

Optical Activity of Sugar

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I. INTRODUCTION

In order to understand how sugar concentration in water affects the polarization of light, we measured the intensity of light exiting a second, constant angle polarizer as a function of the angle of the first polarizer. We used a bright white light source, a photometer, and a series of beakers varying in size with different concentrations of sugar in water. By using two polarizers, one at a constant angle and the other at varying angles, we were able to determine the relative polarization change by the sugar water. For each trial, the first (varying) polarizer began at 90 degrees to the second (constant) polarizer, and was then rotated in 10 degree increments to 0 degrees relative to the second polarizer. We first began by measuring the intensity of light exiting the second polarizer for no beaker, then small, medium, and large beakers with no water. This initial dataset provided us with a baseline for the intensity of light exiting the second polarizer.

II. METHODS

There were several possible sources of uncertainty unrelated to error in measurement. The first was the use of external light sources. A phone flashlight was used to see the angle of the polarizer and the intensity meter. The computer light was also on during the trials in order to input data directly into code. Although the phone flashlight was necessary to make measurements, its effect on the intensity meter could have been minimized by shielding the fiber optic cable from the flashlight's light. The computer light was also necessary to input data, but it was not in the direct line of sight of the intensity meter.

A secondary source of uncertainty could be the swirling of the solution in the beaker. The swirling of the solution could have caused light to scatter unevenly, leading to either higher or lower intensity readings. The possible source of uncertainty stemming from the swirling of the solution could have been minimized by allowing the solution to settle longer prior to taking measurements.

A tertiary source of uncertainty could be the amount of light traveling through each differently sized beakers directly into the fiberglass optical cable. We are unsure if there would be any direct way to minimize the possible uncertainty stemming from the amount of light traveling through each differently sized beaker. However, this uncertainty can be discarded when comparing intensity measurements between trials with the same beaker size.

A final possible source of uncertainty stemmed from

the medium beaker being broken and needing to be replaced prior to the solution 2 experiment. Although unlikely, the replacement beaker could have had slightly different optical properties than the original medium beaker.

III. DATA AND RESULTS

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.00	0.10
80	0.14	0.10
70	0.47	0.10
60	1.00	0.30
50	1.65	0.30
40	2.40	0.30
30	3.00	1.00
20	3.40	1.00
10	3.60	1.00
0	3.80	1.00

TABLE I. This table shows the intensity of light exiting the second polarizer for no beaker. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.00	0.10
80	0.05	0.10
70	0.40	0.10
60	0.78	0.10
50	1.25	0.30
40	1.75	0.30
30	2.20	0.30
20	2.55	0.30
10	2.70	0.30
0	2.85	0.30

TABLE II. This table shows the intensity of light exiting the second polarizer for small beaker with no water. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.00	0.10
80	0.12	0.10
70	0.47	0.10
60	0.94	0.10
50	1.50	0.30
40	2.10	0.30
30	2.65	0.30
20	3.00	1.00
10	3.20	1.00
0	3.30	1.00

TABLE III. This table shows the intensity of light exiting the second polarizer for medium beaker with no water. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.27	0.10
80	0.88	0.10
70	2.50	0.30
60	4.60	1.00
50	7.40	1.00
40	10.00	3.00
30	12.50	3.00
20	14.50	3.00
10	15.50	3.00
0	16.00	3.00

TABLE VI. This table shows the intensity of light exiting the second polarizer for medium beaker with water. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.00	0.10
80	0.10	0.10
70	0.37	0.10
60	0.80	0.10
50	1.30	0.30
40	1.80	0.30
30	2.25	0.30
20	2.50	0.30
10	2.80	0.30
0	2.90	0.30

TABLE IV. This table shows the intensity of light exiting the second polarizer for large beaker with no water. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.09	0.10
80	0.43	0.10
70	1.30	0.30
60	2.40	0.30
50	3.90	1.00
40	5.20	1.00
30	6.60	1.00
20	7.60	1.00
10	8.20	1.00
0	8.60	1.00

TABLE VII. This table shows the intensity of light exiting the second polarizer for large beaker with water. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.88	0.10
80	2.65	0.30
70	6.20	1.00
60	12.00	3.00
50	18.00	3.00
40	25.50	3.00
30	31.00	10.00
20	35.00	10.00
10	38.00	10.00
0	39.00	10.00

