NAME PERIOD DATE

6. SNELL'S LAW

STRUCTURED

Driving Question | Objective

What is the index of refraction of a transparent material provided by your instructor? Using the principles of refraction and Snell's law, experimentally determine the index of refraction of a transparent medium.

Materials and Equipment

- PASCO Basic Optics Ray Table[1]
- Transparent material with unknown index of refraction
- PASCO Basic Optics Light Source[2]

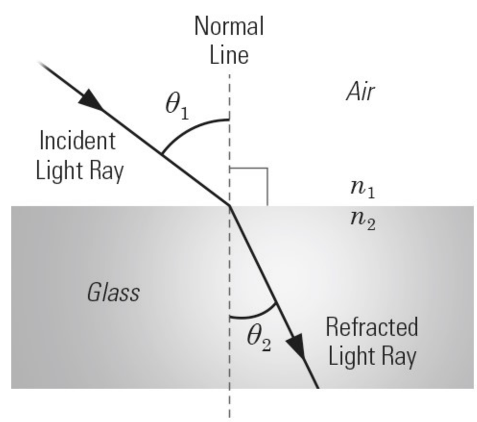
[1]www.pasco.com/ap27 PASCO Basic Optics Ray Table

[2]www.pasco.com/ap26 PASCO Basic Optics Light Source

Background

Light crossing a boundary between two transparent materials changes direction if the speed of light within those materials is different. This direction change is known as *refraction*.

Light traveling from a material in which it has high speed (like air) to a material in which it has slower speed (like glass) experiences refraction *toward* the normal line perpendicular to the boundary, and light traveling from a material in which it has slower speed to a material in which it has greater speed experiences refraction *away* from the normal line.



The amount of refraction experienced by light as it passes between two transparent materials is dependent on the angle at which the light is incident upon the boundary between the materials and the *index of refraction* of each material. The formula relating these quantities is known as Snell's law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \tag{1}$$

where n_1 and n_2 are the indices of refraction of the first and second material, θ_1 is the incident angle the incoming light ray makes relative to the normal line, and θ_2 is the angle the refracted light ray makes relative to the normal line.

In this experiment you will employ Snell's law to determine the index of refraction of a D-shaped piece of transparent material. For the purpose of this experiment, assume that the index of refraction of air is effectively equal to 1.00.

RELEVANT EQUATIONS

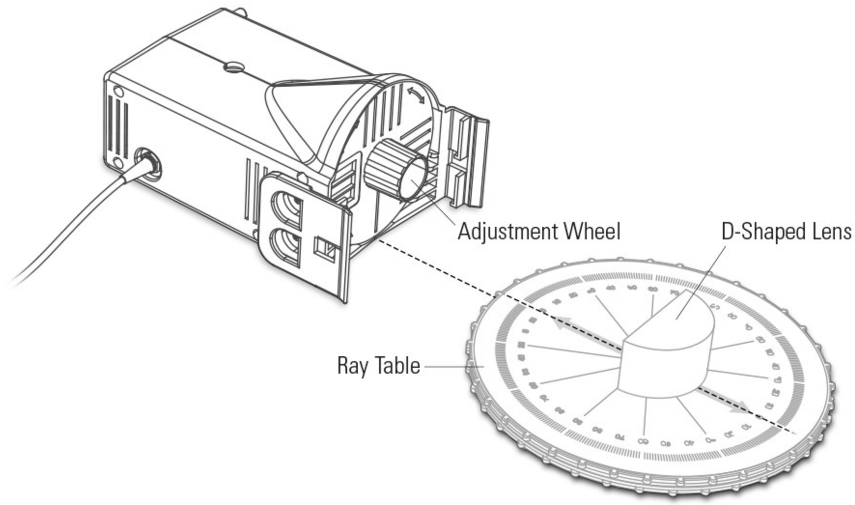
$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \tag{1}$$

Procedure

SET UP

1. Plug in the light source to turn it on, and then turn the wheel on the front of the light source so that a single light ray is emitted. Place the light source flat on the lab table.

2. Place the ray table in front of the light source so it is not more than 10 cm from the light source, and then adjust the position of the ray table so that the single light ray crosses the exact center of the ray table (along the "normal" line).



3. Set the D-shaped lens in the marked outline on the ray table, with the frosted side of the lens down, against the ray table.

4. Rotate the ray table so the light ray enters the lens at the center of its flat surface with an incident angle of 10°. Use the degree scale on the ray table to determine the incident angle.

   NOTE: The light ray refracts as it crosses the boundary from air to the lens material, but it does not *refract as it crosses the boundary from lens to air. This is because the circular shape of the lens causes the incident angle of the light ray at the lens–air boundary to be zero.*

COLLECT DATA

5. Use the degree scale on the ray table to measure the incident and refraction angles. Record both angles in the Trial 1 row of Table 1 in the Data Analysis section below.

6. Rotate the ray table to increase the incident angle by 15° so the light ray enters the lens at the center of its flat surface with an incident angle of 25°.

7. Measure and record the new incident and refraction angles in the Trial 2 row of Table 1.

8. Repeat the data collection steps three additional times, increasing the incident angle by 15° each time. Record the incident and corresponding refraction angles for each trial into Table 1.

