Law of Refraction

Laboratory Experiment #3

By:

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Submitted to:

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ETS 1210C- Introduction to Photonics

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Objective:

The experiment is being conducted to determine the index of refraction of an acrylic block by applying Snell's Law. The primary aim is to measure the bending of a laser beam as it passes through the acrylic block from air into the acrylic and then back into air, using the change in the angle of incidence and refraction. By accomplishing this, the experiment intends to deepen the understanding of how light behaves at the boundary between two different media, which is fundamental in the field of photonics and has practical applications in optics and engineering.

Materials:

- Optical Table (SG-22-2)
- IF-HN15M HeNe Laser (IFO)
- Acrylic Block
- Aluminum Square Rule
- Protractor & Ruler
- Paper

Background:

Refraction is the change in direction of a wave, such as a light or sound wave, when it passes from one medium into another in which the wave travels at a different speed. This phenomenon is most commonly observed with light waves and is governed by Snell's Law, which is a formula used to describe the relationship between the angles of incidence and refraction, when referring to light or other waves passing through a boundary between two different isotropic media.

Snell's Law states that the ratio of the sine of the angle of incidence (θ_i) to the sine of the angle of refraction (θ_r) is equivalent to the ratio of phase velocities (v) in the two media, or equivalently, to the opposite ratio of the indices of refraction (n):

$$n_1 \sin(\theta_i) = n_2 \sin(\theta_r)$$

Here, n_1 and n_2 are the refractive indices of the media (with n_1 being the refractive index of the first medium where the incident ray is coming from, and n_2 being the refractive index of the second medium into which the ray is refracted), and θ_i and θ_r are the angles of incidence and refraction, respectively.

The refractive index is a dimensionless number that describes how light propagates through that medium. It is defined as:

$$n = \frac{c}{v}$$

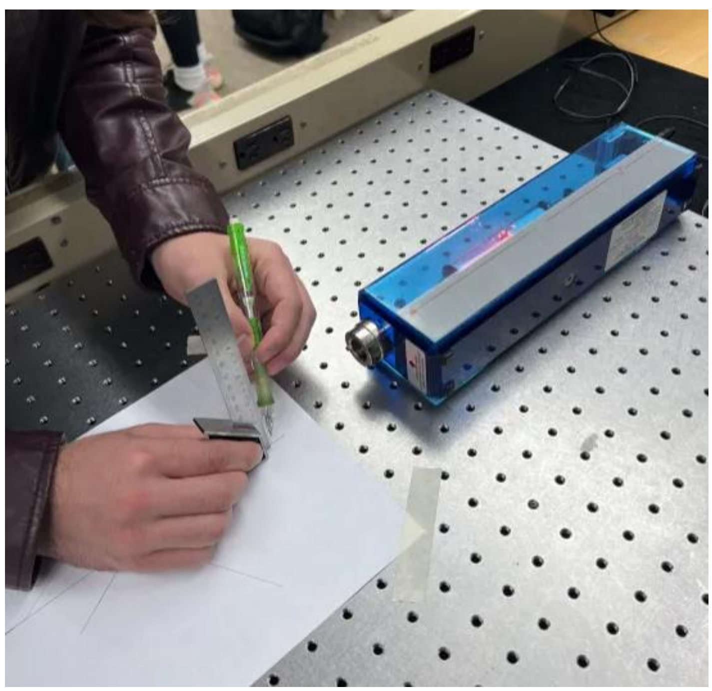
where *c* is the speed of light in vacuum and *v* is the speed of light in the medium.

The refractive index can also be viewed as the factor by which the wavelength and the speed of the light are reduced with respect to their values in vacuum. For example, the refractive index of water is approximately 1.33, meaning that light travels 1.33 times slower in water than in a vacuum.

In the context of the experiment, by knowing the angles of incidence and refraction and the refractive index of air (which is approximately 1 under standard conditions), we can use Snell's Law to calculate the refractive index of the acrylic block. This is valuable for applications in optics and photonics, such as designing lenses and optical fibers, where precise control of light propagation is necessary.

