it produces? The number of vibrations which a source makes in one second is called its frequency. The pitch of the sound it produces depends on this frequency. Vibrations of high frequency produce sounds of high pitch, while vibrations of low frequency produce sounds of low pitch.

The unit of frequency is the hertz, written in short as Hz. If a source vibrates 200 times in 1 s, its frequency is 200 Hz. The sound produced by a vibrating source has the same frequency as that of the source.

ACTIVITY Use the string instrument you made in the preceding activity to find out how you can vary the pitch of the sound produced by it. Alter the tautness of the rubber band by positioning the eraser differently or using two erasers. The pitch of the sound will change with the tightness of the rubber band. A taut string vibrates with a higher frequency than a loose string, so it produces a shriller sound.

You can also alter the pitch by moving the eraser. This will change the length of the rubber band. Shorter strings produce sounds of higher pitch than longer strings. Yet another way of altering the pitch is by changing the thickness of the rubber band. Thin strings produce sounds of higher pitch than thick strings.

How musicians alter pitch

When musicians tune string instruments, they alter the pitch of the sound by rotating knoblike things around which the strings are wound. This changes the tightness of the strings, and hence, the pitch. The strings are also of different thicknesses. The thinner ones produce sounds of higher pitch. While playing, musicians press different parts of the strings to alter their lengths.

In the case of wind instruments, musicians change the frequency by blocking different parts of the pipe. This alters the length of the vibrating air column. The shorter the air column, the higher is the frequency.

Quality

The quality of a sound is also called its tone or timbre. There are two ways in which this property is commonly described.

1. Quality is the pleasant or unpleasant nature of a sound. Musical sounds have a pleasant quality, while noises, such as those produced by vehicles or machinery, have an unpleasant quality.
2. Quality is that property of a sound by which we identify its source.

The sound produced by a source does not usually have only one frequency. There are several frequencies. The lowest frequency is called the fundamental frequency. This determines the pitch of the sound. When we speak of the 'frequency of a sound', we always mean this frequency. The other frequencies present are integral multiples of the fundamental frequency. In other words, if the fundamental frequency is f, the other frequencies present will be $2f$, $3f$, and so on. The frequencies present in a sound are called harmonics. The fundamental frequency is the first harmonic. The frequencies which are present along with the fundamental are called overtones.

Every source emits sounds with its own fixed pattern of overtones. This is what helps us recognise different sources. In general, richer or more pleasant sounds have a greater number of overtones mixed in a higher proportion.

PROPAGATION OF SOUND

How is sound propagated, or how does it travel? The sound emitted by a source reaches our ear through the surrounding air. When the source of a sound vibrates, it pushes against the surrounding air and sets it vibrating. When these vibrations reach our ear, the air inside the ear starts vibrating. This sets the eardrum (a membrane inside the ear) vibrating. You will learn more about how we hear in your biology lessons. For the moment, it is enough to know that sound travels to our ears because the vibrations from its source move through air, as the following activity will show you.

ACTIVITY Stretch a balloon over one end of a cardboard or plastic tube and secure it with a rubber band. Stick a thin strip of paper on the balloon. Speak into the open end of the tube and touch the strip lightly. You will feel it

Fig. 3.9 The vibrations of a source of sound set the air vibrating.

vibrating. The vibrations of the sound you make move through the air in the tube. These vibrations are transmitted to the balloon and then to the strip of paper.

How much the strip of paper moves will depend on how loudly you speak. If the tube is long enough or you speak softly enough, the strip will not move. This should tell you why sounds die out as we move away from the source. The vibrations set up in the surrounding air die out after a certain distance. How far a sound carries depends on the loudness of the sound or the amplitude of the vibrations.

What if you could take out all the air from the tube in the preceding activity? The balloon and the strip of paper would not move. The vibrations of a sound can travel only if there is something through which they can move. Sound does not travel through a vacuum. There is a well-known experiment to show this.

EXPERIMENT An electric bell is suspended inside a large glass jar. A rubber stopper closes the mouth of the jar. The two wires of the bell pass through this stopper. The air in the jar can be pumped out through an opening at the bottom of the jar. Initially, the jar is filled with air. The bell is set ringing, and its sound can be heard clearly from outside. The air is then gradually sucked out by the pump. The sound of the bell becomes fainter and finally cannot be heard at all, although the bell can be seen to be working. If air is then allowed into the jar, the sound of the bell can be heard again.

