Lab Notes: Lab 4

Finding Patterns in Intensity
Date: October 14, 2025
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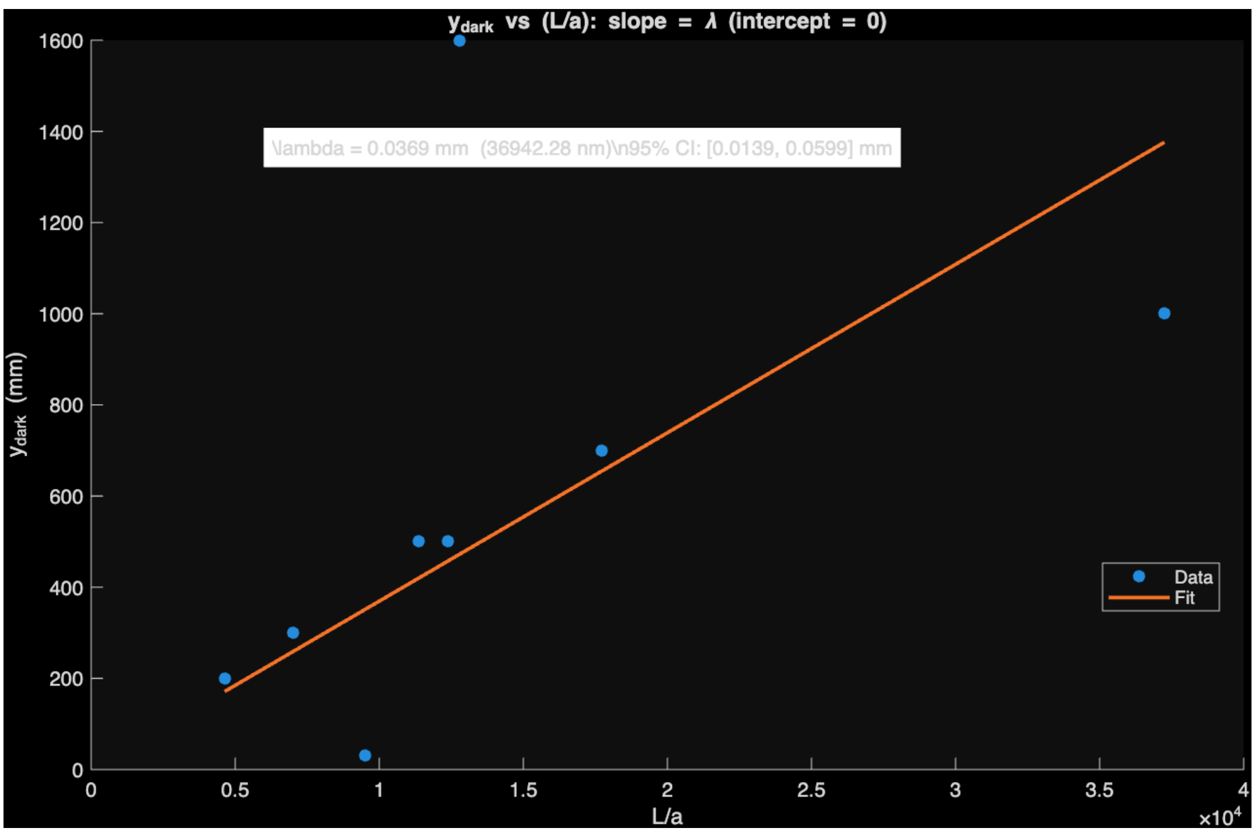
Part 1
Methods

In this experiment we will be quantitatively measuring wavelike properties by shining a light source through small slit patterns. We will be setting up a system that will allow a red laser to shine through a single slit diffraction wheel where it will display an image pattern on the screen. By setting the laser with a beaker clamp we were easily able to change the distance (*L*) for various slit widths (*a*). By doing eight trials with a wide range of measurements there was more confidence in our data. There was a range of *L*'s that started at 45.5cm-76.1cm. For all measurements of a, we must consider +/- .01mm and for any lambda consider +/- 20 nm. At each distance we found a given *a* and calculated a y_{dark}. Once a set diffraction pattern was decided and light shined through to create the image on the screen, tape was used to mark the distance between the slits for easy measuring. We predicted that we would get a positive linear relationship between *L/a* and y_{dark}. Once all measurements were made and put into a table, shown below, we will graph the data to further conclude our measurements. For the t-score analysis, indistinguishability is indicated if t < 1, while 1 < t < 3 indicates inconclusiveness, and t > 3 indicates distinguishability where the larger the t score, the higher the discrepancies.

