UNIT 7

SOUND

Unit outcomes: **After completing this unit you should be able to:**

- ✓ **understand concepts related to sound.**
- ✓ **develop skill of manipulating numerical problems related to sound.**
- ✓ **appreciate the interrelatedness of all things.**
- ✓ **use a wide range of possibilities for developing knowledge of the major concepts with in physics.**

Introduction

One of the most commonly observed phenomenon in nature is sound. You hear different sounds throughout the day. The sound of cars, barking of dogs, friends chatting, a teacher talking and music are some examples of sound. All the above mentioned sounds stimulate your ears and make you recognize the sources of sound and the messages sent through sound.

In this unit you will learn, what a sound is, production and transmission of sound, speed of sound in different media, reflection of sound (echo) and some applications of echo.

7.1. Definition of Sound

Activity 7.1

i. Give some sources of sound.
ii. What organ do you use to hear sound?
iii. Explain in your own words, what is meant by 'sound'.
iv. For what purposes do you use sound?

Have you ever tried to play a "guitar" or "kirar"? When you strike each string, it starts to vibrate and as a result you hear musical sound.
When a tuning fork is struck against a hard object, the prongs vibrate (moves backward and forwards). The vibrations travel away from the tuning fork as a wave called **sound wave.** (Fig 7. 1)

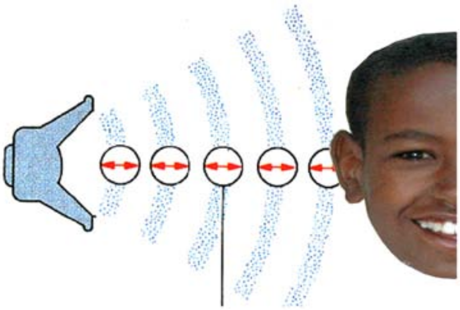

Fig. 7.1 Sound is heard by ears

Sound is a form of wave. If your ears are in the path of the sound wave, then you will hear the sound.

Sound carries energy. It loses its energy as it travels. So, the further the sound travels, the more energy it loses and the quieter the sound becomes. Our ears are designed by nature to pick up sound transmitted through different materials.

Sound is a form of energy. It is generated by the series of vibrations of an object. Every sources of sound are in a state of vibration.

There are other kinds of sounds that human ears cannot hear but other animals can hear.

Check point 7.1

1. What is sound?
2. How does sound reach the ear?

7.2. Production and Transmission of Sound

Activity 7.2 *Group work*

i. Take different materials from your locality: whistle a ruler, a tuning fork, etc and produce a sound using them.
ii. Explain how each material produces sound.
iii. How does the sound reach your ears? Explain it.

Let us see how a ruler produces sound. Take a ruler and press one end of it firmly against a table top such that the other end of the ruler projects outwards from the edge of the table as shown in Fig 7.2.

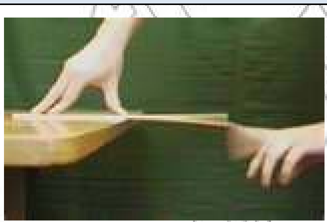

Fig. 7.2 A Vibrating Ruler

When the ruler is struck sharply, the free end vibrates up and down. When this free end of the ruler vibrates up and down, it produces sound. Thus sounds are produced by vibrating objects.

Activity 7.3

i. Cut a long rubber band. Hold one end between your teeth and the other end with one hand stretching the rubber band to some length.
ii. With your other hand pull the centre of the rubber band to one side and quickly let it go. Repeat it for some times. Have you seen the band vibrating? Does it make sound?

This activity leads you to construct different kinds of string musical instruments, such as, “guitar,” “masinko,” and “kirar.” Which part of the instruments mentioned above do you think vibrates to produce sound?

Activity 7.4 *Individual work*

Copy the following table on your note book and try to record the vibrating part of different musical instruments given in the table below.

Sources of sound	Vibrating part
1. Drum	1. _______
2. Guitar	2. _______
3. Kirrar	3._______
4. Masinko	4. _______
5. Flute	5. _______

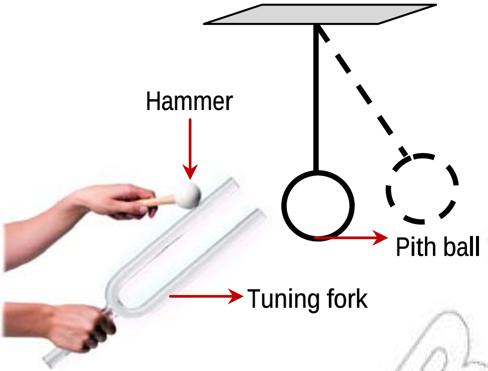

Fig. 7.3.Vibration of a tuning fork

Activity 7.5

i. Tie a pith ball with a thread and suspend it from any height. Bring a tuning fork and touch it as shown in Fig 7.3. What do you observe?

ii. Strike the tuning fork with a rubber hammer or on table edge and touch the pith ball. What do you observe?

iii. What does this show?

