

Introduction

This laboratory is a quantitative investigation of the reflection and refraction of light off optical interfaces. An optical interface is a boundary between two transparent media of different indices of refraction, like air and water, or water and glass. Reflection makes mirrors, refraction eyeglasses and microscopes. Please review chapter 22 of Serway and Faughn before coming to lab.

You should work this lab with the table lamps on and the room lights off. The lower illumination levels will make it easier for you to see the laser beam.

In the experiment, you will be using a collimated light source. Your TA will explain any precautions before you start the lab.

Pre-lab Homework

NOTE that there are five pre-lab homework questions embedded in this lab. They are easy to spot as you read through the lab. You should complete all these questions before coming to lab.

Experiment A: Snell's Law

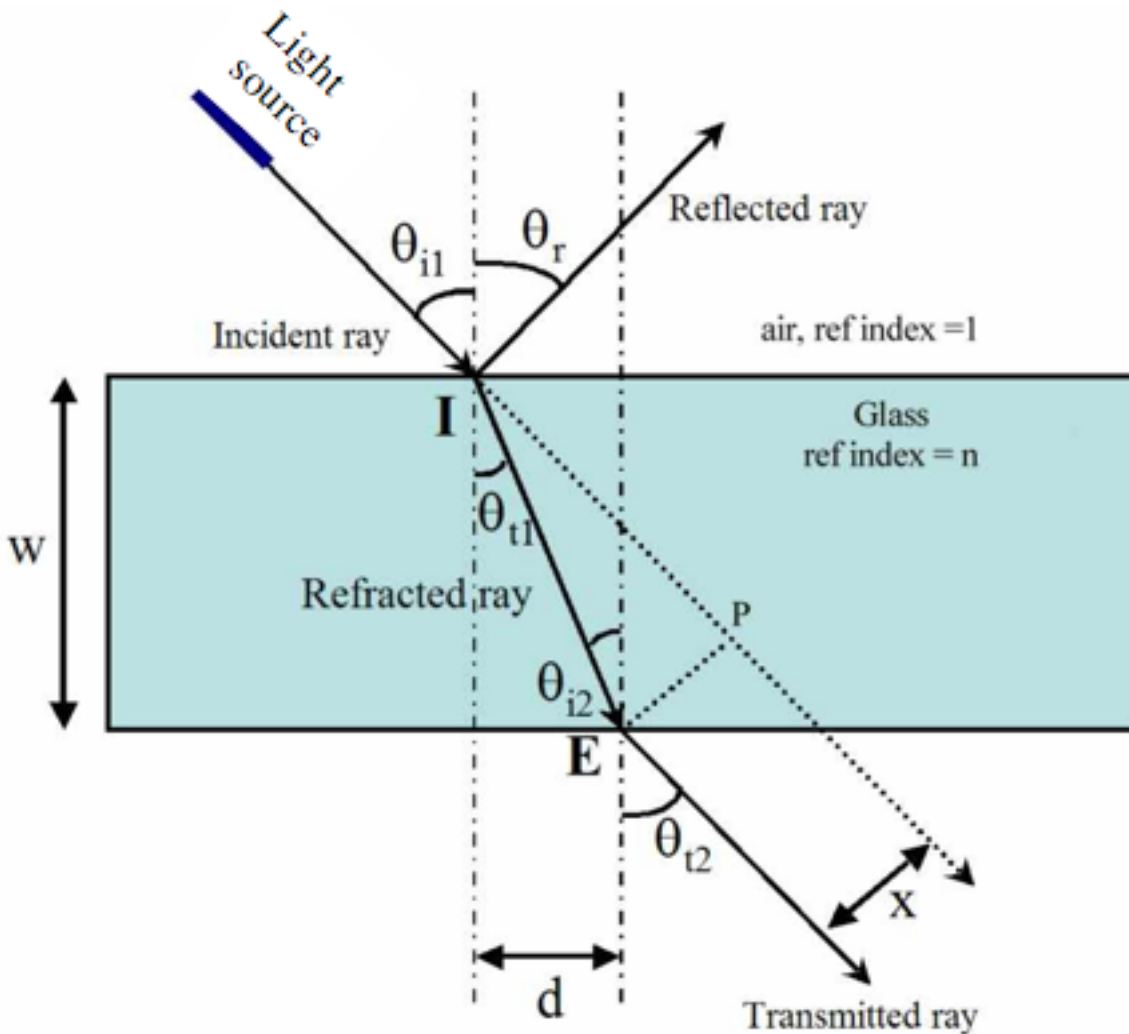
A1. You will find a trapezoidal slab of acrylic at each station. Center this slab on the ray optics table. By positioning the light beam at various places in the upper left quadrant and aiming it at the slab, you can vary the angle of incidence θ_{i1} . Position the laser at the edge of the ray optics table, and select an incident angle of approximately 60° from the vertical.

Pre-lab Homework

1. Compare the incident angle of the light at the top of the block with the exit angle of the light at the bottom of the block (angles θ_{i1} and θ_{t2}). How are they related to each other? Are they the same or different? Why? (Refer to the figure below).

A2. Sketch the path of the light beam. In your lab notebook, make a sketch of the situation. In your sketch include the location of the light source, the trapezoidal slab, the path of the incident light ray, the path of the refracted light ray, the path of the reflected light ray, and the path of the transmitted light ray. Does light travel in a straight line in the uniform medium of still air?

A3. On your sketch, locate **I**, the point of incidence on the interface. From this point measure the angle of the **incident** ray, θ_{i1} , and the angle of the **reflected** ray, θ_r (upper right quadrant). Compare the angle of reflection θ_r to the angle of incidence θ_{i1} . *Hint: You can measure angles with the protractor provided, or by reading off the angles from the ray optics table.*



We adopt the universal convention of measuring angles of all rays with respect to the local normals to the interfaces, these are the two dotted lines through **I** and **E**.

