Teaching Refraction Through Activity-Integrated Inquiry **SCI 313 A**

Grade: VIII
Time period: Two periods

1. Objective

To teach refraction by getting students involved in performing hands-on activities and conducting an inquiry.

2. Learning outcomes

After completing this lesson, the students will be able to understand the following:

1. Light bends when it travels at an angle from rarer medium to a denser medium and vice versa.
2. Prediction of the direction of the bending of light.
3. Total internal reflection occurs when light travels from a denser medium to a rarer medium when the angle of incidence is greater than the critical angle.

3. Pre-requisites

At the beginning of the module, the students should have the basic conceptual understanding of the following:

- Light travels in straight lines.
- An object is visible only if the light from the object reaches the eye of the observer.

4. Materials required

Assumed class size = 30
Number of students per group = 2 – 4

S. No.	Materials	Quantity	Cost in INR (approx)
1.	Empty matchbox	45 (3 per group)	
2.	Coin	15	
3.	Opaque container	15	
4.	Water	6 litres	
5.	Laser pointer	8	480
6.	Transparent glass bottle	8	
7.	Dettol	250 mL	30
8.	Glass tumbler	8	

5. Note to the teacher:

The students are given a worksheet (Refraction—Student Assessment Worksheet). This is to be used as a record sheet for the observations as well as the formative and summative assessment tool for assessing the student's understanding. During the classroom interaction, the students can be asked to respond to specific questions pertaining to the concepts that have been discussed and observed.

Summary of Activity 1: The Path of Light In Activity 1 (See Sec. 6), the students should arrange the matchboxes having holes in the inner tray and observe them from one end. The teacher

should elicit responses from the students in order to help them deduce why the object on the other side is visible in a particular arrangement (where the holes are in a straight line) and not otherwise. The students should arrive at a conclusion on the path of light by themselves.

Summary of Activity 2: Reappearing coin—Effect of Refraction In Activity-2 (See Sec. 7), the students should observe a coin placed in an opaque container. The students should be questioned on how the coin appears after the water is poured. The reason behind the students' answer must be elicited, and this should be formulated as a hypothesis and put to test. For instance, the students may say that the coin started floating once water is poured, and this response can be put to test by touching the coin inside the container and ensuring that it is resting on the bottom of the container. The students should be guided, through questioning, to facilitate an understanding that the light ray bends when water is poured into the container and hence reaches the eyes of the observer. The students should also draw the path of light through which it reaches the observer's eyes.

In testing the hypothesis (See Sec. 8), the students should be questioned on the methods that can be adopted through which they can test the hypothesis that light bends when passing from water to air and reaches the eyes of the observer. The teacher can pose questions, such as "Why are we not able to see the bending of light?", and elicit from the students that white light is not visible to the naked eye. Following this, questions such as "What can be done to make light visible?" or "Have you seen any kind of light which is visible?" will help elicit the idea of using laser from the students. The arrangements for testing the bending of light can also be elicited from the students. They should, in addition to this, be able to make observations on how light bends when it passes from water to air and how light bends while passing from air to water.

Summary of Activity 3: Disappearing Coin—Effect of Total Internal Reflection In Activity 3 (See Sec. 9), a coin is visible only when observed from the side-view through an empty glass placed over it. After water is poured into the glass, the coin disappears when observed from the same side-view. The students should be asked to hypothesize the reason behind the disappearance of the coin based on the conditions for an object to be visible, i.e. an object is visible only when light from it reaches the eye. The teacher should then make the students investigate the reason behind the change in the direction of light, thereby introducing the phenomenon of total internal reflection to the students.

5.1. Precaution: Laser beams should not be directed at the eye, as it may cause harm to the eye. Ensure that the students do not shine the laser beam at each other's eyes.

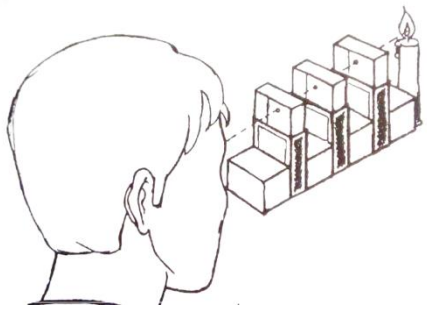
6. Activity 1: Experiment to determine the path of light:

6.1 Objective

To observe and determine the path of light.

