# LESSON 4 - INVESTIGATING REFRACTION

**Overview:**
Through a series of demonstrations, students will learn why waves refract. By observing how different materials shift the position of an object, the concept of the refraction of light waves will be further investigated.

**Suggested Timeline:** 1 hour

**Materials:**
- Investigating Refraction (Teacher Support Material)
- Investigating Refraction (Student Handout)
- Bending Light – A Lab Investigation of Refraction (Student Handout)
- aquarium full of water
- puck
- meter stick
- pencil in a beaker of water
- opaque cups (1 per group of 2 students)
- water
- vegetable oil
- rubbing alcohol
- coins (1 per group of 2 students)

**Method:**

**INDIVIDUAL FORMAT:**
1. Using their student handout and other available resources, have students complete their vocabulary list on 'Investigating Refraction' (Student Handout - Individual).
2. Set up student to complete 'Bending Light – A Lab Investigation of Refraction' (Student Handout - Individual). Review answers to questions with student as formative assessment

**GROUP FORMAT:**
1. Have students complete their vocabulary list on refraction on 'Investigating Refraction (Student Handout – Group).
2. Introduce refraction through a spear fishing demonstration, story and an explanation of mirages as found on 'Investigating Refraction' (Teacher Support Material).
3. Explain the relationship between the speed of light and the medium in which it travels.
4. Define *refraction*, *angle of incidence*, *angle of refraction* through the use of a diagram (found on student and teacher handouts).
5. Summarize new terms using demonstration of pencil in a beaker of water.
6. Have students complete 'Bending Light – A Lab Investigation of Refraction' (Student Handout).
7. Review answers to lab activity together as formative assessment.

**Assessment:**
Assessment of student understanding of refraction through a review of questions from the lab activity.

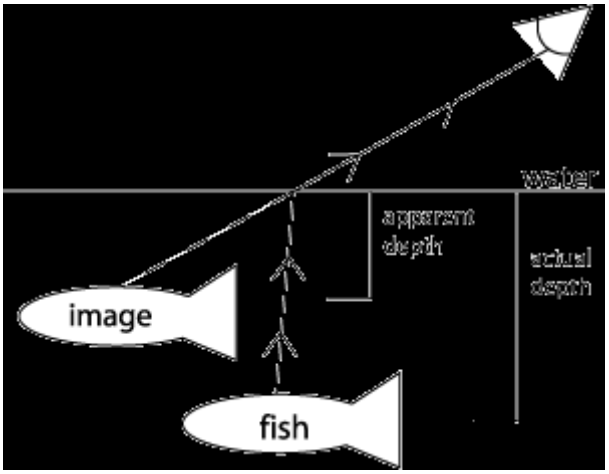
# INVESTIGATING REFRACTION

**Demonstration:** Ask students if any of them have spear fished before. Tell them that many First Nations people of Saskatchewan have, and still do, spear fish in waters that are shallow enough to walk in and that they can clearly see through. Tell students that there is a trick to it, though, and that today they are going to learn it!

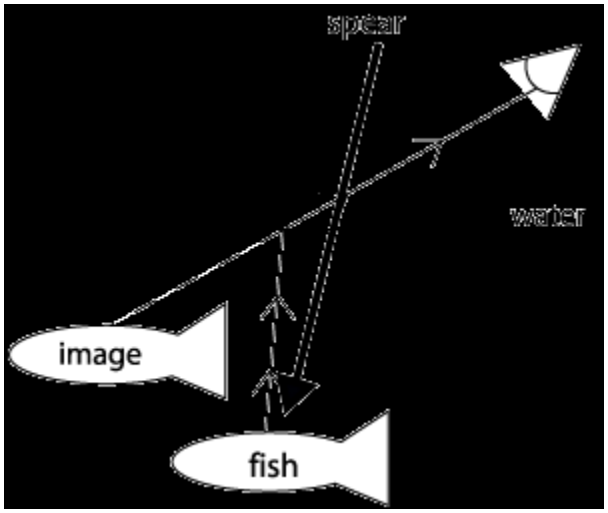
Set up an aquarium full of water and place a puck or other object at the bottom. Give a student a long stick, such as a metre stick, and have him/her stand above the aquarium and quickly spear the 'fish' at the bottom.

Why is it difficult to hit the fish when spear fishing? (Light reflecting from the fish bends when it hits the air from the water. This makes the fish appear to be in a different spot than it actually is.)

