# Lab 7: Reflection and Refraction

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A pdf version of this lab may downloaded here.
The odt version of this lab may be downloaded here.

# Abstract

The purpose of this lab was to test the laws of reflection and refraction, especially using air, water, and glass. By using a plane laser, and various mirrors and transparent bodies, we were able to confirm fundamental optic laws.

The most severe problems that we encountered in this lab were accuracy. Small angles are hard to distinguish when a millimeter can make the difference of several degrees.

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# Contents



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# Objectives

- To test the laws of refection and refraction
- To measure the indices of refraction for water and glass
- To find the position of the image produced by a plane mirror.

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# Methods

**Part A. Law of Reflection and Image Formation by a Plane Mirror**

We folded an 8.5 by 11 inch paper in half both ways to create a set of perpendicular lines through the center. We supported a mirror so that it was perpendicular to the 8.5 inch line and the plane of the paper. We decided to deviate from the wiki's procedure, and make all of our lasers reflect at the origin. We then plotted points and drew lines for three different reflections across the origin. Using a protractor, we measured the angles, and compared them to the following equation.

$$\theta_i = \theta_t$$

Instead of adding a fourth line, we did a more comprehensive analysis of our three lines.

To find the image, we removed the mirror and extended the lines backwards. We set our imaginary "object" to 12cm in front of the mirror. We found the width of the lines at 12cm in front of the mirror, and compared it to the width of the lines 12cm behind the mirror.

**Part B. Index of Refraction of Glass**

We folded an 8.5 by 11 inch paper in half both ways to create a set of perpendicular lines through the center. We placed the rectangular glass plate so that the clear face was centered along the 8.5 inch line. We traced the outline of the plate, and put two points on the entering beam, and two points on the exiting beam. We measured the width of the glass, and drew lines to find a point where they all converged at the center of the glass. The width of the glass was p, and the distance of convergence was q. The ratio between these two was expected to be the index of refraction. We compared this value to the accepted value for glass: 1.52.

**Part C. Index of Refraction of Water**

We folded an 8.5 by 11 inch paper in half both ways to create a set of perpendicular lines through the center. We filled a semicircular container with water and placed it so that if it were a full circle, the center would be at the intersection of the two perpendicular lines on the paper. For angles of 10°, 25°, 40°, 50°, and 60°, we shined a beam into the origin and put a point on where the beam was as it left the curved side of the container. After we collected the data for each point, we took the container away, and drew lines, and used a protractor to find $\theta_t$, the angle of refraction. Using Graphical Analysis, we plotted a graph of $\sin(\theta_i)$ vs. $\sin(\theta_t)$. We found the slope of the line and compared it to the accepted value of the index of refraction of water, which is 1.3330.

**Part D. Critical Angle - Total Internal Reflection**

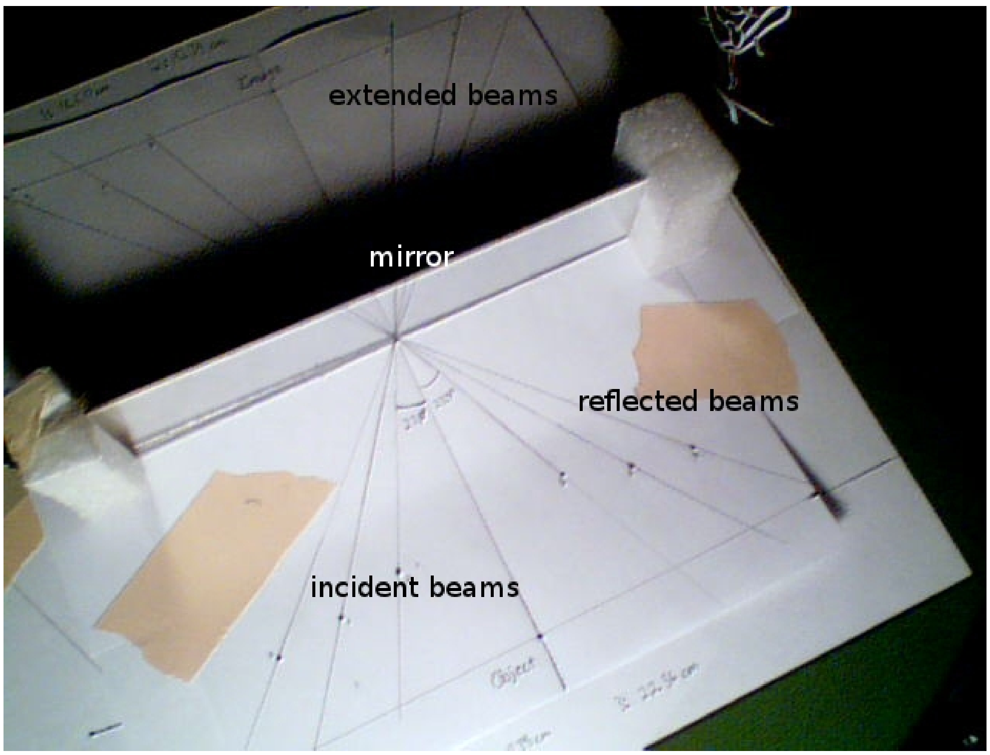
We placed the water-filled semi-desk so that the 11 inch line would bisect it, and so that the straight edge of the disk would lie upon the 8.5 inch line. We then pointed the laser such that the beam entered the disk on the curved side and exited through the center of the straight edge.