When you touch the pith ball with a tuning fork, nothing happens to the pith ball. Now strike the tuning fork by the hammer on the prong by holding on its stem. Then touch the pith ball with the fork, you can see the pith ball will fling away. This shows that the energy on the prong is transferred to the pith ball, and the pith ball starts to vibrate.

All the sounds you hear are produced by a vibrating object. The air near the vibrating object is set in motion in all direction. The produced sound travels in every direction, in the form of energy and reaches your ear. The bell sound in your school is heard any where around the bell in all directions. Sound travels in all directions and around corners.

Challenging questions

1. What are the three requirements of sound?
2. Write some sources of sound?
3. What does vibration mean?

Transmission of sound

Activity 7.6

To show the transmission of sound through solids.

Two students sitting at the two ends of a table will do this activity.

Step i. Let one student from one end scratch the table with his/her finger nail slightly while you are sitting on another end of the table and hearing. Have you heard the scratch or not?

Step ii. Now let the other student who was sitting place his/her ear against the table while you are scratching. Ask the student who placed his/he ear against the table , what he/she has heard. Can you tell the difference between Step 1 and step 2? What do you conclude from this activity?

(a) (b)

Fig 7.4 Sound travels through solids

Sound needs material medium for its transmission. Being in a classroom you hear the school bell ringing, student shouting in a field, telephone call, or an ambulance siren. How does the sound travel and reach your ear? The material through which the sound traveled and reached your ear is called a **medium**. (Media is the plural of medium). Fig 7.4 and Fig 7.5 show solid and liquid bodies transmit sound through them.

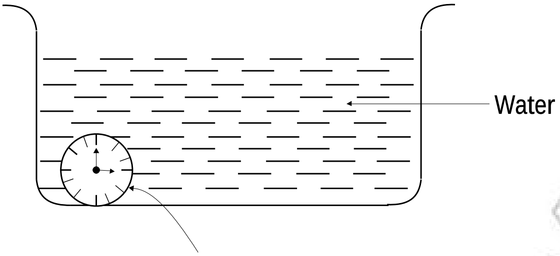

Fig 7.5 Sound travels through water (Liquid)

To observe the travel of sound in a liquid, take an alarm clock and place it at the bottom of a bowl of water. Press the alarm clock with your finger and listen to the sound of clock from outside. Do you hear the sound of the clock?

All materials can transmit sound, but the degree of transmission is not the same for all materials. Solids are better transmitters of sound than liquids and air (gases). Do you know why?

Sound needs material medium for its transmission; it cannot travel through a vacuum. This fact can be demonstrated using an electric bell jar by pumping the air out by a vacuum pump while the bell is ringing as in Fig 7.6. As the air is moved out the sound becomes fainter and fainter until it finally ceases to be heard.

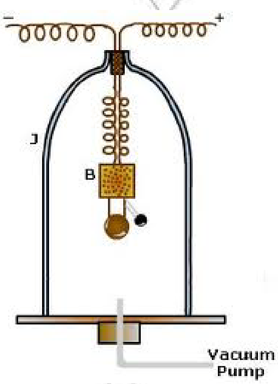

Fig 7.6. Sound cannot travel through a vacuum

This happens because there is no air to carry sound. If the air is now allowed to enter the bell jar again, the sound of the ringing bell will be heard.

Check point 7.2

1. Describe how sound is produced.
2. Explain the importance of material medium for the propagation of sound.

7.3. Speed of Sound in Different Media

Speed of sound in air

During a thunderstorm you may see a distant lightning flash some seconds before you hear the thunder. This suggests that the speed of sound in air is much less than the speed of light.

When a train is about one kilometer away from you, you can often see the smoke coming out from the nozzle before you hear the whistle. This again means that sound cannot travel as fast as light in air.

Activity 7.7

i. When do we hear sound clearly? Is it during a night or a day?

ii. What will you do to the volume of the radio and TV set when you listen to the news or music during a day and a night? Do you change the volume according to the time or not?

The speed of sound in air is about 331 m/sec at 0°C. The speed of sound increases by 0.6 m/sec for every degree Celsius increase in temperature. The speed of sound in air at any temperature (v_T) can be calculated as $\mathbf{v_T = v_0 + \frac{0.6}{1^0c} \times T}$ where v_0 is the speed of sound at $\mathbf{0\ °C}$ and "T" is the change in temperature. Speed of sound in liquids and solids is not affected significantly by the change in temperature, but affected by their body structure.