TABLE V. This table shows the intensity of light exiting the second polarizer for small beaker with water. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
100	0.80	0.30
90	2.25	0.30
80	5.00	1.00
70	8.90	1.00
60	13.00	3.00
50	16.50	3.00
40	21.50	3.00
30	24.00	3.00
20	26.00	3.00
10	25.50	3.00
0	24.00	3.00

TABLE VIII. This table shows the intensity of light exiting the second polarizer for small beaker with Solution 1. The polarization of the first polarizer was varied from 100 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	1.90	0.30
80	3.90	1.00
70	6.20	1.00
60	9.20	1.00
50	11.50	3.00
40	13.50	3.00
30	15.00	3.00
20	15.00	3.00
10	14.50	3.00
0	13.50	3.00

TABLE IX. This table shows the intensity of light exiting the second polarizer for medium beaker with Solution 1. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	9.40	1.00
80	13.50	3.00
70	17.50	3.00
60	21.00	3.00
50	23.00	3.00
40	23.50	3.00
30	24.50	3.00
20	22.00	3.00
10	19.50	3.00
0	15.50	3.00

TABLE XII. This table shows the intensity of light exiting the second polarizer for medium beaker with Solution 2. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	1.30	0.30
80	2.50	0.30
70	4.00	1.00
60	5.40	1.00
50	6.70	1.00
40	7.60	1.00
30	8.30	1.00
20	8.50	1.00
10	8.10	1.00
0	7.20	1.00

TABLE X. This table shows the intensity of light exiting the second polarizer for large beaker with Solution 1. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	2.20	0.30
80	3.10	1.00
70	4.30	1.00
60	5.20	1.00
50	5.80	1.00
40	5.90	1.00
30	6.40	1.00
20	5.80	1.00
10	5.10	1.00
0	3.70	1.00

TABLE XIII. This table shows the intensity of light exiting the second polarizer for large beaker with Solution 2. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	5.00	1.00
80	7.70	1.00
70	11.00	3.00
60	14.00	3.00
50	17.00	3.00
40	18.50	3.00
30	19.00	3.00
20	19.50	3.00
10	17.50	3.00
0	13.50	3.00

TABLE XI. This table shows the intensity of light exiting the second polarizer for small beaker with Solution 2. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	1.70	0.30
80	5.30	1.00
70	11.00	3.00
60	17.50	3.00
50	26.00	3.00
40	34.00	10.00
30	40.00	10.00
20	44.00	10.00
10	46.00	10.00
0	46.00	10.00

TABLE XIV. This table shows the intensity of light exiting the second polarizer for small beaker with Solution 3. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.58	0.10
80	1.75	0.30
70	3.40	1.00
60	5.80	1.00
50	8.40	1.00
40	11.00	3.00
30	12.00	3.00
20	13.00	3.00
10	13.50	3.00
0	13.50	3.00

TABLE XV. This table shows the intensity of light exiting the second polarizer for medium beaker with Solution 3. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.29	0.10
80	1.05	0.30
70	2.55	1.00
60	4.50	1.00
50	6.60	1.00
40	9.20	3.00
30	11.00	3.00
20	12.00	3.00
10	13.00	3.00
0	13.00	3.00

TABLE XVIII. This table shows the intensity of light exiting the second polarizer for medium beaker with Solution 4. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.41	0.10
80	1.10	0.30
70	2.25	0.30
60	3.60	1.00
50	5.10	1.00
40	6.40	1.00
30	7.30	1.00
20	8.00	1.00
10	8.20	1.00
0	8.00	1.00

TABLE XVI. This table shows the intensity of light exiting the second polarizer for large beaker with Solution 3. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	1.20	0.30
80	3.80	1.00
70	9.20	1.00
60	16.00	3.00
50	24.50	3.00
40	32.00	10.00
30	38.00	10.00
20	43.00	10.00
10	46.00	10.00
0	46.00	10.00

TABLE XVII. This table shows the intensity of light exiting the second polarizer for small beaker with Solution 4. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

Polarization (degrees)	Intensity (arb. units)	Intensity Error (arb. units)
90	0.15	0.10
80	0.61	0.10
70	1.55	0.30
60	2.80	0.30
50	4.20	1.00
40	5.50	1.00
30	6.60	1.00
20	7.60	1.00
10	8.00	1.00
0	8.20	1.00

TABLE XIX. This table shows the intensity of light exiting the second polarizer for large beaker with Solution 4. The polarization of the first polarizer was varied from 90 to 0 degrees. The intensity of light exiting the second polarizer was measured by the photometer and recorded in arbitrary units. Lastly, the uncertainty in the intensity of light exiting the second polarizer was also recorded in arbitrary units.