Then, to find the critical angle, ensuring the beam continued to exit from the center of the straight edge, we rotated the paper holding the semi-disk up until the point where the laser beam was fully internally reflected, i.e., no beam exited through the straight edge. We then compared the angle to the expected angle.

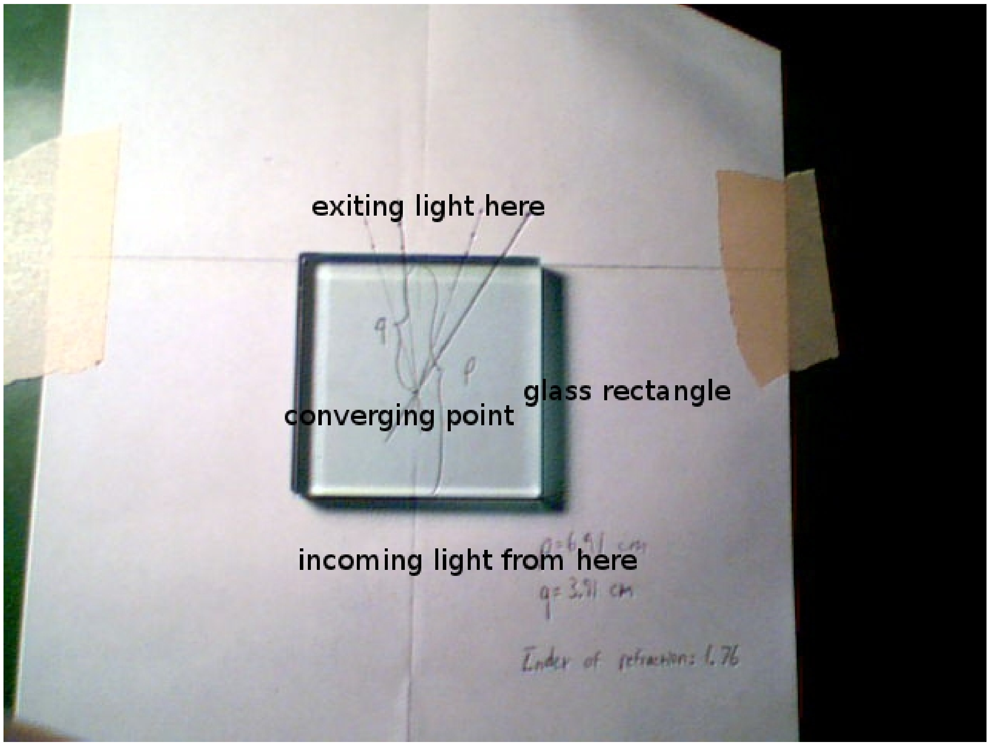
# <u>Setup</u>

Materials:

