Laboratory 10: Reflection and Refraction – Prelab

1 Reflection

A small ball lies in front of the illustrated mirror. Indicate as accurately as possible where the image of the ball (produced by the mirror) is located. Explain your answer.

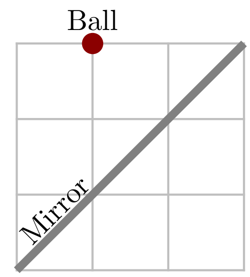

Figure 1: Reflection.

2 Refraction

Light in one material is incident on another as illustrated in Fig. 2; this is refracted within the material. The angle between the incident ray and the normal is labeled θ_1 and the angle between the refracted ray and normal, θ_2. It is observed that $\theta_1 > \theta_2$. Using this information, determine whether the index of refraction of the medium in which the light is incident is larger than, smaller than or the same as that into which it is refracted. Explain your answer.

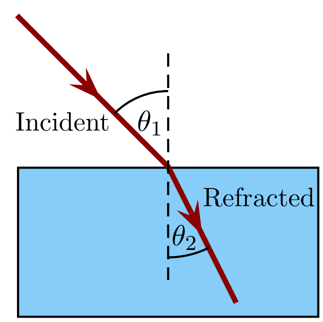

Figure 2: Refraction.

Laboratory 10: Reflection and Refraction – Activity

This series of experiments investigates reflection and refraction, both of which form the basis of geometric optics.

1 Reflection

Figure 3 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.

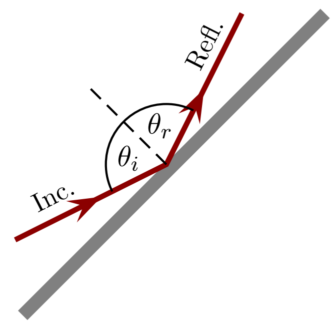

Figure 3: Reflection.

a) The PASCO mirror has three sides, one of which is flat. You will observe reflection off the flat surface. Place the mirror on a sheet of paper and trace and label the flat edge of the mirror.

b) Set up the light source so that it produces a single ray that it strikes the flat surface of the mirror at an angle. Trace **the incident ray** and **the reflected ray.** One way to trace a single ray accurately is to mark two widely separated points along the ray with a pencil and then connect them with a ruler.

c) 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) The PASCO mirror has a concave side. Place the mirror on a flat sheet of paper and trace the concave surface. Set up the light source to produce five incident parallel rays and shine these onto the mirror so that the middle ray strikes perpendicular to the concave surface. Trace the incident and reflected rays and identify the focal point of the mirror on your tracing. Determine the focal length of the concave mirror.

g) Repeat the previous part for the convex surface. Describe similarities and differences between the focal points for the concave and convex surfaces.

h) Attach the original tracings to one member of your lab group's lab package. If it is not attached to your package, indicate who has it.

2 Image formation by a flat mirror

Any mirror can form an image of an object placed in front of it. Geometric optics gives the rules by which the image is formed and determines the location and size of the image.

a) Place the mirror on a sheet of paper with the flat side facing you. Trace the edge of the mirror. This is the **plane of the mirror** and you may have to extend this line later.
b) Take two identical pencils. Hold one of them (call this pencil 1) vertically in front of the mirror at least 6 cm from the mirror and mark its location. Look into the mirror so that you can see the image of pencil 1. While keeping pencil 1 stationary take the other pencil (call this pencil 2) and place it behind the mirror so that it is located where the **image of pencil 1 is formed.** You can identify when pencil 2 is at the location of the image of pencil 1 by moving your head slightly left or right while you observe both pencil 2 and the image. If pencil 2 and the image of pencil 1 move relative to each other when you do this then they are **not at the some location**. Keep adjusting the location of pencil 2 so that this apparent motion ceases. The mark the location of pencil 2. This is the location of the image of pencil 1.
c) Measure the distance from the plane of the mirror to pencil 1. Measure the distance from the plane of the mirror to the image of pencil 1. How does the distance from the original object to the mirror surface compare to the distance from its image to the mirror surface?

3 Refraction and Snell's law.

Figure 4 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,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \qquad (1)$$

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 check Snell's law for a ray passing through a parallel sided piece of plastic.

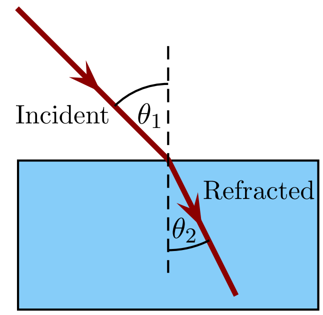

Figure 4: Refraction.

a) Place the piece of plastic on a sheet of paper and set up the light source so that a single ray passes through the plastic as illustrated in Fig. 5. Trace both edges of the plastic, the light ray prior to entering the plastic and the ray after leaving the plastic. Remove the plastic and draw the connecting ray within the plastic.

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 plastic.

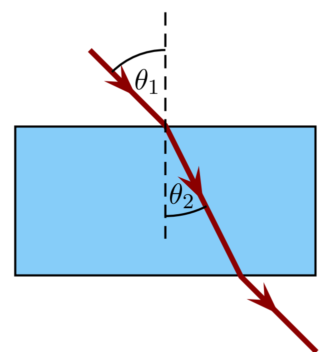

Figure 5: Double refraction through a piece of plastic

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 plastic.

d) 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.

4 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 6 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.

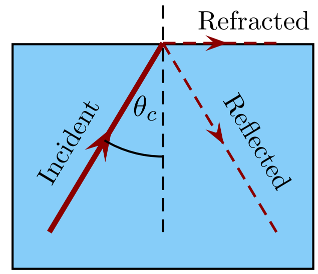

Figure 6: Total internal reflection.

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 a trapezoid as illustrated in Figure 7. The reflection point is labeled P. Shine light into the trapezoid so that this occurs. Observe that there are three rays at point C: an internal incident ray inside the trapezoid, an internal reflected ray inside the trapezoid and an external refracted ray that leaves the trapezoid. Rotate the trapezoid so that the external refracted ray glances the surface at C and then disappears. This is the critical point.

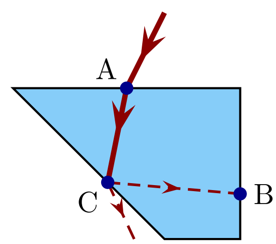

Figure 7: Total internal reflection.

c) When the critical point has been reached, trace the edges of the trapezoid and mark three points A, B and C as illustrated in Fig. 7. Use these to construct the internal incident and internal reflected rays. 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. Repeat the procedure that you used to observe total internal reflection and 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?

5 Demonstrations

a) There will be one or two demonstrations of total internal reflection set up in the lab. Observe each of these, and ensure that the instructor checks that you do this.