Students' Learning Outcomes

After completing this chapter, the students will be able to:

- Explain the wavelength, frequency and amplitude of sound waves and give their units.
- State factors on which sound depends.
- Investigate objects in home and surroundings that are designed and made to produce different sounds.
- Compare audible frequency range of humans and different animals.
- Design a musical instrument to explain the relation between its sound and shape.
- Identify the application of different sounds in daily life.

Water waves are one kind of wave. Other examples of waves are sound, light, radio and microwaves.

Animation 10.2: Wavelength
Source & Credit: isvr

When we throw a stone in a pool of water, waves are produced in water (Fig.10.1). A wave is a disturbance that transfers energy from one place to the other. Waves can be produced in liquids, gases and solids. Many waves require some material to travel through. This material thing is called a medium. Gases (air), liquids (water), and solids(rope or a metal) all act as mediums.

What Causes Waves?

Hold one end of a rope and move it up and down, you will produce waves in it. We see that vibrating movements of some substance can create waves. A vibration is a repeated to-and-fro or up-and-down motion of some substance.

Fig. 10.1: Waves in a pool of water

Fig. 10.2: We can create waves in water by dipping our finger again and again.

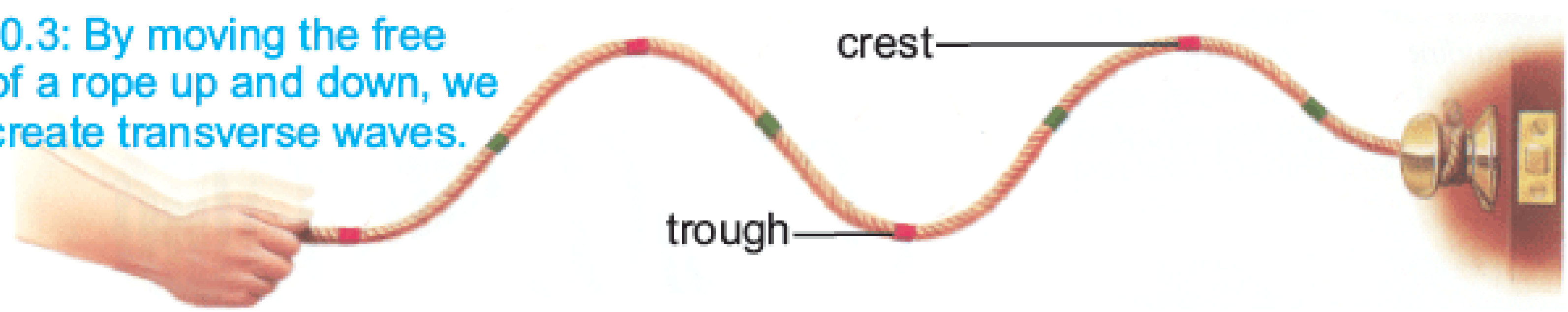
10.1: Transverse and Longitudinal Waves

There are two types of waves, i.e. transverse waves and longitudinal waves.

10.1.1: Transverse Waves

A wave in which particles of the medium move up and down perpendicularly to the direction of the wave is called a **transverse wave**. Waves that are produced up and down in water are transverse waves. Observe transverse waves produced by the up and down movement of a rope in Fig.10.3. The part of the transverse wave where the particles of the medium are above the normal position is called **crest**, while the part of the wave below the normal position is called **trough**.

Fig.10.3: By moving the free end of a rope up and down, we can create transverse waves.



Extend Your Thinking
Suppose a wave moves from one side of a lake to the other. Does the water move across the lake? Explain.

Animation 10.3: Transverse Waves Source & Credit: acs.psu

Animation 10.4: Longitudinal Waves Source & Credit: acs.psu

10.1.2: Longitudinal Waves

A wave in which particles of a medium move back and forth, parallel to the direction of the wave is called a longitudinal wave. Take a slinky spring as shown in Fig.10.4. If we pull and push one end of the slinky spring continuously, we can produce a longitudinal wave (Fig.10.4).

The parts of a longitudinal wave, where particles of the medium are compressed together, are called compressions. The parts of a longitudinal wave, where particles of the medium are spread out, are called rarefactions. As the wave moves, compressions and rarefactions are produced due to the back and forth motion of particles of the medium. Sound from a vibrating body produces longitudinal waves in air. These waves reach our ear and affect the ear drum.

