Basic concepts of sound and its propagation

Duration: 90 minutes

Grade: VIII and IX

1. Objective: To enable students explore how sound is produced and how it propagates in a material medium.

2. Learning Outcomes: At the end of this module, students will be able to**:**

- Identify that sounds are produced through vibrations.
- Begin to understand that sound requires a medium for its propagation and that the propagation of sound varies in different media.

3. Pre-requisites: Basic concepts of density variations between solids, liquids, and gases; rudimentary understanding of the concept of atoms.

4. Materials Required:

Assumed no. of students = 30

Recommended group size = 2 – 3 students per group

S. No.	Materials	Specifications	Quantity	Cost (INR) (approx.)
1	Tuning fork with a rubber mallet	400 Hz	15	300
2	Metal spoon	Thick spoons are recommended	15	300
3	Ping pong ball	Simple, small in size	8	5
4	Thread	Nil	2 m	15
5	Scissors	Nil	4	80
6	Metal Gong or bell.	Nil	1	300
7	Metal rod	15 cm	1	30
8	Steel tumbler	150 mL	15	200
9	Nail	Nil	2	3
10	Paper cups	Nil	30	10
11	Water	Nil		Nil
12	Bucket	Nil	3 L	50
13	Washer	Nil	30	30
14	Steel ruler	30 cm	15	300
15	Plastic bottle	1 L	15	15
16	Tube	It should fit into the cap of the bottle	1 m	25

17	Glue	Nil	2	20
18	Balloon	Nil	10	50

5. Note to the Teacher:

The students have been exposed to sound their entire lives. In this unit, the students will study about the sounds in their environment. They should listen closely to the sounds around them and determine their sources. They are to learn how sounds are produced and how it travels across different materials. The given learning outcomes are aligned to the needs of both grades 8 and 9, i.e. this can be taught in both grades 8 and 9. Multiple activities have been listed in this document, and the teacher can pick appropriate activities for the classroom.

As a pre-activity discussion, the teacher can elicit hypotheses from students through probing questions, such as the ones presented in the pre-activity questions section given in Sec. 6. The students are to note down their responses or hypotheses in the worksheet for the questions asked. During the course of the entire lesson, the teacher should ensure that the students arrive at conclusions on their own, rather than get the answer directly from the teacher.

The teacher can also capture the responses of the students on the blackboard and lead them into performing the experiments with the required materials in order to test their hypotheses. The teacher should guide students to enable them to arrive at the conclusions that sound is a form of energy that is generated[1] through the vibration of objects and that it is transmitted through material media. The teacher should encourage the students to think that they are doing what scientists do all the time, which is testing out theories to take into account the evidences acquired from observations and experiments.

If some students say that simply hitting an object with another metal object produces sound, the teacher should keep a record of such a hypothesis and relate it to the activities, such as cup-telephone activity, in which nothing is hit, and meter-stick activity, in which to the students can closely observe that a meter stick produces a sound even though it has not been struck with any other metal object.

The teacher should ask the students what they know about the sounds that they have heard. The teacher can also ask how sound finds its way to our ears from its source. The students may answer that sound moves or jumps. At this juncture, the students can be asked to brainstorm about different sounds and how those sounds are created with the help of the given activities.

Through this progression, students can understand the connection between sound and vibration in a concrete manner before having to recognize the more typical phenomenon of sound-

[1] Sound is a form of energy. The law of conservation of energy posits that energy can neither be created nor destroyed. Energy can only be transferred from one object to another and transformed from one form to another. Students may use the terms “change” instead of “transform”.

producing objects, which produce vibrations that cannot be easily seen or felt. Tuning forks can be provided to the students on a rotational basis depending on its availability to perform this activity.

6. Pre-Activity Discussion:

The teacher should pose the following questions to elicit a hypothesis from the students, making sure not to provide any answers. The following narration can be used:

A school bell rings every morning.

How does a school bell produce a sound?

How does the sound from the bell reach our ears?

After getting responses from the students, the teacher should hit a metal gong with a metal rod and let it ring for a few seconds. The teacher should then ask the students to observe what happens when the metal gong is hit. Then, the teacher should hit the metal gong once more with a metal rod. However, in this instance, the teacher should firmly touch the metal gong to stop it abruptly from ringing.

