6. TOTAL INTERNAL REFLECTION

Completion Time: 60 minutes

IMPORTANT

1 The critical angle can be calculated using the following formula:

$$\theta_c = \sin^{-1}\frac{n_{acrylic}}{n_{air}}$$

2 Snell's law of refraction:

$n_{air} \cdot \sin\theta_i = n_{acr} \cdot \sin\theta_r$

"It turns out that all Netflix streaming peak on Saturday night can fit inside a single fiber optic, which is the size of one human hair."

(Reed Hastings)

Getting Started

Total internal reflection is an optical phenomenon that occurs when a ray of light strikes a boundary of two different optical media at an angle larger than the critical angle. When that happens, the light beam does not refract, or does not travel through the boundary, but completely reflects. Critical angle is the angle of incidence of light traveling from media of higher optical density to a media with lower optical density, resulting in a 90^o angle of refraction. It means when light strikes the surface at the critical angle, the refracted beam will travel along the surface between those two media. Critical angle is a function of the media indices of refraction and can be calculated using Snell's law. Total internal reflection is used to transfer data using light and thin strands of pure glass, called optical fiber. Applications for fiber optics are many and varying, and include telecommunications, medicine, sensors, security, the automotive industry, and others.

Preparation

Fundamentals of Light and Lasers, OP-TEC
Module 1-1: "Nature and Properties of Light"
Sections: Properties of Light, Light Interactions
Module 1-4: "Basic Geometrical Optics"
Section: Critical Angle and Total Internal Reflection

Equipment

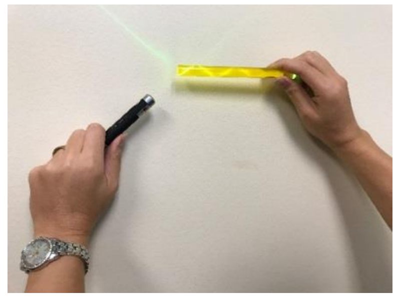
1. Green laser pointer
2. Fiber optics cable sample
3. Acrylic rod
4. Pencil
5. Protractor
6. Masking tape
7. White paper

Learning Outcomes

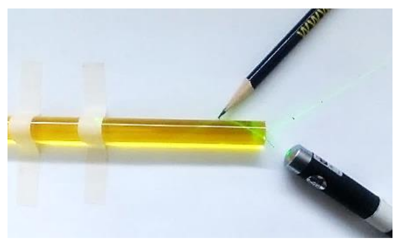
Upon completion of this laboratory, you will be able to:

- Demonstrate the total internal reflection in the arcylic rod
- Set-up the total internal reflection experiment, measure, and record relevant data
- Using the experiment data and Snell's law, calculate the critical angle
- List common applications of the total internal relection phenomena

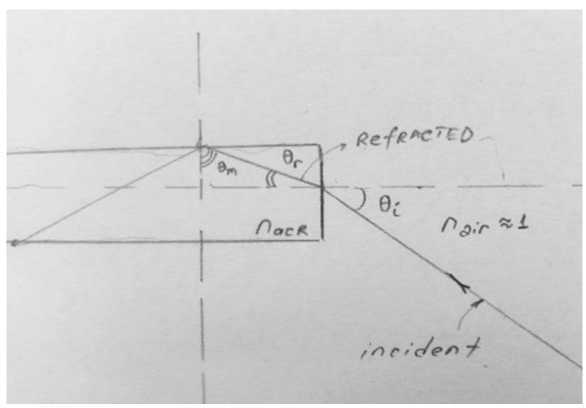
Procedure



1. Dim the lights in the room. Hold the acrylic rod in one hand and a laser pointer in the other.
2. Direct the laser pointer on to the side of the rod. Turn the laser pointer on. When using laser pointers, remember and follow the laser safety!
3. Observe the first refracted ray on the air/acrylic boundary within the rod and the light dot on the ceiling from the second refracted ray on air/water boundary.
4. Slowly start moving the laser beam up and counterclockwise if the laser pointer is in your right hand or clockwise if it is in your left hand.
5. Notice that the beam reflection on the ceiling disappears. Can you explain why this phenomenon is happening?



6. Place the rod onto a white paper, secure it with masking tape, and trace its contour (see picture on the right). Then repeat the experiment above. Try to identify on the paper all the points where the light is totally internally reflected.



7. Remove the rod and connect the pencil dots (see Figure on the right). Identify the angles θ_i and θ_r and measure them with the protractor. Use your knowledge from Lab 3: The Law of Refraction.

8. Use Snell's law $n_{air} \cdot \sin\theta_i = n_{acrylic} \cdot \sin\theta_r$ to calculate the index of refraction of the acrylic rod. Index of refraction of air is close to the index of refraction of vacuum and equals to one: $n_{air}=1$

$$n_{acr} = \frac{n_{air} \sin\theta_{inc}}{\sin\theta_{ref}}$$

9. Use the index of refraction, calculated in the previous step, and find the critical angle using the formula below:

$$\theta_c = \sin^{-1}\frac{n_{acrylic}}{n_{air}}$$

10. Measure angle θ_m and compare it to the critical angle calculated in step 9. Is it greater or smaller than critical angle? Would you be able to observe total internal reflection if the angle is smaller than the critical angle?

11. How may the concept of the total internal reflection be applied in a rain sensor used to control car windshields?

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Standard	**Description**
HS-PS3-1.	Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS4-1.	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
HS-PS4-3.	Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other
HS-PS4-5.	Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.
HS-ETS1-2.	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
MS-ETS1-2.	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-PS4-1.	Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
MS-PS4-2.	Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.