One Complete Wave

A compression and a rarefaction is combined to form a longitudinal wave. What about a transverse wave?

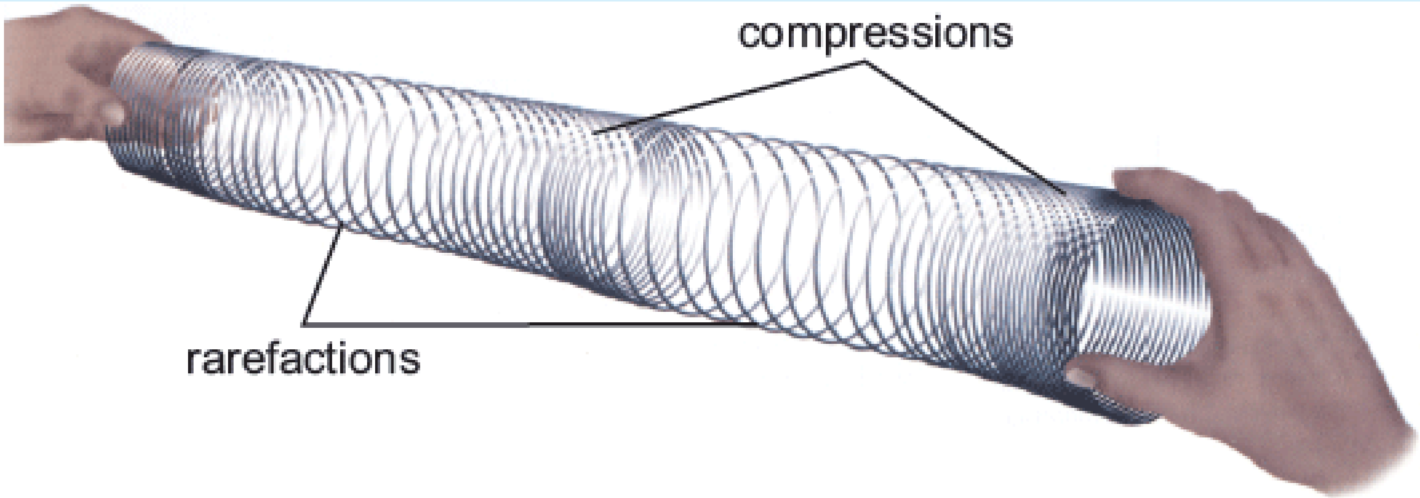
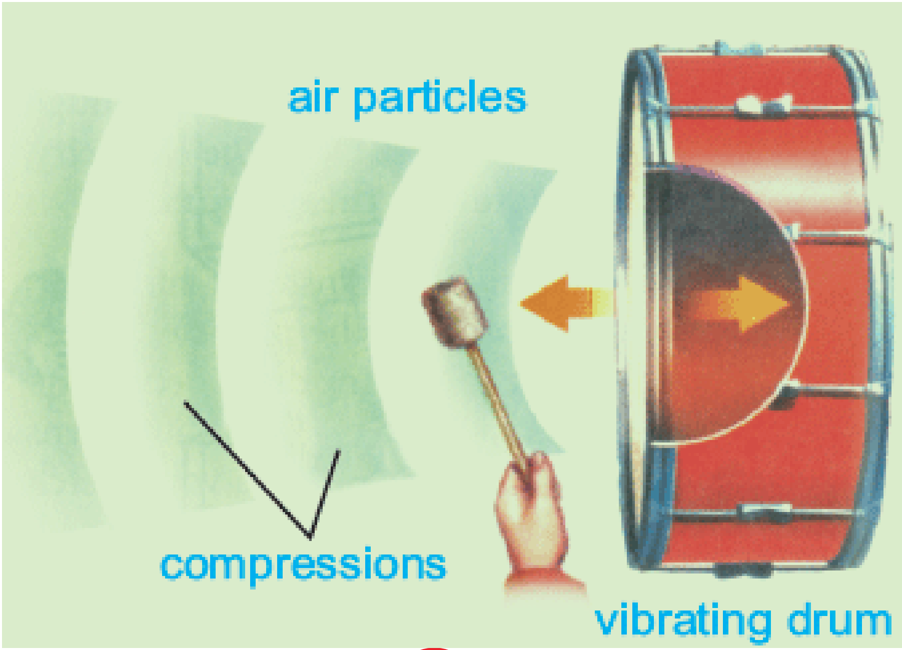


Fig. 10.4: Longitudinal waves in a slinky spring

Sound waves are longitudinal waves

A sound wave traveling through air is a an example of a longitudinal wave. When a drummer beats a drum, the surface of the drum vibrates and creates a disturbance in the air beside it. When the drumhead moves to the left, it compresses the particles of air and create a compression. When the drumhead moves to the right, the particles of the air on the right move farther apart, creating a rarefaction. These compressions and rarefactions travel through the air as longitudinal waves. When the disturbance in the air reaches our ears, we hear the sound of the drum.