6.1 Note to the Teacher

Figure 1: A metal gong

After the teacher hits the metal gong, the teacher should ask the following questions, making sure not to provide any answers to the students. Rather, the teacher should lead the students to come up with answers to the following questions:

1. How does the sound from the metal gong reach our ears?
2. Why does sound from the metal gong abruptly stop when it is touched by our hands?
3. Based on your observations of the ringing metal gong, how do you think sound is produced in material objects?

The students may come up with new hypotheses from their observations regarding the sound produced by the metal gong. They are to note down their answers in the worksheet provided. Now, the teacher should guide the students to compare their first and latest hypothesis (the answer to question number 3 given above). To test this hypothesis, the teacher should provide the required materials to perform the activities.

6.2 Alternate suggestion: If a metal gong is not available, a metal bell can be used. If a metal bell is used instead of a metal gong, the following questions can be posed to the students to elicit hypothesis from the students.

1. A school bell rings every morning.

1. How does a school bell produce sound?
2. How does the sound from the bell reach our ears?

2. The teacher should ring the bell and pose the following questions:

1. When you ring the bell, how does the sound reach your ears?
2. Why does the sound of a ringing bell abruptly stop when the outside surface is touched with your hands?
3. Record your answers in the worksheet. Based on your observations of the ringing bell, how do you think sound is produced in material objects?

7. Activity 1: Chiming spoon

7.1 Objective: To identify that sound is produced by vibrating objects (LO 1)

7.2 Observables:

- Sound
- Vibration

7.3 Procedure:

1. Tie the thread around the spoon handle as shown in Fig. 2. given below.

2. Wrap the ends of the string around your fingers.

3. Gently swing the spoon so that it strikes the edge of a table as shown in Fig. 2s.

4. Record your observations in the notebook (What does it sound like?).

5. Gently insert your index fingers into your ears.

6. Lean over and swing the spoon so that it strikes the edge of the table again as shown in Fig. 3.

7. Record any changes in sound that you noticed in the previous report.

8. Wrap the string around your fingers several more times to make the hanging section shorter. Repeat steps 3 – 7. Record any changes from your previous notes that you notice.

9. Try striking the spoon gently against different surfaces (metal, wood, plastic) to hear if the sounds produced are different.

10. Based on your observations, how do you think sound is produced in all other material objects?

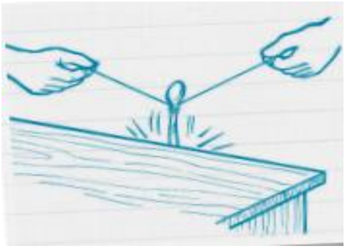

Figure 2: Tie the thread to the middle of the spoon.

Figure 3: Keep the end of the thread inside the ear.

7.4 Note to the Teacher:

The teacher should ensure that the students arrive at the conclusion that when a piece of thread is tied to a metal object, like a spoon, and struck against a solid material, there will be vibrations produced from the spoon which will move along the string. If the thread tied to the spoon touches our ears, the vibrations that are made will travel along the string and into our ears.

When the ends of the thread are not kept at the ears, the vibrations are heard clearly. The teacher should now ask the students how they think sound is produced in all material objects.

Reason behind the production of sound in this activity: Sounds travels in waves. These waves can travel through everything, from air, water, and wood to a piece of string. When a piece of string is tied to a metal object, like a spoon, and struck against an object, the spoon will send out vibrations (sound waves) that will move along the string. If the string and the spoon are touched to the ears, the vibrations that are created will travel along the string and into the ears. From the ears, nerves carry the signal to the brain, where it is interpreted as sound.
Objects made of different materials, such as stainless steel, wood, and plastic, send out different vibrations (sound waves) and produce different sounds.

8. Activity 2: Sound is produced by vibrating objects (LO 1)

8.1 Objective: To identify that sound is produced by vibrating objects.

8.2 Observables:

- Sound (can be heard).
- Vibration (can be seen in the ruler, i.e. back and forth movement of the ruler.)

