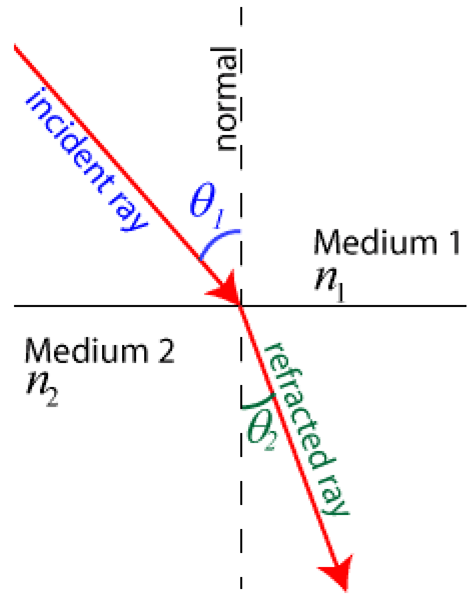
Refraction and Its Applications

Background:



Snell's Law describes how light is refracted as it passes between two mediums. This happens when light travels at different speeds in each medium. The way we describe the speed of light in a medium is by using the *refractive index, n*. A refractive index of n=1 means that light travels at $c = 3.0\times10^8$ m/s, and a larger refractive index indicates that light travels at a slower speed. By the ratio below, we can figure out the angle at which a light ray traveling through one material is refracted as it enters another material:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

θ_1 is the angle of incidence
θ_2 is the angle of refraction
n_1 and n_2 are the refractive indices of mediums 1 and 2
For air, $n \approx 1$.

Experiment 1: Refraction between air and water

Aim: To measure the refractive index of water.

Materials:
Plastic box   Incense stick   Lighter   Laser   Protractor

Method:
1. Fill the plastic box with water up to the center of the protractors.
2. Put the cover on the box. Light the incense, insert it into the hole on the side of the box, and fill the rest of the container with smoke. This will allow you to see the path of the laser light as it travels through air.
3. Use the protractors to shine the laser beam at a 40° angle to water's surface. Make sure to measure the angle coming down from the top! (In the diagram above, we want to make θ_1=40°).
4. Measure the angle of refraction, θ_2, the angle made by the beam visible in the water. Record this in the results table.

5. Using Snell's law, calculate the ratio n_2/n_1 from your measurements. Because n_1 = 1 for air, this will give you n_2, the refractive index of water. Record your data in the results table.
6. Repeat steps 3 and 4 for 30°, 20°, and 10°.
7. Calculate the average refractive index.

Results:

Angle of incidence	Angle of refraction	Refractive index $n_2 = n_2/n_1 = \sin\theta_1/\sin\theta_2$
40°		
30°		
20°		
10°		
		Average:

Question:
The refractive index is a property of the material, so ideally each angle of incidence would give you the same refractive index. What do you think accounts for the difference between the average refractive index and your measurements for each angle?

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Experiment 2: Determining the size of a "damaged zone" in an acrylic block

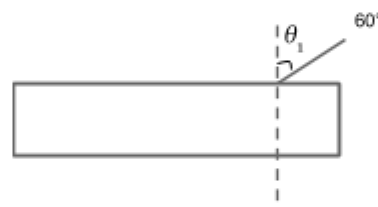
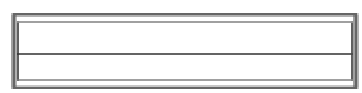
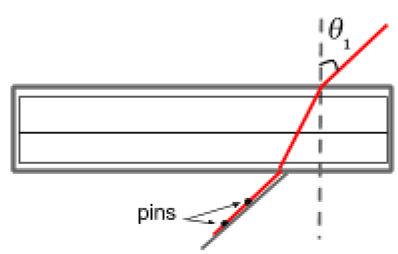
Aim: To use a non-destructive test for measuring the size of a "damaged zone" in a block of acrylic. We will simulate this by using two acrylic blocks with an air gap between them.

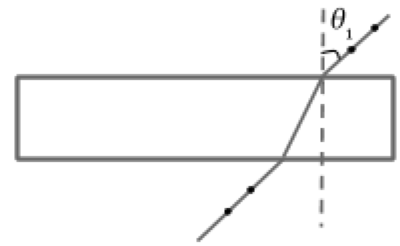
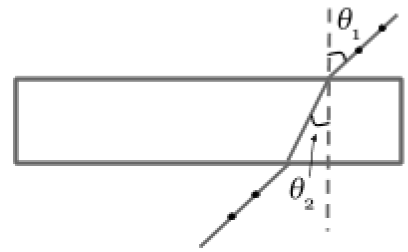
Materials:

2 Acrylic blocks	Worksheet	Poster board	Pencil	Laser
Protractor	4 Pins	Tape		

Part 1 - Finding the refractive index of acrylic

Method:

	Instructions	Diagram
1	Measure the 60° angle of incidence with the protractor to make sure it is accurate. For the 55° and 45° angles, measure and draw the angle of incidence from the dotted line.	
2	Tape the worksheet to the poster board. Place the two acrylic blocks in the outline on the paper. ***Note:*** the blocks have rough sides and smooth sides. Make sure you put the **smooth** sides together (rough sides facing up).	
3	Shine the laser parallel to the table and along the 60° line.	
4	Place two pins on the path of the beam coming out the bottom side of the blocks. Draw a line from the edge of the block and passing through the two pins.	

