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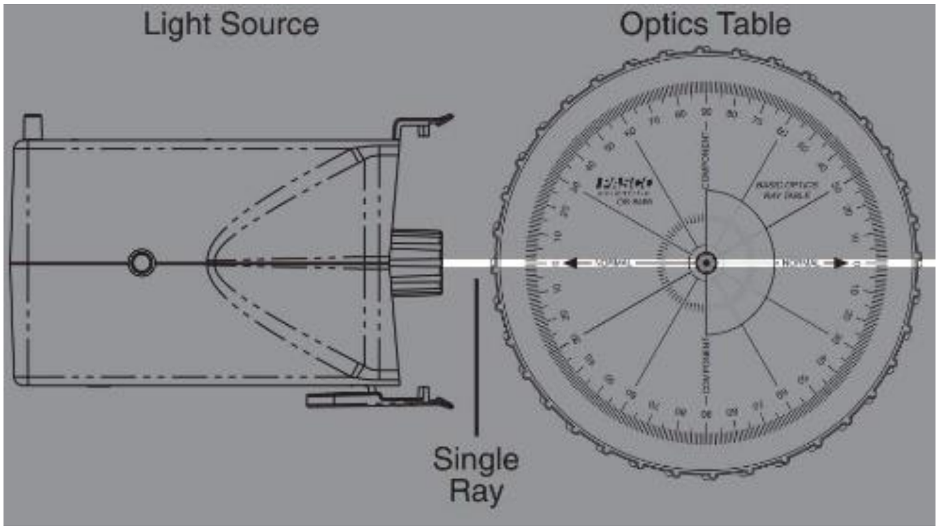
RAY OPTICS LAB. REFRACTION

AP PHYSICS II



Driving Question | Objective

What does refraction mean? How does it affect the path light follows in different mediums?

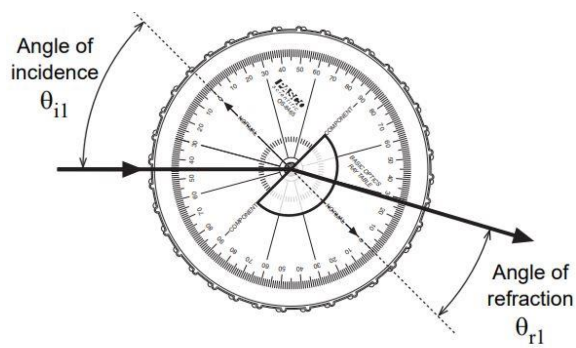
Materials and Equipment

- D-Shaped Lens
- Ruler
- Light Source
- Rotating Ray Table
- White Paper

Part 1: Fast to Slow

1. Place the D-Shaped Lens on the Rotating Ray Table in the outlined portion. Assure that the "fogged" side of the lens is placed downward.

2. With dim lighting in the room, turn on your light source and set it into Ray Box mode to emit 1 ray.



3. Aim the ray perpendicular toward the flat portion of the D-Shaped Lens, as seen in the image above.

4. As the ray is shining through the D-Shaped Lens, note the angle the *incident ray* makes with the normal line as it enters the lens and the angle of the *refracted ray* makes with the normal line in the curved portion of the lens. At first, the incident and refracted rays should be lined up with the normal lines on both sides of the lens. The image to the right might help.

5. Begin *slowly* rotating the ray table, and note the angles of incidence and angles of refraction. Record these values on a piece of paper, as they will be analyzed at a later point in this lab.

6. How do these two angles compare? Which one is smaller/larger?

The refracted ray is always smaller than incident ray.

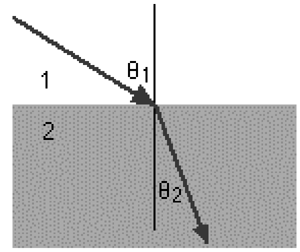
7. As you start to rotate the ray table to larger angles, is there any notable effect that occur aside from the light entering the prism?

The light refracts in a slightly different angle one way, and then when it brought back to 9 degrees it refracts in a different way.

