Experiment 3: Reflection

Required Equipment from Basic Optics System

Light Source

Mirror from Ray Optics Kit

Other Required Equipment

Drawing compass

Protractor

Metric ruler

White paper

Purpose

In this experiment, you will study how rays are reflected from different types of mirrors. You will measure the focal length and determine the radius of curvature of a concave mirror and a convex mirror.

Part 1: Plane Mirror

Procedure

1. Place the light source in ray-box mode on a blank sheet of white paper. Turn the wheel to select a single ray.

2. Place the mirror on the paper. Position the plane (flat) surface of the mirror in the path of the incident ray at an angle that allows you to clearly see the incident and reflected rays.

3. On the paper, trace and label the surface of the plane mirror and the incident and reflected rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions.

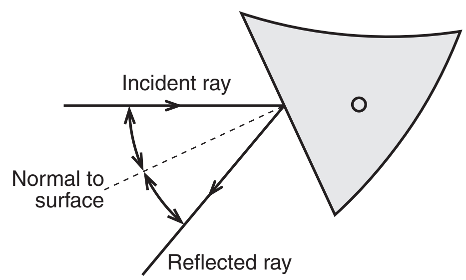

Figure 3.1

4. Remove the light source and mirror from the paper. On the paper, draw the normal to the surface (as in Figure 3.1).

5. Measure the angle of incidence and the angle of reflection. Measure these angles from the normal. Record the angles in the first row Table 3.1.

6. Repeat steps 1–5 with a different angle of incidence. Repeat the procedure again to complete Table 3.1 with three different angles of incidence.

Table 3.1: Plane Mirror Results

Angle of Incidence	Angle of Reflection

7. Turn the wheel on the light source to select the three primary color rays. Shine the colored rays at an angle to the plane mirror. Mark the position of the surface of the plane mirror and trace the incident and reflected rays. Indicate the colors of

the incoming and the outgoing rays and mark them with arrows in the appropriate directions.

Questions

1. What is the relationship between the angles of incidence and reflection?
2. Are the three colored rays reversed left-to-right by the plane mirror?

Part 2: Cylindrical Mirrors

Theory

A concave cylindrical mirror focuses incoming parallel rays at its focal point. The focal length (f) is the distance from the focal point to the center of the mirror surface. The radius of curvature (R) of the mirror is twice the focal length. See Figure 3.2.

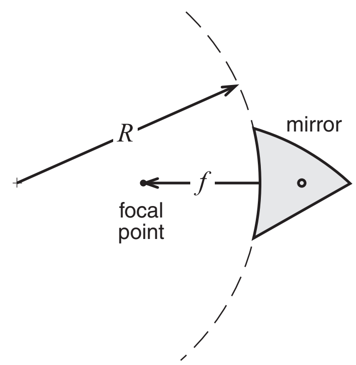

Figure 3.2

Procedure

1. Turn the wheel on the light source to select five parallel rays. Shine the rays straight into the concave mirror so that the light is reflected back toward the ray box (see Figure 3.3). Trace the surface of the mirror and the incident and reflected rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions. (You can now remove the light source and mirror from the paper.)
2. The place where the five reflected rays cross each other is the focal point of the mirror. Mark the focal point.

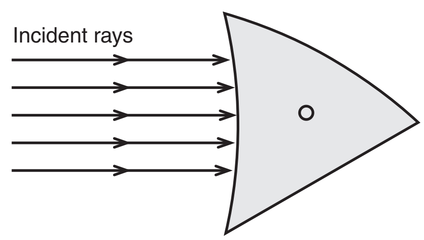

Figure 3.3

3. Measure the focal length from the center of the concave mirror surface (where the middle ray hit the mirror) to the focal point. Record the result in Table 3.2.
4. Use a compass to draw a circle that matches the curvature of the mirror (you will have to make several tries with the compass set to different widths before you find the right one). Measure the radius of curvature and record it in Table 3.2.
5. Repeat steps 1–4 for the convex mirror. Note that in step 3, the reflected rays will diverge, and they will not cross. Use a ruler to extend the reflected rays back behind the mirror's surface. The focal point is where these extended rays cross.