10.2: Wavelength, Speed, Amplitude and Frequency

The basic terms to understand waves are amplitude, wavelength, frequency and speed.

Wavelength

A wavelength is the shortest distance between two adjacent crests or troughs of a transverse wave. For longitudinal waves, it is the distance between two adjacent compressions or rarefactions (Fig.10.5). Wavelength is measured in metres (m).

Fig. 10.5: Distance between two adjacent crests or compressions is the wavelength.

Animation 10.5: Wavelength
Source & Credit: physicsclassroom

Amplitude

Amplitude of a wave is the maximum distance of the particles of the medium from the rest position. We can also say that it is the height of a crest or depth of a trough (transverse wave) measured from the rest position (Fig.10.6). Amplitude is measured in metres (m).

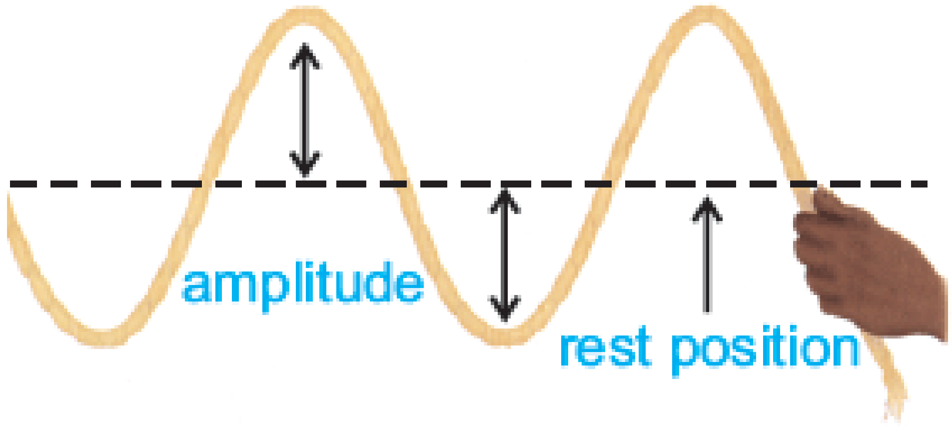


Fig. 10.6: Amplitude of a transverse wave

Frequency

The number of vibrations produced by a vibrating body in one second is called frequency (Fig.10.7). Frequency is measured in units called hertz (Hz). When one wave passes through a point in one second the frequency is 1 wave per second or 1 hertz.

$$\text{Frequency} = \frac{\text{no. of waves}}{\text{time (in seconds)}}$$

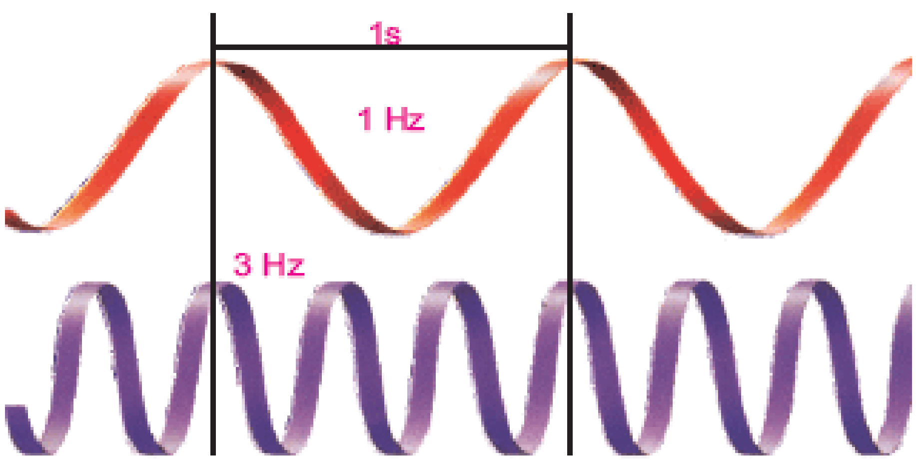


Fig. 10.7: The wave on the bottom has a frequency three times greater than the wave on the top.

