Experiment # 03

Objective: To observe dispersion through an acrylic rhomboid and calculate the different indices or refraction for different color light.

Equipment:

1	Ray Optics Kit	OS-8516
1	Basic Optics Light Source	OS-8470
	Required but not included:	
1	Protractor	
1	Ruler	
1	Sheet of White Paper	
1	Pen or Pencil	

Theory

Ordinary white light is a combination of waves with wavelengths extending over the visible spectrum (from red to violet). The speed of light in a vacuum is the same for all colors of light, but the speed in a material is different for different wavelengths. Therefore, the index of refraction of a material depends on the wavelength (color) of the light that passes through the material, and is a property of the incident light as well as a property of the material. If a beam of light contains more than one color of light, each color will refract by a different amount and each color will come out of the material traveling in a different direction. This is called dispersion: the separation of a beam of light into its component colors by refraction. When ordinary white light passes through a material, the dispersion is observed as a rainbow that comes out the other end.

Setup

1. Place a sheet of white paper on the lab bench, and then set the acrylic rhomboid (frosted side down) near the top-left corner of the paper. Adjust the orientation of the rhomboid to match that in Figure 2.
2. Use the pen or pencil to trace the outline of the rhomboid on the paper and then lift the rhomboid off the paper.

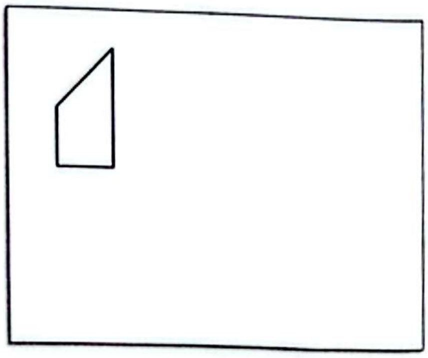


Figure 2: Rhomboid on Paper

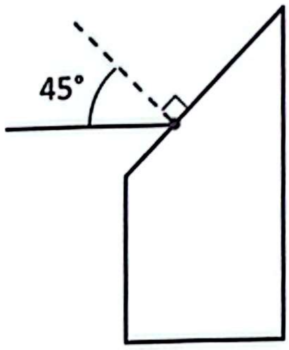


Figure 3: Rhomboid with Lines

3. Choose a point (any point) along the angled side of the outline, and then use the protractor to draw a normal line at that point similar to Figure 3.
4. At the same point, draw a 45° line relative to normal that extends outward from the outline similar to Figure 3.
5. Place the rhomboid back on the paper (frosted side down) and adjust its position so that it sits within the outline.
6. Place the basic optics light source flat on the lab table and rotate the knob on the front of the light source to produce a single ray of light as in Figure 4. Adjust the position of the light source so that the light ray is incident on the angled side of the rhomboid and aligned with the 45° line drawn on your paper.

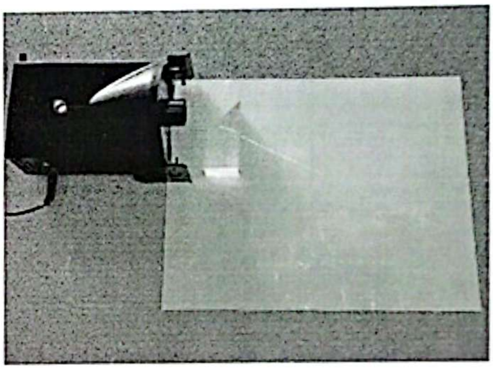


Figure 4: Single Ray of Light

Procedure

1. Observe the refracted light ray as it passes through the rhomboid and travels down the length of the paper. What colors can you see in the dispersed light (you may need to darken the room to see some colors better)?

2. The surface of the rhomboid at which the light ray leaves is called the "dispersion interface". Use the pen or pencil to carefully mark on the outline where the light ray exits the dispersion interface.
3. Follow the dispersed ray of light as far down the paper as possible without going off. At this point, carefully make a small mark where the blue light and red light reach the end of the paper Similar to Figure 5.
4. Remove the rhomboid from the paper and use the ruler to draw a line between the point at which the incident ray hit the rhomboid and where it exited at the dispersion interface.
5. Use the ruler to draw a line connecting the point at which the light ray exited the dispersion interface and each color mark (red and blue) at the end of the paper. Label each line "red" or "blue" to differentiate them.
6. Finally, use the protractor to draw a line normal to the dispersion interface at the point from which the light ray exited, that bisects the dispersion interface, as in Figure 6.