6.2 Procedure

1. The students should be given 3 matchboxes having small holes in the same spot in their inner trays. The inner tray should be positioned differently in each box.



2. The students are expected to position the boxes and the inner trays in a manner so as to view any object on the other side.
3. The position of one of the matchboxes should be changed, and the students should check whether the object on the other side will still be visible or not.

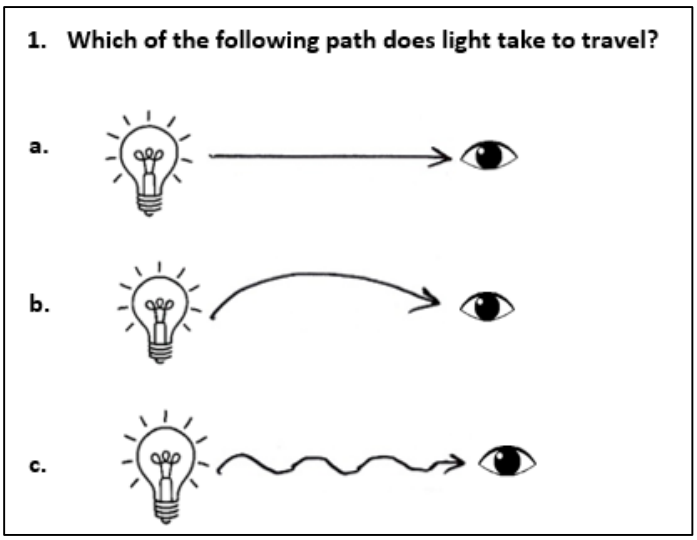
Figure a: *Experiment to show that light travels in straight lines.*

6.3 Question to Students Why is the object no longer visible?

The students are to come up with their own hypotheses. If they do not arrive at the conclusion that light travels in straight lines, they can be asked to reposition the matchboxes in a manner that the object on the other side is once again visible. Following this, they can be asked to pass a straw through the holes. The teacher should question them whether it gives them any idea regarding the path of light.

6.4 Formative Assessment—Worksheet

The students should be asked to respond to **Question No. 1** in the given worksheet.



7. Activity 2: Reappearing Coin—Building a Hypothesis

7.1 Objective:

To observe how the visibility of coin in a container changes when it is immersed in water; to hypothesise on the observation and develop methods to test it.

7.2 Observable(s):

1. Level of coin

The observable helps in identifying the path of light rays.

7.3 Procedure:

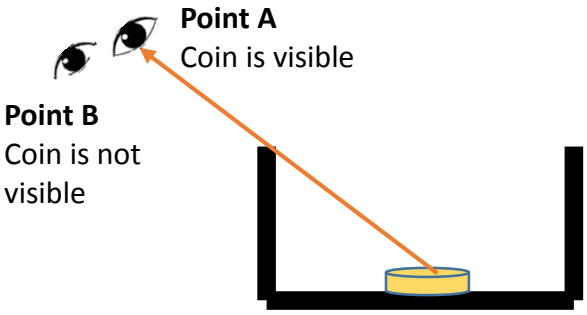


Figure b: *The ray of light reaches the eye of the observer without bending.*

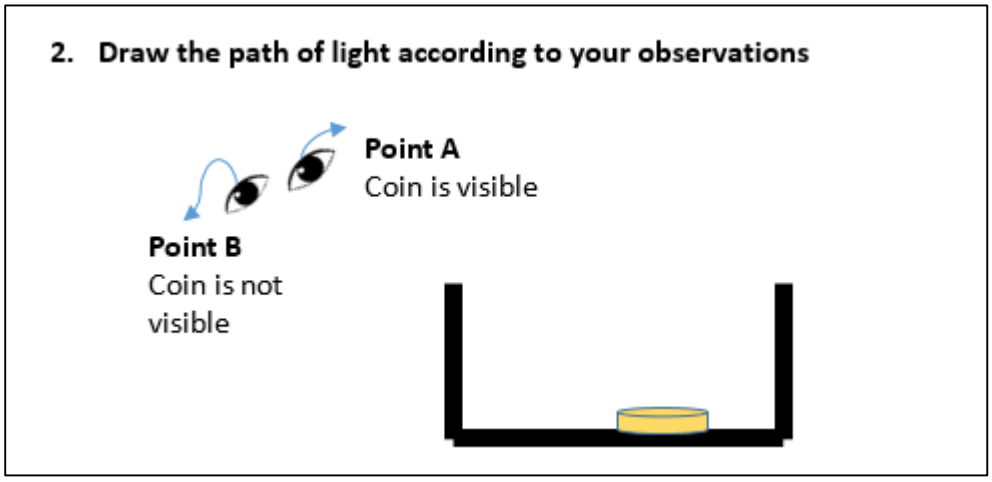
1. The students should be split into groups of two. Each group should be given a coin and a container. The coin is to be placed at the bottom of the empty container. The students in the group should be asked to stand up and look into the bowl to see the coin.
2. The teacher should then ask the students to observe the depth of the container.
3. The students should then be asked to move away from the bowl, keeping their eyes on the coin until it disappears from sight. When the coin disappears from sight, the students should stop moving.