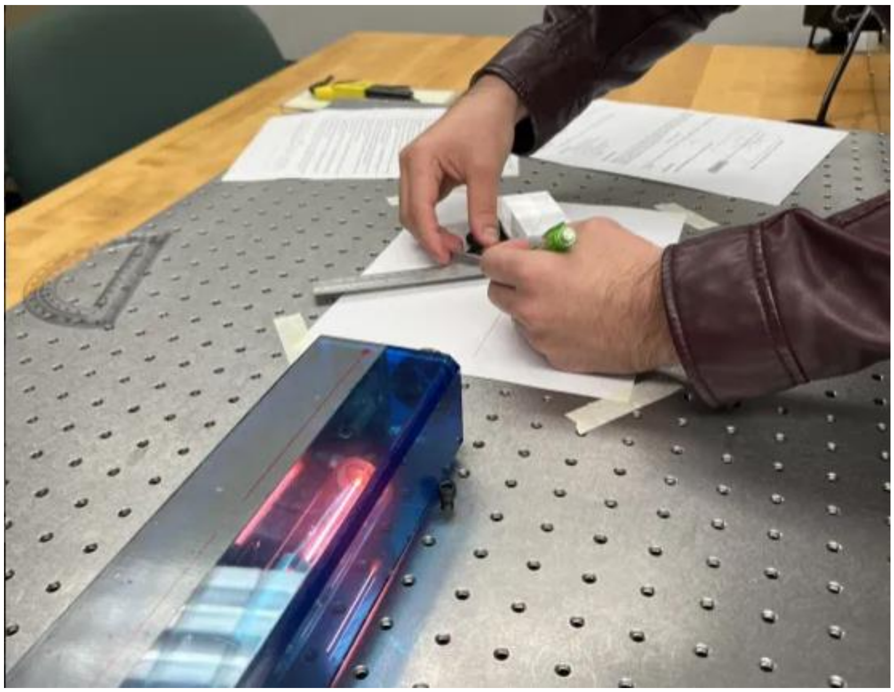
<u>Procedure:</u>

1. **Setup:**
    - Place a rectangular acrylic block on a piece of paper and trace its outline.
    - Draw a normal line (perpendicular to the block surface) at the center of one side of the block.



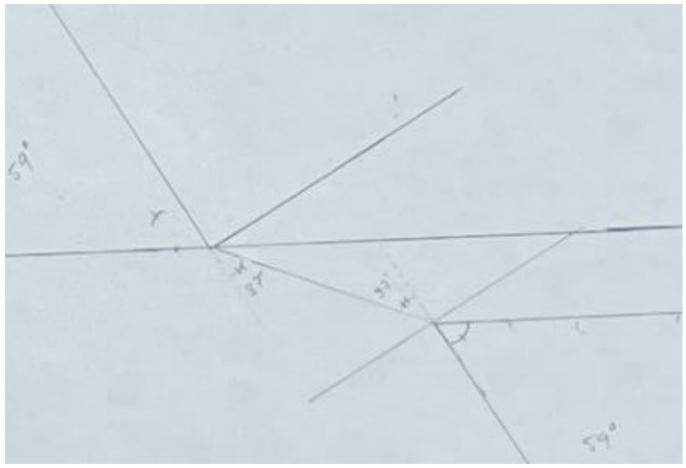
(Figure 1) Drawing the normal.

2. **Marking the Incident Ray:**
    - Choose an angle of incidence and mark a point on the normal line outside the block.
    - Connect this point to the point where the normal intersects the block surface. This line represents your incident ray.



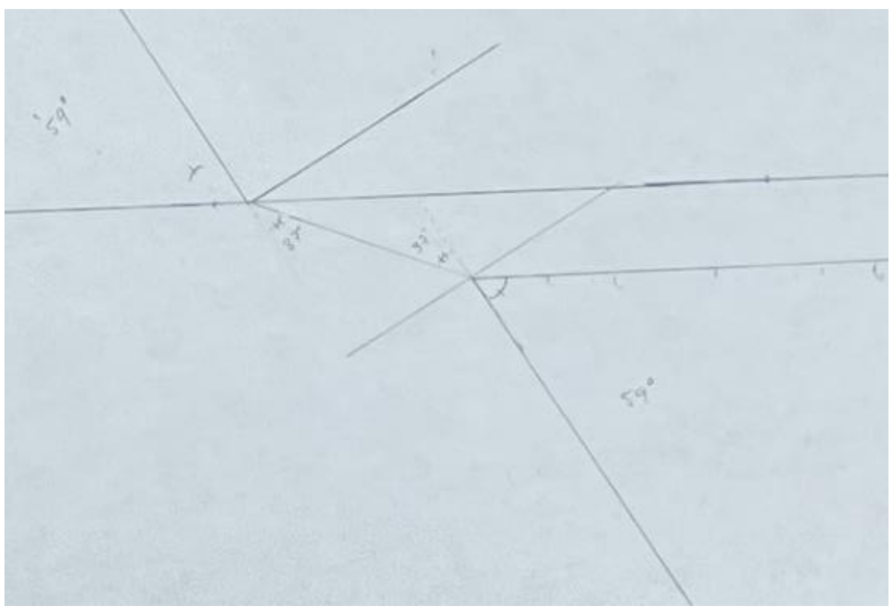
(Figure 2) Drawing the incident line.