Animation 10.6: Wavelength.
Source & Credit: heasarc.nasa

Speed

Imagine watching a flash of lightning and thundering of cloud. First we see the flash of lightning. A few seconds later we hear thunder. This happens because sound and light travel at different speeds. Light travels much faster than sound. Different waves travel at different speeds. The distance a wave covers in unit time is called its speed. Speed is measured in metre per second. Sound travels at different speeds in different mediums.

Fig.10.8. Thunder is always heard after we see lightning. It shows that light travels much faster than sound.

Animation 10.7: Transverse wave
Source & Credit: Wikipedia

Table 10.1: Speed of Sound in different Mediums

Medium	State of matter	Speed (m/sec)
air	gas	330
water	liquid	1,500
brick	solid	3,600
wood	solid	3,800
steel	solid	6,000

Extend Your Thinking

When sound waves travel from air to water what will happen to the speed at which they are moving?

10.2.1: Relationship of Speed, Wavelength and Frequency

The speed, wavelength and frequency of a wave are related to each other by a mathematical formula.

Speed = wavelength x frequency

We can calculate any one of the three values if we know the other two.

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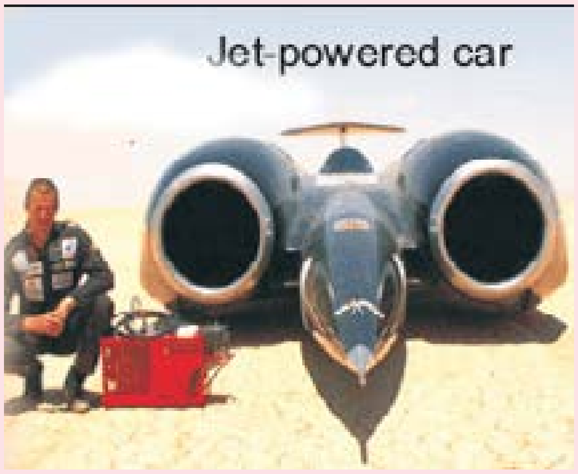

Jet-powered car

On October14, 1947, Captain Chuck Yeager of USA became the first person to fly a plane faster than the speed of sound. Fifty years later on October 15, 1997, Andy Green drove his jet-powered car at 339 metres per second. His speed was faster than the speed of sound.

Animation 10.8: Longitudinal wave
Source & Credit: Wikipedia

Animation 10.9: Wave speed
Source & Credit: acs.psu

10.3: Audible Frequency Range

The word audible means ‘able to be heard’. Our ears cannot hear sounds of all frequencies. The range of frequencies which a person can hear is known as audible frequency range. A healthy human ear can hear sounds of frequencies from about 20 Hz to 20,000 Hz. It is the audible frequency range for humans. Different animals have different audible frequency ranges.

Fig.10.9. The audible frequency range reduces in most old people.

Extend Your Thinking
When a little boy blows a dog whistle, his dog comes, even though the boy can’t hear the whistle. Explain why the boy can’t hear the whistle, but his dog can.

Table 10.2: Audible Frequency Ranges of Different Animals

Animals	Frequency range(Hz)	Animals	Frequency range(Hz)
dog	20 - 45,000	dolphin	150 - 150,000
cat	45 - 64,000	rat	200 - 76,000
cow	23 - 35,000	bat	2,000 - 110,000
horse	55 - 33,500	elephant	1 - 20,000

10.4: Pitch and Loudness

Everyday, we hear a great variety of sounds. We enjoy some sounds. Some sounds are undesirable. Sounds produced by radio, television and musical instruments are pleasant. Sounds produced by machines, traffic on a road, etc. are undesirable. How can we distinguish between the sounds? Pitch and loudness are the characteristics that help us to decide whether a sound is pleasant or not.

Pitch

The voice of a girl is more shrill than the voice of a boy. This difference is due to the pitch. A shrill sound is called a high pitch sound, whereas a less shrill sound is called a low pitch sound. Pitch is the shrillness or graveness of a sound.

Pitch of the sound depends on the frequency of the sound wave. The higher the frequency, the higher the pitch is.