Data Analysis

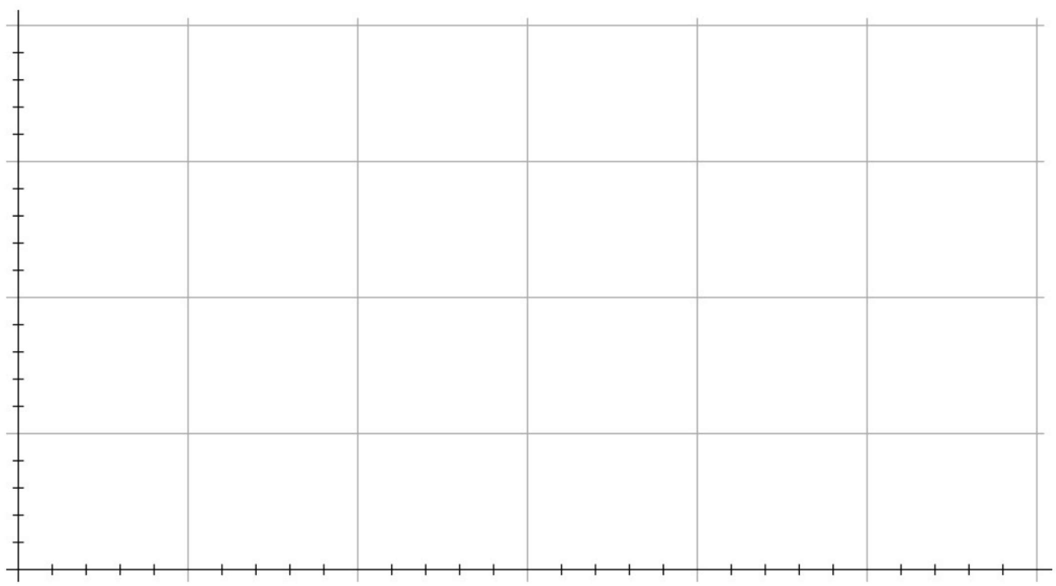
Table 1: Incident and refraction angles of a light ray crossing from air into an unknown transparent medium

Trial	Incident Angle θ_1 (°)	Refraction Angle θ_2 (°)	sin θ_1	sin θ_2
1				
2				
3				
4				
5				

1. Calculate the sine of the incident angle θ_1 and refraction angle θ_2 for each trial. Record your results into Table 1.

2. Plot a graph of *sin* θ_1 versus *sin* θ_2 in the blank Graph 1 axes below. Be sure to label both axes with the correct scale and units (if any).

Graph 1: Sine of incident angle versus sine of refraction angle for a light ray crossing from air into an unknown transparent medium



3. Draw a line of best fit through your data in Graph 1. Determine and record the equation of the line here:

   Best fit line equation: ____

4. Use the slope from the best fit line to determine an experimental value for the index of refraction n_2 of the D-shaped transparent material:

   $\text{slope} = \frac{n_2}{n_1}$ where $n_1 = 1.00$ (index of refraction for air)

   Index of Refraction n_2: ____

Analysis Questions

1. What is your experimental value for the index of refraction of your transparent material? How did you determine this value from your data?

2. Below is a list of refractive indices for common materials. Use this table and your experimental value for the index of refraction to determine a potential candidate for your transparent material. Calculate the percent error between your experimental value and the index of refraction value of your candidate.

Material	Index of Refraction
Quartz	1.41
Acrylic glass	1.49
Polycarbonate	1.58
Dense crown glass	1.67
Diamond	2.42

$$\text{Percent error} = \left|\frac{\text{Theoretical} - \text{Experimental}}{\text{Theoretical}}\right| \times 100$$

3. Find another lab group that tested the same transparent material. Calculate the percent difference between your experimental value and their experimental value of the index of refraction.

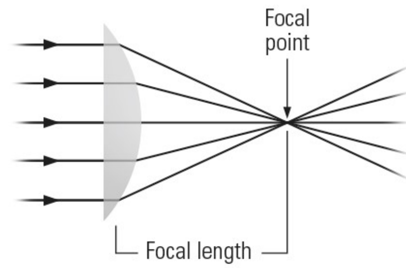
$$\text{Percent difference} = \frac{\left|\text{Group}_2 - \text{Group}_1\right|}{\left|\left(\text{Group}_1 + \text{Group}_2\right)/2\right|} \times 100$$

4. What are factors that might have caused error in your measured value of index of refraction?

Synthesis Questions

1. A solid piece of clear transparent material has an index of refraction of 1.61. If you place it into a clear transparent solution and it seems to disappear, approximately what is the index of refraction of the solution? How do you know?

2. Some lenses are shaped with one flat side and one spherically-shaped side. This shape is designed to focus parallel light rays onto a single point. In a few sentences, explain how the spherical shape of the lens' surfaces causes parallel light rays to focus on a single point. (Assume the light is travelling through air into a lens with an index of refraction greater than that of air.)



3. A ray of light travels from glass to air with an incident angle of 37° from the normal. What is the refraction angle? Assume $n_{\text{glass}} = 1.50$ and $n_{\text{air}} = 1.00$.

4. A laser beam is incident at an angle of 38.7° on a 0.0253 m thick piece of glass with a fully reflective coating on its bottom surface. Part of the laser beam is reflected off the top surface of the glass at point A, and part is transmitted through the glass to point B where it is reflected and sent out of the glass at point C. If both surfaces of the glass are flat and parallel, what is the perpendicular distance d between the two outgoing beams? Assume $n_{\text{glass}} = 1.50$ and $n_{\text{air}} = 1.00$.