7.3.1 Question to Students: Why is the coin no longer visible?

The teacher should continue with probing questions until the students respond that an object is visible only if the light from the object reaches the eyes of the observer. (The teacher should write down this response on the board.)

7.3.1.1 Formative Assessment—Worksheet

The students should be asked to respond to **Question No. 2** in the given worksheet.



4. While the student is standing still and looking into the bowl, another student in the group should slowly pour water into the container until the coin reappears in view.

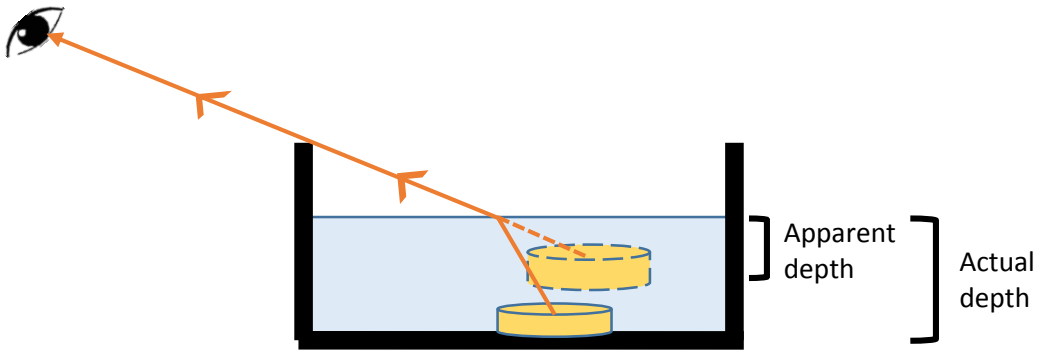


Figure c: *The ray of light reaches the eye of the observer when water is poured into the container.*

5. The teacher should ask the students to observe how the depth of the container appears after it is filled with water.

7.3.1.2 Assessment—Worksheet

The students should be asked to respond to **Question No. 3** in the given worksheet.

> **3. How does the depth of the container appear when the bowl was filled with water? Tick one of the options below based on your observations.**
> a. appears shallower b. appears deeper c. remained same

7.3.2 Questions to the Students:

1) How did the coin reappear after the water was poured into the container?

The students can come up with their hypotheses.

Note to the teacher: The teacher must be open to listening to the responses of the students in order to understand their thought process. It is essential to not give away the answers at this stage.

7.3.2.1 Formative Assessment—Worksheet

The students should be asked to respond to **Question No. 4 (A)** in the given worksheet.

> **4. A) Write down the reason for the reappearance of the coin after water was poured into the container.**

Reiterate the previous response of the students (noted on the board) that an object is visible only if the light from the object reaches the eye of the observer. Emphasise this concept by marking it on the board.

7.3.3 Question to the Students: But, how did light from the coin reach the observer after water was poured into the container?

Wait for the students to respond.

Before the students begin to draw the path of light in their worksheets, they should be asked about how light travels. The following three types of path should be drawn on the board for the students to choose from.