Activity 10.1 **Frequency and Pitch**

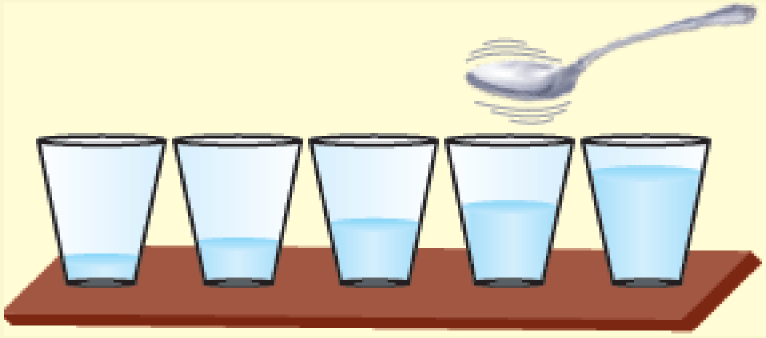
- Rotate the wheel of your bicycle as shown in the figure.
- Touch a piece of cardboard to the spokes of the rotating wheel and listen to the sound produced.
- Now increase the speed of rotating wheel and again listen to the sound produced.

We observe that on increasing the speed of the wheel, the sound becomes more shrill due to increase in its frequency. In other words we can say that the pitch of the sound has increased.

Activity 10.2 **Making High and Low Pitched Sounds**

You will need:
- 5 empty glasses
- Metal spoon
- Water

Procedure
1. Put different amounts of water in each glass.
2. Carefully tap each glass with the spoon. Observe what you hear.
3. Arrange the glasses from the lowest to the highest sound.



Questions
i. Which glass has the lowest pitch?
ii. Which glass has the highest pitch?

Loudness
Sometimes, we need to shout in a louder voice. We have to use an extra energy. Loudness is related to the amplitude of a sound. The larger the amplitude, the louder the sound. Loudness helps us to distinguish a soft sound from a loud sound of the same frequency.

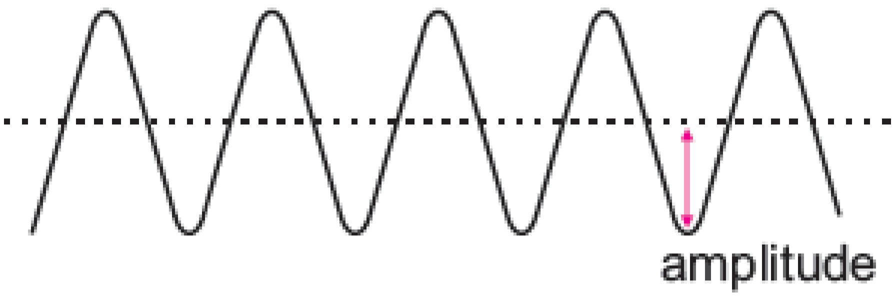


Fig.10.10: Waves of a loud amplitude sound have large amplitudes.

Fig.10.11: Waves of a soft sound have small amplitudes.

Making Sounds

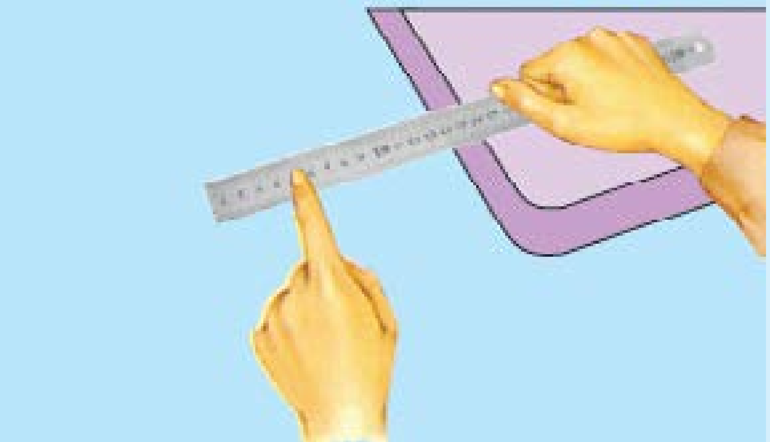
It is not difficult to make sounds but it is sometimes difficult to see what is happening when sounds are made.

Spoon Sounds

Hit a spoon on the edge of an empty bowl, listen to the sound produced. Try it on different objects.

