AP Physics 2

INDEX OF REFRACTION LAB REPORT

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Billy

with Raven & Michael

Introduction

In the Index of Refraction Lab, we were missioned to measure the index of refraction of a glycol box, as well as the critical angle for a laser moving into a water container, using provided materials.
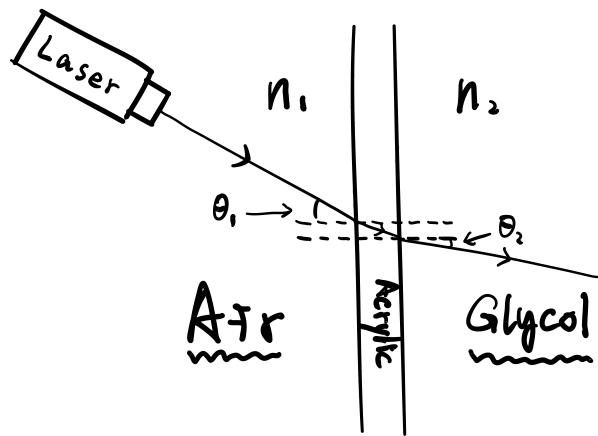
Experimental Setup

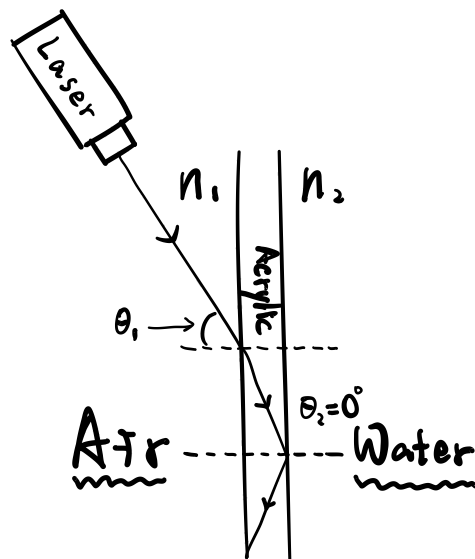**Figure 1:** Experiment Setup 1 (reflection not drawn); in our expectation, $n_1 \sin \theta_1 = n_2 \sin \theta_2$

Figure 2: Experiment Setup 2

Data & Result

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Yielded Data for Experiment 1

Angle of Incidence	Angle of Refraction
70°	42°
60°	38°
50°	32°
40°	28°
30°	20°
20°	16°
10°	8°

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Table 1: Yielded data for experiment 1, including Angles of Refraction (θ_2) and Angles of Incidence (θ_1)

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Yielded Data for Experiment 2

Critical Angle	51°
n of the Container	about 1.49

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Table 2: Yielded data for experiment 2, where n is the refractive index of the container

Sample Calculation

To calculate the index of refraction, we apply Snell's law:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2, \qquad \text{(Snell's Law)}$$

$$n_2 = \frac{n_1 \sin \theta_1}{\sin \theta_2}. \qquad (1)$$

Take row $\theta_1 = 50°, \theta_2 = 32°$ as an example:

$$n_2 = \frac{n_1 \sin \theta_1}{\sin \theta_2} = \frac{1 \times \sin 50°}{\sin 32°} \approx 1.45$$

Calculating critical angle based on known index of refraction:

$$n_1 \sin \theta_c = n_2 \sin \theta_2 \qquad \text{(Snell's Law)}$$

$$\sin \theta_c = \frac{n_2}{n_1} \sin 90°$$

$$\theta_c = \arcsin \frac{n_2}{n_1} \qquad \text{(Critical Angle Equation)}$$

Result

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Result for Experiment 1

Angle of Incidence	Angle of Refraction	Reflective Index
70°	42°	1.40
60°	38°	1.41
50°	32°	1.45
40°	28°	1.37
30°	20°	1.46
20°	16°	1.24*
10°	8°	1.25*
Average n		1.42

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Table 3: Result for experiment 1, derived by using Equation (1); the average reflective index for glycol, $n \approx 1.42$ (*since the last two row appear to be outliers, they are ignored when calculating the average value).

Discussion Questions

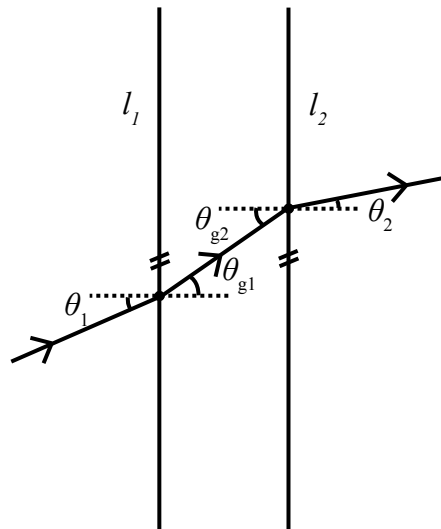## Do we need to consider the central medium when calculating the index of refraction?

Figure 3: Ray Diagram for Experiment 1

No, we don't need to consider the central when calculating the reflective index. The reason is

that since $l_1 \parallel l_2$, $\theta_{g1} = \theta_{g2}$. By employing Snell's law,

$$\begin{cases} n_1 \sin \theta_1 = n_g \sin \theta_{g1} \\ n_g \sin \theta_{g2} = n_2 \sin \theta_1 \\ \theta_{g1} = \theta_{g2} \end{cases} ,$$

we get $n_1 \sin \theta_1 = n_2 \sin \theta_2$, which doesn't involve n_g. Thus, it should be fine to ignore the intermedium.

