(TA INITIALS)

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Experiment 4

Refraction of light

Part 1: Refraction into a denser medium

You will verify Snell's Law using a semi-circular plastic prism as the second medium, as shown in Figure 4.1. Arrange the prism so that it is *concentric* with the paper protractor, with the flat surface lined up with the 90° line so that the normal (0°) is perpendicular to the flat face of the prism.

Since the incident beam of light has a finite width, the same edge of the beam should be used to set the incident angle i and to measure the refracted angle r. Make sure that this edge of the beam passes through the centre point of the protractor, otherwise your angle measurements will be incorrect.

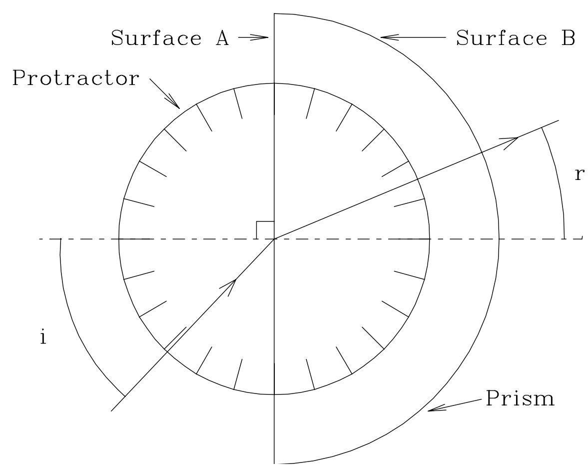

Figure 4.1: Refraction into a denser medium

? Does the refracted beam display any notable dispersion? Should the beam exhibit this dispersion? On what line of reasoning do you base your conclusion?

- Vary the incident angles i by rotating the prism/protractor combination, in 10° increments from 0° to 80°, and measure the corresponding refracted angle r values. Enter your results in Table 4.1.

? What is the resolution of the protractor scale? How well can you estimate a value for an angle with this scale? Did you express the above measurements to this precision?

- Calculate the values of $\sin i$ for the incident angles i and $\sin r$ for the refracted angles r. Enter the results in Table 4.1.

Equation 4.2 can be rearranged to give $\sin i = (n_{II}/n_I)\sin r$. This is the equation of a line with slope (n_{II}/n_I). Because in our case the incident medium is air, with index of refraction $n_I \approx 1$, a plot of $\sin i$ as a function of $\sin r$ will yield a line of slope n_{II}.

- Close any running Physicalab windows, then start a new session by clicking on the Desktop icon and login with your Brock student ID. You will email yourself all the graphs for later inclusion in your lab report.

- Enter the pairs of values ($\sin r, \sin i$) in the Physicalab data window. Select **scatter plot**. Click **Draw** to generate a graph of your data. The displayed data should approximate a straight line.
- Select **fit to: y=** and enter **A*x+B** in the fitting equation box. Click **Draw** to fit a straight line to your data. Label the axes and title the graph with your name and a description of the data being graphed. Click **Send to:** to save a copy of the graph.
- Record the values for the slope and the standard deviation of the slope obtained from the graph.

$$n_{II} = \ldots\ldots\ldots\ldots\ldots\ldots \pm \ldots\ldots\ldots\ldots\ldots\ldots$$

$i°$	0	10	20	30	40	50	60	70	80
$r°$									
$\sin i$									
$\sin r$									

Table 4.1: Exprimental results for Part 1

Part 2: Refraction from a denser medium

The refractive index n for the plastic was determined in Part 1 using light travelling from air to plastic.

? Should n for the plastic prism be the same if it is measured using a light ray passing from plastic to air? On what line of reasoning do you base your conclusion?

- To test your hypothesis, place the light source on the opposite side of the prism, as shown in Figure 4.2. Aim the beam of light so that it passes through the curved prism face (surface B).

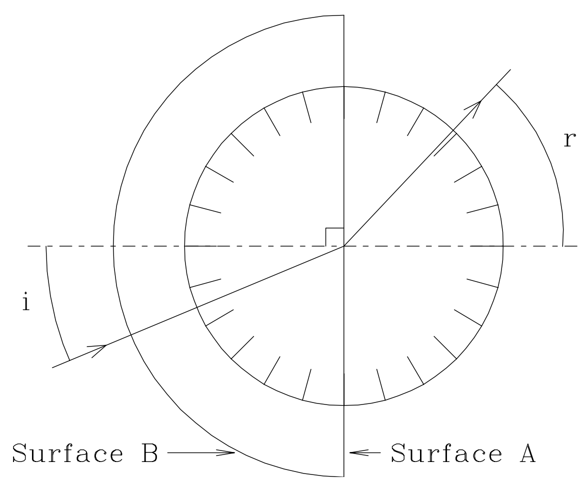

Figure 4.2: Refraction from a denser medium

Make sure that you use the side of the beam that is closer to the normal as your reference edge and that this edge goes through the centre point of the protractor. The angle of incidence i is now measured inside the prism and angle r is outside.

- Vary the angle i of the incident beam in 5° increments from 0° to 40° and measure the corresponding values of r.

- Calculate the values of $\sin i$ for the incident angles i and $\sin r$ for the refracted angles r. Enter your results in Table 4.2.

Remember that now the index of the refracted beam n_{II} is that of air, hence $N_{II} \approx 1$. With this in mind, we can conclude that the calculated value of the slope from the graph will be the inverse of the refractive index n_I of the incident medium.

