Lab 0 Report

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1 Exercise - Parallax

Setup: Take two pencils. Hold one of them in front of you at arm's length and the other at roughly half that distance. Close one eye and focus on a point far away. Then move your head side to side and record what you observe

Observation: When moving my head side-to-side, the further pencil seems to be near-stationary while the closer pencil moves a lot more relative to my eyes. When the pencils are *the same distance* away from my eye, both appear to move equally when my head oscillates.

Experimental Design: The distance is inversely proportional to how much the pencils seem to move relative to my eyes. If the pencil moves less, in this case the further one, it is farther away. Therefore, the formula for how far an object is should be of the form $d = 1/\theta$

2 Experiment 1 - The Law of Reflection

The goal of this experiment is to demonstrate the law of reflection by comparing the incident and reflected angles of a laser incident on a plane mirror.

We place the plane mirror on the top of the protractor where the mirror is normal to the 0 degree axis. To ensure the mirror is calibrated such that the incident and reflected angles should equate, we first shot a laser at the 45 degree mark as it has a much longer tick mark which helps with aiming the laser. We rotated and aligned the plane mirror until the 45 degree incident also resulted

in a 45 degree reflection.

Of course, the goal of this experiment itself is to demonstrate this equality, but it is intuitively obvious and so we used it to help in our initial calibration

2.1 Experimental Design

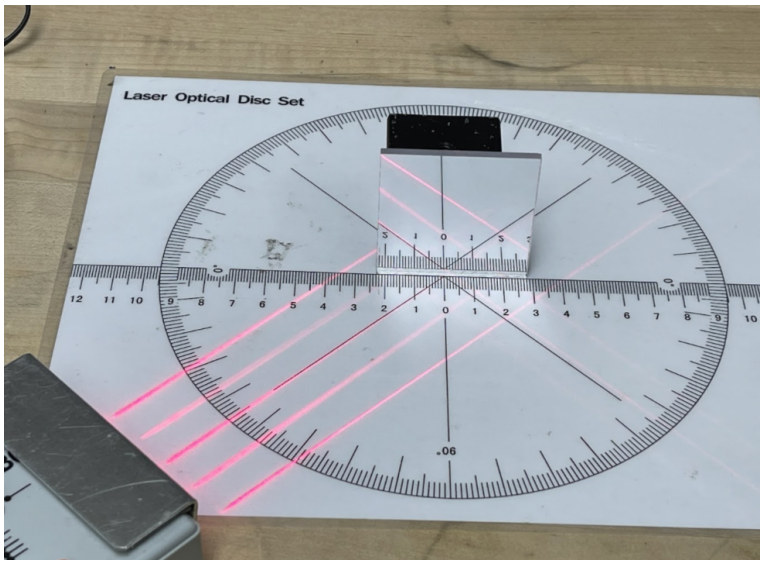

Figure 1: Experiment 1 Setup

Verify / Refine:

To check whether our lab setup is viable we checked our precision errors. After initially setting up the plane mirror such that the incident and reflected angles are equal, we performed some more checks on angles that did not have as large of a guideline as the 45 degree angle.

For 30 degrees, our reflected angle was half a degree smaller (29.5) which we assume means our mirror isn't perfectly straight, or the width of the laser itself causes some uncertainty. After the light turned off, our measurements became much better.

Uncertainties:

- Width of the laser – does not change over the angle range (minimize by looking at center of beam)
- Mirror angle/translation offsets - minimize by calibrating beforehand

- Precision error of the protractor - constant for the whole experiment
- Error in the angle of the laser emitter (minimized by ensuring the reflection is off the center of the protractor) - changes based on each measurement
- Turning the lights off makes the beam much more clear
- Line up the laser such that the incident occurs at the center of 0 degree axis – helps especially for smaller angles

2.2 Data Collection

Incident	Deval	Michaela	SuryaNeil
5	5.5	5.1	5.05
20	20.3	20.1	20.5
40	40.5	41	40
60	60	60	60
80	80	80	80

The precision error for the protractor is 0.5 degrees. We began with 5 degrees as 0 degrees just illuminated the edge of the mirror without a reflection. We found that for larger angles, we got more and more precise. This is likely because, from the perspective of larger angles, it is easier to line up the incident to occur exactly at 0 degrees at the center of the mirror. This will yield more accurate reflected angles which in turn yields a better accuracy and precision.

