First Lab Report - Group 3
PHY 192

Question 3.1

In this first report, our group (Group 3) explores the refractive indices of lenses composed of different materials.

For the first part of the experiment, we aim to determine the index of refraction of a C-shaped lens by studying how it bends light when a red laser beam is shone through it.

Specifically, we will analyze the refraction angle (dependent variable) produced by the lens when the laser is incident at different angles (independent variable).

The relationship between the dependent and independent variables is governed by a fundamental equation in optics: Snell's Law. This equation is given by:

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

where n_1 and n_2 are the refractive indices of the two materials. The refractive index is defined as the ratio of the speed of light in a vacuum to the speed of light in the material. The angles θ_1 and θ_2 represent the angles of incidence and refraction, respectively.

Question 3.1.1

If the laser beam does not pass through the center of the lens, refraction will still occur, as light always refracts when transitioning between materials with different refractive indices.

However, a significant issue arises: the angles of incidence and refraction become difficult to measure. The proposed lab setup is designed to simplify the measurement of these angles, but deviation from the intended setup may introduce measurement challenges.

Question 3.1.2

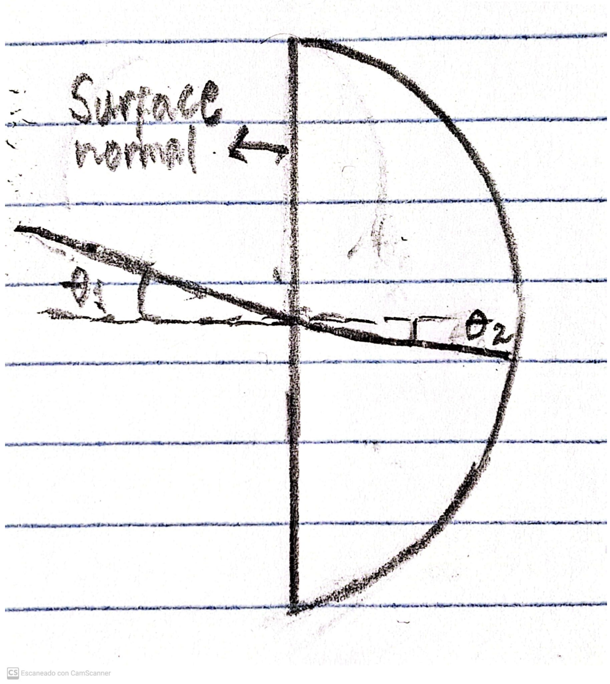

Figure 1: In this diagram the incident angle is marked with the label θ_1 and the refracted angle is marked with the label θ_2, the surface normal is also labeled as such.

Question 3.1.3

We have that the sine of the angle of incidence is given by:

$$\sin(\theta_1) = \frac{n_2}{n_1} \sin(\theta_2) \tag{2}$$

We can easily assume that n_1 being the refractive index of air is equal to 1, so the equation simplifies to:

$$\sin(\theta_1) = n_2 \sin(\theta_2) \tag{3}$$

It is also physically impossible for the refractive index of the lens to be less than 1 because that would imply that light is going faster than the speed of light in a vacuum which isn't possible. As such we can assume that $n_2 > 1$, as such we know as a fact that the sine of the angle of incidence is always less than or equal to 1, so we can conclude that the refracted angle is always more than the incident angle.

As the sine of an angle is directly proportional to the angle itself, we can conclude that the refracted angle is always greater than the incident angle.

