PHYS 1402
General Physics II

EXPERIMENT 7
INDEX OF REFRACTION, REFLECTION AT BREWSTER'S ANGLE AND POLARIZATION

I. OBJECTIVE:

The objective of this experiment is to measure the index of refraction of lucite glass by measuring the angles of incidence and refraction. We will also measure the critical angle and Brewster's angle (the polarizing angle) for air/lucite.

II. THEORY:

When light travelling in one medium encounters another medium of different properties, generally at the interface between the two media, part of the light is reflected and the other part is refracted (passes to the second medium). At the interface between air and glass, the large part of the light is refracted. The angle the ray of light in medium 1 makes with the normal (the perpendicular) to the interface is the angle of incidence, θ_1 and the angle the refraced ray makes with the normal is the angle of refraction θ_2.
Snell's law gives us a relationship between the angle of incidence θ_1 and the angle of refraction θ_2

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

where n_1 and n_2 are the indices of refraction of the first and second media respectively. Light passing from a less dense medium (like air) to a more dense medium (like water or glass) will refract towards the normal and vice versa.

III. APPARATUS:

Helium-neon laser, Hartl disc with semicircular glass prism, mounting rods and clamps and polaroid sheets.

IV. EXPERIMENTAL PROCEDURE:

PROCEDURE (1): REFRACTION

1. CAUTION: DO NOT LOOK DIRECTLY INTO THE BEAM.

2. Mount the laser and place the Hartle disk as shown in Figure (1).

3. Make sure the semicircular prism is centerd on the protractor. Align the system such that the beam enters the flat surface of the prism at the center (along the center line) and leaves the other side of the prism undeflected. Situate the Hartle disk to make it easy for you to read the angles.

4. Rotate the prism 180°. Now the light is incident on the curved side along a radial direction and therefore passes through the air- glass interface undeflected. The deflection will happen at the flat side (the glass/air interface).

5. Set the angles of incidence as given in Table (1) and measure the angles of reflection and refraction and record the data in Table (1). Notice that the reflection and refraction of interest here are off the flat side of the prism. Hence the medium 1 (described by n_1) is glass and medium 2 (described by n_2) is air.

PROCEDURE (2): INTERNAL REFLECTION

1. Increase the angle of incidence and watch as the angle of refraction approaches values close to 90°. The angle of incidence for which the angle of refraction is 90° is the critical angle for air/glas refraction. Record the measured critical angle in Table (1).

2. For angles of incidence larger than the critical angle, the beam will reflect internally and there will be no refracted beam. Observe total internal reflection by measuring the angle of reflection for the three cases given in Table (1). Is the angle of reflection equal to the angle of incidence?

PROCEDURE (3): BREWSTER'S ANGLE

1. Rotate the Hartle disk 180°. Now the beam enters the semicircular prism from the flat side.

2. Place a ploarizer in the way of the beam. Place the polarizer over the opening of the laser. Now increase the angle of incidence and watch for the reflected beam. You may have to turn the room light off for this procedure. You should reach an angle where the reflected beam vanishes. Record the angle of incidence where this happens. This is the polarizing angle or Brewster's angle for air/glass.

3. If you do not reach an angle where the reflected beam vanishes, rotate the polarizer by 90° and repeat the procedure. Now you will reach an angle of incidence where the reflected beam vanishes. Note: It is best to have the polarizer upright and not tilted because the polarization axis is parallel to one of the sides and it is easiest to keep track of how much you rotated the polarizer if you have it upright.

V. ANALYSIS

1. Calculate the index of refraction of glass for each of the cases of procedure (1) using Snell's law:

$$n_{\text{glass}} \sin\theta_i = n_{\text{air}} \sin\theta_r \tag{2}$$

   The index of refraction of air is $n_{\text{air}} = 1.000293$ and for our purposes can be taken to be $n_{\text{air}} = 1.00$.

2. Calculate the index of refraction of glass using the critical angle case. Snell's law applied to this case becomes:

$$n_{\text{glass}} \sin\theta_{\text{crit}} = n_{\text{air}} \sin 90^\circ. \tag{3}$$

3. Calculate the index of refraction of glass using the Brewster's angle. Snell's law applied to this case becomes $n_{\text{air}} \sin\theta_p = n_{\text{glass}} \sin(90 - \theta_p)$. This simplifies to $n_{\text{air}} \sin\theta_p = n_{\text{glass}} \cos\theta_p$ and therefore

$$n_{\text{glass}} = \tan\theta_p. \tag{4}$$

4. Calculate the average value for the index of refraction of glass. There are many types of glass each of which has its own index of refraction. We are not given the value of the index of refraction for the glass piece you used in this experiment for comparison purposes. However, a nice round number to use is 1.5. Find the % difference between this value and the value you calculated from your data.

5. Assume the critical angle for glass/air is $\theta_{\text{crit}} = 41.8^\circ$ and calcualte the % difference between this value and the measured θ_{crit}.

6. Assume the accepted value for Brewster's angle is 56.3° and calculate the % difference between this value and the measured value.

7. Draw a diagram showing the semicircular lucite glass and the incident light at angle of incidence 30° and the refracted light at the measured angle of refraction.

8. Draw a diagram similar to the one above showing the incident light at the critical angle and the refracted light.

9. In your conclusion, comment on the accuracy of this experiment. What is the largest percent difference? What are the two most important sources of error?

Experiment (7) Data Table				
Procedure	Angle of Incidence θ_{i} (degrees)	Angle of Reflection θ_{refl} (degrees)	Angle of Refraction θ_{refr} (degrees)	Index of Refraction of Lucite n
Reflection and Refraction	15			
	20			
	25			
	30			
	35			
	40			
Critical Angle			90	
Total Internal Reflection	45		XXXXXXXXX	XXXXXXXXX
	50		XXXXXXXXX	XXXXXXXXX
	55		XXXXXX XXX	XXXXXXXXX
Brewster's Angle			XXXXXXXXX	
				$n_{\mathrm{ave}} =$