How does one know where to aim? (Draw the following diagram on the board)



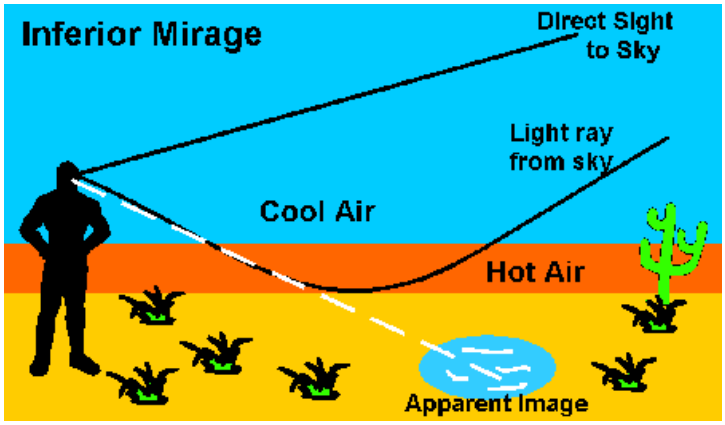

(If the fish appears above where it actually is, then you must aim BELOW where the fish appears!)



**Share the following story with students:**

In 1271, at the age of 17, Marco Polo set out on a journey with his father and uncle from Venice to China. Upon returning to his home in Italy in 1295, he wrote the classic *Travels of Marco Polo*, a book that gave Europeans their first glimpse of the wonders of Asia and inspired future explorers such as Christopher Columbus. One of the greatest obstacles in Marco Polo's travels was the massive Gobi Desert of central Asia. In Mongolian, the name "Gobi" means "place without water," a good description for a region whose rainfall is often less than 3 inches per year! In the summer, temperatures may reach 50°C and the Polo's were often faced with the threat of dehydration or heat exhaustion.

In traveling across the sands, the Polo's would often see what appeared to be oasis (places with water), but as they eagerly approached, the water would vanish from sight. They were seeing **mirages**. Mirages result from the fact that light bends as it moves from one medium to another. The air directly above the sand is very hot and the air just above that is cooler. At the boundary or border between the two layers of air, the light ray bends so much that the light from the sky is reflected back to one's eye. The 'water' that one sees as a mirage is actually just the reflection of the blue sky!



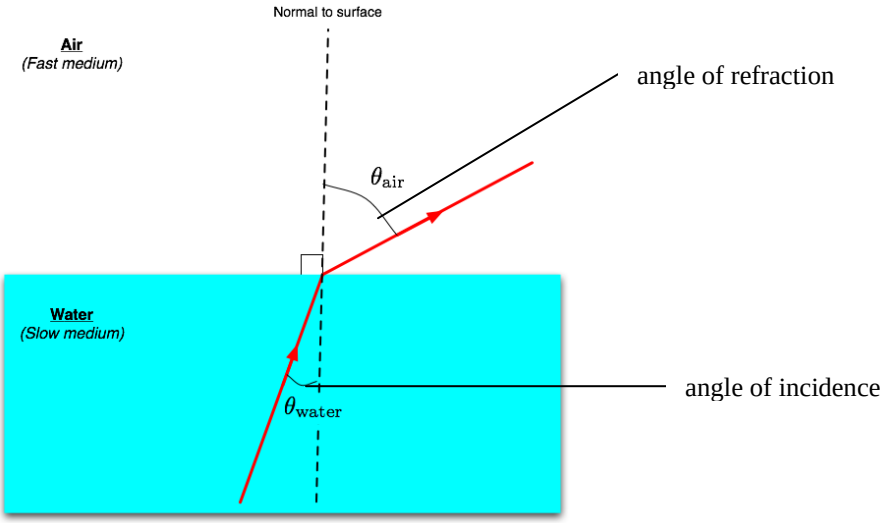

**The speed of light, like the speed of any wave, depends upon the medium in which it travels.**

Light travels the fastest in a vacuum (where there is an absence of matter, like outer space) and slows down as the optical density increases. The optical density is a characteristic of a material that is determined by how much matter there is per unit area and how light passes through it. A medium in which light travels quite quickly, like air, is described as having a low optical density, while one in which it travels relatively slowly, like glass, is described as having a high optical density.

**KQ:** In which of the following materials would light travel the fastest?

a) water b) air c) outer space d) glass

**Since light travels at different speeds in different substances, it bends or <u>refracts</u> when passing from one substance to another** (e.g., light passing from water to air).




**Demonstration:** Put a pencil in a beaker of water. Have students note how the pencil appears to be 'broken' due to the bending of light as it reflects up from the pencil and passes from water to air (same situation as diagram above).