Ruler Sounds

Hold one end of a steel ruler on the edge of a table. Push down the other edge of the ruler. Let it go and try to hear sound.



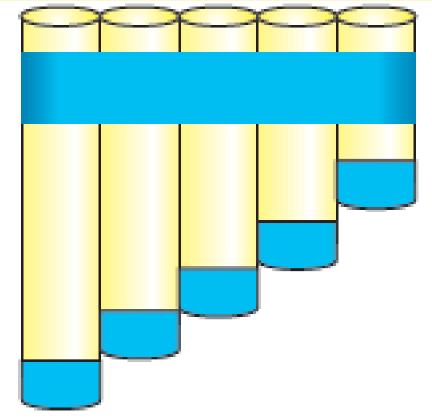
Wind Instrument — Flute

A flute is a wind instrument. The flautist has to blow it to make music. Flutes are hollow tubes with a mouthpiece and a series of holes. The holes can be closed to control the length of the vibrating column of air inside the tube. A flute can be made of wood, metal and plastic. The flautist changes the sound by opening and closing the holes in the flute.

Activity 10.3 Making High and Low Sounds

You will need

- 2 feet of ½ -inch PVC sprinkler water pipe
- 5 coins of the size of the diameter of the pipe
- 2-inch wide tape



Procedure

1. Cut the PVC pipe into five sections of different lengths.
2. Place a coin over one end of each pipe and cover each coin with the tape.
3. Wrap the tape around the set of pipes as shown in the figure.
4. Blow across the top of each pipe — it is just blowing on a soda bottle.

Questions

i. What happens to the sound as you go from longest pipe to the shortest pipe?
ii. Which pipe makes the lowest pitch of sound?
iii. Which pipe makes the highest pitch of sound?

Extend Your Thinking

Sound waves need a material medium to travel. In a science fiction movie, a nearby spaceship explodes. You hear the explosion. Is this realistic?

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Sound waves with frequencies above the normal human range (20,000Hz) of hearing are called **ultrasound**. The sound waves which have frequencies below 20Hz are called **infra-sound**.

- Doctors use ultrasound to examine a patient internally.
- Manufacturers of concrete slabs use ultrasound waves to check the cracks or cavities in concrete slabs.

10.5: Applications of Different Sounds

Making Sounds

Sounds are very important in our lives. We use many devices which produce different sounds.

Doorbell
Sound of a doorbell indicates that someone is at the door.

Telephone
Sound of a telephone attracts our attention to attend to the person on line.

Security System Alarm
Some buildings are fitted with security system alarm. The alarm produces sound to alert people to the danger.

Stereo Player
Listen to your favourite singer using a stereo player.

Siren
A siren warns us about danger.

Radio
We listen to music, news, etc. on a radio.

Smoke detector
A smoke detector produces alarming beeps on detecting smoke of fire.

Key Points

- In transverse waves particles of the medium vibrate at right angle to the path of the wave. In a longitudinal wave, particles of the medium vibrate back and forth, parallel to the path of the wave.
- Sound waves are longitudinal waves.
- Wavelength of a sound wave is the distance between two adjacent compressions or rarefactions. It is measured in metres (m).
- Frequency is the number of vibrations produced by a vibrating body in one second. It is measured in hertz (Hz).
- Amplitude of a wave is the maximum distance the wave vibrates from its rest position. It is also measured in metres (m).
- Pitch and loudness are the characteristics on which sound depends.
- A healthy human ear can hear sounds of frequencies from about 20Hz to 20,000Hz. Different animals have different audible frequency ranges.
- We use doorbells, sirens, telephones, alarms, stereo players, etc. that produce different sounds.

Questions

1. Complete each of the following sentences by writing the correct term.

i. The lower portion of a transverse wave ________
ii. The Shrillness or graveness of a sound ________
iii. The distance a wave covers in one second ________
iv. A compression and a rarefaction combine to form ________
v. A material thing through which a wave travels ________

3. Give short answers.

i. Sketch a transverse wave and label a crest, a trough, a wavelength, and amplitude.
ii. Define the wavelength of a longitudinal wave.
iii. Name a few devices that use different sounds in our everyday life.
iv. What makes some sounds louder than others?
v. What is the relationship between frequency and pitch?
vi. How does sound travel?

4. Compare transverse waves and longitudinal waves.

5. What type of waves are sound waves, and how do they transfer sound energy?