- Equipment
  - PASCO Optics track- used to measure *L* and to hold screen, laser, and diffraction wheel in place
  - Screen- used to display light source
  - Laser (red)- light source
  - Diffraction Wheel- used for various diffractions patterns (*a*)
- Variables
  - Independent variable: *L/a*
  - Dependent variable: y_{dark}
  - Constant variables: wavelength of light, light source
- Statistical and Analytical Tools
  - Linear fitting
  - Weighted slope formula
    - $m = \frac{\Sigma m x^2}{\Sigma x^2}$
  - Weighted slope uncertainty
    - $\delta m = \sqrt{\frac{1}{N-1}\frac{\Sigma(m-m)^2 x^2}{\Sigma x^2}}$

Data

Laser Lambda (nm)	Trials	L (cm)	a (cm)	L/a	ydark (mm)	m (estimated)	lambda (nm)
650+/-20	1	74.5	0.002	37250	1000	41	654.8
650+/-20	2	70.9	0.004	17725	700	61	647.4
650+/-20	3	45.5	0.004	11375	500	68	646.4
650+/-20	4	51.1	0.004	12775	1600	193	648.9
650+/-20	5	76.1	0.008	9512.5	30	5	630.7
650+/-20	6	56.2	0.008	7025	300	66	647
650+/-20	7	74.2	0.016	4637.5	200	66	653.4
650+/-20	8	49.5	0.004	12375	500	62	651.7



T-Score

$\lambda_m = \lambda_{(nm)} \times 10^{-6} \Rightarrow y_{dark} = \lambda_{mm} \times \frac{L}{a}$

trials	ydark (measured)	y dark (calculated)	difference
1	1000	24.38	975.62
2	700	11.47	688.53
3	500	7.36	492.64
4	1600	8.29	1591.71
5	30	6.00	24.00
6	300	4.55	295.45
7	200	3.03	169.97
8	500	8.07	491.93
Mean:	603.75mm	9.89 mm	$\bar{d}$ = 595.61

$$\delta x_m = \frac{S_m}{\sqrt{n}} = 184.1\,mm \qquad \frac{\delta_c}{\sqrt{n}} = 2.50\,mm$$

$$\text{T-score} = \frac{|x_m - x_c|}{\sqrt{(\delta x_m)^2 + (\delta x_c)^2}}$$

$$= \frac{|603.75 - 9.89|}{\sqrt{(184.1)^2 + (2.50)^2}}$$

$$= 3.23$$

$|t| > 3$: distinguishable

Conclusion

Based on our data, the model $\Delta ydark = \frac{\lambda L}{a}$ does not hold. There presented to be a notable difference between the collected experimental values, $\frac{\lambda L}{a}$, and the theoretical value, $\Delta ydark$, resulting in the t-score: 3.23. The t-score was deemed distinguishable which confirmed that the theoretical and experimental values collected were statically distinguishable. The collected wavelengths had an approximate range of 630.7nm to 654.8nm, whereas the theoretical wavelength including uncertainty was to be about 650 ± 20nm, again showcasing the strong deviation from the theoretical. The discrepancies of this experiment occurred largely due to systematic and human error. When measuring $\Delta ydark$ through the positions of the dark bands, it presented to be difficult due to the miniscule projected images. Overall the general trend did follow what the predicted relationship was to be, indicated by an increase in a leading to a decrease in the measured $\Delta ydark$.

