Snell's Law: Refraction of Light

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1 Introduction

When light passes from one medium to another, the ray both reflects and refracts. The purpose of this experiment is to verify Snell's Law and to find the refractive index of water. Snell's Law is given by the equation $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$ where n_1 and n_2 are the refractive indexes of the first and second media, respectively, θ_1 is the angle of incidence, and θ_2 is the angle of refraction. Since the experiment tests the refraction of light going from air to water, we have $n_1 = 1$. Then, applying Snell's Law to find θ_2 we get the following:

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

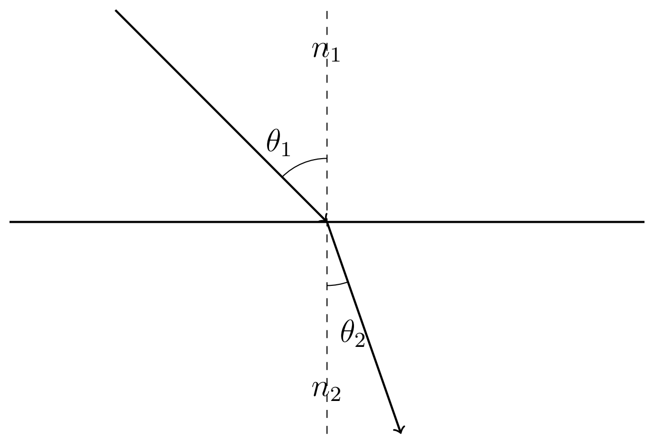
The graph of $\sin\theta_2$ vs. $\sin\theta_1$ should produce a linear trend line with a slope of $\frac{1}{n_2}$. Using the graph, n_2 can be found by taking the reciprocal of the slope. In theory, the calculated n_2 should equal 1.33. Next, to calculate the critical angle using Snell's Law, the equation $n_2 \sin(\theta_c) = n_1 \sin(90°)$ is used, where θ_c is the critical angle. Then, to find θ_c, the equation can be rearranged to get:

$$\sin(\theta_c) = \frac{n_1}{n_2} \implies \theta_c = \sin^{-1}(\frac{n_1}{n_2})$$

Substituting $n_1 = 1$ and $n_2 = 1.33$, we obtain the critical angle $\theta_c = \sin^{-1}(\frac{1}{1.33}) = 48.8°$.

2 Materials and Method

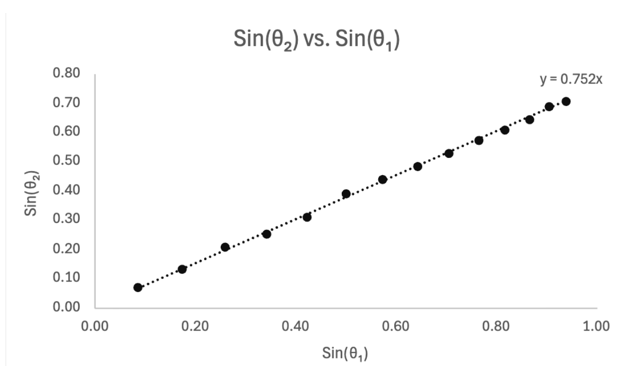
The materials required for this experiment are a laser refraction tank and water. To set up this experiment, a laser refraction tank was filled halfway with water so that the water line aligns with the horizontal, or 0°. Next, the laser was set to align with 5°. Once the laser was exactly positioned at 5°, the laser was shown to refract once reaching the water's surface. This angle of refraction was measured against the normal line and recorded in a table containing θ_1 and θ_2, where θ_1 is the original angle, and θ_2 is the angle of refraction, as shown in the diagram below. This process was repeated in intervals of 5°until 70°.



After recording the data for each of these angles, the laser was set along the normal line in the bottom half of the tank in order to find the critical angle. The laser was gradually moved upwards until the angle of refraction was 90°. Then, the critical angle, or the original angle that caused this 90°refraction, was measured. Next, with all of the recorded data, the original table was expanded to also include $\sin(\theta_1)$ and $\sin(\theta_2)$. A graph of $\sin(\theta_2)$ vs. $\sin(\theta_1)$ was created using these values. In addition, the critical angle was also used to measure the refractive index of water.

3 Results

θ_1°	θ_2°	$\sin(\theta_1)$	$\sin(\theta_2)$
5	4.0	0.09	0.07
10	7.5	0.17	0.13
15	12.0	0.26	0.21
20	14.5	0.34	0.25
25	18.0	0.42	0.31
30	23.0	0.50	0.39
35	26.0	0.57	0.44
40	29.0	0.64	0.48
45	32.0	0.71	0.53
50	35.0	0.77	0.57
55	37.5	0.82	0.61
60	40.0	0.87	0.64
65	43.5	0.91	0.69
70	45.0	0.94	0.71



The slope of the graph gives $n_2 = \frac{1}{\text{slope}} = \frac{1}{0.7454} = 1.34$ as the index of refraction of water. This index is also calculated using the critical angle: $\theta_c = 47.5 \implies n_2 = \frac{1}{\sin\theta_c} = \frac{1}{\sin(47.5°)} = 1.35$.

4 Conclusion and Discussion

The results of this experiment produce a graph of $\sin(\theta_2)$ vs. $\sin(\theta_1)$ that has an increasing linear trend line. This graph can be used to find the refractive index of water by taking the reciprocal of the slope of the trend line. When calculated, the refractive index of water is 1.34. The measured critical angle can also be used to find the index of refraction by calculating $n_2 = \frac{1}{\sin(\theta_c)}$, where θ_c is the critical angle. The critical angle was measured to be 47.5°, so the refractive index is $\frac{1}{\sin(47.5)} = 1.35$. Both of these measured values slightly differ from the actual index of refraction for water, which is 1.33. This could be due to human error in correctly measuring the angles of refraction during the experiment.