IV. DISCUSSION

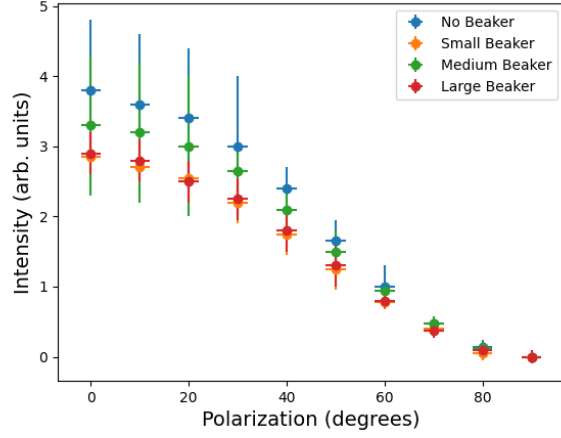


FIG. 1. Intensity vs. Polarization for varying beaker sizes with no water.

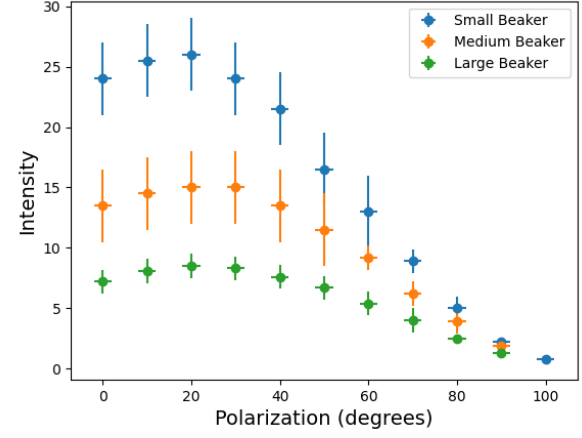


FIG. 3. Intensity vs. Polarization for varying beaker sizes with solution 1.

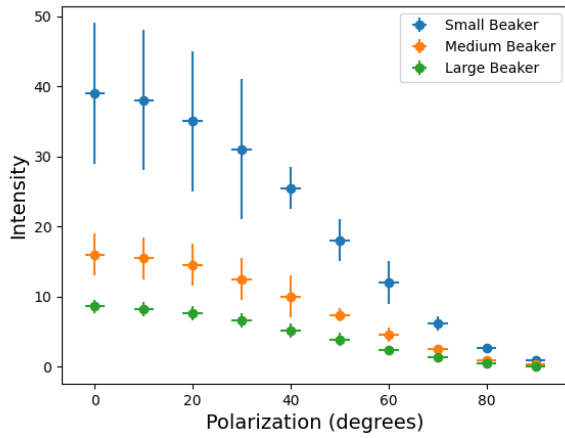


FIG. 2. Intensity vs. Polarization for varying beaker sizes with water.

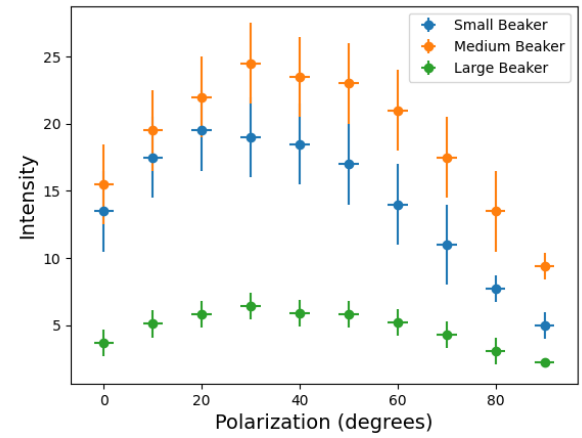


FIG. 4. Intensity vs. Polarization for varying beaker sizes with solution 2.

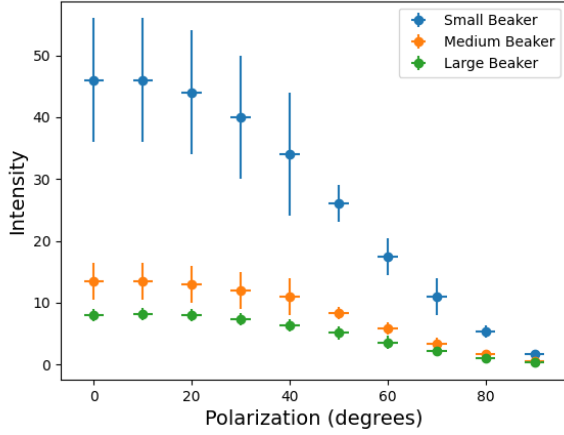


FIG. 5. Intensity vs. Polarization for varying beaker sizes with solution 3.