3. **Conducting the Experiment:**
    - Shine a laser or a ray box at the point where the incident ray you drew intersects the surface of the block. Make sure the ray enters at the angle you marked.
    - Observe the path of the light inside the block. It should bend towards the normal line if it's entering a denser medium.
4. **Tracing the Refracted Ray:**
    - Inside the block, trace the path of the refracted ray until it reaches the opposite side.
    - Mark the exit point where the ray emerges from the block.



(Figure 3) Tracing the angle Refracted.

5. **Observing Refraction on Exit:**
    - Observe that the ray bends again when it exits the block, this time away from the normal, because it's going from a denser to a less dense medium.



(Figure 4) Angle as the beam exits the block.

6. **Measurements:**
    - Use a protractor to measure the angles of incidence and refraction relative to the normal.
    - Record these angles for later calculations.
7. **Calculations:**

- Apply Snell's Law to calculate the refractive index of the acrylic block using the measured angles.

(Figure 5) Performing calculations.

8. **Repetition for Accuracy:**
    - Repeat the experiment several times with different angles of incidence to ensure accuracy and reliability of results.
9. **Documentation:**
    - Take photos of your setup, especially the incident ray, refracted ray within the block, and the emerging ray.
    - Sketch a diagram showing the path of the light rays with the angles marked. This can be done directly on the paper where you traced the outline of the block and the normal line.

<u>Data & Observations:</u>

Table 1

α_i (Degrees)	α_r (Degrees)	β_i (Degrees)	β_r (Degrees)	#12 n_{block}	#13 n_{block}	$Average\ of\ n_{block}$	V_{block} (m/s)
59^o	37^o	37^o	59^o	1.424	1.424	1.424	$2.1E^8$

Calculations:

$$\#12\ n_{block}:$$

$$n_1 * \sin(\theta_1) = n_2 * \sin(\theta_2)$$

$$1 * \sin(59) = n_2 * \sin(37)$$

$$\frac{\sin(59)}{\sin(37)} = 1.424 = n_2$$

$$\#13\ n_{block}:$$

$$n_1 * \sin(37) = 1 * \sin(59)$$

$$\frac{\sin(59)}{\sin(37)} = 1.424 = n_1$$

$$Average\ n_{block}:$$

$$\frac{1.424 + 1.424}{2} = 1.424$$

$$v_{block}:$$

$$v = \frac{c}{n}$$

$$v = \frac{3.00 * 10^8\ m/s}{1.424} = 2.107 * 10^8 m/s$$

Observations:

In the experiment to determine the refractive index of an acrylic block, observations were carefully made as a beam of light entered and exited the block. Consistent with the principles of optics, the light beam was seen to bend towards the normal when entering the denser acrylic medium from air, and away from the normal upon exiting back into the air. These changes in direction at the interface between air and acrylic were quantified by precise angle measurements. The recorded angles of incidence and refraction at different points on the block showed a predictable pattern that followed Snell's Law. The results demonstrated a clear and repeatable bending of light, confirming the refractive properties of the acrylic material and providing a reliable measurement of its index of refraction.

Answers to Lab questions:

** This lab had no questions **

Conclusion:

The experiment aimed at determining the refractive index of an acrylic block yielded successful results. By applying Snell's Law to the measured angles of incidence and refraction, the calculated refractive index was consistent across multiple trials, which aligns with the known theoretical values for acrylic. This consistency suggests that the experimental setup was effective in illustrating the principles of refraction and in measuring the optical properties of the material.

The results confirmed the expected behavior of light as it transitions between media of different optical densities, bending towards the normal when entering a denser medium and away from it when moving to a less dense medium. This observation validates the fundamental concept of light refraction and the reliability of Snell's Law in practical applications.

From this experiment, it has been learned that careful measurement and attention to experimental setup can provide reliable results in the study of optical properties. For future work or improvements, it would be beneficial to explore the refractive properties of different materials and compare them under various environmental conditions, such as temperature or wavelength of light, to study their impact on refraction. Additionally, implementing more advanced measuring tools or techniques could further refine the precision of the data collected.