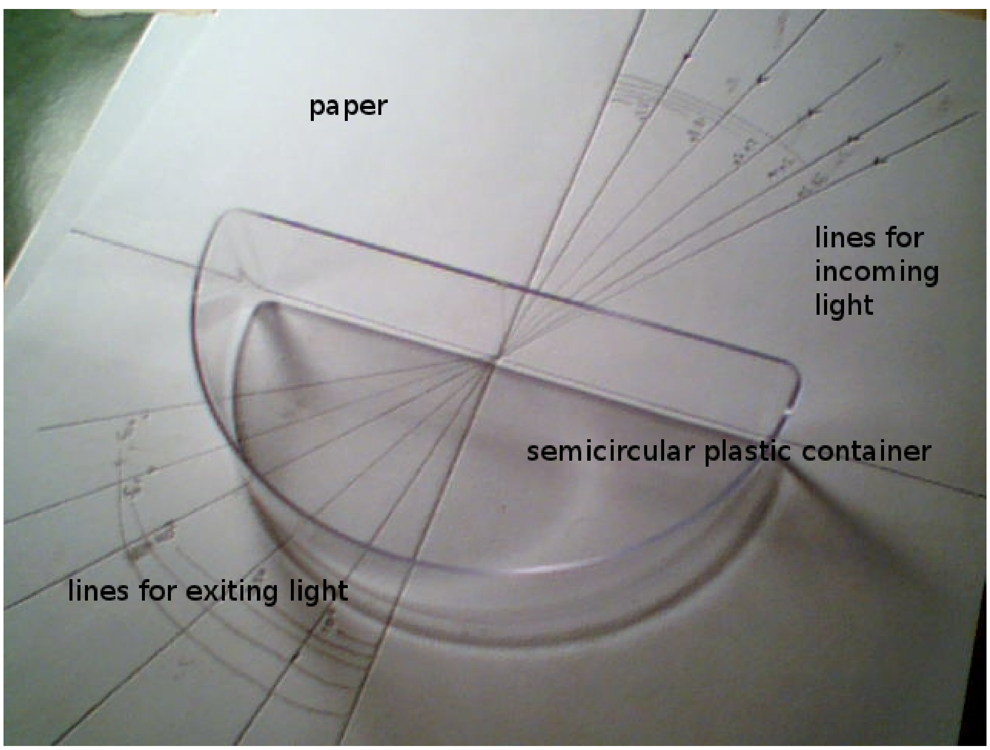
- Plane mirrors and wooden holders
- Crown glass rectangular plate
- Plastic semi-disk container
- Protractor, ruler
- Craftsman Laser Trac™ leveling tool
- Desk lamp
- Graphical Analysis software