8.3 Procedure:

1. Take the ruler and place it in such a manner that one half is on the table and the other half is over the edge of the table.

2. Firmly hold down half of the ruler on the table with your hand (hold it down tightly). Use your other hand to push up the part of the ruler that is hanging over the table.
3. Let go of the ruler and listen to the ruler. Observe what happens. Keep repeating this action. Note down your observations of the movement of the ruler.
4. Move the ruler further from the table. Try the same thing again with the ruler further on the table. Note down your observations in the worksheet.
5. Can you make higher or lower sounds by changing the protruding length of the ruler? Why does this happen?
6. What is the reason for the sound you hear?
7. Relate the effect of the rapid and slow movement of the ruler with the movement of air in the atmosphere. What can you conclude from this?

8.4 Note to the Teacher:

This activity aims to make the students arrive at the conclusion that sound is produced in material objects through vibrations. This activity can be performed to teach about pitch and loudness as well. The teacher can restrict this activity only to the greater and lesser vibrations in view of changing the protruding length of the ruler without getting into the loudness and pitch. The teacher should ask the students to relate the effect of the rapid movement of the ruler with the movement of air in the atmosphere to arrive at the causes of the sound.

The teacher should ensure that the students are able to arrive at the conclusion that the vibrating ruler pushes air molecules, making them bunch together. The lower the movement of the ruler, the lower is the sound it produces, since the ruler pushes the air slowly when the length of the ruler from the edge of the table is longer. Similarly, when the ruler is shorter, it vibrates more quickly, thereby pushing the air rapidly and producing a louder sound.

If the students are unable to arrive at a conclusion, the teacher can demonstrate this activity by vibrating the ruler very slowly in his/her hand to show the students the back and forth movements. Then, the teacher should speed it up to show what it looks like at a higher speed. Following this, the teacher can pose the following questions:

- Can you hear anything when the ruler vibrates?
- Can you hear anything when the vibrations stop?
- What do you think makes the sound?

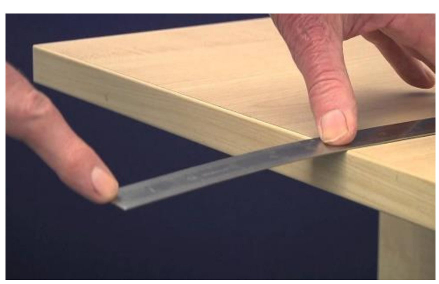

Figure 4: Keep the ruler protruded from the edge of the table

9. Activity 3: Sound involves propagation of vibrations

9.1 Objective: To investigate into or provide evidence for the fact that vibrating materials can produce sounds and that sound makes materials vibrate.

9.2 Observables:

- Vibrations (can be seen in the movement of the ball due to the tuning fork).
- Sound (can be heard from the vibrating tuning fork).

9.3: Procedure:

1. Make one student stand while holding a thread tied to the ping-pong ball at an arm's length. Be sure that the student is holding it as still as possible. It will be good if the ball is suspended from the clamp of a burette-stand so that the ping-pong ball remains suspended without facing any obstructions as shown in Fig. 6 given below.
2. Make another student gently strike a tuning fork with rubber mallet and bring it close to the ping-pong ball until it just barely touches it. The students should note the observations in the worksheet.
3. Make the same student gently touch the ping-pong ball with the tuning fork one more time.
4. Ask the following questions:
    - Did anything surprise you when the tuning fork touched the ping-pong ball? Why do you think the ping-pong ball moved?
    - What else did you notice (observe) with your eyes or ears?
    - Can we see sound move objects?

Figure 5: Movement of the ball by the vibration of the tuning fork.

9.4 Note to the Teacher:

If the students are unable to conclude that the vibrations produced from the tuning fork start after it was hit by a rubber mallet produces sound, and these vibrations cause the ball to move, the teacher can ask the students to perform the following steps to elicit the answer from the students:

1. Gently hit a tuning fork with a rubber mallet and bring it to the edge of a steel tumbler filled with water. What did you feel when you touched the tuning fork after you hit it? What happens to the water? What is the reason for the observation on the surface of the water?
2. How do we move objects? What do we need to move objects?
3. What can you conclude from this activity?