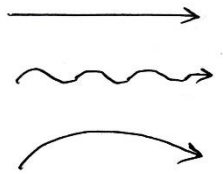


Figure d: *The teacher should question the students regarding the path that light takes to travel. The students should choose the correct path among these options.*

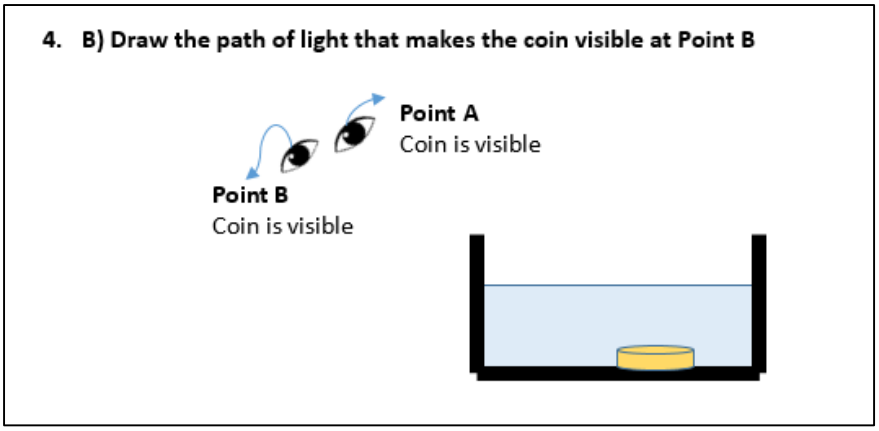
The students should unanimously agree that light travels in straight lines. This understanding has to be ensured by questioning the reason behind that conclusion. It is expected that the students will be able to connect this understanding with the inference that had been derived from the matchbox experiment done earlier.

The teacher should write 'Conditions' on the board and list the following:

- The coin is visible only if light from the coin reaches the eye. (Already written on the board.)
  Oral instruction to the students: The arrow is to be directed from the coin to the eye
- Light travels in straight lines.
  Oral instruction to the students: A scale should be used to draw the lines.

7.3.3.1 Formative Assessment—Worksheet

The students should be asked to respond to **Question No. 4 (B)** in the given worksheet.



8. Experiment for Testing the Hypothesis—What happens when light enters water?

8.1. Objective

To observe the path of a laser beam as it passes from air to water and from water to air; to test the hypothesis that light bends as it passes from water to air.

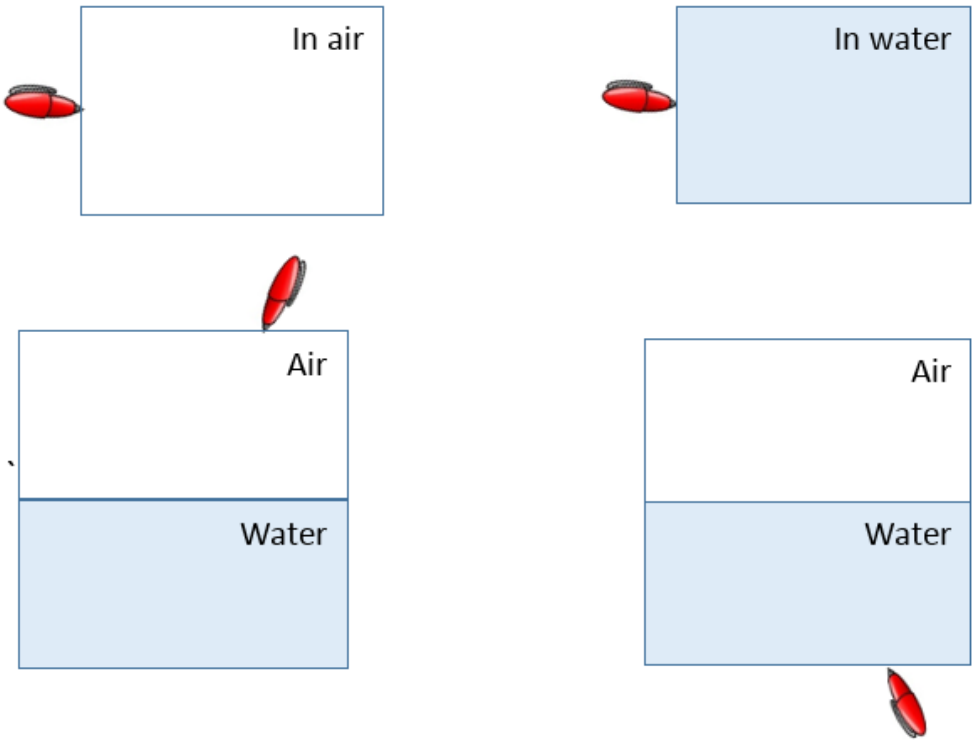
8.2. To be observed

The laser beam and its deviation towards and away from the normal needs to be observed, as this illustrates how light bends when it passes from a rarer medium to a denser medium and vice versa.