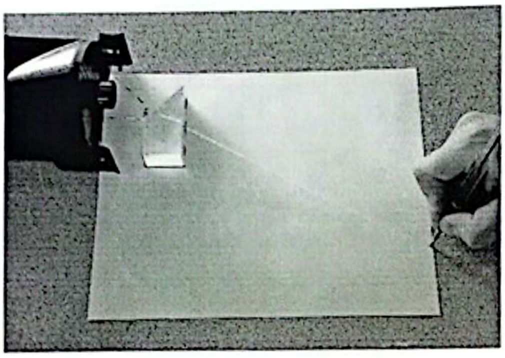


Figure 5: Marking the Paper

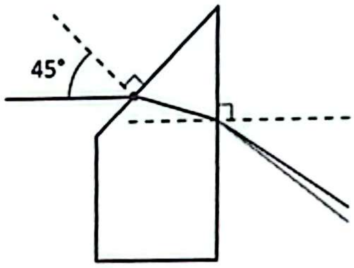


Figure 6: Dispersion

Lines

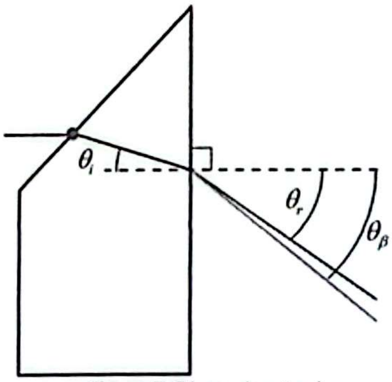


Figure 7: Dispersion Angles

Analysis

1. Use the protractor to measure the incident angle at the dispersion interface ϑ_i, as well as the dispersion angles ϑ_r for red light and ϑ_β for blue light as seen in Figure 7. Record all angles in degrees.

$\theta_i = 17°$, $\theta_r = 26°$, $\theta_b = 30°$

2. Based on the two different dispersion angles between red light and blue light, which color traveled faster in the acrylic rhomboid? How do you know?

The red color component of the white light traveled faster in the acrylic rhomboid because its refraction angle is smaller than blue color light. The faster the light ray, the less refraction it will experience.

3. Use Snell's Law to calculate the index of refraction for the two different colors of light (n_r for red and n_β for blue) in the acrylic rhomboid. Assume that the light ray basically remains a single white light ray (does not disperse much) as it travels through the rhomboid, and the index of refraction for air is 1.

$n_r = 1.499$

$n_b = 1.710$

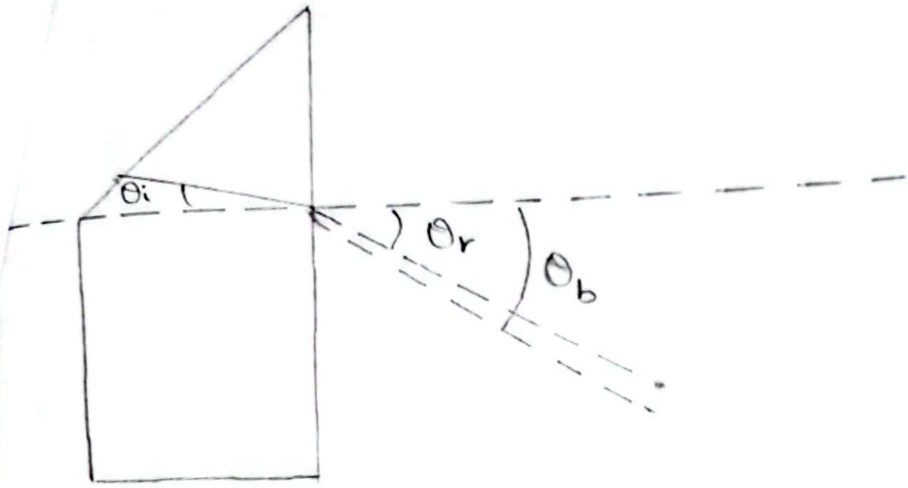
4. Given the definition of index of refraction, and your values from the previous question, calculate the speed of each color light (v_r for red and v_β for blue) in the acrylic rhomboid. Record the results below.

$v_r = 200.133 \times 10^6$ m/s

$v_b = 175.438 \times 10^6$ m/s

5. In your own words, describe in a sentence or two the relationship between wavelength of light and the speed at which it travels through a medium (like acrylic).

In a medium like acrylic, lights with longer wavelengths travel faster, while the lights with shorter wavelengths travel slower.



→ Measurements

Angle of incidence (θ_i) = 17°
Angle of refraction of Red Light (θ_r) = 26°
Angle of refraction of Blue Light (θ_b) = 30°

→ Red Light

Refractive Index (n_r) $= \frac{\sin \theta_r}{\sin \theta_i} = \frac{\sin(26°)}{\sin(17°)} = 1.499$

$\boxed{n_r = 1.499}$

Speed of Red Light (v_r) $= \frac{c}{n_r} = \frac{3 \times 10^8}{1.499} = 200.133 \times 10^6$

$\boxed{v_r = 200.133 \times 10^6 \text{ m/s}}$

→ Blue Light

Refractive Index (n_b) $= \frac{\sin \theta_b}{\sin \theta_i} = \frac{\sin(30°)}{\sin(17°)} = 1.710$

$\boxed{n_b = 1.710}$

Speed of Blue Light (v_b) $= \frac{c}{n_b} = \frac{3 \times 10^8}{1.710} = 175.438 \times 10^6$

$\boxed{v_b = 175.438 \times 10^6 \text{ m/s}}$