The teacher can answer these questions as given below if needed:
The sound made by the tuning fork create a pattern of waves that showed in the water. If we could see the air around us, we would be able to see waves as sound moves through the air. The tuning fork can be replaced with any other vibrating object.

The teacher should ensure that the students arrive at the conclusion that the tuning forks vibrates after it is hit by a rubber mallet, which in turn gets vibrated. These vibrations push the air back and forth by naturally oscillating in a simple back-and-forth motion. By placing the vibrating tuning fork next to a light hanging object, such as a ping-pong ball, the vibrations of the tuning fork make the ping-pong ball swing in a simple oscillatory motion.

10. Activity 4: Making a Telephone

10.1 Objective: To describe how sound travels through a solid medium and that sound requires a medium to propagate.

10.2 Observables:

- Sound in the cup

10.3 Note to the Teacher:

The teacher should initiate this activity with the conversation as given below:

Have you ever tried to have a conversation with someone so far away that you couldn't really hear each other without using a mobile phone?

The teacher can ask the students to come up with their ideas on this topic. If none of the students can come up with any answer, the teacher can tell the answer given below at the end of the activity. The teacher should guide the students through each step of the procedure given below. The teacher should also ensure that the students arrive at the conclusion that their voice vibrated the air inside of the cup, which in turn made the bottom of the cup vibrate, on their own. These vibrations were transferred to the thread and then to the bottom of their partner's cup, which made the air inside of his or her cup vibrate to become detectable sound.

If the string is loose, the alterations in tension will not vibrate the listener's cup. This is because a loose string causes the vibrations to travel all around, rather than directly across the string.

10.4 Procedure:

1. Make a small hole at the bottom of two paper cups.
2. Tie a thread through the holes; tie each end to a washer so that the string does not slip through.
3. Have a friend hold one cup while you hold the other cup.
4. Keep the thread very loose and take turns talking into the cup and listening. Why do you think these phones do not work?
5. Gently pull the cups until the string is tight. Take turns talking into the cup and listening. Be sure that you keep the thread taut. Why do you think these phones work now?
6. While one speaks through the cup and another listens to it, have another student cut the thread. Why do you think these phones do not work anymore?
7. Describe to your partner what you think is happening and the reason behind it. Then, report it to the class.
8. How is the sound traveling to your friend listening to you?

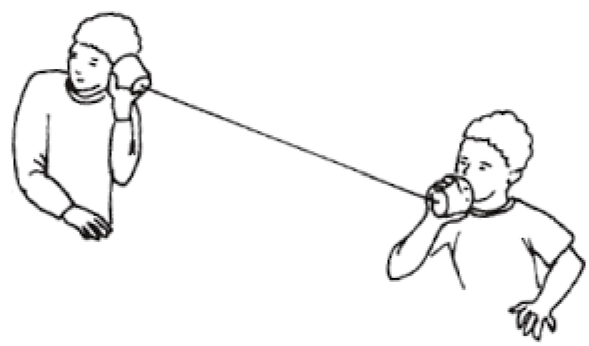

Figure 6:The cup-telephone.

11. Activity 5: Stethoscope

11.1 Objective: To demonstrate how sound waves travel through enclosed spaces

11.2 Observables:

- Sound (transmitted through the cup).

11.3 Note to the Teacher: The teacher should ask the students "Have you ever wondered how a stethoscope works?". The students will come up with different answers. The teacher should instruct and guides the students through each step given in the procedure. The teacher should also ensure that the students arrive at the conclusion on their own that a stethoscope works by enhancing the sounds made within the human body and transmitting those sounds to the listener's ear; the air inside the cup vibrates the funnel, which in turn transmits the sound to the tube.

The actual model of a stethoscope has a flat, round chest piece covered by a thin, tightly-stretched skin of plastic called a diaphragm. The diaphragm vibrates when sound occurs. These high-frequency sounds travel up the hollow plastic tube into hollow metal earpieces and finally into the doctor's ears. In the experiment, the balloon acts as the diaphragm. The teacher should ensure that the students inquire why sound is not heard if one or more elements of the device, such as the balloon or the funnel, are removed.

