Exploring the Wacky World of Water Optics

Physics 5CL Capstone Project Presentation

Andrew Binder Eric Du Aren Martinian

University of California, Berkeley

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Introduction

Motivation

We saw some stuff in 5B, and we wanted to recreate it!

Objectives

- Confirm inverse behavior of lenses in media with greater refractive indices
- Confirm Brewster's angle for water
- Show index of refraction varies as function of wavelength of incident light

Theory

Lens Equation:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

Lensmaker's Equation:

$$\frac{1}{f} = \frac{n_{\text{lens}} - n_0}{n_0}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

(Take $n_{\text{air}} = 1$, $n_{\text{water}} = 1.33$, $n_{\text{glass}} = 1.53$)

Radius of Curvature:

$$R \approx \frac{d\sqrt{d^2 + h^2}}{h}$$

Brewster's Angle:

$$\theta_B = \arctan\left(\frac{n_{\text{lens}}}{n_0}\right)$$

Sellmier:

$$n^2(\lambda) = 1.7726479 - \frac{0.0315734}{2.2535795 - \lambda^2} + \frac{0.00701841}{\lambda^2 - 0.0092513}$$

$$\text{General Form: } n^2(\lambda) = 1 + \sum_i \frac{B_i \lambda^2}{\lambda^2 - C_i}$$

Experimental Design

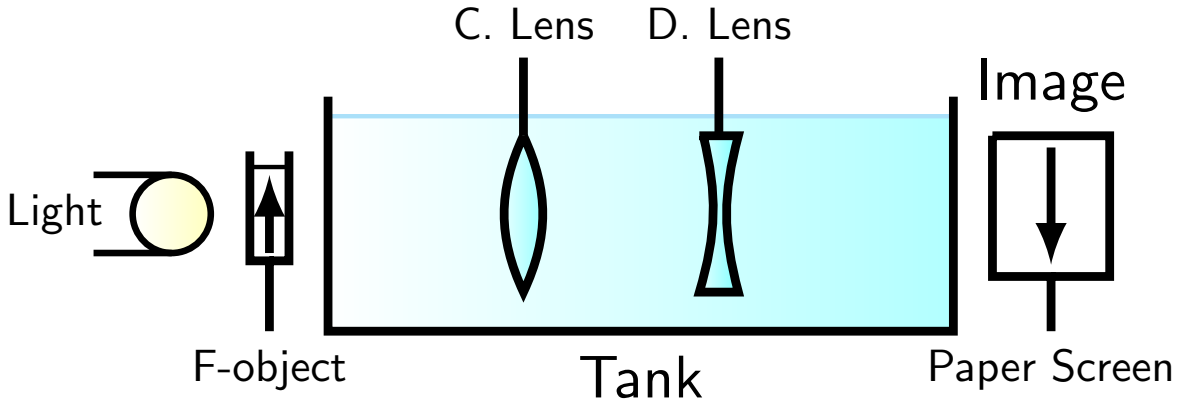
Materials (main experiment):

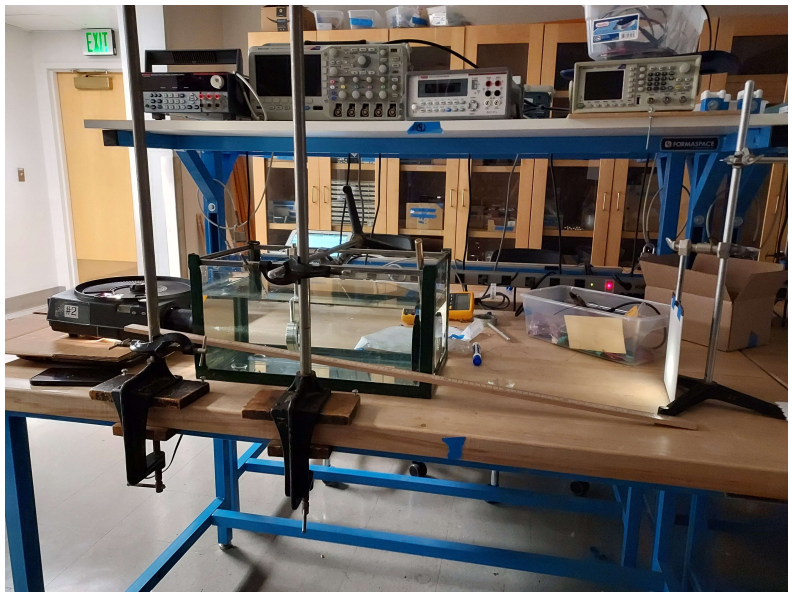
- Diverging & Converging Lenses
- Tank w/ Water
- Screen
- Light Source (collimated projector)
- F Object