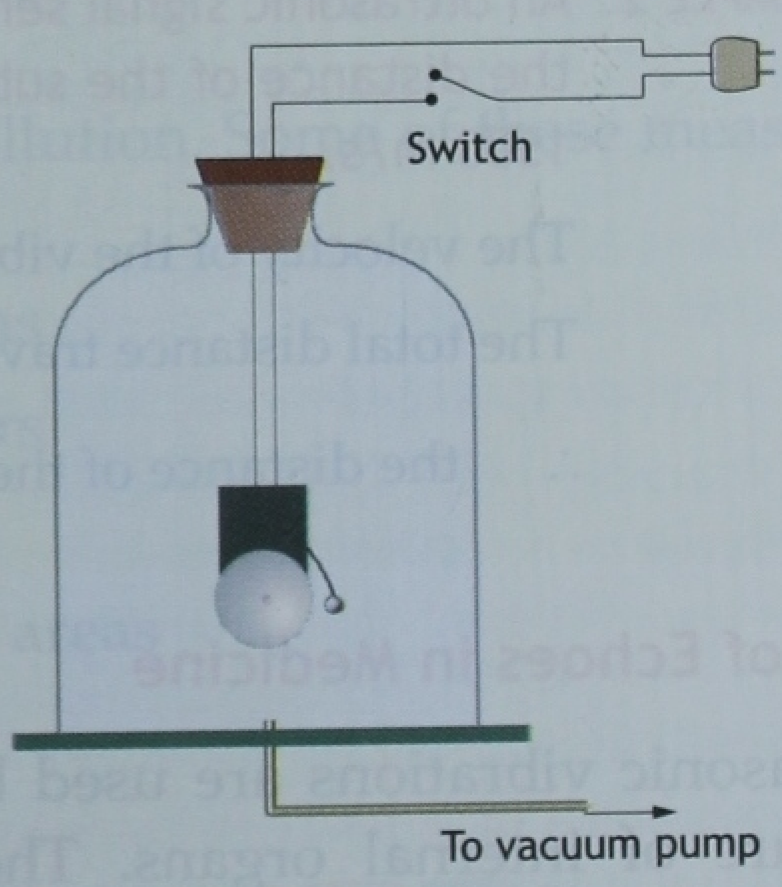


Fig. 3.10

Sound does not travel only through air. It can travel through all gases. The velocity of sound in air is around 340 m/s under usual conditions. In other gases, its velocity is different.

Propagation through Liquids and Solids

Sound travels better through liquids and solids than through air. Its velocity in water is about 1500 m/s, and in steel is about 5000 m/s. Quite apart from these velocities, you can easily see that sound travels much better through solids than through air.

ACTIVITY Stand against a door and tap the door very gently with a pencil, close to your knee. The sound should be so soft that you cannot hear it. Continue tapping and put your ear to the door. You will hear the tapping quite clearly.

ECHO

Echoes occur because sound gets reflected (or bounces back) from solid surfaces. In fact, echoes are reflected sounds. We can distinguish between a sound and its echo only if the echo reaches us about 1/15 of a second after we hear the sound. (That is how our brain functions.) If it arrives sooner than that we cannot distinguish it as another sound.

You have learnt that the speed of sound in air is about 340 m/s. Thus, it travels $(340 \times 1/15)$ m in 1/15 of a second. This works out to about 22.6 m. Hence, the distance of the reflecting surface must be at least (22.6/2) m or 11.3 m for a person to hear a clear echo.

EXAMPLE 1. A boy standing near a hill on a hot day claps his hands and hears an echo after 0.8 s. If the velocity of sound is 340 m/s, how far is he from the hill?

The total distance travelled by the sound = $340 \text{ m/s} \times 0.8 \text{ s} = 280$ m.

$\therefore$ the distance of the hill from the boy $= \frac{280}{2}$ m = 140 m.

Sonar

An apparatus called sonar is used in ships to locate underwater objects and to find the depth of water. It sends out high-frequency sound vibrations, called ultrasonic vibrations, into the water. The time taken by the vibrations to return (after reflection) is then used to calculate the distance of the reflecting surface.

EXAMPLE 2. An ultrasonic signal sent out from a ship gets reflected from a submarine and returns in 1.2 s. Find the distance of the submarine from the ship. The velocity of ultrasonic vibrations in sea water is 1500 m/s.