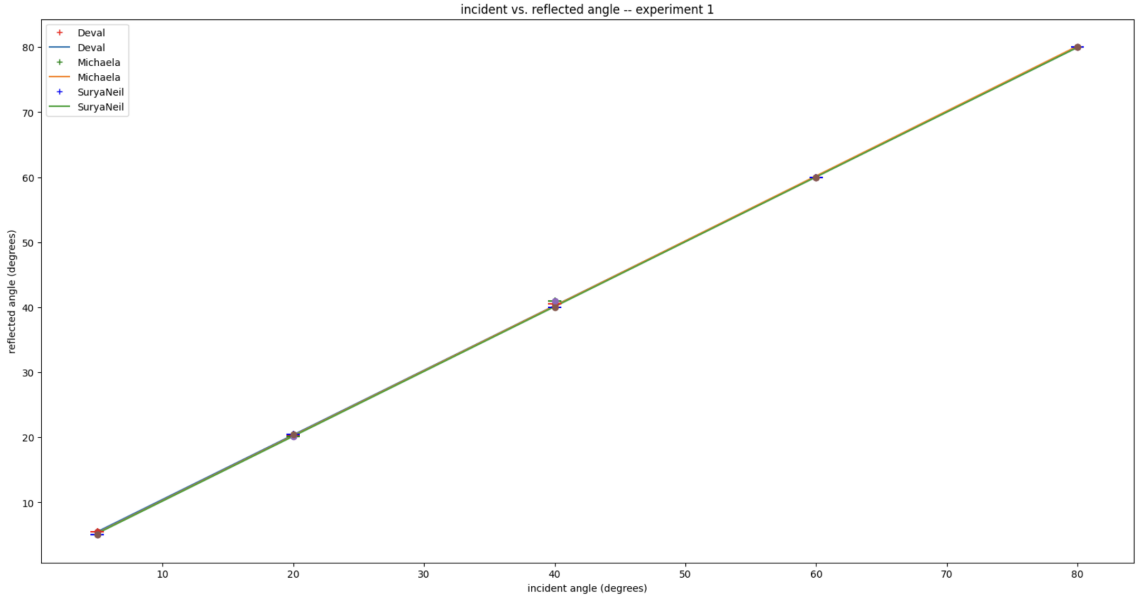

Figure 2: Data Collection for Experiment 1

They may not be visible, but the above graph does include error bars. For both horizontal and vertical we set an above and below error of 0.25 to account for 0.5 degrees error total. Since all of the error bars do intersect the best-fit curve, we can consider the linear regression a good fit to the data.

Including the law of reflection itself in the graph – $\theta_{in} = \theta_{out}$ yields the following graph:

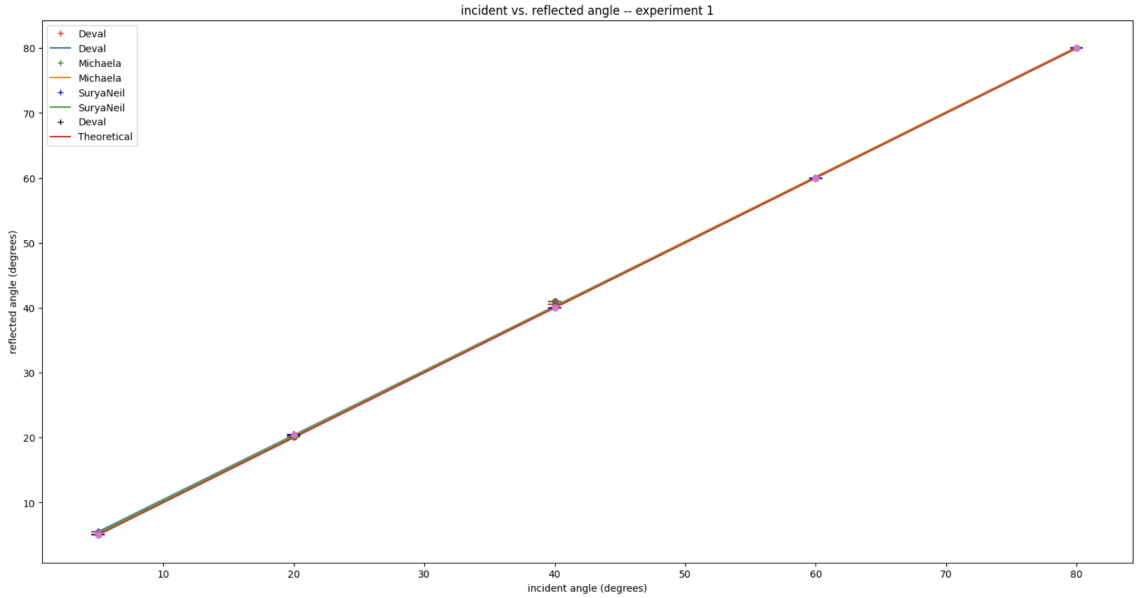

Figure 3: Data Collection vs. Law of Reflection

As you can see our collected data lines up near-perfectly with the law of reflection.

2.3 Determining Reduced Chi Squared Value

Implementing the chi square formula:

$$\chi^2 = \sum \frac{(y_i - y(x_i))^2}{\alpha_i^2}$$

such that the reduced chi squared $\tilde{\chi^2} = \chi^2/\nu$, where $\nu = 15 - 1 = 14$, we get

$$\chi^2 = 7.45$$
$$\tilde{\chi^2} = 0.53$$

And since $\tilde{\chi^2} < 1$, we say the model is falling within the expected uncertainty range.