Question 3.1.4 - 3.1.6

θ_0	θ_1	θ_{2L}	θ_{2R}	θ_2 avg	$d\theta_2$
0	10	5	7	6	0.5
0	20	10	15	12.5	0.5
0	30	15	21	18	0.5
0	40	21	26	23.5	0.5
0	50	26	33	29.5	0.5

Table 1: Here is a table where θ_0 is the normal angle, θ_1 is the angle of incidence, θ_2 is the angle of refraction, θ_{2L} and θ_{2R} are the angles of refraction measured on the left and right side of the lens respectively, and $d\theta_2$ is the uncertainty in the angle of refraction. **All the angles are measured in degrees.**

Question 3.1.7

The following mathematic can be used to do perform the calculations:

$$\begin{aligned} n_1 \cdot \sin(\Theta_1) &= n_2 \cdot \sin(\Theta_2) \\ n_1 &= 1 \\ n_2 &= n \\ X &= \sin(\Theta_2) \\ Y &= \sin(\Theta_1) \\ \Rightarrow X &= n \cdot Y \end{aligned}$$

Question 3.1.9

X	Y	dX	dY
0.1045284633	0.1736481777	0.004339420389	0.004297034447
0.2164396139	0.3420201433	0.00425989495	0.004100182547
0.3090169944	0.5	0.004149766895	0.003778748675
0.3987490689	0.6427876097	0.004001429434	0.003342499437
0.4924235601	0.7660444431	0.003797643139	0.002804690045

Table 2: Here is the table with the requested results.

Question 3.1.10

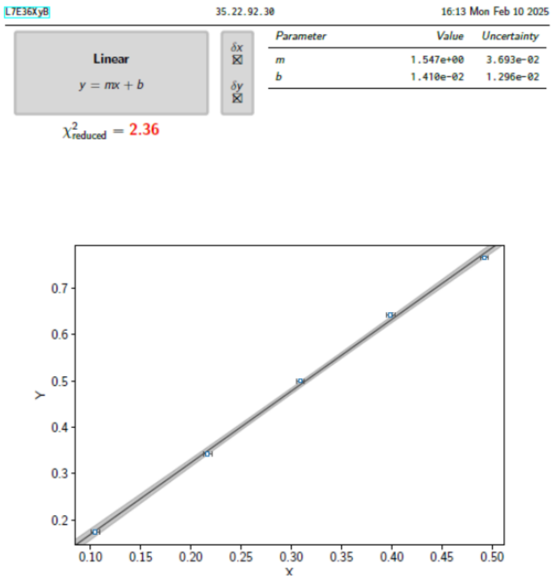

Figure 2: Here is the plot plus some data relating to the uncertainty of the measurements.

Also, for reference the value of n was 1.547, and that of dn was 0.03693

Question 3.2.2

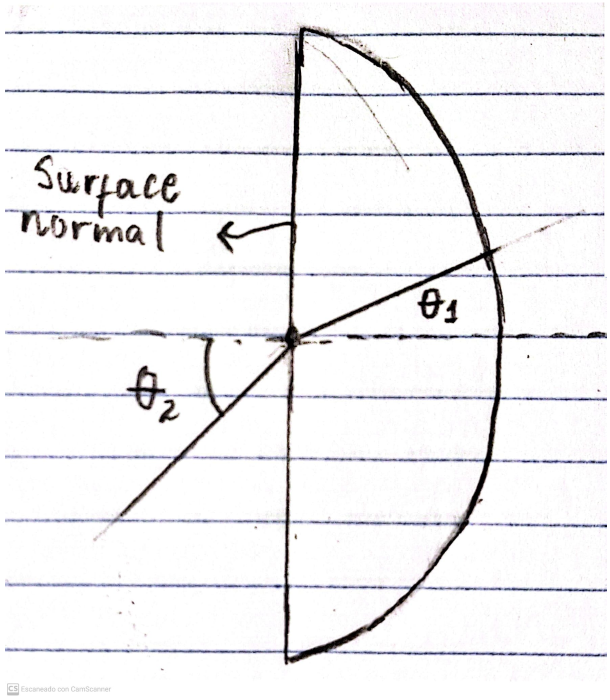

Figure 3: In this diagram the incident angle is marked with the label θ_1 and the refracted angle is marked with the label θ_2, the surface normal is also labeled as such.