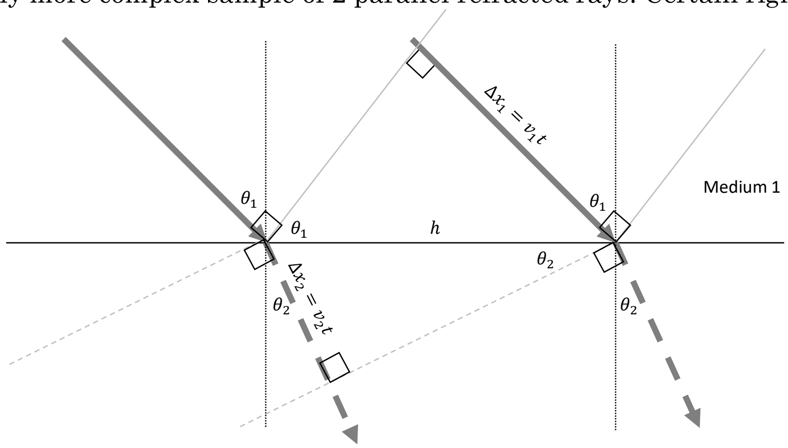
Analysis

❷ 1. Let's create a relationship between the indices of refraction and the angles of incidence and refraction.

a) Let's begin by looking at a basic sample of a refracted ray.



b) Now let's look at a slightly more complex sample of 2 parallel refracted rays. Certain right angles have been identified.



c) Defining a few variables, we have:

   a. $\boldsymbol{\theta_1}$**:** The angle of incidence. There are some other geometrically equivalent angles labeled above.
   b. $\boldsymbol{\theta_2}$**:** The angle of refraction. There are some other geometrically equivalent angles labeled above.
   c. $\Delta \boldsymbol{x_1} = \boldsymbol{v_1 t}$**:** The distance the incident light travels in a time t.
   d. $\Delta \boldsymbol{x_2} = \boldsymbol{v_2 t}$**:** The distance the refracted light travels in *the same time* t.
   e. $\boldsymbol{h}$**:** an arbitrary distance between the 2 incident rays when they change mediums.

d) Using the variables above, express h in terms of $\boldsymbol{v_1 t}$ and $\boldsymbol{\theta_1}$. $\boldsymbol{h} = v_1 * t/\sin(\theta_1)$

e) Using the variables above, express h in terms of $\boldsymbol{v_2 t}$ and $\boldsymbol{\theta_2}$. $\boldsymbol{h} = v_2 * t/\sin(\theta_2)$

f) Set these h's equal to each other. $\frac{v_2 t}{\sin(\theta_2)} = \frac{v_1 t}{\sin(\theta_1)}$

g) Now lets define an **index of refraction** of a material, n, to be the ratio of the speed of light in a vacuum, c, to the speed of light in that material, v: $\boldsymbol{n} = \frac{c}{v}$

   a. Thus $n_1 = \frac{c}{v_1}$, and $n_2 = \frac{c}{v_2}$.

h) Find an algebraic method to incorporate the indices of refraction, n_1 & n_2 into your equation from f).

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

This equation is called ***Snell's Law***. *I would like for you to do the trhetaigonometry above to derive the equation for Snell's Law. However, if you must, you can google the equation.*

Data

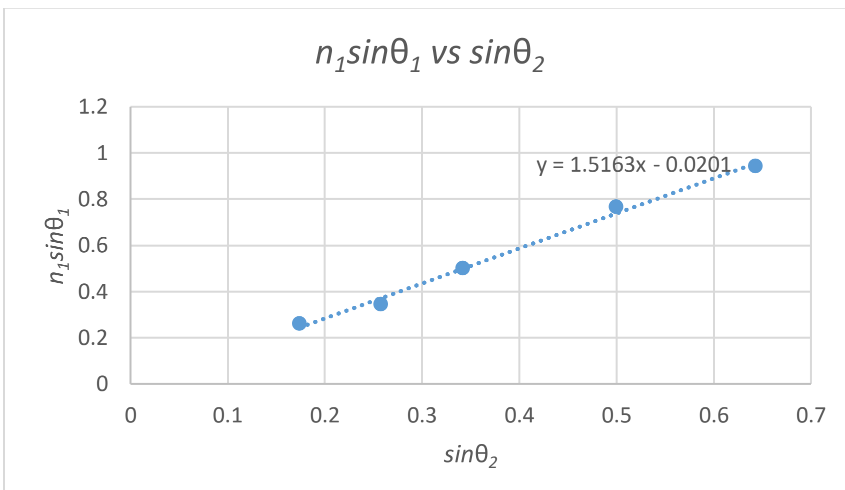
1. Watch the walkthrough video found on Schoology and complete the data below:
    a. n_1: The index of refraction of the medium in which the incident light is present.
    b. n_2: The index of refraction of the medium in which the refracted light is present.
    c. θ_1: The angle of incidence, as measured from the normal of the surface.
    d. θ_2: The angle of refraction, as measured from the normal of the surface.