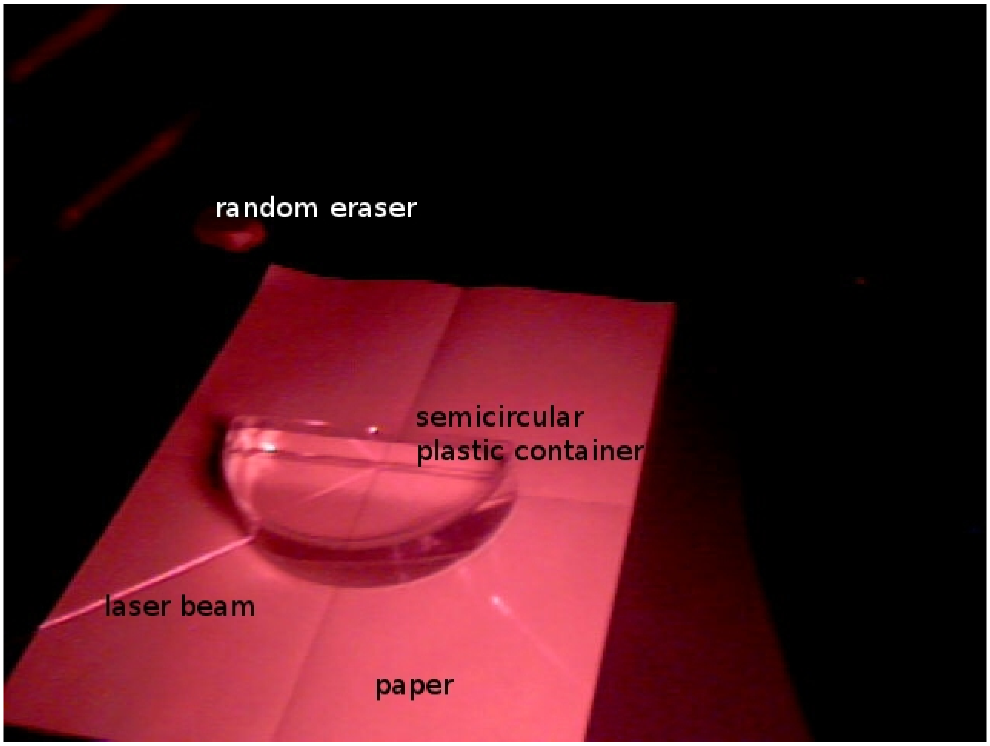

Our setup for part a




Our setup for part b




Our setup for part c




Our setup for part d

# Data and Analysis

## Part A. Law of Reflection and Image Formation by a Plane

| $\theta_1$ | $\theta_2$ | %Error | $d_{object}$(cm) | $d_{image}$(cm) | %Error |
|---|---|---|---|---|---|
| 34.5 | 34.1 | 1.16% | 16.42 | 16.60 | 1.10% |
| 23.0 | 23.4 | 1.74% | 10.38 | 10.39 | 0.10% |
| 43.0 | 42.2 | 1.86% | 22.36 | 22.14 | 0.98% |

The equations given seem to hold true

If the mirror were to be moved so that it was no longer parallel with the axis, then the reflected angle would not be the same as the incident angle. We tried to keep the mirror still, but every time we bumped the table, the mirror shook a little. The pencil lines that we used to create the lines and measure the angle were not infinitely thin, but had a thickness. Also, the degree marks on the protractor were somewhat close together and occasionally required a best guess to get an exact amount. This could easily account for much of the error.

## Part B. Index of Refraction of Glass

p (The width of the glass) = 6.91cm
q (The perceived depth of the glass) = 3.91cm
p/q = 1.76
$n_{glass}$=1.52
%Error = 15.8%

As with the previous part of the experiment, much of the error came from our limited ability to get an accurate angle reading. The degree marks on the protractor were rather close together, and the pencil lines were not infinitely thin. Also, our outline of the glass rectangle was done on the outside of the glass, not on the actual boundary. We tried to compensate for this, but there would be a little error even with the compensation.

As our lines all converged at the same point, it is likely that the error in this part is due to an actual difference in the index of refraction, and not some persistent systematic error.

## Part C. Index of Refraction of Water


A graph of $\sin(\theta_t)$ $\sin(\theta_i)$. The slope of this line is expected to be the index of refraction of water.

| $\theta_i$ | $\theta_t$ | $\sin(\theta_i)$ | $\sin(\theta_t)$ | n | %Error |
|---|---|---|---|---|---|
| 10.0 | 8.2 | 0.1736 | 0.1426 | 1.217 | 8.67% |
| 25.0 | 18.8 | 0.4226 | 0.3223 | 1.311 | 1.62% |
| 40.0 | 27.5 | 0.6428 | 0.4617 | 1.392 | 4.43% |
| 50.0 | 34.6 | 0.7660 | 0.5678 | 1.349 | 1.20% |
| 60.0 | 39.2 | 0.8660 | 0.6320 | 1.370 | 2.79% |

Slope = 1.414
$n_{water}$ = 1.333
%Error=6.07%

As you may have guessed, much of the error in this part may have been caused by a lack of accuracy. But in this part, another source of error was intruded. In between the air and the water was a thin layer of plastic which constituted the container itself. This plastic had a refraction which we did not account for and may have thrown off the angle by a small amount. Although the thickness of the container is not so thick as to cause too much of a deviation, it still could cause the angle to be off by one or two degrees.

## D. Critical Angle - Total Internal Reflection

| |
|---|
| The line vanished when $\theta_i$>42° |
| We would expect this value to be equal to |
| $\text{asin}(1/n_{glass}) = 48.6°$ |
| %Error=13.58% |

The primary source of our error was probably due to our procedure. Around the beam that exited the straight edge, there was a hazy red region, and a second, less intense beam. We only rotated our apparatus until the more intense beam of light was fully reflected. If we had continued to rotate so that all the light was totally reflected, then we would have had a critical angle of about 48 degrees, much closer to the theoretical value for the critical angle. It is also possible that the water in the plastic disk had a higher index of refraction than that of pure water. The plastic container and impurities in the water could have changed the refractive properties of our system to produce a value slightly different than that of pure water. Using our experimental value for water's refractive index from the last part, we find that the critical angle is 45 degrees, much closer to our experimental value of 42.

# Conclusion

Overall, I believe this lab was a success. Most of our error was reasonable considering that our %Error was heavily dependent on angles, which are very difficult to get exact with small protractors and lasers and pencil lines that are about a millimeter wide.