Table 3.2: Cylindrical Mirror Results

	Concave Mirror	Convex Mirror
Focal Length		
Radius of Curvature (determined using compass)		

Questions

1. What is the relationship between the focal length of a cylindrical mirror and its radius of curvature? Do your results confirm your answer?
2. What is the radius of curvature of a plane mirror?

Experiment 6: Convex and Concave Lenses

Required Equipment from Basic Optics System

Light Source

Convex Lens from Ray Optics Kit

Concave Lens from Ray Optics Kit

Other Required Equipment

Metric ruler

Purpose

In this experiment, you will explore the difference between convex and concave lenses and determine their focal lengths.

Theory

When parallel light rays pass through a thin lens, they emerge either converging or diverging. The point where the converging rays (or their extensions) cross is the *focal point* of the lens. The *focal length* of the lens is the distance from the center of the lens to the focal point. If the rays diverge, the focal length is negative.

Procedure

1. Place the light source in ray-box mode on a white sheet of paper. Turn the wheel to select three parallel rays. Shine the rays straight into the convex lens (see Figure 6.1).

   Note: The lenses used in this experiment have one flat edge. Place the flat edge on the paper so the lens stands stably without rocking.

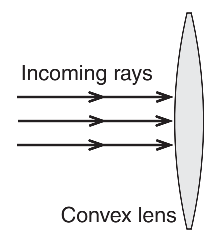

Figure 6.1

2. Trace around the surface of the lens and trace the incident and transmitted rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions.

3. The point where the outgoing rays cross is the focal point of the lens. Measure the focal length from the center of the lens to the focal point. Record the result in Table 6.1.

Table 6.1: Results

	Convex Lens	Concave Lens
Focal Length		

4. Repeat the procedure with the concave lens. Note that in step 3, the rays leaving the lens are diverging and do not cross. Use a ruler to extend the outgoing rays straight back through the lens. The focal point is where these extended rays cross. (Remember to record the focal length as a negative number.)

5. Nest the convex and concave lenses together and place them in the path of the parallel rays (see Figure 6.2). Trace the rays. Are the outgoing rays converging, diverging or parallel? What does this tell you about the relationship between the focal lengths of these two lenses?

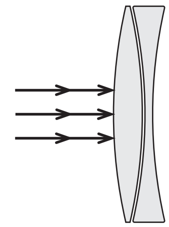

Figure 6.2

6. Slide the convex and concave lenses apart by a few centimeters and observe the effect. Then reverse the order of the lenses. Trace at least one pattern of this type. What is the effect of changing the distance between the lenses? What is the effect of reversing their positions?

Experiment 7: Hollow Lens

Required Equipment from Basic Optics System
Light Source
Hollow Lens from Ray Optics Kit
Box from Ray Optics Kit (with lenses and foam insert removed)
White Plastic Sheet from Ray Optics Kit

Other Equipment
Water
Paper towels
White paper
Small weight (to stop lens from floating)
Eye-dropper (optional, for removing water from the hollow lens)

Purpose

In this experiment you will explore how the properties of a lens are related to its shape, its index of refraction, and the index of refraction of the surrounding medium.

Background

A conventional lens is made of a material whose index of refraction is higher than that of the surrounding medium. For instance, the lenses in a pair of eyeglasses are usually made from glass or plastic with an index of refraction of 1.5 or higher, while the air surrounding the lenses has an index of refraction of 1.0. However, a lens can also have a *lower* index of refraction than the surrounding medium, as is the case when a hollow lens is "filled with air" and surrounded by water. (The index of refraction of water is about 1.3.)

