Experiment 18
REFLECTION AND REFRACTION

EQUIPMENT

Video: "Geometrical Optics"

Phet™ interactive simulation

INTRODUCTION

The purpose of this experiment is to investigate the behavior of light at the boundary of two media.

Light ordinarily travels in straight lines. When going from one medium to another, light will take the most time-efficient path to go from one point to another. It is this idea which underlies all the formulas that describe light paths. It is referred to as Fermat's principle of least time: light takes the path that requires the least time when it goes from one place to another.

If a surface is smooth, an incident (incoming) light ray will be reflected off the surface at the same angle from which it was incident. In other words, the angle of incidence equals the angle of reflection. This is the *law of reflection*.

The *law of refraction* describes the path of a light ray which passes from one medium into another. *A ray of light entering a transparent medium with a different index of refraction at an oblique angle will be bent.* This bending is caused by the difference in the speed of light in the two media.

In this laboratory exercise you will investigate for yourself the laws of reflection and refraction using a simulation program. You will describe the behavior of incident, reflected, and refracted rays. Through these descriptions you will (hopefully) satisfy yourself of the correctness of these laws.

Optics Review/Introduction

View a short video and answer questions on page 4 of procedure. The video is on YouTube®.

Copy and paste the following link.

https://youtu.be/pzlaDuz1RII

To complete this portion of the lab you will use a simulation program called PhET interactive simulations

Go to the PhET website to run the simulation. Webpage: https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html

If you have problems with 'Firefox', you might want to try 'Chrome' or 'Safari' (browsers).

You are reminded that the speed of light in a vacuum is 3 x 10^8 m/s or c (also 1.0 c). Please note that the index of refraction n is defined as

$$n = \frac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ medium}$$

The index of refraction is always either 1 (one) or greater than 1(one).

PROCEDURE

A. **Reflection of Light Rays** (Review section 28.2 of text).

What is not commonly known is that light incident upon a transparent medium (of a different refractive index) will be both refracted and reflected. **The reflected light obeys the law of reflection.** See figure below from PhET simulation.

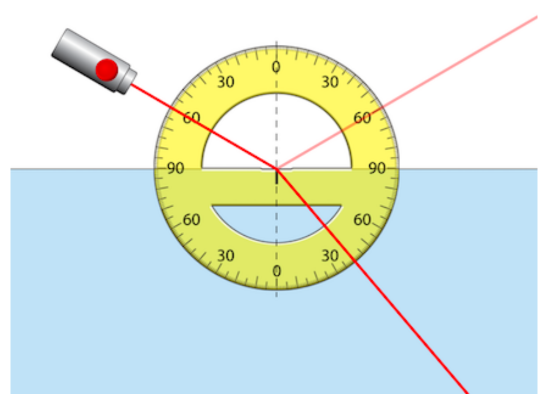


Figure 18-1

When you download the **PhET simulation** the you should see the following screen. Click on "Intro".

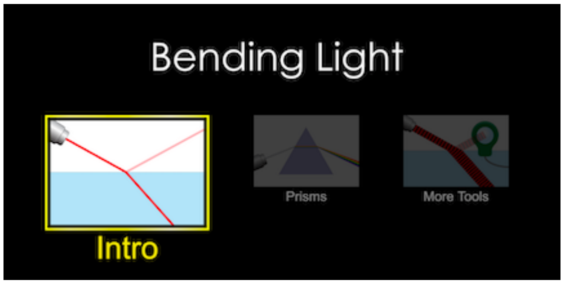


Figure 18-2

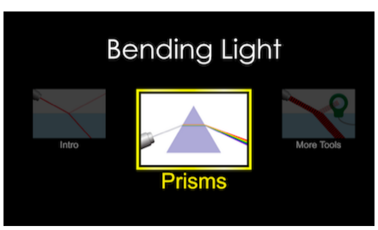
1. You should see a laser, protractor and light intensity meter. Create a simulation that looks similar to figure 18-1 above **(the angle does not matter as long as it is not zero or ninety degrees).** The program is very easy to use. You simply drag and drop. Click on red button to turn laser on. Vary the angle and see what happens.

2. Position the laser at some incident angle between 0 and 90 degrees. Next drag the intensity meter ('round' glass part) into the laser light coming out of the laser. Note the intensity. Next, drag the glass part into the reflected beam. Note the intensity. Lastly, drag the glass part into refracted beam (i.e., the beam in the water). **Record these values in question # 8 below.**

B. Refraction of Light Rays

Whenever light travels to a medium with a different index of refraction it will either speed up of slow down and travel in a path defined by Fermat's principle. As mentioned in the introduction a ray of light entering a transparent medium with a different index of refraction *at an oblique angle* will be bent

1. Go to the start page of **Phet** simulation (you may have to reload) and click on "Prism". See figure below.



2. Create a simulation similar to what is in the figure below. **Click on the 'square' prism.** Move laser to some angle. The angle does not matter **(make it some angle smaller than 60 degrees).** Click on protractor box to make a protractor appear.

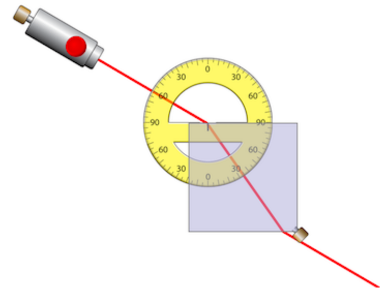


Figure 18-3

3. You will notice that the default material of the prism is glass, and the laser is in air (i.e., "environment" is air.)