8.3. Procedure

1. Fill an empty glass bottle with water. Add a few drops of Dettol to the water till the water appears cloudy. This makes it easier to see the light beam as it passes through the water.
2. A lit-up *agarbatti* can be used to make the air above the water smoky, so as to make the path of the laser beam visible in air, and the lid can be closed.
3. The path of light in air is shown with the help of the smoke from the *agarbatti*.
   The students should record the path in the corresponding space provided in Question 5 in the worksheet.
4. The laser light is flashed through the water.
   The students should record the path in the corresponding space provided in Question 5 in the worksheet.
5. Now the laser is flashed in a way such that the light travels through air and then passes through water. It is seen that the light bends towards the normal as it enters the water (denser medium).
   The students should record the path in the corresponding space provided in Question 5 in the worksheet.
6. Now, the laser is flashed at an angle from under the transparent container so that the laser light travels through the water and comes out into the air above it.
   (**Note to the Teacher:** The teacher is to ensure that total internal reflection is not demonstrated.) It can be seen that the light bends away from the normal when it comes out of water. The teacher should ask the students to pay attention to the direction of bending as they observe.
   The students should record the path in the corresponding space provided in Question 5 in the worksheet.

5. Record your observations on the path of the laser beam:



8.4 Discussion with the students:

When does light bend?
The teacher should elicit responses from the students. It is expected that the students will come up with response that light bends when it travels from air to water and vice versa.

The teacher should direct the students to observe the differences in the direction of bending in both the scenarios and ask them to share their observations.

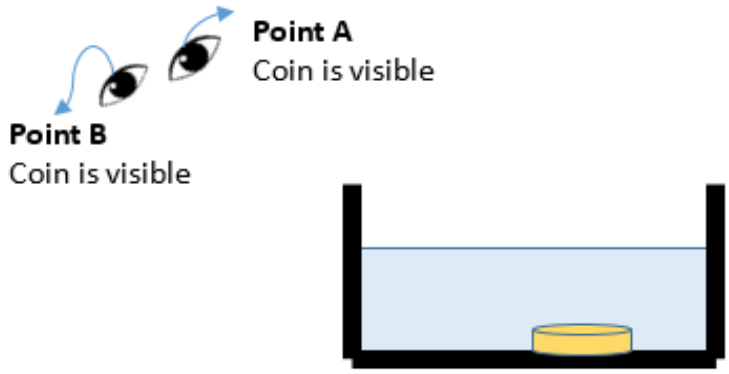
The teacher can then introduce the two terms—"rarer" and "denser"—with regards to medium. When the light rays bend towards the normal while travelling from the first medium to the second medium, the second medium would be called the "denser" medium and the first medium would be called the "rarer" medium.

Note to the Teacher: The optical density of a medium (determined by the speed of light in the medium) is different from the physical density of the medium (which is Mass/Volume). Physically denser substances might not always be optically denser, e.g. the physical density of oil is less than that of water; but oil has a higher optical density than water, i.e. the speed of light in oil is slower than in water.

8.4.1 Summative Assessment—Worksheet

The students should be asked to respond to **Question No. 6 (A & B)** in the given worksheet.

6. A) Draw the path of light that makes the coin visible at Point B



6. B) Write down the reason for the reappearance of the coin after water is poured into the container.

Next, the students should be asked to predict what would be the case if the water in the container is replaced by glass and justify their answer with proper reasons. If they respond that light would bend towards the normal when it enters glass, they can be asked to guess whether the bending would be greater or lesser than the bending in water and why they think it would be so.

A Follow-Up Question to Assess Students' Understanding
What do you think will happen when light passes from water to glass and glass to water? Why?

The students should be able to identify the denser and rarer medium between the two and then predict the direction of bending based on it.