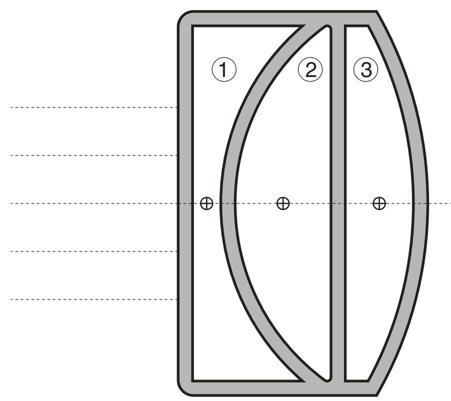

Figure 7.1: The hollow lens

The hollow lens in this experiment has three sections: a plano-concave section and two plano-convex sections. We will refer to these as sections 1, 2, and 3 (see Figure 7.1).

You will determine whether each section acts as a converging or diverging lens when it is *a)* filled with water and surrounded by air and *b)* filled with air and surrounded by water.

Procedure

1. Before you test the hollow lens, make some predictions: For every configuration in Table 7.1, predict whether incoming parallel rays will converge or diverge after passing through the lens. Record your predictions in the table.

2. Place the light source in ray-box mode on a white sheet of paper. Turn the wheel to select five parallel rays.

3. Fill section 1 with water and place the lens in front of the light source so the parallel rays enter it through the flat side. Do the rays converge or diverge after passing through the lens? Record your observation in Table 7.1.

Repeat this step with water in different section of the lens to complete the first four rows of Table 7.1.

Table 7.1: Predictions and Observations

Lens surrounded by:	Section 1 filled with:	Section 2 filled with:	Section 3 filled with:	Prediction (converging or diverging)	Observation (converging or diverging)
Air	Water	Air	Air		
	Air	Water	Air		
	Air	Air	Water		
	Water	Air	Water		
Water	Air	Water	Water		
	Water	Air	Water		
	Water	Water	Air		

4. Put the white plastic sheet in the transparent ray-optics box. Put the hollow lens in the box on top of the sheet as shown in Figure 7.2. Place a small weight on top of the lens to stop it from floating. Position the light source outside of the box so that the rays enter the hollow lens through the flat side.

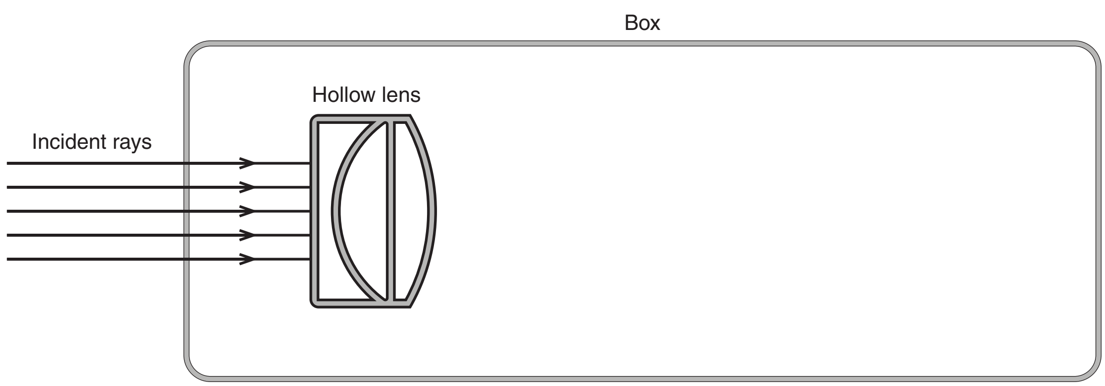

Figure 7.2: Hollow lens set up for testing surrounded by water

5. Fill the box with water to just below the top of the lens. Fill sections 2 and 3 of the lens with water (leaving section 1 "filled" with air). Record your observation in Table 7.1.

   Repeat this step with air in different section of the lens to complete Table 7.1.

Questions

1. Under what conditions is a plano-convex lens converging? Under what conditions is it diverging?

2. If a plano-concave lens of an unknown material is a diverging lens when surrounded by air, is it possible to know whether the lens will be converging or diverging when placed in water? Explain.