In future iterations, we could

- Use more precise measurement tolls to reduce the uncertainties and improve accuracies when measuring $\triangle ydark$.
- Test with more than two colors to check for effects of differing wavelengths
- Test with closer distances, smaller L's to ensure we get a larger visible image that is able to be properly measured.

Part 2

Methods

In Part 2, we are creating an experiment that will further investigate various patterns to find if they obey the equation: $\triangle ydark\ =\ \frac{\lambda L}{a}$. We will be utilizing the diffraction wheel to create more complex patterns on the image screen. The two that we will be testing will be the holes aperture and the circular aperture. We will be using the same techniques when measuring the slit length between light images. The laser will be the same, along with the optics track and imaging screen. To keep consistency, we did eight trials for each aperture to get a total of sixteen trails. The range of *L* distances started at 44.0cm and the furthest being 83.9cm. We had three different *a* values: 0.6mm, 0.2mm, and 0.4mm. We predicted that our data will obey the equation, $\triangle ydark\ =\ \frac{\lambda L}{a}$. As before, once all data is collected it will then get plotted on a graph to further analyze the relationship between Δy and *L/a*. For the t-score analysis, indistinguishability is indicated if $t < 1$, while $1 < t < 3$ indicates inconclusiveness, and $t > 3$ indicates distinguishability where the larger the t score, the higher the discrepancies.