Estimate visually the intensity of the light reflected from the slab compared to the intensity of the incident ray: would you say it is less than 10%, about half, or more than 90%?

A4. Repeat step A3 on the ray of light transmitted through the sample that exits from point **E** (lower right quadrant). Measure the angle of exit θ_{t2} and compare it to the angle of incidence θ_{i1} . Would you say the amount of light transmitted is less than 10%, about half, or more than 90% of the incident light? Is this estimate consistent with the one you made in step A3? Explain.

A5. By measuring w , the width of the slab, and d , the distance along the interface between the points of incidence (I) and (E), deduce the angle of refraction θ_{tI} . If your sample scatters enough light sideways to be seen looking down into it, then you can measure the angle of refraction directly with a protractor without measuring d .

Pre-lab Homework

2. Assume the slab is perfectly rectangular and has width W . (a) From the right-angled triangle with vertices IPE calculate the lateral displacement x in terms of the incident and refracted angles and the width of the sample. (b) If the incident angle is 60° , $n=1.81$ (crystal instead of usual glass), and $W=8.0$ cm, what is x ?

3. If the incident angle is just a little less than 90° , what is x ? Compare x to w . Can x ever be greater than w ? If the incident angle is zero, what is x ?

A6. Calculate $(\sin \theta_{iI} / \sin \theta_{tI})$ to find the refractive index using Snell's law. Take the index of refraction of air to be 1.00.

A7. Find and plot as many other beams as you can (e.g., what happens to the beam that is reflected at the second surface?) Note the intensity of each beam relative to the incident beam.

A8. Remove the sample. Extend the line of step A2, the incident ray. Measure x , the (perpendicular) distance between the incident and transmitted rays, at two different places along the rays: are these two rays parallel to each other? Compare x to your answer to Pre-lab homework 3.

A9. Repeat the steps from A1 to A6 with incidence angles of 30° , 45° , and 60° to measure the lateral displacement, x , as a function of incidence angle. You need only do the parts required to measure the lateral displacement, x . From the result of Pre-lab Q2, calculate the expected value of x at each incident angle you used. Make a table of the data in your lab books. Use a format like this:

Incident angle (degrees)	Refracted angle (degrees)	Calculated Lateral Displacement (cm)	Measured Lateral Displacement (cm)
30			
45			
60			

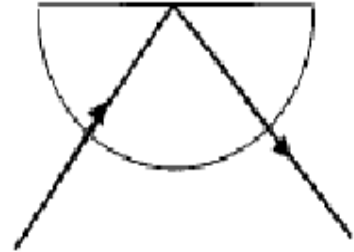
A10. Make a graph to illustrate your data. Plot incident angle horizontally and lateral displacement vertically. Show your calculated values as "X" symbols and the measured values as "O" symbols. Do your calculations and measurements agree? If yes, do they

agree exactly? Comment on any differences between the XXX's and the OOO's. If your measurements and calculations are quite different, explain how this might happen.

Pre-lab Homework

4. Given a block of glass that is semi-circular, a laser pointer, protractor/ruler, and index card, design your own experiment to observe and measure total internal reflection. Describe how you would shine the laser onto the glass block, what angles you would measure and how you would determine the critical angle from your measurements.

Draw the block of glass and the beam going through it at the critical angle. Show where total internal reflection occurs. (For the homework assume $n = 1.52$.) Draw this angle and all others as accurately as you can with a protractor. Label the critical angle and give its value. Remember total internal reflection occurs only when light goes from a denser medium (the sample) into one of lower index (air)

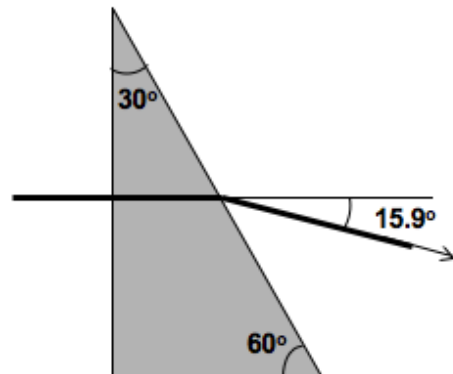


Experiment B: Measuring the Critical Angle

Do the experiment you have designed in Pre-lab question 4 (using the collimated light source instead of the laser). Follow your own instructions about how to setup the measurements. If you need to make modifications or additions to your procedure for Pre-lab Q4 make notes of your revised plan and why you needed to make changes. Can you verify you have total internal reflection? Note the critical angle and calculate the refractive index of the glass.

Pre-lab Homework

5. The figure shows a laser beam coming from the left, deflected by a $30^\circ - 60^\circ - 90^\circ$ prism. What is the prism's index of refraction?



Experiment C: Fiber Optics

There is a single setup of this apparatus. Watch for when it is available, and take time out from your lab work to use the equipment. Shoot the laser through the plastic beam guide. If you can get the beam “in” at one end, does it always come out at the other? What happens when it hits the “walls” of the guide? Are the reflections of the laser beam off the walls total internal reflections? If they are, what energy is lost at each reflection? Can you see any laser beams “leaking out” of the beam guide? Compare the brightness of the laser light as it emerges from the guide to the brightness before it enters. Can you detect (by eye) that energy has been lost?

Use the fiber optics bundle. Can you shoot the laser through it? What happens if you put the end down on the page over a letter? How do you think the fibers are arranged inside? What medical uses are made of these fiber bundles?

Conclusion:

1. *Please do a write-up for the section of the lab that your TAs specified*