# Light Speed and Refraction

## *Overview:*

Students learn about the index of refraction and its effect on the speed of light as it passes through a substance. Students use the index of refraction in calculations and make discoveries about the relationship between the density of an object and the speed of light passing through the object.

## *Objectives:*

The student will:

- calculate the speed of light in different substances; and
- correlate the density of substances with the speed of light in the substance.

## *Materials:*

- Calculators
- STUDENT WORKSHEET: "Light Speed and Refraction"

## *Answers to Student Worksheet:*

*1. Data Table:*

| Substance | Density in gr/cm$^3$ | Index of Refraction | Speed of Light in Substance (300,000,000 m/s ÷ Index of Refraction) |
|---|---|---|---|
| Air | | 1.00014 | 299,958,000 m/s |
| Ice | .931 | 1.309 | *229,182,582 m/s* |
| Glass | 2.5 | 1.517 | *197,758,734 m/s* |
| Quartz | 2.65 | 1.544 | *194,300,518 m/s* |
| Emerald | 2.72 | 1.576 | *190,355,330 m/s* |
| Diamond | 3.2 | 2.417 | *124,120,811 m/s* |

*2. A) The greater the density of the substance, the higher the index of refraction.*

*3. D) The light changes angles, or refracts, as it passes through the window, and that slows it down.*

*4. B) The light speeds back up to the speed it was traveling outside the window.*

 

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## *Activity Procedure:*

1. Explain that in the vacuum of outer space, light photons travel at a speed of 300,000,000 miles per second. Since Earth is about 150 billion meters from the sun, this means light from the sun reaches Earth about 8.4 minutes after it was produced. The aurora occurs 96,000 to 965,000 meters above Earth's surface, so light from the aurora reaches Earth less than 1 second after it was produced.
2. Explain that when light passes through a window or hits the surface of a lake, it bends or refracts. This refraction slows the speed at which light photons travel. Through scientific inquiry, an index of refraction has been determined for a number of substances. This index can be used to find the angle at which light will refract, or bend, as it passes through the material. The formula for calculating the angle of refraction is called **Snell's Law**.
3. Explain that during this activity, students will use the index of refraction to determine the speed at which light will travel through common substances like ice, glass and a diamond.
4. Distribute calculators and the STUDENT WORKSHEET: "Light Speed and Refraction." Ask students to find the speed of light as it passes through the substances listed on the Data Table. Students will divide the speed of light in a vacuum (300,000,000 miles per second) by the index of refraction for each substance listed. Ask students to record their findings on the worksheet.
5. Next, ask students to compare the density of each of the solids listed on the Data Table to the index of refraction and speed of light in the solid. They should conclude that there is a direct correlation between the density of a substance and the speed at which light travels through the object.

 

**Name: _____** **Student Worksheet**

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**Directions:** The speed of light in a vacuum is 300,000,000 miles per second, but this speed changes depending on the medium (air, water) that light travels through. Calculate the speed of light in each of the substances listed in the Data Table, then consider how the density of a substance affects its index of refraction by comparing the data within the table.

1. Calculate the speed of light in each substance listed in the Data Table by dividing the speed of light in a vacuum by the index of refraction for each substance. Round answers to the nearest whole number. Write your answers in the "Speed of Light in Substance" column.

   Example: Find the speed of light in air.

   300,000,000 m/s ÷ 1.00014 (index of refraction in air) = 299,958,000 m/s

   Data Table:

| Substance | Density in gr/cm$^3$ | Index of Refraction | Speed of Light in Substance (300,000,000 m/s ÷ Index of Refraction) |
|---|---|---|---|
| Air | | 1.00014 | 299,958,000 m/s |
| Ice | .931 | 1.309 | |
| Glass | 2.5 | 1.517 | |
| Quartz | 2.65 | 1.544 | |
| Emerald | 2.72 | 1.576 | |
| Diamond | 3.2 | 2.417 | |

2. The Data Table lists both the density and the index of refraction for several solids. What is the correlation between the two sets of numbers?
   A) The greater the density of a substance, the higher the index of refraction.
   B) The greater the density of a substance, the lower the index of refraction.
   C) The density of a substance is equal to the index of refraction.
   D) There is no correlation between the density of a substance and its index of refraction.

3. Why does light travel more slowly through a window that it does through the air outside?
   A) The window absorbs some of the light's energy, so the light moves slower.
   B) Photons turn to slow-moving protons when they pass through a window.
   C) The window is more dense than air, so light coming through runs into a lot of atoms, which slow it down.
   D) The light changes angles, or refracts, as it passes through the window, and that slows it down.

4. Once light passes through a window and enters a room, at what speed does it travel?
   A) The light stays at the speed it slowed to when passing through the glass.
   B) The light speeds back up to the speed it was traveling outside the window.
   C) The light stops all together because it has reached its destination.
   D) The light moves slower than it did when it was passing through the glass.

 