- Equipment
    - PASCO Optics track- used to measure *L* and to hold screen, laser, and diffraction wheel in place
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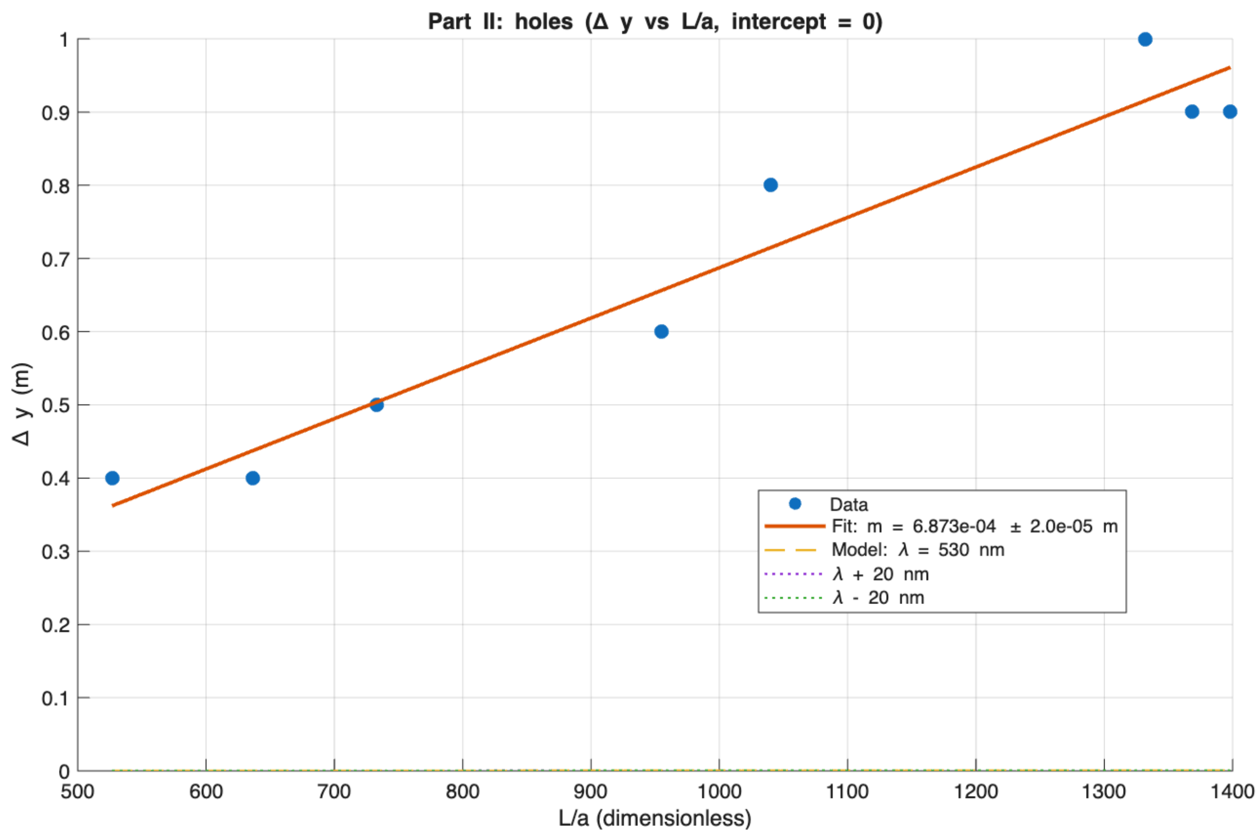
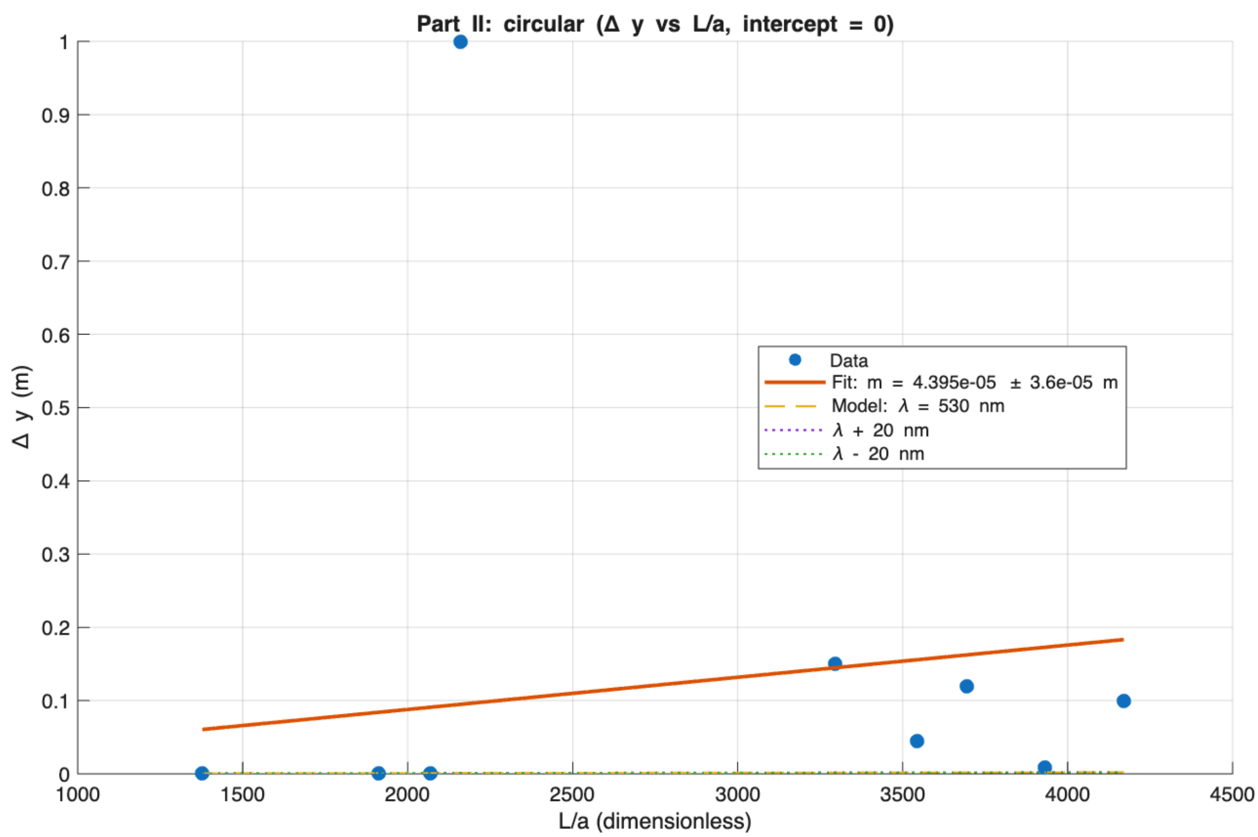
- Statistical and Analytical Tools
    - Linear fitting
    - Weighted slope formula
        - $m = \frac{\Sigma m x^2}{\Sigma x^2}$
    - Weighted slope uncertainty

