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PHY 105N

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Lab 0: Reflecting on Measurement

Part 1

Method

The equipment used for this part of the lab for the experiment is: flashlight, multiple lasers, PASCO light source, protractor, mirror(s), and graph paper. The purpose of the experiment is to test the Law of Reflection, which predicts that the angle of incidence equals the angle of reflection ($\theta = \theta'$). I hypothesize that this law would hold true for the chosen mirror.

I conducted 5 trials at different incident angles $\{15°, 30°, 45°, 60°$, and $75°\}$. For each trial, I used graph paper to trace the incident and reflected rays, then measured both the incident angle (θ) and reflected angle (θ') using a protractor with a precision of $\pm 0.5°$. I calculated the angle difference ($\theta - \theta'$) for each trial and determined the uncertainty using $\delta(\theta - \theta') = \sqrt{(\delta\theta)^2 + (\delta\theta')^2} = 0.71°$. I also calculated the percent error for each measurement (as demonstrated below); our criteria for consistency with the model was that the angle difference should fall within the stated measurement uncertainty.

Here are the set of equations and sample calculations that I did to complete our data set and analysis:

Angle Difference:

$$\theta - \theta' \equiv \theta_i - \theta_r$$

$$15^\circ - 16^\circ = -1^\circ \text{ [Trial 1]}$$

Uncertainty in Angle Difference:

$$\delta(\theta - \theta') = \sqrt{(\delta\theta)^2 + (\delta\theta')^2}$$

$$\delta(\theta - \theta') = \sqrt{(0.5)^2 + (0.5)^2} = \sqrt{0.5} = 0.71^\circ \text{ [Trial 1]}$$

Percent Error:

$$PE = \frac{\theta - \theta_i}{\theta_i} \times 100\,\%$$

$$PE = \frac{16^\circ - 15^\circ}{15^\circ} \times 100\,\% = 6.7\,\% \text{ [Trial 1]}$$

Data

Table 1: Angles and Percent Error

Trials	Angle of Incidence (θ)	Angle of Reflection (θ)	Angle Difference (θ)	Percent Error (%) $PE = \frac{\theta - \theta_i}{\theta_i} \times 100\,\%$
1	15 ± 0.5	16 ± 0.5	$+1 \pm 0.71$	6.7 ± 4.7
2	30 ± 0.5	31 ± 0.5	$+1 \pm 0.71$	3.3 ± 2.4
3	45 ± 0.5	45 ± 0.5	0 ± 0.71	0 ± 1.6
4	60 ± 0.5	60 ± 0.5	0 ± 0.71	0 ± 0.8
5	75 ± 0.5	74 ± 0.5	-1 ± 0.71	1.3 ± 1.0

Conclusion

I concluded that our data supports the Law of Reflection; across all five trials, the angle differences ranged from -1° to $+1^\circ$, all within our measurement uncertainty of $\pm 0.71^{\circ}$. Furthermore, the percent errors were all small (ranging from $0\,\%$ to $6.7\,\%$), confirming that the incident and reflected angles are equal as predicted. This agrees with our initial hypothesis that the Law of Reflection would hold for the mirror. However, our measurements were limited by the $\pm 0.5^{\circ}$ fine precision of the protractor, which could bias our uncertainty. Additionally, I only tested the set of angles declared in the method section, which could create gaps in our investigation.

For future iterations of the part of the experiments, some improvements that I would suggest are an increase in precision. Such as using a more precise angle-measuring device such as a digital protractor to reduce measurement uncertainty and see if smaller deviations from the model emerge. Refine the number of angles in the set by 1° degree increments/differences to see if the law still holds.

Part 2

Method

For the second part of the experiment, I investigated whether the Law of Reflection holds when using a blue-colored laser as our light source, hypothesizing that the law would still apply regardless of light wavelength. We kept the same experimental setup and testing angles $(15^{\circ}, 30^{\circ}, 45^{\circ}, 60^{\circ}, 75^{\circ})$ as in Part 1; however, we switched from our original light source to a blue laser pointer. The more focused beam of the laser allowed for easier ray tracing on the graph paper and potentially more precise angle measurements. I used the protractor ($\pm 0.5^{\circ}$ precision), measurements procedures, and statistical analysis methods as in Part 1. The criteria we established for consistency remained, so that the angle differences should fall within measurement uncertainty.

Below are the sample calculations that were formulated for our dataset along with the statistical tools:

Angle Difference:

$$\theta - \theta' \equiv \theta_i - \theta_r$$

Uncertainty in Angle Difference:

$$\delta(\theta - \theta') = \sqrt{(\delta\theta)^2 + (\delta\theta')^2}$$

Percent Error:

$$PE = \frac{|\theta - \theta_i|}{\theta_i} \times 100\,\%$$

$$PE = \frac{|17^\circ - 15^\circ|}{15^\circ} \times 100\,\% = 13.3\,\% \text{ [Trl.1]}$$

Data

Table 2: Angles and Percent Error for Blue Colored Laser

Trials	**Angle of Incidence** (θ)	**Angle of Reflection** (θ)	**Angle Difference** (θ)	**Percent Error** $(\%)$
1	15 ± 0.5	17 ± 0.5	$+2 \pm 0.5$	13.3 ± 4.7
2	30 ± 0.5	30 ± 0.5	0 ± 0.5	0.0 ± 1.6
3	45 ± 0.5	46 ± 0.5	$+1 \pm 0.5$	2.2 ± 1.6
4	60 ± 0.5	59 ± 0.5	-1 ± 0.5	1.7 ± 1.2
5	75 ± 0.5	75 ± 0.5	0 ± 0.5	0.0 ± 0.8

Conclusion

The data collected supports the Law of Reflection for the blue laser, although with slightly larger deviations than Part I. Four out of five trials showed angle differences within or very close to our $\pm 0.5^{\circ}$ uncertainty (0°, $+1^{\circ}$, -1°, and 0°). However, Trial 1 showed a larger deviation of $+2 \pm 0.5^{\circ}$ which falls outside the range of our measurement uncertainty; furthermore, the percent errors ranged from $0.0\,\%$ to $13.3\,\%$ with Trial 1 again showing the largest error. Overall, the Law of Reflection holds for the blue laser for the majority of our trials although with the slightest reduction in accuracy compared to Part 1.

For future iterations of this experiment, I suggest that we run more trials ($n > 5$) at each angle rather than one trial per angle, as this could have led to higher percent error and angle difference. Furthermore, it would also help us determine if the larger deviation at 15° in Trial 1 was due to random error or a systematic issue with shallow angle measurements using the laser.