   You will now need to measure the incident angle (θ_i) and the refracted angle θ_r. **See figures below.**

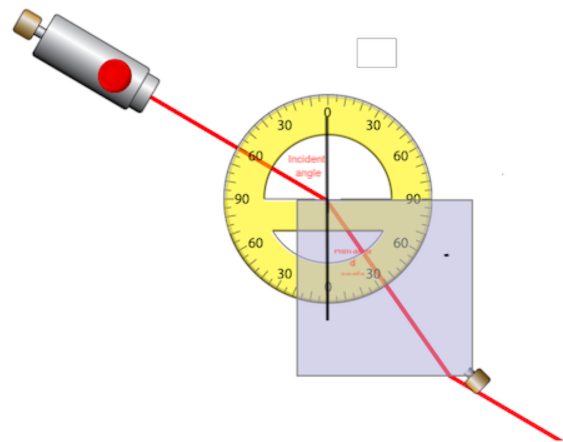


Figure 18-4

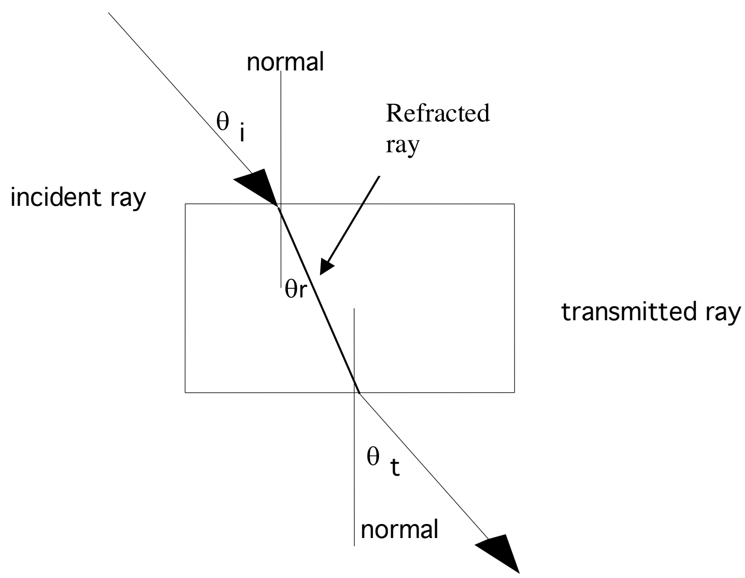
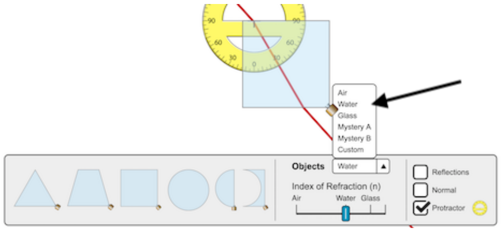


Figure 18-5

4. You should now be able to answer Post Lab question # 9.

5. Once you have completed post lab question 9 click on objects and change the material to “water”. See figure below.



6. You will notice that the refracted angle changed once you changed the medium from glass to water. Remeasure with the protractor. Complete Post Lab question # 10.

7. Go to the bottom menu and click on ‘intro’. See figure 18-2. This is the same simulation used in Part A steps 1) and 2).

   Change the material that the laser is in to “water” and the material of the exit beam to “air”.

   You now have a laser immersed in water shooting a beam through the bottom of a transparent container.

   Rotate the laser counterclockwise until there is no refracted beam.

8. What is this phenomena called? What is the measured angle (it will not necessarily be exactly the same as given in the textbook. See section 28.6 of Hewitt. Complete Post Lab question # 11.

Experiment 18

REFLECTION AND REFRACTION: REVIEW QUESTIONS

Use YouTube video from Optics Review/Introduction to answer questions 1 through 6

1) What is the value of the speed of light in air or free space?

2) What are some common sources of light which make objects visible?

3) What evidence exists to show that light travels in a straight line?

4) What is the law of reflection relating the incident and reflected angles?

   Draw a diagram to illustrate this concept and **label each angle**.

5) When light is refracted, what changes that causes its path to bend?

   Is light bent *away from* or *toward* the normal when passing from water into air?

   Draw a diagram showing the path of light passing from water into air. Be sure to **label** the angles of incidence and refraction, the normal, the names of the two media, and indicate the direction the ray is travelling.

6) What is the difference between diffuse and specular reflection? Give examples of each.

POST LAB QUESTIONS

7) Do your results for Part A (step 1) support the Law of Reflection)? **If you say yes** be sure and explain why.

8) What incident angle did you use?

What is the intensity (%) of the laser coming out of the laser?

What is the intensity (%) of the **reflected beam** at the angle you used?

What is the intensity (%) of the **refracted beam**?

Do they add to 100%?

9) See step 3 of Part B of procedure above. The index of refraction the glass is given by the following equation

$$n_{glass} = \frac{sin\theta_{incident}}{sin\theta_{refracted}}.$$

Use this equation to determine the index of refraction for glass. Show work. Include a diagram similar to figure 18-5 which shows your measured angles.

Since **speed of light in glass** is given by $\frac{3 \text{ x } 10^8 \text{ m/s}}{n_{glass}}$ what is the speed of light in the glass? Show work.

10) See step 5 of Part B of procedure above. **The index of refraction the water** is given by the following equation

$$n_{water} = \frac{sin\theta_{incident}}{sin\theta_{refracted}}.$$

Use this equation to determine the index of refraction for water. Show work. Include a diagram similar to figure 18-5 which shows your measured angles.

Since **speed of light in water** is given by $\frac{3 \text{ x } 10^8 \text{ m/s}}{n_{water}}$ what is the speed of light in the water? Show work.

11) What is the phenomena observed in Part B step 7 called? See section 28.6 of text.

What was the measured incident angle at the point that the refracted beam disappeared?

What would happen to the reflected beam if you changed the material that surrounds the laser **into air**?