Other than accuracy errors, there were other errors. We may have bumped the table to cause marks and objects to move slightly. In part b, our glass may have actually had a slightly different index of refraction, since all of the lines converged to the same point. In parts c and d, the thin layer of plastic may have caused our indices of refraction to be off since we did not account for the refraction of the plastic. And lastly, due to a judgment error on our part between which of two lines to use, our error could be due to a misprocedure on our part.

If this lab were to be improved, I would have used larger protractors or image analysis. By fitting lines to the dots, and then analyzing them with a computer for more accurate angles.

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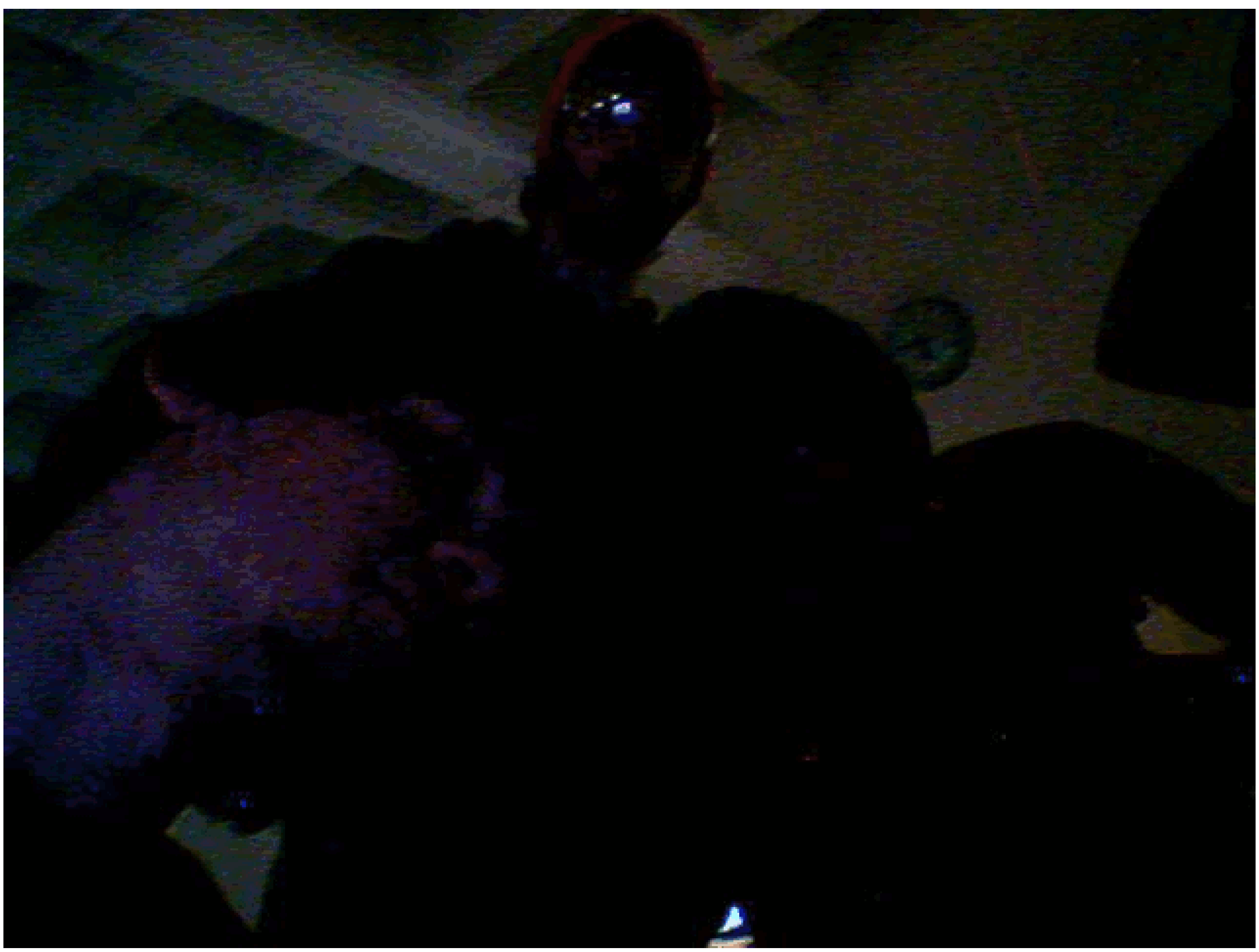
# Signature



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