The difference in speeds of sound in different materials can be easily understood from the structure of molecules of a substance. (From your chemistry course revise what molecules are and their structure in different states of substances).

The transmission of sound in different substances depends on the structure of the particles in the substances.

Since the particles in solids are close to each other they easily pass the sound to the next particles by collision and the sound moves faster.

But in liquids and in gases, the particles are far apart and the collision between the particles takes place rarely. They pass the sound slower than in solid. Similarly the particles in gases pass the sound much slower than in liquid. Thus, sound travels slower in liquid than in solid and sound travel slower in gases than in liquids.

The speed of sound in water is greater than the speed of sound in air and its speed in steel is greater than the speed in water. The speed of sound in different material is given in Table 7.2

Table 7.1. Speed of sound in various substances at 0 °C

Substance	Speed (m/s) 0 °C
Gases	
Oxygen	316
Air	331
Liquids	
Ethanol	1150
Mercury	1438
Water (distilled)	1410
Sea water	1450
Solids	
Lead	1948
Copper	4998
Glass	5628
Steel	5948

Activity 7.8 Questions- use Table 7.1

i. In what material does sound travel fastest?
ii. In what material does sound travel slowest?
iii. Compare the speed of sound in liquid and in solids.

Example 7.1

1. A thunder was heard 4 s later after the lightning is seen. If the distance of the lightning is 1396 m away from the observer, what is the speed of sound at that temperature?

Given	Required	Solution
t = 4s	v = ?	s = vt
s = 1396m		$v = \frac{s}{t}$
		$v = \frac{1396\ m}{4s}$
		= 349 m/s

Check point 7.3

1. Describe how it is possible to determine the speed of sound in air?
2. What is the factor affecting the speed of sound in air?

7.4. Reflection of Sound (Echo)

Activity 7.9

Discuss with your friends on the following questions

i. What do you hear if you shout in a big empty hall standing on one corner?
ii. What do you call this sound?

When you throw a ball towards the wall the ball bounces and returns to you. We call this the reflection of the ball. The same is happening when you shout in an empty hall. The sound will bounce back from the wall and comes towards you.

We call this the reflection of sound. The reflection of sound from hard surfaces is called an "**echo**".

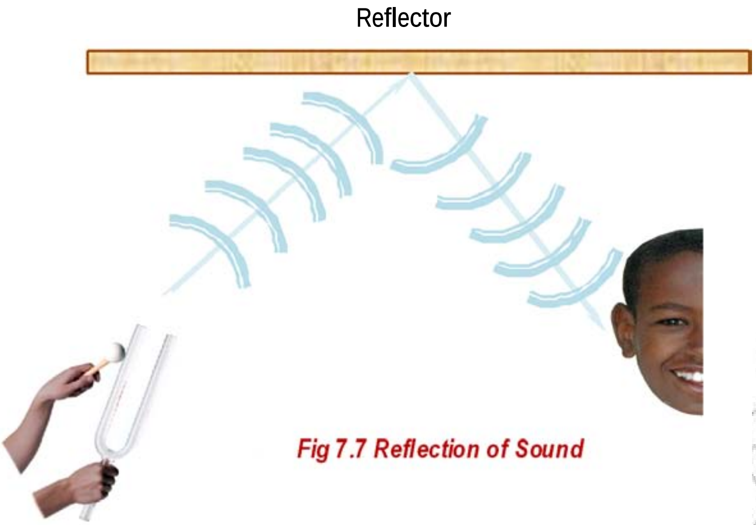

Fig 7.7 Reflection of Sound

Whenever sound meets a boundary or an obstacle on its way, some of the sound energy is absorbed and other is reflected. This reflection of sound at a boundary is called an echo.

Hard substances such as walls, rocks, hills, metals, wood, buildings, etc. are good reflectors of sound since they are polished and hard. But when sound strikes soft surfaces such as wool, cloth, etc. most of the sound energy is absorbed.

When you shout or whistle while you are at some distance away from a tall building or a mountain, you may be able to hear the original sound and the reflected sound as two separate sounds. This will be true if the echo/reflected sound reaches you 0.1 sec later than the original sound. This means that your ear is able to distinguish the two sounds as a separate ones only if they reach you at least 0.1 second later.

Check point 7.4

1. What is echo? Explain how it occurs.
2. Give at least three examples for each of the following
   a) Sound reflectors
   b) Sound absorbers.