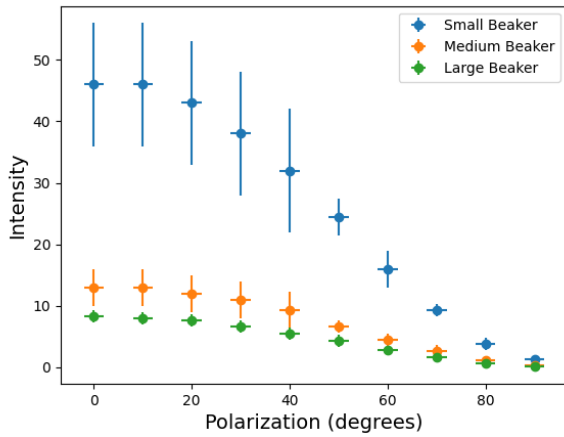


FIG. 6. Intensity vs. Polarization for varying beaker sizes with solution 4.

Each of the following graphs show the phase shift as a function of sugar concentration in water, with each separate graph containing data from one beaker size. The phase shifts were found by fitting the intensity vs. polarization data to a cosine function. By representing phase shift versus sugar concentration, we can quantify how the polarization of light changes as a function of sugar concentration in water.

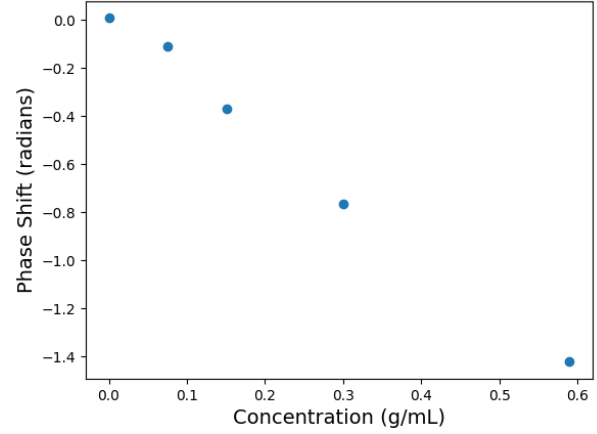


FIG. 7. This graph shows the phase shifts for large beaker.

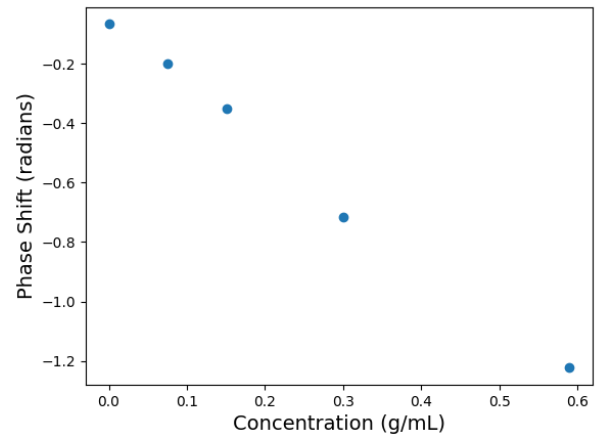


FIG. 8. Phase shifts for medium beaker.

V. CONCLUSION

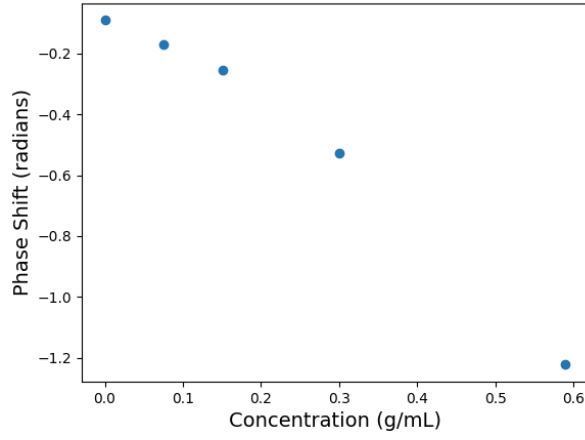


FIG. 9. Phase shifts for small beaker.