Question 3.2.3

We have that the sine of the angle of incidence is given by:

$$\sin(\theta_1) = \frac{n_2}{n_1}\sin(\theta_2) \tag{4}$$

We can easily assume that n_1 being the refractive index of air is equal to 1, so the equation simplifies to:

$$\sin(\theta_1) = n_2 \sin(\theta_2) \tag{5}$$

It is also physically impossible for the refractive index of the lens to be less than 1 because that would imply that light is going faster than the speed of light in a vacuum which isn't possible. As such we can assume that $n_2 > 1$, as such we know as a fact that the sine of the angle of incidence is always less than or equal to 1, so we can conclude that the refracted angle is always more than the incident angle.

As the sine of an angle is directly proportional to the angle itself, we can conclude that the refracted angle is always greater than the incident angle.

Question 3.2.4

The lens is rotated slowly from one side until the reflected ray no longer emerges after or before the lens. This is repeated by rotating the lens to the other side. The estimate for the critical angle is 39 ± 0. 25 degrees. $\frac{1}{sin(39)} = n_1 = 1.59$

Question 3.2.5

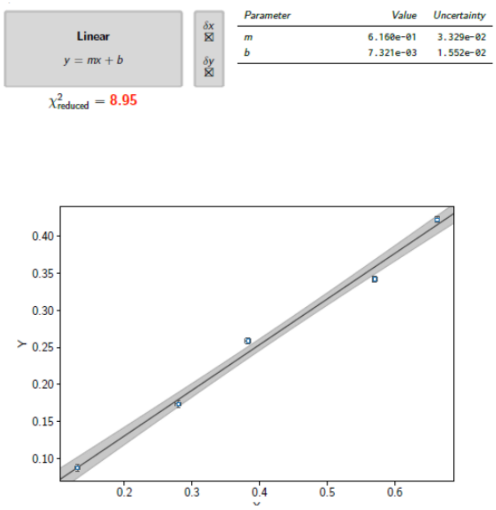

Figure 4: Here is the plot plus some data relating to the uncertainty of the measurements.

Question 4.1

For the first part of the experiment, we aim to determine the deviation angle and the deviation of the laser from the normal line associated with a cuboid lens when a red laser beam is shone through it. Specifically, we will analyze the refraction angle (dependent variable) produced by the lens when the laser is incident at different angles (independent variable). The relationship between the dependent and independent variables is governed by the equation:

$$d = \frac{T}{\cos(\theta_2)} \cdot \sin(\theta_1 - \theta_2)$$

where T is the thickness of the lens. The angles θ_1 and θ_2 represent the angles of incidence and refraction, respectively.

Question 4.2

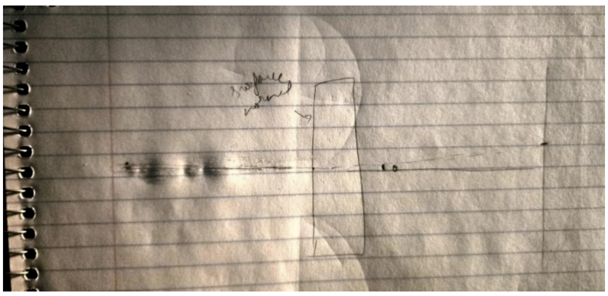

Figure 5: Here is the requested diagram.

Question 4.5

We measured a T value of 25 mm

Question 4.7

Incident Angle (θ_1)	Ideal Deviation (mm)
10	0.6616918211
20	2.910497625
30	3.862272453
40	5.012791106
50	4.425952952

Table 3: Table showing the ideal deviation of a laser beam for different incident angles when passing through a cuboid lens. The deviation is calculated based on the theoretical model and represents the expected displacement from the normal line.

Question 4.8

θ_{dev}	$\Delta\theta_{\text{dev}}$
0.003838308179	0.0002473895821
0.002589502375	0.00002094463001
0.003137727547	0.00001820788572
0.004987208894	0.00002480878619
0.008074047048	0.00005891633863

Table 4: Table showing the deviation angle (θ_{dev}) and the uncertainty in the deviation angle ($\Delta\theta_{\text{dev}}$) for different measurements. As requested.