Experiment 8: Lensmaker's Equation

Required Equipment from Basic Optics System

Light Source

Concave Lens from Ray Optics Kit

Other Required Equipment

Metric ruler

Purpose

In this experiment you will determine the focal length of a concave lens in two ways: *a)* by direct measurement using ray tracing and *b)* by measuring the radius of curvature and using the lensmaker's equation.

Theory

The lensmaker's equation is used to calculate the focal length (in air or a vacuum), f, of a lens based on the radii of curvature of its surfaces (R_1 and R_2) and the index of refraction (n) of the lens material:

(eq. 8.1)

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

In this notation, R is positive for a convex surface (as viewed from outside the lens) and R is negative for a concave surface (as in Figure 8.1).

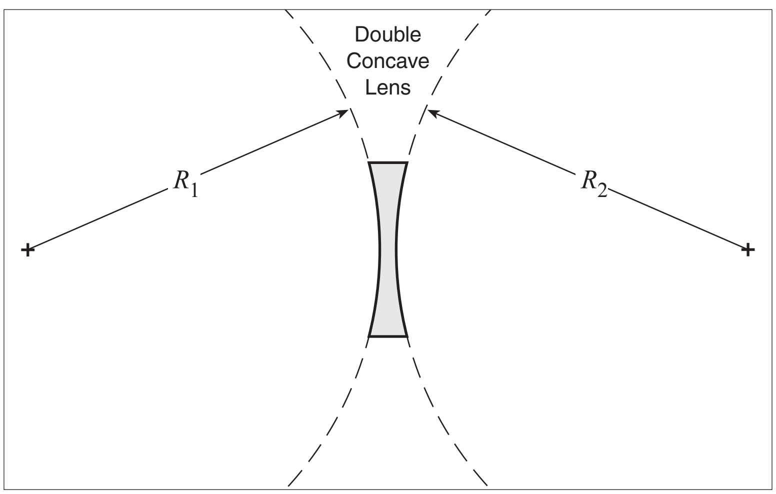

Figure 8.1

Procedure

1. Place the light source in ray-box mode on a white sheet of paper. Turn the wheel to select three parallel rays. Shine the rays straight into the convex lens (see Figure 8.2).

   Note: The lens has one flat edge. Place the flat edge on the paper so the lens stands stably without rocking.

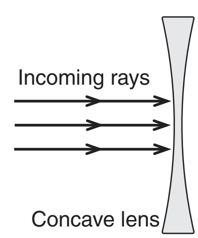

Figure 8.2

2. Trace around the surface of the lens and trace the incident and transmitted rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions.

3. Remove the lens. To measure the focal length, use a ruler to extend the outgoing diverging rays straight back through the lens. The focal point is where these extended rays cross. Measure the distance from the center of the lens to the focal point. Record the result as a negative value:

f = _______________ (measured directly)

4. To determine the radius of curvature, put the concave lens back in the path of the rays and observe the faint reflected rays off the first surface of the lens. The front of the lens can be treated as a concave mirror having a radius of curvature equal to twice the focal length of the effective mirror (see Figure 8.3).

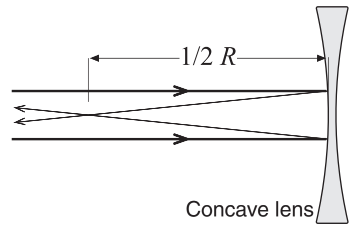

Figure 8.3: Reflected rays from the lens surface

Trace the surface of the lens and mark the point where the central ray hits the surface. Block the central ray and mark the point where the two outer rays cross. Measure the distance from the lens surface to the point where the reflected rays cross. The radius of curvature is *twice* this distance. Record the radius of curvature:

R = _______________

5. For this lens, it is not necessary to measure the curvature of both sides because they are equal ($R_1 = R_2 = R$). Calculate the focal length of the lens using the lensmaker's equation (Equation 8.1). The index of refraction is 1.5 for the acrylic lens. Remember that a concave surface has a negative radius of curvature.

f = _______________ (calculated)

6. Calculate the percent difference between the two values of f from step 3 and step 5:

% difference = _______________