5	Remove the acrylic blocks. Connect the ends of the two lines you've drawn with a third straight line. This line represents the direction the light traveled through the block.	
6	Measure the angle of refraction using the line drawn in step 5.	
7	Use the formula for Snell's law to calculate the refractive index.	
8	Repeat steps 2-6 for 55° and 45° angles of incidence.	
9	Calculate the average refractive index for the 3 angles of incidence.	

Results:

Angle of incidence	Angle of refraction	$n_2 = n_2/n_1 = \sin\theta_1/\sin\theta_2$
45°		
55°		
60°		
		Average:

Question:

The refractive index of acrylic is 1.49. How did your calculation compare? What do you think might have caused your results to differ?

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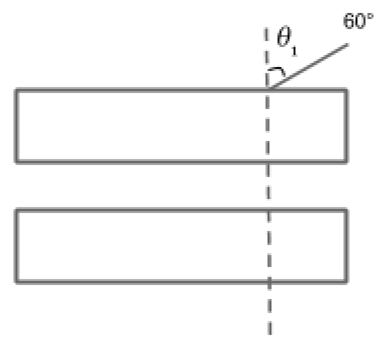
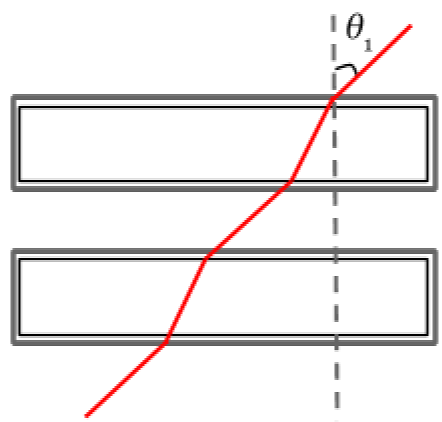
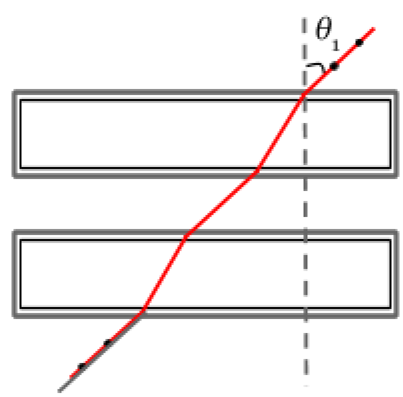
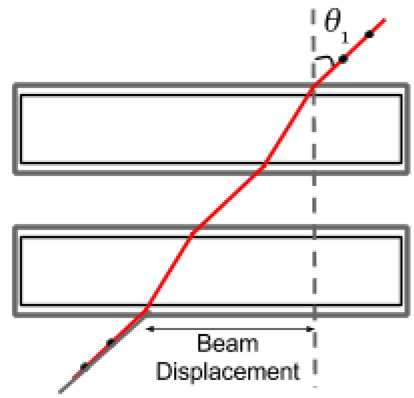
Part 2 - Determining the size of the air gap between two acrylic blocks

Method:

	Instruction	Diagram
1	Now take out the worksheet with the blocks placed a small distance apart. This simulates a "damaged area" inside a block of acrylic, and your goal is to figure out the size (width) of this region using the refractive properties of light.	
2	Check to make sure the 60° angle of incidence is accurate. For the 55° and 45° angles, measure and draw the angle of incidence from the dotted line.	
3	Place the acrylic blocks in their outlines. Shine the laser parallel to the table and along the 60° line.	
4	Place two pins on the path of the beam coming out the bottom side of the blocks. Draw a line from the edge of the block and passing through the two pins.	

5	Measure the distance between the dotted line and the point on the lower block where the light comes out. Record under “Beam displacement” in the results table.	
6	Use the computer program provided by your teacher to calculate the width of the air gap. This program uses Snell’s law at each of the four interfaces and calculates the expected gap width. Record this in the results table.	
7	Now, you can use a ruler to measure the actual width of the air gap. Record in the results table.	
8	Repeat steps 2-7 for 55° and 45° angles of incidence.	

Results:

Angle of incidence	Beam displacement (cm)	Calculated gap size (cm)	Actual gap size (cm)
45°			
55°			
60°			

Calculate the percent error for each of your angles. ***Show your work below.***

Error = $\left| \frac{\textit{Calculated gap size} - \textit{Actual gap size}}{\textit{Actual gap size}} \right|$, then convert from decimal to percent

45°	55°	60°

Did you have any errors greater than 5%? If so, what might have caused this?

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