Physics Lab 18: Refraction, Polarization of Light

Goals: Improve communication skills; Improve ability to make, describe, and record observations; Observe and/or measure the interaction of light and matter, in particular refraction, total internal reflection, and polarization; Use Snell's Law of Refraction to calculate index of refraction; Find fun with physics phenomena.

Equipment: Polarizing filters; light sources; water tank. Semi-circular tanks (D tanks); angle template; tray; protractor & ruler; graph paper; laser; backstop; index card; fiber optic cables; various plastic shapes; water and sugar water; graduated cylinders/beakers.

Groups & Lab Notebook: You will be assigned to lab pairs (there may be one lab triple). Draw representative set-ups and other figures as directed. Organize data into tables. Update Table of Contents. Your physics lab notebook should reflect your learning and your engagement, and should serve as a ***stand-alone*** representation of what you did and what you learned.

Part 0: Overview, Theoretical Background, and Experimental/Equipment Orientation

Today's lab consists of two distinct sections. In Part 1: Polarization, one or two lab groups at a time will be brought over to the Polarization Station and guided through the activities. Begin your lab notebook with one page devoted to this part. You can do this part at any time, so work on the other parts of the lab (in order) until brought over to the Polarization Station. The other parts of the lab deal with refraction of light. As a class, we'll discuss the theory of refraction, safety issues, and how to make measurements.

Part 1: Polarization Station

In your lab notebook, record the various activities and observations. We'll use your observations during lecture discussion. Activities: looking at various light sources through one, two, or three polarizers oriented at various angles.

Part 2: Refraction – Air into Water

CAUTION REMINDER: Don't look directly into laser beam. Use backstop to prevent laser beam from going into other people's eyes and minimize uncontrolled reflections.

REMINDER: All angles are measured with respect to the *normal*, i.e., from a line that is perpendicular to the interface.

1. Set up your system so you measure angles for light in air going into water as the straight interface.
2. Carefully set your incident angle to be 0^o, and confirm that your refracted angle is also 0^o.
3. Carefully set your incident angle to be 30^o. See if you can notice that the reflected beam is also at 30^o. Confirm that your refracted angle is between 20^o and 24^o. If not, call over an instructor for trouble-shooting. Carefully measure and record your refracted angle to the nearest 0.5^o.
4. Draw and label a schematic figure showing a top-down view of your set-up and experimental results, with angles indicated (use a protractor). Note: Don't draw figures for other measurements in this part.
5. Collect data for incident angles of 10^o, 20^o, 30^o, 40^o, 50^o, 60^o, 70^o, 80^o. Record your data in a table with three columns: (set) angle of incidence θ_1, (measured) angle of refraction θ_2, and any notes about the measurement, particularly if there were any difficulties.

Part 3: Refraction – Water into Air

1. Set up your system so you measure angles for light in water going into air at the straight interface.
2. Carefully set your incident angle to be 0^o, and confirm that your refracted angle is also 0^o.
3. Carefully set your incident angle to be 30^o. See if you can notice that the reflected beam is also at 30^o. Confirm that your refracted angle is between 40^o and 44^o. If not, call over an instructor for trouble-shooting. Carefully measure and record your refracted angle to the nearest 0.5^o.
4. Draw and label a schematic figure showing a top-down view of your set-up and experimental results, with angles indicated (use a protractor). Note: Don't draw figures for other measurements in this part.
5. (Try to) Collect data for incident angles of 10^o, 20^o, 30^o, 40^o, 50^o, 60^o, 70^o, 80^o. Spoilers: you will have some issues with some angles. Record your data in a table with three columns: (set) angle of incidence θ_1, (measured) angle of refraction θ_2, and any notes about the measurement, particularly if there were any difficulties (you will have some difficulties with some angles).
6. You probably noticed that above a certain critical angle of incidence, there was no longer a refracted beam, but only a reflected beam. This phenomenon is known as **total internal reflection.** Try to measure the critical angle of incidence for which the refracted beam disappears and there is only a reflected beam. It might be hard to notice when the refracted beam disappears, but when it does, the reflected beam might become noticeably brighter. As best you can, record the critical angle of incidence, and record θ_{cr} along with some estimate of the uncertainty in the angle measurement.

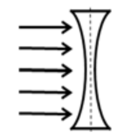
Note: You can do Part 4, Part 5, and Part 6 in any order. If all the plastic shapes you need for Parts 4 and 5 are being used, work on Part 6, or move on to the ANALYSIS section. When you are done with a plastic piece, please return it to its original box, and pass it on to another group.

