Experiment 5: Total Internal Reflection

Required Equipment from Basic Optics System

Light Source

Trapezoid from Ray Optics Kit

Other Required Equipment

Protractor

White paper

Purpose

In this experiment, you will determine the critical angle at which total internal reflection occurs in the acrylic trapezoid and confirm your result using Snell's Law.

Theory

For light crossing the boundary between two transparent materials, Snell's Law states

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where θ_1 is the angle of incidence, θ_2 is the angle of refraction, and n_1 and n_2 are the respective indices of refraction of the materials (see Figure 5.1).

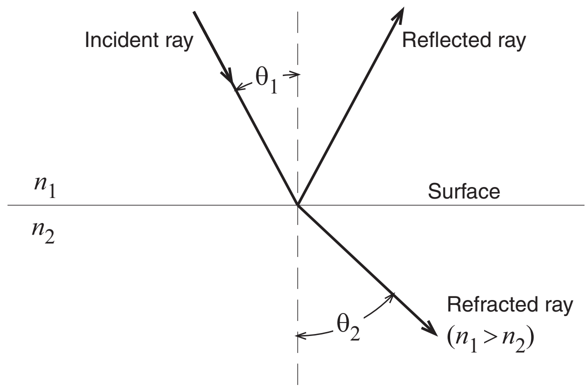

Figure 5.1

In this experiment, you will study a ray as it passes *out* of the trapezoid, from acrylic (n = 1.5) to air (n_{air} = 1).

If the incident angle (θ_1) is greater than the critical angle (θ_c), there is no refracted ray and total internal reflection occurs. If $\theta_1 = \theta_c$, the angle of the refracted ray (θ_2) is 90°, as in Figure 5.2.

In this case, Snell's Law states:

$$n \sin \theta_c = 1 \sin 90°$$

Solving for the sine of critical angle gives:

$$\sin \theta_c = \frac{1}{n}$$

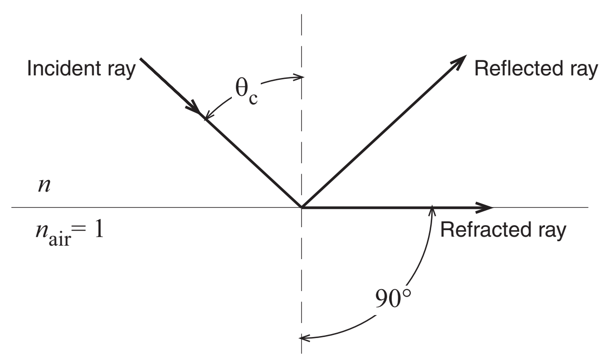

Figure 5.2

Procedure

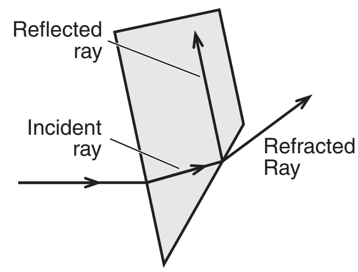

Figure 5.3

1. Place the light source in ray-box mode on a sheet of white paper. Turn the wheel to select a single ray.

2. Position the trapezoid as shown in Figure 5.3, with the ray entering the trapezoid at least 2 cm from the tip.

3. Rotate the trapezoid until the emerging ray just barely disappears. Just as it disappears, the ray separates into colors. The trapezoid is correctly positioned if the red has just disappeared.

4. Mark the surfaces of the trapezoid. Mark exactly the point on the surface where the ray is internally reflected. Also mark the entrance point of the incident ray and the exit point of the reflected ray.

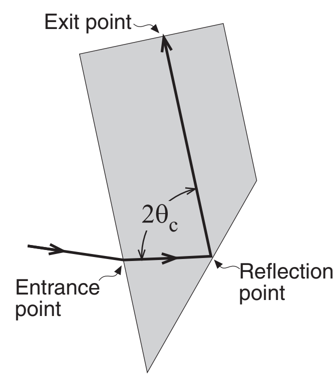

Figure 5.4

5. Remove the trapezoid and draw the rays that are incident upon and reflected from the inside surface of the trapezoid. See Figure 5.4. Measure the angle between these rays using a protractor. (Extend these rays to make the protractor easier to use.) Note that this angle is twice the critical angle because the angle of incidence equals the angle of reflection. Record the critical angle here:

   θ_c = _______ (experimental)

6. Calculate the critical angle using Snell's Law and the given index of refraction for Acrylic (n = 1.5). Record the theoretical value here:

   θ_c = _______ (theoretical)

7. Calculate the percent difference between the measured and theoretical values:

   % difference = _______

Questions

1. How does the brightness of the internally reflected ray change when the incident angle changes from less than θ_c to greater than θ_c?

2. Is the critical angle greater for red light or violet light? What does this tell you about the index of refraction?