9. Activity 3: Building a Hypothesis on Disappearing Coin—Total Internal Reflection

Figure e: *The coin under the empty glass tumbler is visible to the observer.*

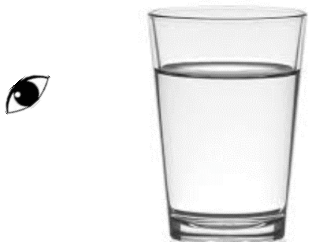


Figure f: *The coin under the glass tumbler is not visible to the observer once the glass is filled with water.*

- A coin is placed on the table, and a glass tumbler is placed over the coin.
- A blurred image of the coin is visible from the observer's position as shown in the figure.
- Water is poured into the glass till it is half full.
- Now, the coin disappears from view.

9.1. Question to the Students: Why has the coin disappeared?

The students should come up with their hypotheses. The teacher should listen to students and must not give away the answer at this stage.

The students are asked to respond to **Question No. 7** in the given worksheet.

7. Why did the coin disappear after water was poured into the tumbler? Write down the reasons for the same.

The conditions for an object to be visible, which is 'The light from the object has to reach the observer' and 'Light travels in straight lines', should be elicited from the students once again.

9.2 Question to the Students: But, why did the light from object not reach the observer?

For every wrong hypothesis that the students come up with, the teacher is to provide a reasoning on why that is not the case. The students may come up with the response that the glass or the water obstructs the path of light. Both the cases can be proved wrong, as the coin was visible before the water was poured into the glass tumbler, and water does not obstruct the light as a coin placed inside the glass tumbler is visible. Also, if one peeps into the glass from the top, the coin would become visible once again.

9.3 Investigation

The teacher should tell the students that they will be investigating how the coin disappeared.

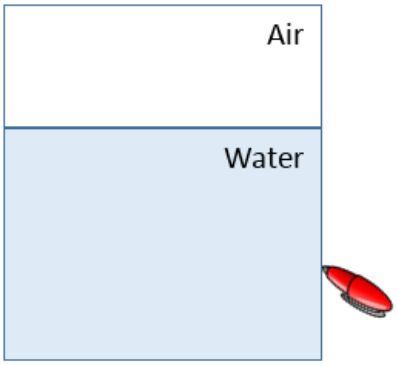
Procedure:

Total Internal Reflection

- The teacher should flash a laser beam from the bottom of the bottle containing the Dettol-mixed water. It will be seen that the light ray emerges out of water into the air.
- The laser position should then be changed from the bottom of the bottles to the sides, and the laser beam should be flashed at the water at an angle. The light would completely reflect back into the water.
- The teacher should then introduce a new concept, 'Total internal reflection', where when light travels from a denser medium to a rarer medium at an angle that is greater than a particular critical angle, the light is completely reflected back into the same medium.
- The teacher should once again flash the laser from the air to the water at different angles and asks students what they observe. It is seen that the light penetrates the water medium at all angles.

The students should be asked to answer why flashing a light through the sides of the container from air to water is different from flashing a light from water to air.
The students should record their observations in **Question No. 8** in the given worksheet.

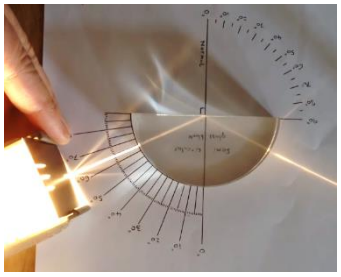
8. Trace the path of light when a laser beam is flashed from the position as shown



Now, the teacher should ask the students whether they can guess what could have happened with respect to the disappearing of the coin. The students should share their hypotheses.
The students should then be asked to respond to **Question No. 9** in the given worksheet.

9. Why did the coin disappear after water was poured into the tumbler? Write down the reasons for the same.

9.4 Video on Total Internal Reflection



The following video can be shown to the students: https://www.youtube.com/watch?v=NAaHPRsveJk.
In this video, it can be seen that with the increase in the angle of incidence, the angle of refraction increases correspondingly till the angle of incidence reaches a certain critical angle at which the angle of refraction is 90°. From that point, increasing the angle of incidence further would result in total internal reflection. The video can be paused at suitable places to explain the phenomenon to the students.

The following concepts are to be emphasised by the teacher:
Total internal reflection occurs only when light passes from a denser medium to a rarer medium and the angle of incidence exceeds the critical angle.

Video of situations of total internal reflection in real life—formation of mirage in a desert:
https://www.youtube.com/watch?v=pMMJo2q5ADM

10. Summative Assessment

The students should be asked to respond to **Question No. 10** in the given worksheet in order to test their understanding.