Materials (other experiments):

- Red, Green, & UV lasers
- Semicircular & Rectangular Plastic Boxes w/ Water
- Chalk & UV Fluorescent Dye
- iPhone Flashlight

Experimental Setup





Experimental Procedure

1. Place collimated projector on one side of liquid-filled tank
2. Place screen some distance away on other side
3. Place F object & holder between light source & tank
4. Fix distance from light source to converging lens & submerge/align lenses such that light hits screen
5. Move diverging lens between converging lens & tank edge
6. Record F object size & final distances from F object to both lenses and to the screen

Data Collection

Measurements:

- Distance from F object to converging lens: 17.8 cm
- Size of F object: 1.55 ± 0.05 cm
- Radii of curvature:

Lens	Center	Side	Difference (± 0.02)	Length (± 0.01)
Fishbowl	0.69	0.23	0.46	5.7
Double convex	0.88	0.34	0.54	1.6

Table of Data:

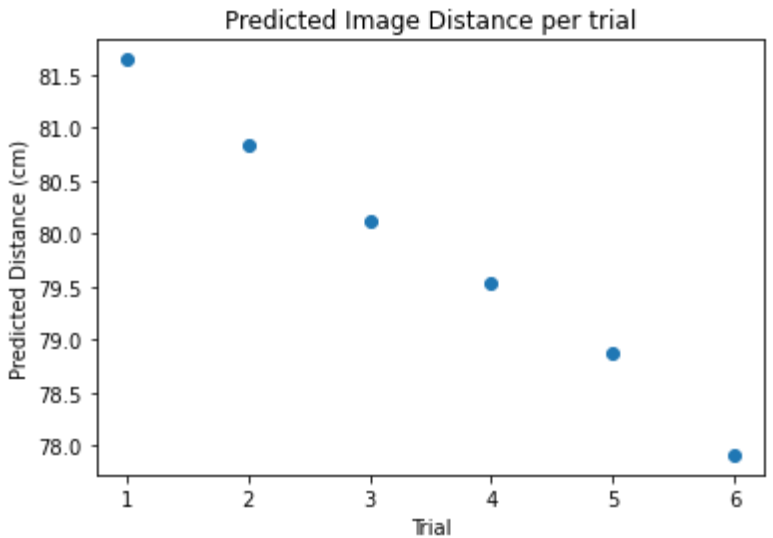
Trial	F to D Lens	F to Screen	Size of F
1	23.7	85.3	6.3
2	28.0	85.3	6.0
3	31.8	85.3	5.5
4	34.8	85.3	5.1
5	38.2	85.3	5.0
6	42.9	85.3	4.5

(All values in cm)

Data Analysis

Calculated Values:

Trial	Calculated Image Distance (cm)
1	81.6
2	80.8
3	80.1
4	79.5
5	78.8
6	77.9



Values don't agree well with experimental results! (Experimental ≈ 50)