2. In the data table below, please record your data of multiple incident angles, θ_1

$$n_1 = n_{air} \approx 1$$

θ_1	θ_2	$n_1 \sin \theta_1$	$\sin \theta_2$
15	10	.258	.174
20	15	.342	.258
30	20	.500	.342
50	30	.766	.500
70	40	.940	.643

3. From your data above, plot a $n_1 sin\theta_1$ vs. $sin\theta_2$ graph.



4. What type of relationship exists with the graph above?

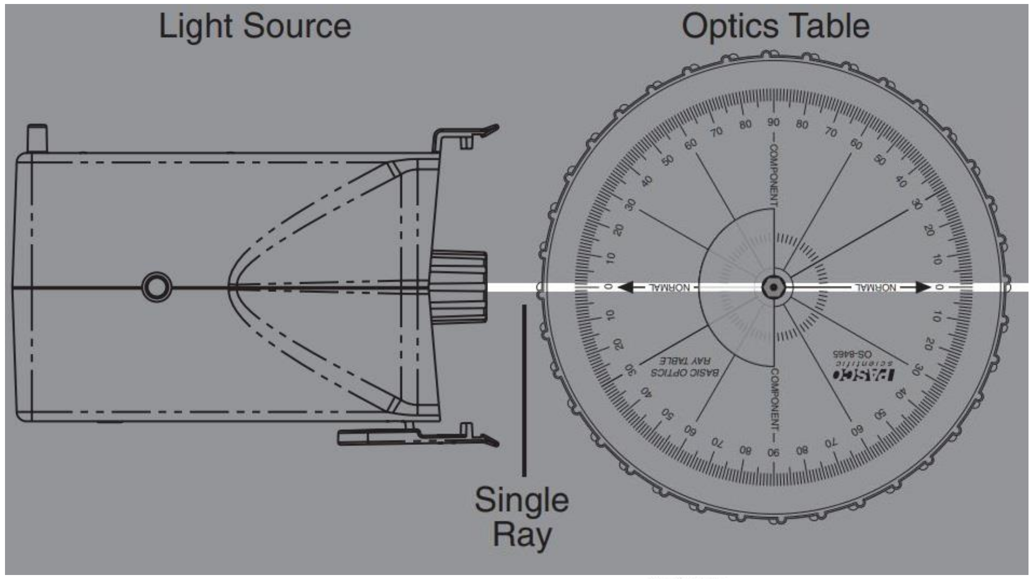
Direct linear relationship

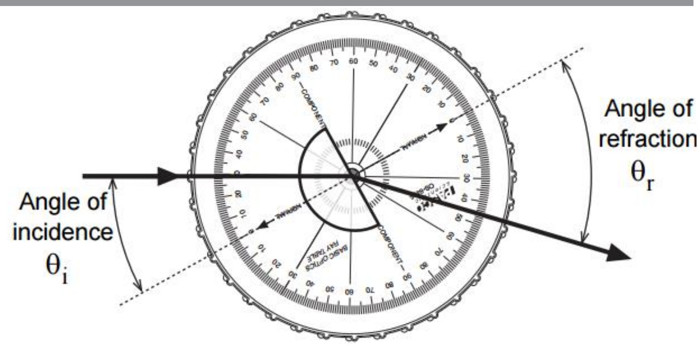
5. What aspect of the graph would represent the index of refraction of the acrylic D-shaped lens? What is the actual value of the index?

The slope of the graph is the index of refraction. The index of refraction we found was ~1.5163.

Part 2: Slow to Fast

1. We are going to do a similar experiment, but this time with the light ray going from a slow medium (acrylic) to a fast medium (air). Begin by setting up the equipment in the orientation seen in the image to the side.
2. Begin rotating the Ray Table and note the angles of incidence and angles of refraction.





3. Continue rotating the Ray Table until the refracted angles become very close to 90 degrees. Is there anything interesting happening? The angle of refraction is always larger than the angle of incidence and as the angle of refraction approaches 90, the light refracted compared to the incidence light is more and more obviously bent.
4. Note that the maximum angle of refraction possible is 90 degrees. The angle of incidence in which this occurs is referred to as the **critical angle** of the material!
5. Please note that a critical angle can only be determined IF the light transitions from the slow (high index) material to the fast (low index) material.
6. Critical Angle Formula: Use the space below, while beginning with Snell's Law to determine the equation for critical angle:

$$n_1 \sin \theta_{critical} = n_2 \sin 90$$

$$\theta_{critical} = \text{arcsin(n2/n1)}$$

Interesting Note: Some real applications of this effect would be technology called "Fiber Optics," in which data is sent down clear cables. The light bounces around the cable