Why doesn't the critical angle match up with our expectation. Should it?

The critical angle of air to water, according to Snell's law, should be the θ_1 when $\theta_2 = 90°$, $n_1 = 1$, and $n_2 = 1.33$. Plugging in the numbers into the critical angle equation we derived before, we end up with the expected critical angle: $\theta_{expected} \approx 48.75°$.

Though the measured critical angle ($51°$) is not far away from the expected one, we would admit that they still don't match. One possible explanation could be that our measurement is not accurate (surely our fault, because the equipment is said to be expansive). Another reason could be that the milky wather itself has a larger index of refraction (which, according to the equation, should lead to a larger critical angle).

Despite these intervening factors, the critical angle should match up with the calculated expectation – that is, the container would not affect the result, as long as its refractive index is greater than that of the milky water (which we have proven to be true, as shown in the previous section). The reason is that since the critical angle θ_c, between the central meduim is $\arcsin \frac{n_2}{n_i}$ (where n_i is the refractive index of the intermedium), by applying Snell's on the air-container surface, we get $n_1 \sin \theta_c = n_i \sin \theta_{c\prime}$, which could be rewriten (by substituting $\theta_{c\prime}$ with $\frac{n_2}{n_i}$), as $\sin \theta_c = \frac{n_2}{n_1}$. The derived equation apparently has nothing to do with the container, yet being exactly the critical angle we expected.
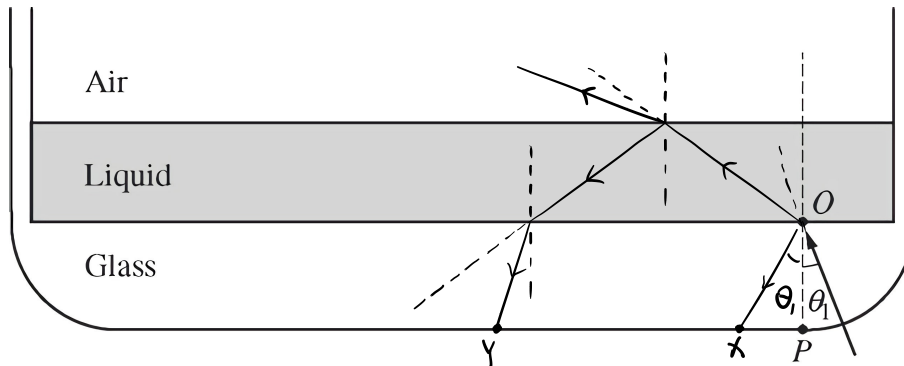
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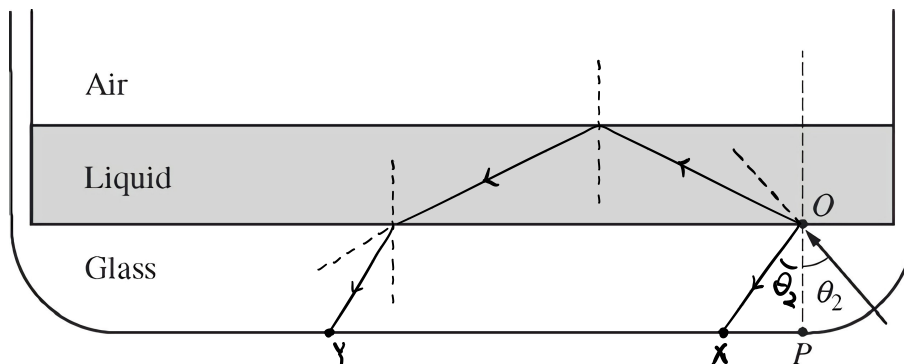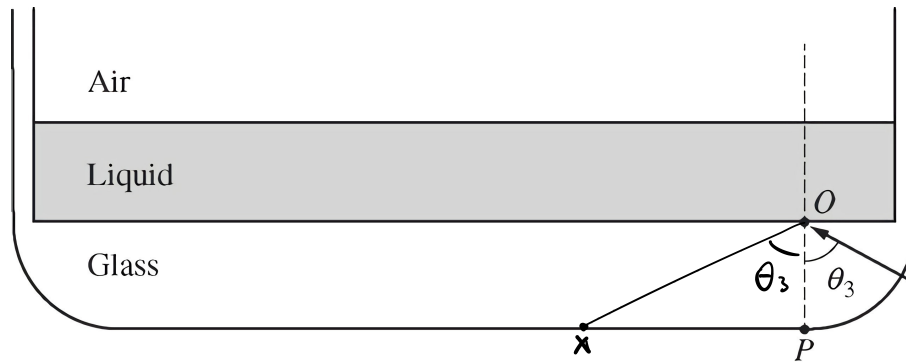
a.

Figure 4: Ray Diagram for Part A

b.

Figure 5: Ray Diagram for Part B, where due to total internal reflection (no more energy loss on Air-Liquid surface), spot Y becomes brighter.

c.

Figure 6: Ray Diagram for Part C

When the incident angle increases, spot that disappears, if any, would be the farther one (Y). It is because if and only if θ_3 reaches the liquid-glass critical angle would no refracted beam pass into the liquid to cause the second reflection (which forms spot Y).