The velocity of the vibrations = 1500 m/s.

The total distance travelled by the vibrations = $1500 \text{ m/s} \times 1.2 \text{ s} = 1800$ m.

$\therefore$ the distance of the submarine from the ship $= \frac{1800}{2}$ m = 900 m.

Use of Echoes in Medicine

Ultrasonic vibrations are used by doctors to get a picture of internal organs. The reflection of the vibrations by the organs helps to create images. The technique is generally called ultrasonography. In the case of the heart, however, the term echocardiography is used.

Fig. 3.11 Image of a baby inside its mother's womb taken by using ultrasonography

Sound Insulation

In any large hall or auditorium, sound gets reflected repeatedly from the walls, roof and floor. This is called reverberation, and causes the sound to become indistinct (unclear). Several measures are taken to overcome this problem in theatres, concert halls, and so on. These include covering the walls and ceilings with materials that can absorb sound, and carpeting the floor. The ceiling is also constructed in such a way that echoes are broken up. Sound recording studios, especially, are made completely free from echoes, and insulated from external sounds. They are called 'dead' rooms.

NOISE

When we use the word 'noise' we generally mean meaningless, unpleasant sounds that are usually loud. Loud noise heard over a long time is not only disturbing, but can also cause health problems like stress, anxiety and sleep disturbance. Very loud noise can also damage one's hearing. Noise that damages the health and disturbs animal life is called noise pollution. Some causes of noise pollution are heavy traffic, irresponsible use of horns, inefficient silencers on automobiles, the use of loudspeakers at private and public functions, the bursting of firecrackers and loud music systems.

Table 3.2 Loudness of common sounds

Type of noise	Decibel level
Normal conversation	40
Loud conversation	60
Loud music	80
Workshop or factory	90–100
Discotheque (disco)	110–120

Measurement of Noise Levels

The intensity or loudness of sound can be measured by instruments. Its unit is the decibel, which has the symbol dB. Table 3.2 will give you some idea of noise levels in terms of decibels. A noise level of around 120 dB can hurt the ears. Even a noise level of about 90 dB can damage the hearing if one is exposed to it for long periods of time.

Controlling Noise Pollution

Large cities are gradually introducing measures to reduce noise pollution. Some of these measures are as follows.

- Regulating the use of loudspeakers and public address systems
- Enforcing the use of proper silencers in vehicles and generators
- Limiting the noise levels of firecrackers
- Shifting noisy workshops and factories away from residential areas
- Planting trees to absorb sound

POINTS TO REMEMBER

- Sound is produced by vibrations.
- The larynx is the organ that produces sound when we speak.
- In most musical instruments, sound is produced by the vibrations of strings or of a section of trapped air or of a stretched membrane.
- Frequency is the number of vibrations made by the source in one second. Its unit is the hertz (Hz).

- The loudness of a sound is also called its intensity. It is measured in decibels (dB). It depends on the amplitude. The amplitude is the maximum displacement of a source during its vibration.
- The sharpness or dullness of a sound is called its pitch. It depends on the frequency.
- Quality is the pleasant or unpleasant nature of a sound. It is also that property of a sound by which we identify its source.
- A single sound has several frequencies. The minimum frequency or the fundamental frequency is called the first harmonic. The other frequencies called overtones are integral multiples of this frequency. They are also called the second harmonic, third harmonic, and so on. We identify a source by the pattern of its harmonics.
- Sound does not travel through a vacuum. It can travel through all gases. It travels much better through solids and liquids than through air. Its velocity is around 340 m/s in air.
- Solid surfaces reflect sound. Echoes are reflected sounds. The reflecting surface must be at least 11.3 m away for us to hear an echo clearly.
- Sonar is used to locate underwater objects and to find the depth of water. Ultrasonography and echocardiography are techniques for imaging internal organs with the help of the reflection of ultrasonic vibrations.
- Repeated reflections of sound cause reverberations. Auditoriums, theatres, recording studios, etc., use absorbent materials to reduce echoes.

EXERCISE

Short-Answer Questions

1. What are vibrations? How are they related to sound?
2. Which organ in our body helps us produce sounds?
3. Give two examples each of string, wind and percussion instruments.
4. What is the frequency of a sound? What is the unit of frequency?
5. What are reverberations? How are they reduced?
6. Mention one way in which we put echoes to use.