11.4. Procedure:

1. Cut the top off of a plastic bottle to make a funnel. Punch a hole in the cap and enlarge it so that the tube or straw just fits through it.

2. Push one end of the tube through the cap and seal around the outside with modeling clay and tape.

3. Cover the funnel end with a balloon. Carefully place the tube in your ear. Hold the funnel portion near a clock or a watch. How loud does the ticking sound?

Figure 7: A toy stethoscope

4. Hold the funnel portion against a friend's chest and see if you can hear his/her heartbeat.

5. Remove the balloon from the funnel and repeat step 4. What is the reason for your observation?

5. Do some jumping jacks; run around for about 1 min.; repeat step 4.

6. What is the reason why you hear the sound through the cup?

12. Activity 6: Which materials transmit sound better?

12.1 Objective: To explain how the propagation of sound varies in different media.

12.2 Observables: Intensity of sound coming from different objects

12.3. Note to the Teacher:

To start this activity, the teacher should ask the students how fast they think sound travels. Have them recall a thunder storm. Ask them why they usually see the lightning first and hear the thunder a while later. If they do not answer correctly, the teacher can tell the students that both the lightning and the thunder occur at the same time. The teacher then can tell that there are variations in the speed of light and the speed of sound. In this activity, the students will investigate which materials transmit sound better. The pencil needs to be taped in a similar manner to observe a clear result.

The speed of sound varies depending upon the medium sound travels through. The speed of sound in a medium is determined by a combination of the medium's rigidity (or compressibility in case of gases) and its density. The more rigid (or less compressible) the medium, the faster the speed of sound. The greater the density of a medium, the slower the speed of sound. The speed of sound in air is low because air is compressible. Since liquids and solids are relatively more rigid and difficult to compress, the speed of sound in such media is generally faster than in gases.

12.3.1. Amplitude and Pitch in Different Media:

The amplitude of a sound wave decreases with the distance from its source because the energy of the wave gets spread over a larger and larger area. Since the wave only transports energy from on point to another, the energy of the wave does not increase or decrease as it is transferred from one medium to another; a tighter medium will have a reduced amplitude, and a looser medium will have an increased amplitude. With regard to sound, amplitude refers to the magnitude of compression and expansion experienced by the medium that the sound wave travels through. Thus, the amplitude of sound waves is in following the order:

gas>liquid>solid

Since pitch is a close proxy for frequency, it is entirely determined by how quickly a sound wave makes the particles vibrate. It has almost nothing to do with the intensity or amplitude of the wave. That is, a "high" pitch suggests very rapid oscillation, and a "low" pitch corresponds to slower oscillation. Thus, the pitch of sound is in following the order:

solid>liquid>gas

12.4 Procedure:

1. Fill a plastic bag with air. Cover one ear with your hand and the other ear with the bag of air. Have a person tap the bag with a pencil. How does it sound?
2. Now, fill the bag with water and seal it. Hold the water-filled bag against one ear while covering the other ear with your hand. Have a person tap this bag with a pencil. How does it sound?
3. Finally, hold a wooden block over one ear while covering the other ear with your hand. Have a person tap the block with the pencil. How does it sound?
4. What do you conclude from all your observations?

Probing questions:

- Through which type of matter did sound travel best? Why?
- Explain why you may never be in a place where there are no sounds.

If the students are unable to come up with the answer relating sound with the density and arrangement of particles in solid, liquid, and gaseous medium, the teacher should give a clue about the arrangement and density of the particles in solids, liquids, and gases. If the students are still unable to arrive at the conclusion, the teacher can demonstrate the arrangement of particles in solid, liquid, and gas as given below:

1. Have books/sticks lined up with different gaps between them. Discuss how the relationship between the spacing of the books/sticks and the speed of them falling over is a great illustration of how the speed of sound is directly related to the spacing of the atoms or molecules of the medium in which the sound is traveling.
2. Now, imagine that there is a greater gap between the particles, and there is nothing to transmit the sound at all. How will the sound be?