AP Physics 2

INDEX OF REFRACTION LAB REPORT

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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

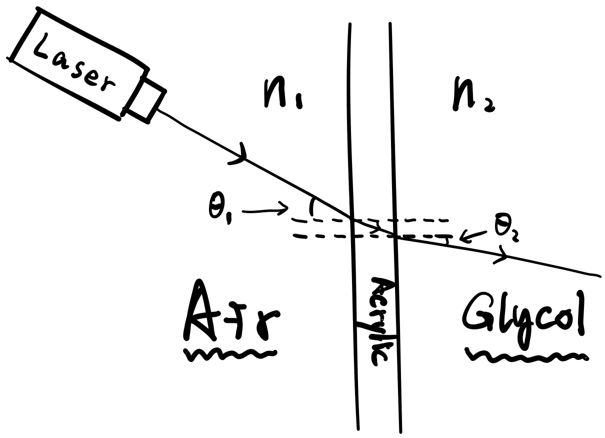

Figure 1: Experiment Setup 1 (reflection not drawn); in our expectation, $n_1 \sin\theta_1 = n_2 \sin\theta_2$

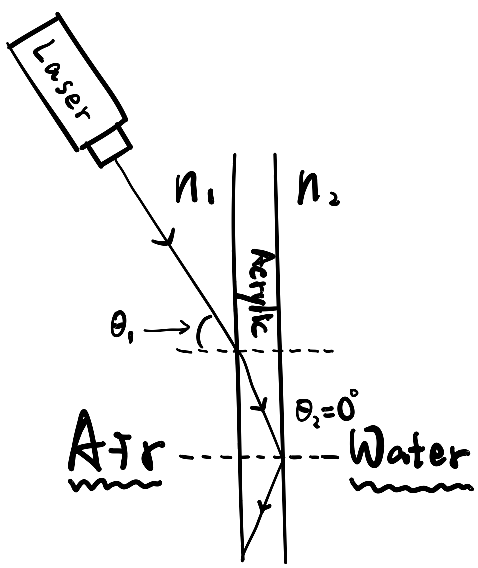

Figure 2: Experiment Setup 2

Data & Result

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°

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

Yielded Data for Experiment 2

Critical Angle	51°
n of the Container	about 1.49

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

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

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?

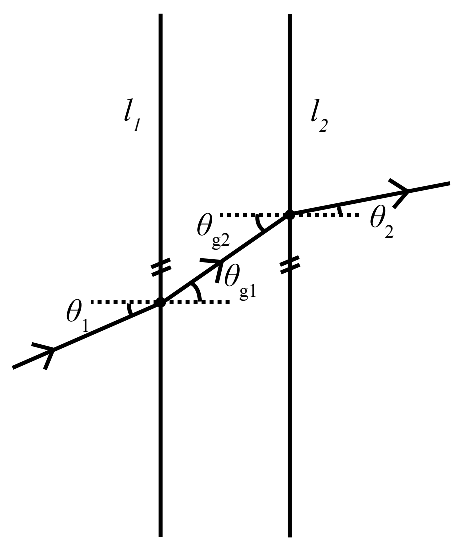

Figure 3: Ray Diagram for Experiment 1

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). Nevertheless, a more legitimate excuse is that the expected and the measured should not match at all, due to the "unexpected" central material (i.e., the container). Unlike the previous discussion question, where the intermedium does not matter, the critical angle we measured is actually that between the container and the milky water (see: Figure 2) – that is, before the incident ray reaches water surface, it has already been refracted once (into a smaller angle, according to Snell's Law when $n_2 > n_1$). Thus, we would say that it is impossible to get the same result; instead, a slightly larger one is quite normal.

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a.

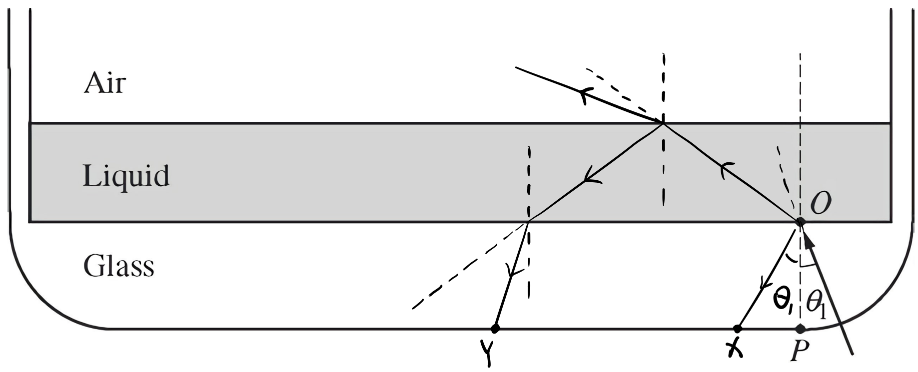

Figure 4: Ray Diagram for Part A

b.

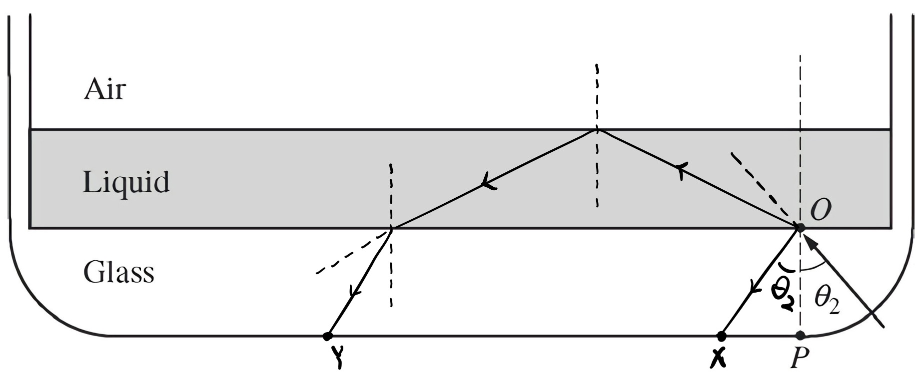

Figure 5: Ray Diagram for Part B, where due to total internal reflection (no more energy loss on Air-Liquid surface), spot Y becomes brighter.

c.

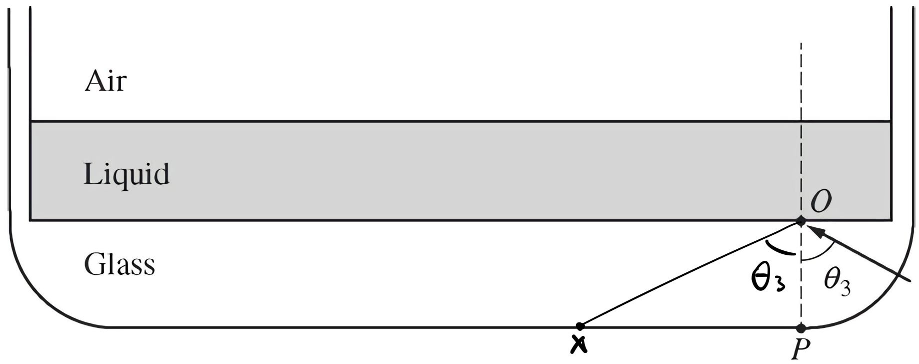

Figure 6: Ray Diagram for Part C

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).