Reflection and Refraction Lab

Determining the Index of Refraction and Critical Angle

PURPOSE: The purpose of this experiment is to study the two fundamental laws of geometric optics: the law of reflection and refraction between air and liquid.
Observe the total internal reflection of a ray in the liquid and determine the critical angle for water-air interface..
Calculate the index of refraction for water and compare it to the standard value of 1.333.

APARATUS: Diode laser, a circular acrylic tank, water.

DESCRPTION OF APARATUS:

A circular acrylic water tank with a clear front has a white back with a printed protractor. A pivoting arm attached to the back plate can be rotated 360° around the tank and carries a magnetically mounted diode laser with a built-in beam spreader. The tank will be half-filled with water, and a bright, narrow ray is directed onto the water surface from above or below to measure the incident and refracted angles. The critical angle and total internal reflection can also be clearly demonstrated.

BACKGROUND:

Reflection of light from a surface is what allows us to see objects that are not luminous. Different colored objects reflect different colors of light. A mirror is a smooth surface that reflects light in such a way that we can view images of objects.

Law of Reflection:

The Law of Reflection states that if the incoming light forms an angle of incidence (θ_i) with a line normal to the surface, then the light reflected off the surface will form an *angle of reflection* (θ_r) with the normal line which is equal to the angle of incidence.

This is shown in Figure 1.

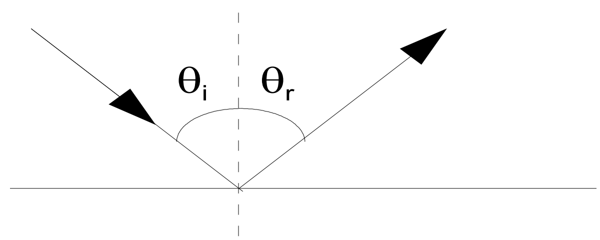

Fig. 1

$$\theta_i = \theta_r$$

Refraction occurs when light changes direction as it passes from one medium to another. For example, a straw in a glass of water may appear bent or disjointed at the surface of the water because the direction of propagation of the light changes when traveling between water, glass, and air.

Law of Refraction:

Snell's Law states that if the incoming light is traveling in a medium with an index of refraction of n_1 and forms an angle of θ_1 with a line normal to the surface as shown in Figure 2, then the light that enters the second medium of index n_2 will form an angle of θ_2 with the normal line where the refracted angle is given by the equation

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Snell's Law predicts that the light will get bent toward the perpendicular line if $n_1 < n_2$ (such as for light in air entering glass) and will get bent away from the perpendicular line if $n_1 > n_2$ (such as for light in glass entering air).

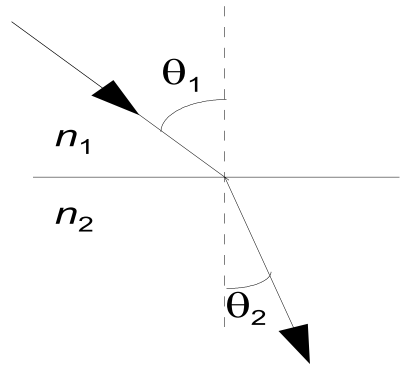

Fig. 2

Experimentally, when $\sin(\theta_2)$ becomes equal to 1, no refraction will take place and the ray is completely reflected back into the first medium. This is called total internal reflection, which occurs if the angle θ_1 is greater than a certain critical angle θ_c.

This angle can be used to check the index of refraction:

$$\sin\theta_c = 1/n$$

PROCEDURE:

CAUTION: Never look directly into the laser beam: it may damage the retina.

Set up the experiment:

1. Place the unit on a flat surface such as a table top.
2. Add water to the tank until it's level reaches the horizontal line on the scale.
3. If the surface of the water does not line up with the horizontal line, adjust the leveling screw(s) at the base to bring them into alignment.
4. Rotate the switch on the laser to turn it on.
5. The laser can move around the tank after the wing nut is loosened. Tighten the wing nut when the lase is set to a desired position.

MEASUREMENTS:

1. Turn on the laser.
2. Loosen the wing nut. Move the laser to the 4th quadrant (right lower corner) and set the angle of incidence to 20^o. Record the angle of reflection and refraction in your table. Theoretically, the angle of incidence and reflection should be equal. Are they (within experimental error)?
3. Change the angle of incidence to 30^o, 40^o, 45^o. Record the angle of reflection and refraction in the table. Observe the brightness of the reflected rays. Compare the angles of incidence with their corresponding angle of refraction.

4. Continue to increase the angle of incidence while observing the change to the reflected ray. At certain point the ray will disappear. The reflection at this point is called total internal reflection. Record the angle of incidence which is called critical angle.
5. Continue to increase the angle of incidence to 50º,70º, 80º. Record in the table the values of angle of reflection and refraction.

Repeat steps 1-5 for the first quadrant (right upper corner). Record your date in the table.

CALCULATIONS:

1. Calculate the $\sin(\theta_1)$, $\sin(\theta_2)$ and $\sin(\theta_3)$.
2. Plot a graph of $\sin(\theta_3)$ vs. $\sin(\theta_1)$ (Table 1). Don't forget to label your axes and write their units.
3. Determine the slope of the graph and calculate the water refraction index.
4. Compare your water refraction index with the standard value of 1.333. Calculate the percent difference.
5. On the same graph plot the $\sin(\theta_3)$ vs. $\sin(\theta_1)$ from Table 2.
6. Discuss the two graphs. How are they different?

Table 1 (water-air)

$\theta_1=\theta_{incidence}$	$\theta_2=\theta_{reflection}$	$\theta_3=\theta_{refraction}$	$\sin(\theta_1)$	$\sin(\theta_2)$	$\sin(\theta_3)$
20					
30					
40					
45					
$\theta_c=$					
50					
70					
80					

Plot a graph of $\sin(\theta_3)$ vs. $\sin(\theta_1)$ (Table 1). Don't forget to label your axes.

Determine the slope of the graph and calculate the water refraction index.
How is the slope related to the water refraction index.

Compare your value with the standard value for water refraction index of 1.333 using the percent difference formula.

Table 2 (air-water)

$\theta_1=\theta_{incidence}$	$\theta_2=\theta_{reflection}$	$\theta_3=\theta_{refraction}$	$\sin(\theta_1)$	$\sin(\theta_2)$	$\sin(\theta_3)$
20					
30					
40					
45					
50					
60					
70					
80					

On the same graph plot $\sin(\theta_3)$ vs. $\sin(\theta_1)$ from Table 2.

Discuss the two graphs. How are they different?

0.5 Centimetre Graph Paper