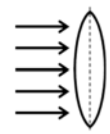
Part 4: Refraction – Plastic

1. Obtain a solid plastic semi-circle. Set up so you measure angles for light in air going into plastic at the straight interface.
2. As before, measure the angles of refraction for angles of incidence 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°. Don't draw any schematics. Record your data in a table.
3. Set up the system so light goes from plastic into air at the straight interface. Find θ_{cr}.

Part 5: Other Plastic Shapes

1. Obtain a plastic rectangle and the two lens shapes as shown below. Also get a piece of graph paper. You will place the shapes on the paper, and trace shapes and lines onto that paper, which you will cut and tape into your lab notebook.
2. Use the plastic rectangle. Shine the laser so it makes a straight line on the graph paper, following one of the graph lines, and carefully trace that straight laser line on the paper (use a ruler). Place the middle of the plastic rectangle in the path of the beam such that the angle of incidence is <u>**not**</u> 0°. Trace the plastic rectangle on the graph paper and mark the point where the beam enters and exits. Trace the path of the beam leaving the rectangle.
3. Use the plastic "lens" shaped as in the figure to the right. Place it on the graph paper, oriented so that the dashed line as shown in the figure is on one of the graph paper lines, and trace the lens. Shine the laser beam through the lens at one side of the lens making sure that the laser beam is aimed ***perpendicular*** to the center line of the lens. Trace the laser line. On the paper beyond the lens, trace the exit beam. Move the laser, and repeat for a total of five parallel lines. Remove the lens, and extend the exit beams using a ruler.
4. Repeat the previous step, but this time use the plastic "lens" shaped as in the figure to the right.





Part 6: Refraction – Sugar Water

1. Fill your D tank with sugar water (also record the concentration, which is noted on the board). Set up so you measure angles for light in air going into sugar water at the straight interface.
2. As before, measure the angles of refraction for angles of incidence 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°. Don't draw any schematics. Record your data in a table.
3. Set up the system so light goes from sugar water into air at the straight interface. Find θ_{cr}.
4. Return the sugar water to its original beaker.

ANALYSIS

1. From Snell's Law of Refraction and your data from Part 2, determine $n_{water} = n_2$ using each θ_1 and corresponding θ_2. Recall that $n_1 = n_{air} \approx n_{vacuum} = 1$. Find the average of the n_{water} results you find for the 8 calculations. Determine the standard deviation of these measurements. Report your average value and standard deviation for n_{water}.
2. From Snell's Law of Refraction and your data from Part 3, determine $n_{water} = n_1$ using each θ_1 and corresponding θ_2. Recall that in this case $n_2 = n_{air}$. Find the average of the n_{water} results you find for the 8 calculations. Determine the standard deviation. Report the average value and standard deviation for n_{water} that you find.
3. Discuss whether the two values you determined for n_{water} are consistent with each other.
4. Discuss whether the two values you determined for n_{water} are consistent with accepted value $n_{water} = 1.33$.
5. Total internal reflection occurs when the angle of refraction is 90°. This means that the refracted beam lies along the interface and never actually enters the second region. So, for $\theta_1 = \theta_{cr}$ then $\theta_2 = 90°$. Recall that for this geometry, $n_1 = n_{water}$ and $n_2 = n_{air} = 1$. Use this information to determine n_{water} using θ_{cr}. Discuss whether the value obtained for n_{water} in this analysis is consistent with your previous reports for n_{water} and the accepted value.
6. Repeat these analyses to determine $n_{plastic}$.
7. Repeat these analyses to determine $n_{sugar\ water}$. Have Paul show you the refractometer.

CHALLENGE: DETERMINING CONCENTRATION OF UNKNOWN. Begin if there is time.

Obtain a sugar water solution of unknown concentration. Make a calibration curve for $n_{sugar\ water}$ vs. concentration for various concentrations of sugar water that you dilute from the starting stock solution. Measure $n_{unknown}$ and use your calibration curve to determine the unknown concentration. A prize will be awarded to each person in each group that can determine the unknown concentration.

CLEAN-UP: Return all equipment to location where you obtained it, particularly returning plastic pieces to their original cases/boxes. Water and sugar water can be poured down sink. Rinse out tanks with DI water, and place them on drying racks. Wipe off/dry lab tables. Ask Paul or Krishna if there are any community tasks (there might not be for this lab).