Other Attempts

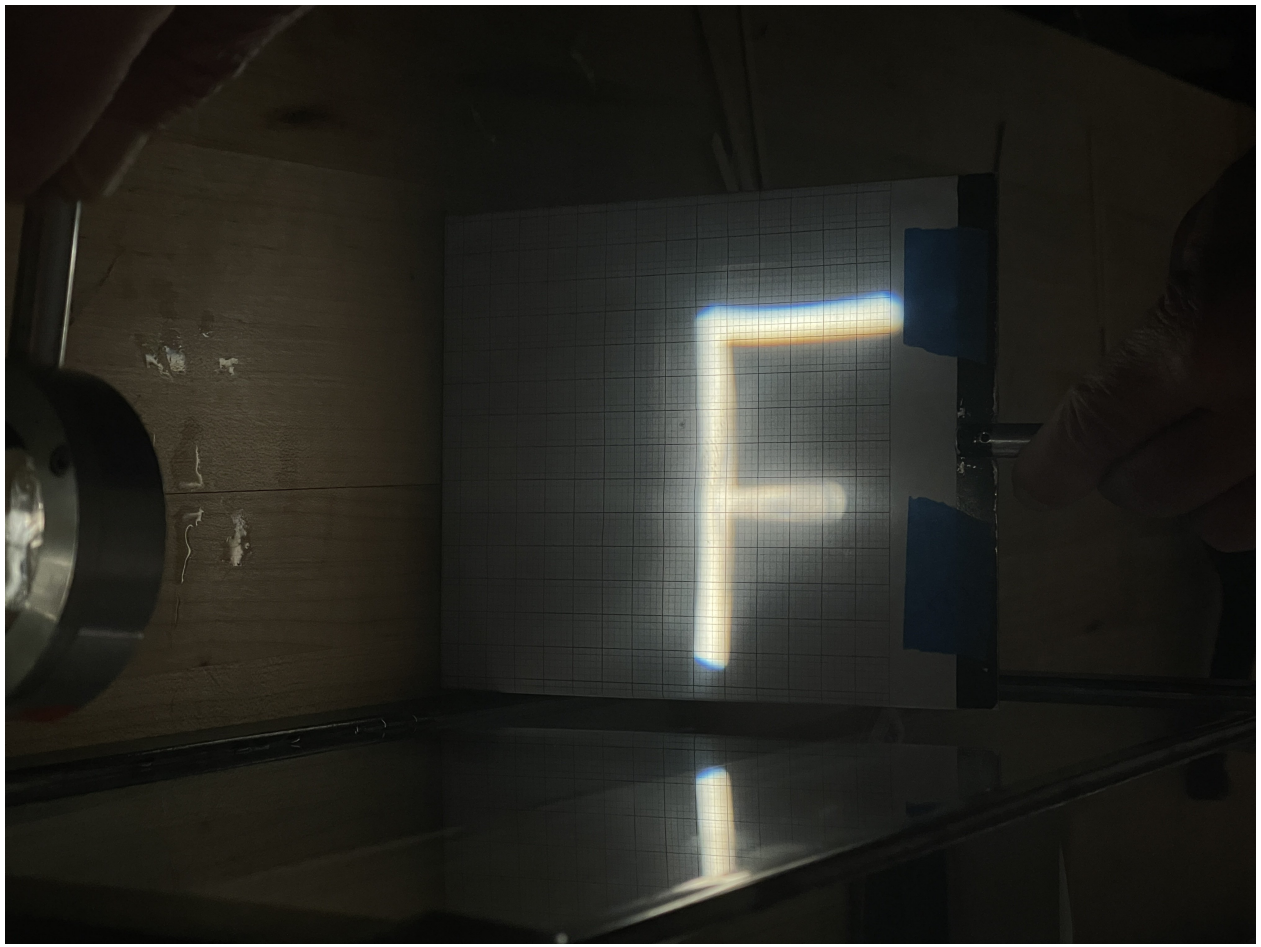
3D Printed Lenses

Attempted to 3D print hollow plastic lenses

Spherical Lenses

Attempted to hot glue two lenses together to create watertight seal

Chromatic and Spherical Aberrations



Wavelength & Index of Refraction Experiment

Goal: Confirm relationship between refractive index & wavelength

Experimental Procedure (Experiment 1):

1. Prepare setup as shown in image (next slide)
2. Shine laser at some angle incident to flat stretch of semicircle
3. Estimate angle & adjust polarizer to minimize transmission
4. Fine tune angle
5. Repeat procedure for red, green, & UV lasers

Note: Green & Red: use chalk dust; UV & use fluorescent dye

Results & Conclusions:

- Observed opposite trend from what was expected
- Underestimated errors & imprecise measurements
- Good value for refractive index (1.33), but not precise