- - ■ $\delta m = \sqrt{\frac{1}{N-1} \frac{\Sigma(m-m)^2 x^2}{\Sigma x^2}}$
  - ○ y_{dark} model
    - ■ $\Delta ydark = \frac{\lambda L}{a}$

Data

Laser Lambda	Pattern Type	Trials	L (cm)	a (mm)	L/a	ydark (m)
530+/-20	Holes Holes Holes Holes Holes Holes Holes	1	79.9	0.6		1
530+/-20		2	62.4	0.6		0.8
530+/-20		3	82.1	0.6		0.9
530+/-20		4	57.3	0.6		0.6
530+/-20		5	44	0.6		0.5
530+/-20		6	83.9	0.6		0.9
530+/-20		7	31.6	0.6		0.4
530+/-20		8	38.2	0.6		0.4
530+/-20	Circular Circular Circular Circular Circular Circular Circular Circular	9	83.4	0.2		0.1
530+/-20		10	65.9	0.2		0.15
530+/-20		11	43.2	0.2		1
530+/-20		12	73.9	0.2		0.12
530+/-20		13	78.6	0.2		0.009
530+/-20		14	70.9	0.2		0.045
530+/-20		15	76.5	0.4		0.00021
530+/-20		16	82.8	0.4		0.0002
530+/-20		17	55.1	0.4		0.00004


Part II: holes (Δ y vs L/a, intercept = 0)
Δ y (m)
L/a (dimensionless)
Data
Fit: m = 6.873e-04 ± 2.0e-05 m
Model: λ = 530 nm
λ + 20 nm
λ - 20 nm


Part II: circular (Δ y vs L/a, intercept = 0)
Δ y (m)
L/a (dimensionless)
Data
Fit: m = 4.395e-05 ± 3.6e-05 m
Model: λ = 530 nm
λ + 20 nm
λ - 20 nm

Holes

$$T = \frac{|1687.5 - 0.529|}{\sqrt{(228.6)^2 + (0.16)^2}}$$

$= 3.01$

$t > 3$: distinguishable

Circular

$$T = \frac{|158.5 - 1.541|}{\sqrt{(328.0)^2 + (0.52)^2}}$$

$= 0.48$

$|t| < 1$: indistinguishable

Conclusion

Based on our data, $\triangle y \ = \ \frac{\lambda L}{a}$ does not hold across the two apertures testes: holes and circular. The holes aperture had a calculated t-score of 3.01, indicating a statically difference between the theoretical values and the collected experimental calculations. As a result, the model was not precisely presented based on the fact that it exceeded the range 530 ± 20. The circular aperture, however, had a t-score of 0.48, which indicates its statistically indistinguishable. As a result, the data collected accurately supported the model $\triangle y \ = \ \frac{\lambda L}{a}$ as it fits within the uncertainty range of 530 ± 20. Overall both apertures aligned with the trend of an increase in a leading to a decrease in $\triangle y$ Despite there being a difference in L,$\triangle y$, and λ,we can see that there is a consistent relationship between the variables as the overall general trend was seen for both the circular and holes aperture. Nevertheless, when looking at the data overall, measurement uncertainty and human error were contributing factors to the observed discrepancies. Accurately measuring $\triangle y$ was difficult due to smaller and irregular patterns which then contribute to difficulty in accurately measuring $\triangle y$. In addition, tools such as a tape measure rather than a caliper aided in measurement uncertainty. Overall, the data from Part 2 supported the general trend of the model $\triangle y \ = \ \frac{\lambda L}{a}$ between variables L, $\triangle y$ and λ but did not altogether support it specially regarding the holes aperture.

In future iterations, we could

- Reduce the uncertainty of the holes aperture by using pore precise tools like a caliper
- Using smaller image distances to increase the size of the projected image
- Test the same variables but with differing wavelengths