Long-Answer Questions

1. Explain the term 'intensity' of sound. Give examples of sounds of high and low intensity. What does the intensity of a sound depend on?
2. What is meant by the pitch of a sound? Give a few examples of sounds of high and low pitch. Explain, with examples, how pitch is different from intensity.
3. What are overtones? How are they related to the quality of a sound?
4. Describe an experiment to show that sound does not travel in a vacuum.
5. Explain why and when we hear echoes. Describe how a sonar is used.
6. What is meant by noise pollution? How can it be controlled?

Objective Questions

Choose the correct option.

1. The intensity of a sound at a point does not depend on
   (a) the tone of the sound
   (b) the distance of the point from the source
   (c) the amplitude of vibrations
   (d) the power of the source
2. The pitch of a sound at a point depends on
   (a) the distance of the point from the source
   (b) the frequency of the sound
   (c) the amplitude of vibrations of the sound
   (d) the tone of the sound
3. The tone of a sound depends on the
   (a) fundamental frequency
   (b) amplitude of vibration
   (c) harmonics present
   (d) velocity of sound in the medium

4. An echo will be heard clearly if the distance of the observer from the reflecting wall is
   (a) 5 m (b) 10 m
   (c) 15 m (d) 7 m
5. Materials that absorb sound are used
   (a) in recording studios
   (b) to reduce noise pollution
   (c) in sonar apparatus
   (d) in musical instruments

Fill in the blanks.

1. Sound is produced in the larynx by the vibration of the ....
2. The ...... of a sound depends on its amplitude.
3. An echo is produced by the ...... of sound.
4. The pitch of a sound depends on its ....
5. The unit for measuring loudness is ....
6. The velocity of sound is ...... in solids than in air.

Write true or false.

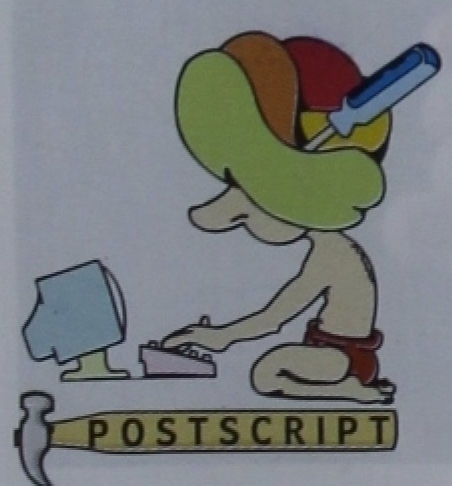
1. The intensity of a sound depends only on its source.
2. The pitch of a sound depends only on its source.
3. A loud sound must have a high pitch.
4. The pitch of a vibrating string depends on how hard it is plucked.
5. A sonar utilises the reflection of vibrations.
6. The level of loudness in a noisy factory is about 60 dB.

Numericals

1. Sound travels a certain distance through a steel rail in 0.3 s. How much time will it take to travel the same distance in water? The speed of sound in steel is 5000 m/s and that through water is 1500 m/s.
2. A man standing beside a river sees a gun being fired on the other side of the river. He hears the sound 0.3 s after he sees the smoke. What is the width of the river? The velocity of sound in air = 332 m/s.
3. A man standing 170 m away from a hill fires a gun. After how long will he hear the echo? The velocity of sound = 340 m/s.
4. A child standing in front of a wall claps his hands and hears the echo after 0.5 s. Find his distance from the wall. The velocity of sound = 340 m/s.
5. A sonar apparatus in a ship sends out a signal vertically downwards. The signal returns after 1.6 s. Find the depth of the sea. The velocity of sound in water = 1500 m/s.

Answers

1. 1 s 2. About 100 m 3. 1 s
4. 85 m 5. 1.2 km



Something very interesting happened during India's first war of independence in 1857. Some British families were held captive in the basement of the Lucknow Residency (official residence of a British representative). A little girl sleeping on the floor suddenly announced that British troops were arriving to help them. She had heard their marching steps faintly through the floor. She was right.

The phrase "have (or keep) an ear to the ground" means to have the latest information on events and trends. This originates from army scouts listening to sounds in the ground to keep track of movements.

ACTIVITY The jal tarang is an ancient musical instrument played with 15 or more bowls of different sizes. You can make one easily. Pour different amounts of water into five or six glasses or bottles. Strike each with a pencil. Which glass produces the shrillest sound?