Other Experiment Continued

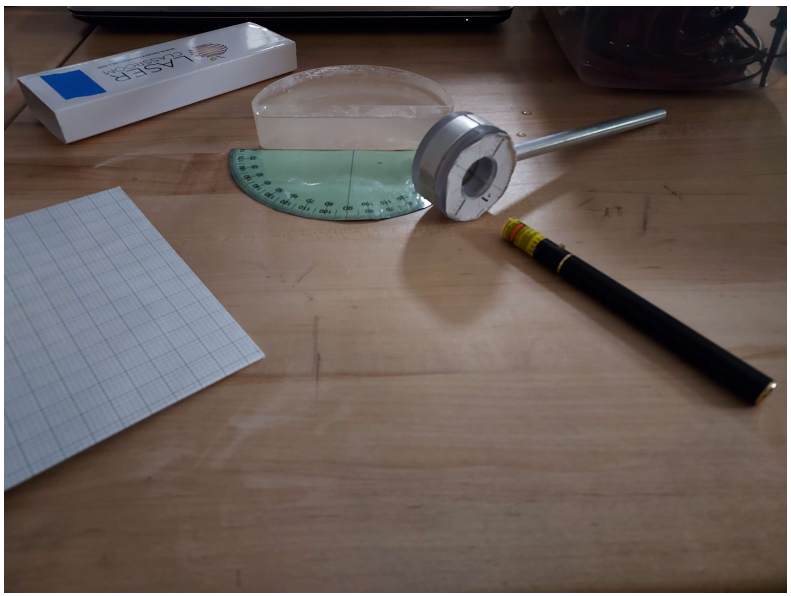
Experimental Procedure (Experiment 2):

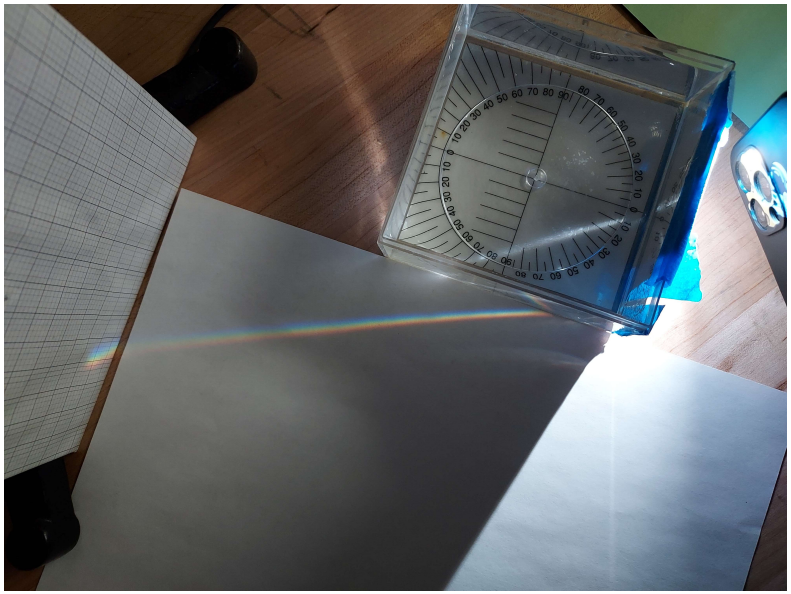
1. Shine iPhone camera light into water-filled plastic rectangular prism instead

Results & Conclusions:

- Challenging to precisely measure angle & avoid small shifts
- Correct discrepancy (0.015) despite incorrect refractive index

New Experimental Setups





Results and Conclusions

What Went Wrong

- Data was difficult to take
- Data doesn't exactly agree with theoretical results

What Went Right

- Proper behavior is confirmed
- Lenses were a good fit
- Setup did not fall apart

Future Directions

Challenges

More time could yield more accurate/precise results, but expected pattern was observed

Alternative Setups

- **Glycerin**: fill tank with glycerin (higher refractive index)
- **Epoxy resin**: cast lens shape into resin mold
- **Epoxy resin take 2:** Inject lens-shaped air bubbles into resin

Could've worked better since we'd have actual air bubbles

Conclusion

Main Takeaway: Physics 5B did not lie to us about the optics

Thank you!

References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