Laboratory 11: Reflection and Refraction (Animations)

This series of experiments investigates reflection and refraction, both of which form the basis of geometric optics. The activities use the "Bending Light" animation provided by the PhET group at the University of Colorado. This can be found at

https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html

1 Reflection

Figure 1 illustrates a ray of light being reflected off a flat surface. The angle between the incident ray and the normal is labeled θ_i and the angle between the reflected ray and normal, θ_r. The purpose of the law of reflection is to describe the process of reflection via a relationship between these angles.

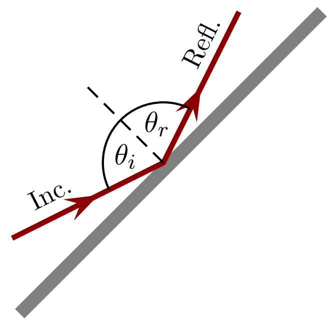

Figure 1: Reflection.

a) Run the PhET animation "Bending Light" using the link above.
b) Activate the light source by clicking on the red button. Ensure that the button "Ray" is selected. Note the the light source can be dragged so as to change the angle at which the light hits the surface. Identify the incident and reflected rays.
c) Using the protractor provided by the animation, measure θ_i and θ_r and record these.

d) Repeat parts 1 b) and 1 c) for two more different angles of incidence and record the angles.

e) Considering the three cases you investigated, how is θ_r related (same, similar, different, . . .) to θ_i for the flat mirror?

f) Take a screenshot of the PhET animation for one of the situations that you considered, save it and submit it as part of or with your lab packet.

2 Refraction and Snell's law.

Figure 2 illustrates a ray of light being refracted as it passes from one material to another. The angle between the incident ray and the normal is labeled θ_1 and the angle between the refracted ray and normal, θ_2. These angles are related by Snell's law,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \tag{1}$$

where n_1 is the index of refraction for the material in which the incident ray travels and n_2 the incidence of refraction of the material in which the refracted ray travels. This experiment will use the animation and Snell's law for a ray passing through a parallel sided object.

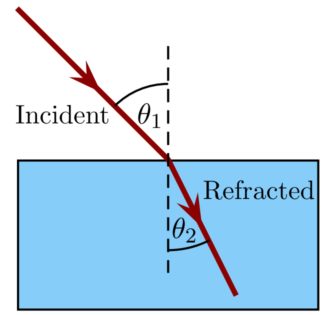

Figure 2: Refraction.

a) In the "Bending Light" PhET animation, select the "Prisms" option (look at the bottom of the window). Drag the square object into the middle of the window and activate the light source. In the "Objects" menu select "Glass." Rotate the square object so that the beam passes through the parallel sides as it does in Fig. 3.

b) Note that the ray is refracted **twice,** once at each surface. Pick one of the points of refraction and measure the two angles θ_1 and θ_2. Use these, Snell's law and the fact that the index of refraction of light in air is approximately 1.00 to determine the index of refraction of the glass.

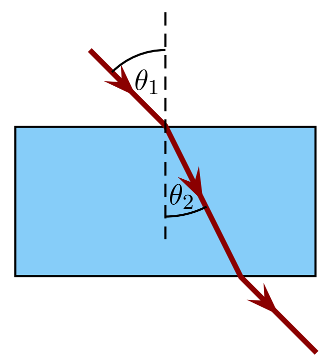

Figure 3: Double refraction through a piece of plastic

c) Repeat the entire procedure for two more angles of incidence (the larger these are the better). Determine the average of your values for the index of refraction for glass. Take a screenshot of at least one of your cases and attach it with the lab packet.

d) In the "Objects" menu, select "Mystery A," and repeat the procedure with at least three angles to to find the index of refraction of the mystery material.

e) Consider the direction of the light ray that emerges from the plastic in comparison to that entering the plastic. Use geometry plus Snell's law at each refraction point to relate the direction of the final transmitted ray in comparison to the first incident ray. Your results must be true for all possible angles of incidence.

3 Total internal reflection

Total internal reflection occurs when the incident light ray attempts to pass from a medium with a larger index of refraction into one with a lower index of refraction **and** the angle of incidence is large enough. Figure 4 illustrates the limiting case when this occurs; there is both a reflected ray and a refracted ray. The law of reflection gives the angle at which the reflected ray emerges. The smallest angle between the incident ray and the normal at which total internal reflection occurs is called the critical angle θ_c.

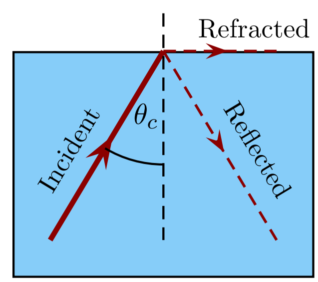

Figure 4: Total internal reflection.

a) Use Snell's law to show that the critical angle satisfies

$$\sin\theta_c = \frac{n_2}{n_1} \tag{2}$$

where n_1 in the index of refraction of the medium in which the light is incident and n_2 in the index of refraction of the medium into which the light would otherwise be refracted.

b) Total internal reflection can be observed by passing light through an object as illustrated in Figure 5. Using the "Prisms" option, select the second object from the left (with the sloped sides) and use the "glass" option. Shine the beam into this and observe the ray that is transmitted through the object. Now rotate the bottom right corner counterclockwise until the moment at which the transmitted ray disappears. This is the critical point.

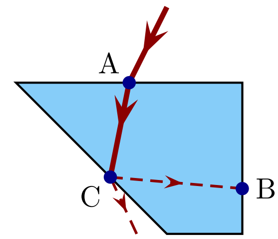

Figure 5: Total internal reflection.

c) When the critical point has been reached, measure the angle between the internal incident and internal reflected rays. How is this related to the critical angle?

d) Using the measured angle between the internal incident and internal reflected rays, determine the critical angle and use this to determine the index of refraction of the trapezoid material.

e) Perhaps the critical angle and the index of refraction depends on the color of the incident light. Select the white light option (on the right) and repeat the procedure that you used to observe total internal reflection. Observe carefully as the refracted ray disappears. Do all colors disappear at the same time? If not, which disappears first? What does this say about the index of refraction for red light versus violet light?