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.

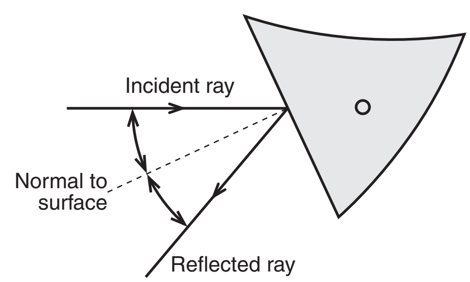

Figure 3.1

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.

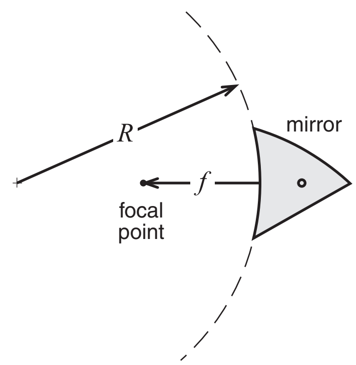

Figure 3.2

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.

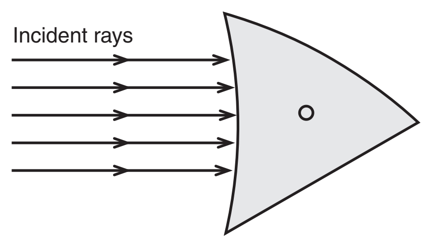

Figure 3.3

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 13: Focal Length and Magnification of a Concave Mirror

Required Equipment from Basic Optics System

Light Source

Bench

Concave/convex Mirror

Half-screen

Other Equipment

Metric ruler

Optics Caliper (optional, for measuring image sizes), PASCO part OS-8468

Purpose

The purpose of this experiment is to determine the focal length of a concave mirror and to measure the magnification for a certain combination of object and image distances.

Theory

For a spherically curved mirror:

(eq. 13.1)

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

where f is focal length, d_o is the distance between the object and the mirror, and d_i is the distance between the image and the mirror. By measuring d_o and d_i the focal length can be determined.

Magnification, M, is the ratio of image size to object size. If the image is inverted, M is negative.

Part I: Object at Infinity

In this part, you will determine the focal length of the mirror by making a single measurement of d_i with $d_o \cong \infty$.

Procedure

1. Hold the mirror in one hand and the half-screen in the other hand. Use the concave side of the mirror to focus the image of a *distant* bright object (such as a window or lamp across the room) on the half-screen. (See Figure 13.1.)

2. Have your partner measure the distance from the mirror to the screen. This is the image distance, d_i.

   d_i = _______________

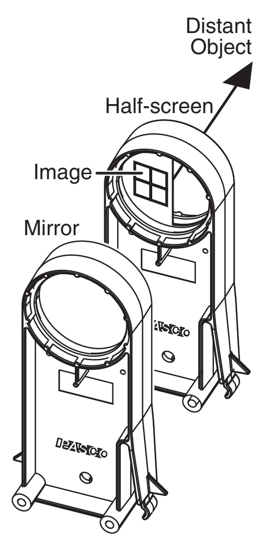

Figure 13.1

Analysis

1. As d_o approaches infinity, what does $1/d_o$ approach?

2. Use the Equation 13.1 to calculate the focal length.

   $f =$ _______________

Part II: Object Closer Than Infinity

In this part, you will determine the focal length of the mirror by measuring several pairs of object and image distances and plotting $1/d_o$ versus $1/d_i$.

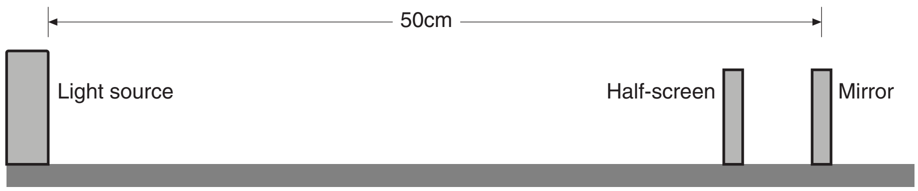

Figure 13.2

Procedure

1. Place the light source and the mirror on the optics bench 50 cm apart with the light source's crossed-arrow object toward the mirror and the concave side of the mirror toward the light source. Place the half-screen between them (see Figure 13.2).

2. Slide the half-screen to a position where a clear image of the crossed-arrow object is formed. Measure the image distance and the object distance. Record these measurements (and all measurements from the following steps) in Table 13.1.

3. Repeat step 2 with object distances of 45 cm, 40 cm, 35 cm, 30 cm, 25 cm.

4. With the mirror at 25 cm from the light source and a clear image formed on the half-screen, measure the object size and image size. To measure the image size, hold a small scrap of paper against the half-screen and mark two opposite points on the crossed-arrow pattern (see Figure 13.3). If at least half of the pattern is not visible on the screen, have your partner slightly twist the mirror to bring more of the image into view. Remove the paper and measure between the points. Measure the object size between the corresponding points directly on the light source.

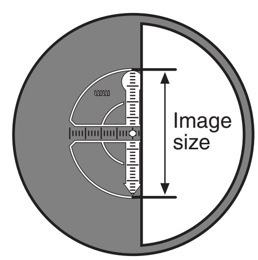

Figure 13.3

Table 13.1: Image and Object Distances

d_o	d_i	$1/d_o$	$1/d_i$	Image Size	Object Size
50.0 cm					
45.0 cm					
40.0 cm					
35.0 cm					
30.0 cm					
25.0 cm					

Analysis Part A: Focal Length

1. Calculate $1/d_o$ and $1/d_i$ for all six rows in Table 13.1.

2. Plot $1/d_o$ versus $1/d_i$ and find the best-fit line (linear fit). This will give a straight line with the x- and y-intercepts equal to $1/f$. Record the intercepts (including units) here:

   y-intercept = $1/f$ = _______________

   x-intercept = $1/f$ = _______________

Note: You can plot the data and find the best-fit line on paper or on a computer.

3. For each intercept, calculate a value of f and record it in Table 13.2.

4. Find the percent difference between these two values of f and record them in Table 13.2.

5. Average these two values of f. Find the percent difference between this average and the focal length that you found in Part I. Record these data in Table 13.2.

Table 13.2: Focal Length

	f
Result from x-intercept	
Result from y-intercept	
% difference between results from intercepts	
Average of results from intercepts	
Result from Part I	
% difference between Average of results from intercepts and result from Part I	

Analysis Part B: Magnification

1. For the last data point only (d_o = 25 cm), use the image and object distances to calculate the magnification, M. Record the results in Table 13.3.

(eq. 13.2)
$$M = -\left(\frac{d_i}{d_o}\right)$$

2. Calculate the absolute value of M using your measurements of the image size and object size. Record the results in Table 13.3.

(eq. 13.3)
$$|M| = \frac{\text{image size}}{\text{object size}}$$

3. Calculate the percent differences between the absolute values of M found using the two methods. Record the results in Table 13.3.

Table 13.3: Magnification

M **calculated from image and object distances**	
$\|M\|$ **calculated from image and object sizes**	
% difference	

Questions

1. Is the image formed by the mirror upright or inverted?

2. Is the image real or virtual? How do you know?

3. By looking at the image, how can you tell that the magnification is negative?

4. You made three separate determinations of f (by measuring it directly with a distant object, from the x-intercept of your graph, and from the y-intercept). Where these three values equal? If they were not, what might account for the variation?