PHYS 1112L - Introductory Physics Laboratory II

Laboratory Advanced Sheet
Snell's Law

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1. Objectives. The objectives of this laboratory are

    a. to determine the index of refraction of a liquid using Snell's law.

    b. to determine the indices of refraction of transparent solid plates of materials using multiple reflections and Snell's law.

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2. Theory.

    a. Snell's law states

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

    where

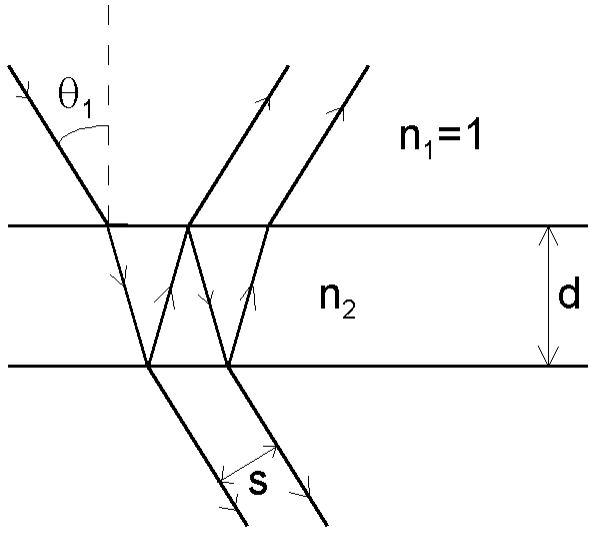
        n_1 is the index of refraction of the medium in which the light is incident,
        θ_1 is the angle of incidence,
        n_2 is the index of refraction of the medium in which the light is refracted, and
        θ_2 is the angle of refraction.

    b. In both experiments conducted in this laboratory, the medium in which the light is incident will be air. Thus,

$$n_1 = 1$$

    c. In the first experiment to be conducted in this laboratory, a narrow beam of light of a single wavelength will be incident on a tank containing a liquid. The angle of incidence of the beam will be varied and the angle of refraction will be measured. According to Snell's law, a graph of the sine of the angle of incidence versus the sine of the angle of refraction should yield a straight line whose slope is the index of refraction of the liquid.

d. In the second experiment to be conducted in this laboratory, a narrow beam of light of a single wavelength will be incident on plates of transparent solids. When incident light strikes a slab of material at an angle other than perpendicular, the beam is both transmitted and internally reflected multiple times (see figure below).



The separation distance between adjacent beams of light transmitted through the slab is given by

$$s = 2d \sin\theta_1 \cos\theta_1 / (n_2^2 - \sin^2\theta_1)^{1/2}$$

where

s is the separation distance between adjacent transmitted beams,
d is the plate thickness,
θ_1 is the angle of incidence, and
n_2 is the index of refraction in the slab medium.

This equation can be used with direct measurements of the beam separation distance, plate thickness and angle of incidence of the incident beam to calculate the index of refraction. The mean of measurements at different angles of incidence will be used to estimate the index of refraction of the slab material.

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3. Apparatus and experimental procedures.

a. Equipment.

1) Snell's law apparatus (tank with angle of incidence grid, index mark and liquid).

2) He-Ne lasers (2).

3) Micrometer.

4) Tape.

5) Optical bench.

6) Rotational mount.

7) Scale for measuring separation distance.

8) Acrylic and glass plates.

b. Experimental setup. Figures 1 and 2 (to be provided by the student) show the equipment configured for the two experiments.

c. Capabilities. Capabilities of the equipment items listed in paragraph 3a will be provided by the student.

d. Procedures. Detailed instructions are provided in paragraph 4 below.

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4. Requirements.

a. In the laboratory.

1) Your instructor will introduce you to the equipment to be used in the experiments and provide a laser safety briefing. Each laboratory group will perform the measurements with the Snell's law apparatus first (liquid) and then make measurements to determine the indices of refraction of transparent plates.

2) Measure the width of the tank.

3) Fill the tank with the liquid provided by the instructor.

4) Align the laser beam along the zero degree angle of incidence line using the wire in the angle arm and the index mark on the front of the tank.

5) Using the tape provided, mark the position of the laser beam emerging from the back of the tank. All measurements of the refracted beam will be made with respect to this position.

6) Vary the angle of incidence, and measure and record the distance along the back wall of the tank between the tape and the exit point of the refracted beam. Make measurements at a five (5) degree increment.

7) Using a micrometer, measure the thickness of the acrylic and glass plates.

8) Using the optical bench, align the laser, the plate on the rotating stand and the scale to measure beam separation to obtain a zero degree incident laser beam (laser beam perpendicular to the plate's surface). Record the value of the angle on the rotating stand associated with zero degree incidence.

9) Rotate the plate to produce beams on the separation scale due to multiple reflections in the plate. Record the value of the angle on the rotating stand and measure the separation distance between the primary beam and the multiply reflected beam on the separation scale. Repeat for three angles of incidence for each material.

b. After the laboratory. The items listed below will be turned in at the beginning of the next laboratory period. A complete laboratory report is **not** required for this experiment.

Para 3. Apparatus and experimental procedures.

1) Provide figures for the two experiments (para 3b).

2) Provide descriptions of the capabilities of equipment used in the experiment (para 3c).

Para 4. Data. Data tables are included at Annex A for recording measurements taken in the laboratory. A copy of these tables must be included with the lab report. Provide the items listed below in your report in

the form a Microsoft Excel™ spreadsheet showing data and calculations. The spreadsheet will include:

1) Original data tables.

2) The width of tank of Snell's law apparatus.

3) A table of angles of incidence, sines of angles of incidence, beam displacement distance and sines of angles of refraction.

4) A graph of the sine of the angle incidence versus the sine of the angle of refraction with regression (trend) line.

5) Calculation of the percent discrepancy in the index of refraction of the liquid. Your instructor will provide the actual value.

6) The thicknesses of the acrylic and glass plates.

7) The angle of the rotating stand corresponding to zero degree incidence.

8) A table of rotating stand angles, beam separation distances and calculations of the index of refraction for the acrylic and glass plates.

9) Calculations of the means of the indices of refraction for the acrylic and glass plates.

10) Calculation of the percent discrepancies in the indices of refraction of the acrylic and glass plates. Your instructor will provide the actual values.

Para 5. Results and Conclusions.

a. Results.

1) A statement of the index of refraction of the liquid and its percent discrepancy.

2) A statement of the indices of refraction of the acrylic and glass plates and their percent discrepancies.

b. Conclusions. Description of sources of error in each of the two experiments.

Annex A
Data

1. Experiment with Snell's law apparatus.

a. Width of the tank in Snell's law apparatus.

w = _____ cm

b. Refracted beam displacement.

θ_1 (degrees)	x (cm)
0.0	0.0
5.0	
10.0	
15.0	
20.0	
25.0	
30.0	
35.0	
40.0	
45.0	
50.0	
55.0	
60.0	
65.0	
70.0	

c. Actual value of index of refraction of liquid.

n_2 = _____

3. Multiple reflection experiment.

a. Angle of rotating stand corresponding to zero degree incidence.

θ_0 = _____

b. Beam separation distance.

1) Acrylic plate.

θ_{stand} (degrees)	s (cm)

2) Glass plate.

θ_{stand} (degrees)	s (cm)

c. Actual value of index of refraction of acrylic plate.

n_2 = _____

d. Actual value of index of refraction of glass plate.

n_2 = _____

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