Experiment 5: Total Internal Reflection

EQUIPMENT NEEDED

- Ray box (single ray)
- Rhombus
- Protractor (SE-8732)
- White paper

Purpose

To determine the critical angle at which total internal reflection occurs and to confirm it using Snell's Law.

Theory

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.

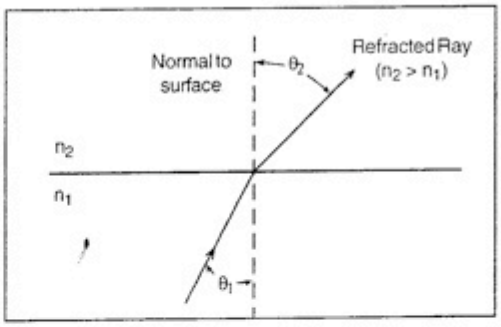

Figure 5.1

If a ray of light traveling from a medium of greater index of refraction to a medium of lesser index of refraction is incident with an angle greater than the critical angle (θ_c), there is no refracted ray and total internal reflection occurs. If the angle of incidence is exactly the critical angle, the angle of the refracted ray is 90 degrees. See Figure 5.2. In this case, using Snell's Law,

$$n \sin \theta_C = (1)\sin (90°)$$

assuming the medium of lesser index of refraction is air with $n_2 = 1$ and the medium of greater index of refraction is the Acrylic rhombus with $n_1 = n = 1.5$. Solving for the critical angle gives

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

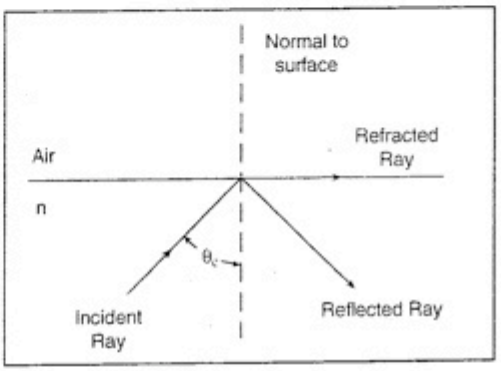

Figure 5.2

Procedure

① Place the ray box, label side up, on a white sheet of paper on the table. Slide the ray mask until only one white ray is showing.

② Position the rhombus as shown in Figure 5.3. Do not shine the ray through the rhombus too near the triangular tip.

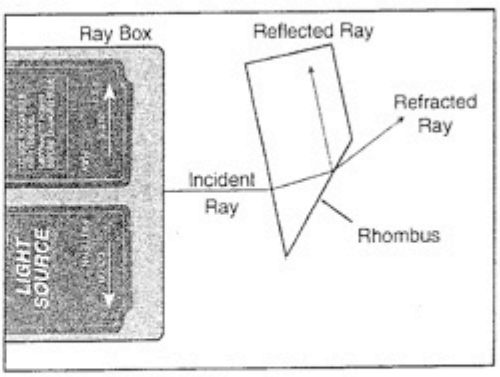

Figure 5.3

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

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

⑤ Remove the rhombus and draw the rays that are incident upon and that reflect off the inside surface of the rhombus. See Figure 5.4. Measure the total angle between these rays using a protractor. If necessary, you may extend these rays to make the protractor easier to use. Note that this total angle is twice the critical angle because the angle of incidence equals the angle of reflection. Record the critical angle here:_____

⑥ Calculate the critical angle using Snell's Law and the given index of refraction for Acrylic. Record the theoretical value here:_____

⑦ Calculate the percent difference between the measured and theoretical values:
% difference = _____

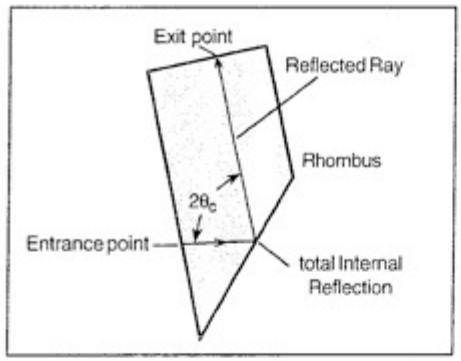

Figure 5.4

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?