

## Experiment 7

# The Focal Length of a Curved Mirror

### Preparation

Prepare for this week's experiment by reviewing old material and by reading about mirrors, real, and virtual images.

### Principles

When parallel rays of light strike a small section of a spherical concave mirror they will all be reflected through the same point. This point is called the **focal point** and it will be located halfway between the vertex of the mirror and the center of curvature. The **focal distance** is denoted by  $f$ , and the **radius of curvature** by  $R$ . Both  $f$  and  $R$  are considered **positive** for **concave** or **converging mirrors**.  $R$  is equal to  $2f$ .

If parallel rays of light strike the convex side of a spherical mirror they will diverge and appear to have come from the focal point. For a convex, or **diverging**, mirror  $f$  and  $R$  are considered to be **negative**, as is the **image distance**.

In both cases, the relationship between the focal length,  $f$ , the **object distance**,  $d_o$ , and the **image distance**,  $d_i$ , is the thin lens equation:

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

There are two easy ways to find  $f$  and  $R$ . In one method an object is placed a very large distance from the mirror. Then as  $d_o$  approaches infinity  $\frac{1}{d_o}$  approaches 0. Then  $d_i$  will be

approximately equal to  $f$ . In the other an object is placed near the mirror, an image is formed and the values for  $d_o$  and  $d_i$  are measured and entered into the thin lens equation.

**Linear magnification**,  $m$  is the relationship between the **size of the object**,  $h_o$ , and the **size of the image**,  $h_i$ . It is also the negative of the ratio of the image distance to the object distance:

$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$$

If the image is inverted  $h_i$  and  $m$  are negative. If the absolute value of  $m$  is greater than 1 the image will be larger than the object; if it is less than 1 the image will be smaller than the object.

If the object is in front of the mirror, it is called a real object, and  $d_o$  is positive. If the image is formed by converging rays, it will be in front of the mirror. It is called a real image and  $d_i$  is positive. Real images can be projected onto a screen. An image that is behind the mirror can be seen with the unaided eye but cannot be projected onto a screen. This is a virtual image and  $d_i$  is negative.

An image can be characterized as real or virtual, upright or inverted, enlarged or reduced.

### **Equipment**

- 1 optical bench
- 3 optical bench carriages
- 1 lens or mirror holder
- 1 screen holder
- 2 short rods
- 1 longer rod
- 1 large object lamp
- 1 small object lamp
- 1 concave/convex mirror
- 1 thin rod
- index cards

### **Procedure**

For this experiment you will use an optical bench. For each procedure record the **positions** of the mirror, the object, and the image. Characterize the image in each case, that is, note whether it is upright or inverted, enlarged or reduced. **Be sure you record the appropriate sign for each value.**

### **Distant Object**

1. Set the large object light on the opposite end of the table from the optical bench. Make your object distance as large as possible. Mount the mirror and an index card on the optical bench so that the concave side of the mirror faces the object light. Place the screen between the object and the mirror; you will have to adjust your mirror and screen so that the screen does not block the incoming light. Turn the lamp on and move the screen on the bench until a sharp image is formed. Record the positions of the mirror and image and characterize the image. The distance from the mirror to the screen is very close to  $f$ .

### **Nearby Object ( $d_o > R$ )**

2. Mount the small object light on the optical bench and position the mirror so that  $d_o$  is greater than  $R$ . Form a sharp image. Record the positions of the light, mirror and screen. Measure the size of some feature on the object light and measure the size of the same feature on the image. Characterize the image.

### **Nearby Object ( $R > d_o > f$ )**

3. Mount the screen in a holder again and position the light and mirror so that  $d_o$  is less than  $R$  but greater than  $f$ . Record the data as you did in the last procedure.

4. Reduce  $d_o$  by small increments. At each change of  $d_o$  move the screen to keep the image sharp. Describe what happens to the image as  $d_o$  approaches  $f$ .

### **Parallax Method**

Use the method of parallax to find the virtual image produced by the convex (diverging) side of the mirror as follows:

5. Place an aluminum rod in a holder. Place the holder in front of the convex side of the mirror. Put the thin rod in a holder and place it behind the mirror.
6. Parallax is the apparent displacement that two objects at different distances from the observer undergo. As the observer moves, the farther object will seem to move in the same direction as the observer; the closer object will move in the opposite direction. Two objects the same distance from the observer will appear to move together. Observe the reflection of the rod in front of the mirror and the thin rod in back of the mirror and adjust them until the rod and the image move together. When this happens the rod behind the mirror is located at the same place as the image of the rod in front of the mirror. Record the positions of the mirror and the two rods.

### **Analysis**

#### **Distant Object**

1. The difference between the positions of the mirror and image is  $f$ . Calculate  $R$ .

#### **Nearby Object**

2. Find  $d_o$  and  $d_i$  and calculate  $f$  using the data from the second and third procedures. For each set of positions calculate  $m$  using both  $h_i/h_o$ , and  $-d_i/d_o$ . For each case find the percent difference between the two values for  $m$ . Find the percent difference between the value for  $f$  you find in each case and the value you found using the distant object.

#### **Parallax Method**

3. Find  $d_o$  and  $d_i$  for the image formed by the diverging mirror. Remember that  $d_i$  will be negative because the image is behind the mirror. Calculate  $f$ .