7.5. Application of Echo Sounding

Activity 7.10

Measuring the speed of sound using the echo method.

i. Go out into an open field in a group where you can find a big tree or a mountain.
ii. Stand infront of the tree (mountain) and clap your hands or shout loudly.
iii. Do you hear the echo of your clap. Move back and forth until you hear the echo.
iv. Ask your friend to measure, the time taken for the clap sound to move to the mountain /big tree/ and comes to you as an echo using a stop watch .
v. At this point, measure the distance between the place where you stand and the big tree or (bottom of the mountain).
vi. Apply the formula of speed. **v =** $\frac{s}{t}$ and calculate the speed of sound for that day (temperature).

From the above activity, you can calculate the minimum distance of the reflecting surface and speed of sound taking 0.1 second as the minimum time required to have an echo reach you.

i.e. 2s = vt (since the distance traveled by the sound is the sum of the distance from the source to the reflector and back from the reflector to the source)

$$\Rightarrow s = \frac{vt}{2} = \frac{331 m/sec}{2} \times 0.1 \, sec = 17m$$

Hence, the minimum distance for an echo to be produced is 17 m. No separate echo can be heard for distances less than 17 m if the speed of sound at that temperature is 340 m/sec.

When sound strikes a reflecting surface obliquely, nearly all the sound is reflected. This fact has been applied in the doctors stethoscope for listening to sounds of heart beat, or lung movement. These are some applications of an echo in medical field.

Example 7.2

What is the speed of sound at a given temperature if an echo is heard 4 seconds later from a mountain which is 664 m away?

Given	Required
s = 664 m t = 4s	v = ?

Solution

$$\text{Speed of sound} = \frac{\text{Total distance}}{\text{Total time}} = \frac{2s}{t}$$

$$= \frac{2 \times 664\text{m}}{4\text{s}} = 332\text{m/s}$$

The above sample problem shows the importance of the echo method in finding the speed of sound in air.

On the other hand, knowing the speed of sound in air at a certain temperature, and recording the time interval between hearing the original sound and the echo will enable us to calculate the distance of the reflecting surface. The echo method is used to measure the depth of a sea or an ocean.

Check point 7.5

1. State some examples of applications of echo.
2. Explain how an echo from a cliff could be used to measure the speed of sound in air.

Summary

In this unit you learnt that:

- sound is a wave heard by the ears. Sound is produced by vibrating objects and travels through solid, liquid and gas media. Sound is a form of energy.
- the speed of sound in solid is greater than the speed of sound in liquid, and the speed of sound in liquid is greater than the speed of sound in gases.
- as the sound travel against different bodies, it either reflects totally or partially reflected or partially absorbed. Sound travels in all direction and around corners. The reflection of sound from hard surfaces is called an echo. An echo is used to measure the distance of cliffs, sea bed or big building from a given sources of sound.

Review Questions and Problems

I. Write true if the statement is true and false if the statement is false

1. **All sounds are produced by the vibration of bodies.**
2. **Sound travel through vacuum.**
3. **Sound is transmitted faster in air than in liquids.**
4. **As the temperature of air rises the speed of sound in air decreases.**
5. **The speed of sound in air is four times as its speed in steel.**
6. **The speed of sound in air is greater than the speed of sound in solids.**

II. Fill in the Blank spaces with appropriate word or words.

1. **The three prerequisites of having sound are________, __________, ________.**
2. **An echo is not produced unless the reflecting surface is at least __________ meters from the source of sound.**
3. **The speed of sound in air at 0 ^{o}C is__________ m/s.**

III. Short answer Questions

1. **Explain how sound is produced.**
2. **What is sound?**
3. **Explain how an echo is formed.**
4. **Explain why the speed of sound in solid and liquid are greater than the speed of sound in gases.**
5. **List two applications of an echo.**

Iv. Match column A with column B

Column A	Column B
1. Sound	**a) the speed of sound in glass at 0°c**
2. Echo	**b) the speed of sound in air at 0°c**
3. 4998 m/s	**c) the speed of sound in copper at 0°c**
4. 5628 m/s	**d) the reflection of sound**
5. Flute	**e) a series of disturbances in material to which the human ear is sensitive**
6. 331 m/s	**f) Air vibrating musical instrument.**

v. Problems

1. **How far away should a cliff be from a source of sound to give an echo in 5.3 seconds? (Given speed of sound at 0 °C =331 m/s)**
2. **A ship's sonar sends messages and receives the echoes from the ocean bottom 0.6 seconds after the sound is sent down from the ship. How deep is the water beneath the ship? (Given speed of sound in still water = 1450 m/s)**
3. **How far away is a train if you see the steam from its nozzle 4.5 seconds before you hear its sound? (Take speed of sound as 331 m/sec)**