- Use the Physicalab software to graph the pairs of values ($\sin r$, $\sin i$).
- Summarize below the values for the slope and the standard deviation of the slope displayed in the fitting parameter window, and from these determine a value and error for the index of refraction of the prism n_I.

$$slope = \dots\dots\dots\dots \pm \dots\dots\dots\dots$$

$$n_I = \dots\dots\dots\dots = \dots\dots\dots\dots = \dots\dots\dots\dots$$

$$\Delta(n_I) = \dots\dots\dots\dots = \dots\dots\dots\dots = \dots\dots\dots\dots$$

$$n_I = \dots\dots\dots\dots \pm \dots\dots\dots\dots$$

i°	0	5	10	15	20	25	30	35	40
r°									
$\sin i$									
$\sin r$									

Table 4.2: Exprimental results for Part 2

Part 3: Critical angle for total internal reflection

For light incident on a boundary from a denser medium, Snell's Law indicates that there is a certain angle of incidence i for which the reflected angle will be $r = 90°$. This angle of incidence is known as the *critical angle* θ_c. If $i > \theta_c$, there will be no refracted beam and the incident ray will undergo total internal reflection from the boundary, back into the denser medium. For this special case, Snell's Law may be written as:

$$n = \frac{1}{\sin\theta_c}. \tag{4.1}$$

Using the experimental setup of Part 2:

- Observe the refracted beam and adjust the angle i of the incident beam to set the angle of refraction r at 90°so that the refracted beam disappears as in Figure 4.3.

? How well were you able to estimate a critical angle measurement?

- Repeat this measurement of θ_c several times to fill Table 4.3.

? What is the point of repeating the same measurement so many times?

trial	1	2	3	4	5	6	7	8	9	$\langle\theta\rangle_c$	$\sigma(\theta_c)$
θ_c											

Table 4.3: Critical angle results for Part 3

Close any open Physicalab windows, then start a new Physicalab session by clicking on the desktop icon and login with your Brock student ID. You will be emailing yourself all the graphs that you create for later inclusion in your lab report.

- In Physicalab, click `File, New` to clear the data entry window, then enter in a column the critical angle values. Click `Options, Insert X index` to insert a column of indices to your data points. Select `bellcurve`, click `bargraph` then **Draw** to view the distribution of your data. Click **Send to:** to email yourself a copy of the graph.

- Physicalab has calculated the average $\langle\theta\rangle_c$ and standard deviation $\sigma(\theta_c)$ of your data set and these values are shown in the graph window as $\langle\theta\rangle_c \pm \sigma(\theta_c)$. Enter these two values in the $\langle\theta\rangle_c$ and $\sigma(\theta_c)$ columns of Table 4.3.

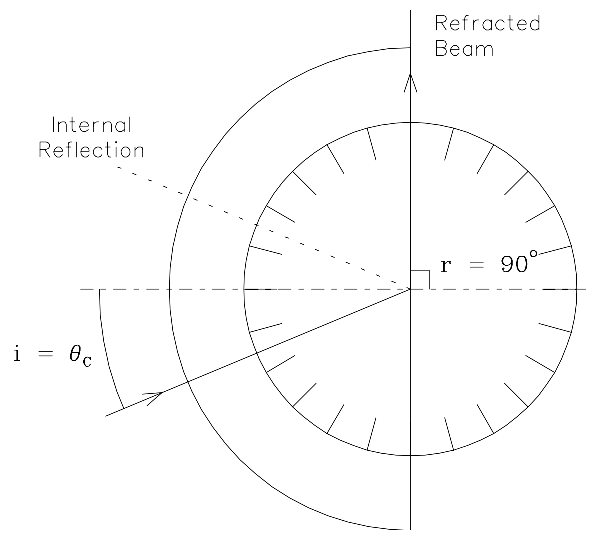

Figure 4.3: Critical angle setup for Part 3

- From these results *converted to radians*, calculate a value of n for the prism from Equation 4.1 and the error $\Delta(n)$ using the appropriate error propagation relation, then report properly rounded final results for θ_c and n:

$$n = \ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots$$

$$\Delta(n) = \ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots = \ldots\ldots\ldots\ldots$$

$$\theta_c = \ldots\ldots\ldots\ldots \pm \ldots\ldots\ldots\ldots$$

$$n = \ldots\ldots\ldots\ldots \pm \ldots\ldots\ldots\ldots$$

Part 4: Measurements of Index of Refraction of water

- Fill the hollow hemispherical lens with water and then determine its index of refraction. Decide which measurements you will make and then neatly record the measurements and their errors. Then calculate the index of refraction from your measurements and include an appropriate error.

Part 5: Measurements of Focal Lengths of Lenses

- Determine the focal length of the converging lens. Decide which measurements you will make and then neatly record the measurements and their errors. Then determine the focal length and include an appropriate error.
- Determine the focal length of the diverging lens. Decide which measurements you will make and then neatly record the measurements and their errors. Then determine the focal length and include an appropriate error.

(!) Important! Be sure to have this printout signed and dated by a TA before you leave at the end of the lab session. All your work needs to be kept for review by the instructor, if so requested.

Lab report

Go to the "Lab Documents" web page to access the online lab report template for this experiment. Complete the template as instructed and submit it to Turnitin before the lab report submission deadline, late in the evening six days following your scheduled lab session. Do not wait until the last minute. Turnitin will not accept overdue submissions. Unsubmitted lab reports are assigned a grade of zero.