Student Handout

# Investigating Refraction

**VOCABULARY -** Many of the words may be found in the reading below or in previous lessons.

refraction –

medium –

optical density -

normal –

index of refraction –

incident ray –

refracted ray –

angle of incidence –

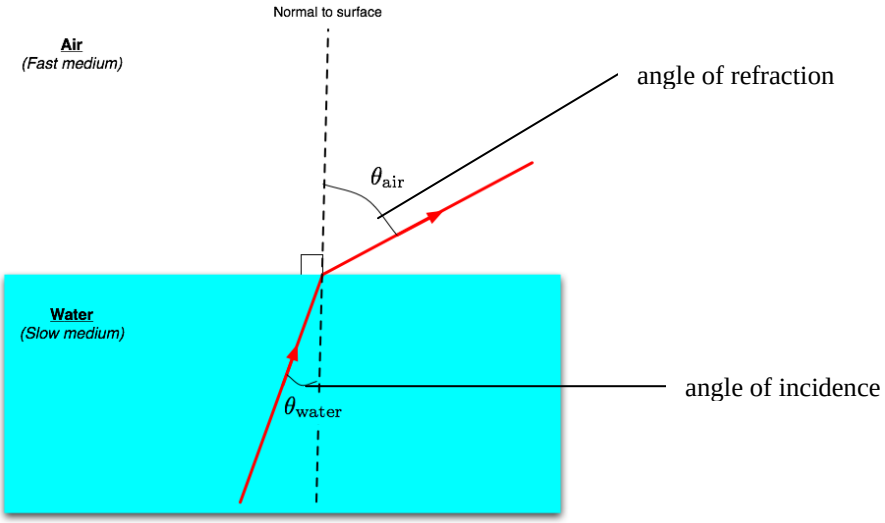
angle of refraction –

**The speed of light, like the speed of any wave, depends upon the medium in which it travels.**

- Light travels the fastest in a vacuum (where there is an absence of matter, like outer space) and slows down as the optical density increases.
- The optical density is a characteristic of a material that is determined by how much matter there is per unit area and how light passes through it.
- A medium in which light travels quite quickly, like air, is described as having a low optical density, while one in which it travels relatively slowly, like glass, is described as having a high optical density.

Student Handout

**Since light travels at different speeds in different substances, it bends, or <u>refracts</u> when passing from one substance to another.**




Everyday examples:

- mirages
- position of puck in a pool is in different spot when looked at above the water than below the water
- a pencil placed in a beaker of water appears broken when viewed from the side

Student Handout

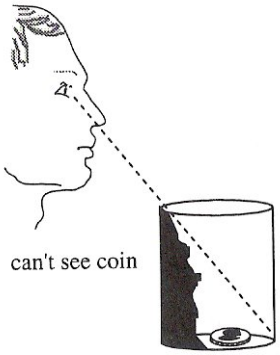
Name: _____ Date: _____ Period: _____

# Bending LIGHT – A Lab Investigation of Refraction

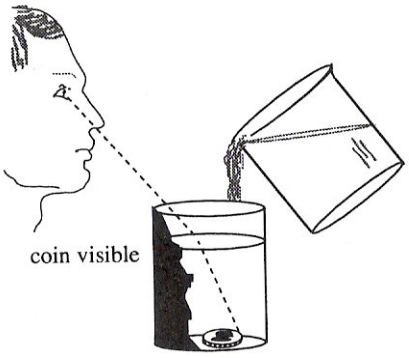
**Purpose:**
To investigate the concept of refraction and index of refraction by observing how different materials affect the pathway of light.

**Materials:** opaque cup (one that you cannot see through), water, coin, vegetable oil, rubbing alcohol, 30 cm ruler

**Procedure:**
1. Place a coin in the bottom of an opaque cup. Position it so that it is just out of view (see figure below).




2. Slowly add water to the cup. In the chart below, record the height of the water in the cup when the coin *just* becomes visible (see figure below). Be sure to keep yourself in the same position as you were in step #1!




3. Repeat steps #1 and #2 using vegetable oil and rubbing alcohol.

Student Handout

**Observations:**

**Chart of Heights of Different Liquids at Which Coin Became Visible**

| **Type of Liquid** | **Height of Liquid When Coin Becomes Visible** (cm) |
|---|---|
| water | |
| oil | |
| rubbing alcohol | |

**Analysis Questions:**

1. As you know, light bends when it travels between media with differing **optical densities.** As light reflected from the coin strikes the boundary between water and air, oil and air or alcohol and air, it speeds up. This causes the light to bend away from the normal. (Remember the diagram from class?) Thus, while the coin is initially out of sight, the addition of the liquid makes it visible. The more the light is bent, the earlier you will see the coin when pouring liquid into the cup (e.g., less liquid will have to be added).

   Examine your observations as recorded in your chart.
   a) Which type of liquid bent the light the most? _____
   b) Which type of liquid bent the light the least? _____

2. The **index of refraction** is a number assigned to a material based on how fast light travels through it. The higher the index of refraction, the slower light passes through the material. The higher the index of refraction, the more light bends or refracts when passing into that material.
   a) Based on your observations, which type of liquid has the *highest* index of refraction? _____
   b) Based on your observations, which type of liquid has the *lowest* index of refraction? _____

Adapted from "Refraction", pp. 451-452 *Hands-On Physics Activities with Real-Life Applications*