Curved Mirrors

GOALS
In this activity you will:
• Identify the focus and focal length of a curved mirror.
• Observe virtual images in a convex mirror.
• Observe real and virtual images in a concave mirror.
• Measure and graph image distance versus object distance for a convex mirror.
• Summarize observations in a sentence.

What Do You Think?
The curved mirror of the Palomar telescope is five meters across. Mirrors with varying curvatures are used in amusement parks as fun-house mirrors. Store mirrors and car side-view mirrors are also curved.

• How is what you see in curved mirrors different from what you see in ordinary flat mirrors?

Record your ideas about this question in your Active Physics log. Be prepared to discuss your responses with your small group and with your class.

For You To Do
1. Carefully aim a laser pointer, or the light from a ray box, so the light beam moves horizontally, as you did in the previous activity. Place a glass rod in the light beam so that the beam spreads up and down.
2. Place a convex mirror in the light beam, as shown in the diagram.

3. Shine a beam directly at the center of the mirror. This is the incident beam. Show its path by placing three or more dots on the paper, as you did in the previous activity. Connect the dots to make a straight line. Find the reflected ray and mark its path in a similar way. Label the two lines so you will know they go together.

4. You will move the light source sideways to make a series of parallel beams. To make sure the incident beams are parallel, line up each one with the dots you made to show the incoming beam in Step 3. Mark the path of the incoming ray with three dots.

5. Each parallel beam makes a reflected beam. Show the path of each of these reflected rays. Label each incident and reflected beam so you will know that they go together.
   a) Write a sentence to tell what happens to the parallel beams after they are reflected.
   b) Make a drawing in your Active Physics log to record the path of the light.

6. Remove the mirror. With a ruler, extend each reflected ray backwards to the part of the paper that was behind the mirror.
   a) You probably noticed that all the lines converge in a single point. The place where the extended rays meet is called the focus of the mirror. The distance from this point to the mirror is called the focal length. Measure and record this focal length.

7. Place the concave side of the mirror in the light beam. To help you remember the name concave,
think of the concave mirror as “caving in.” Repeat **Steps 3** through **5** for this mirror.

1. a) Write a sentence to tell what happens to the parallel beams after they are reflected from the concave mirror.
   
   b) Make a drawing in your *Active Physics* log to record the path of the light. The place where the beams cross is called the focus. The distance from the focus to the mirror is the focal length.
   
   c) Measure and record the focal length.

2. d) How do concave and convex mirrors reflect light differently? Record your answer in your log.

8. Use the concave mirror. Use a 40-W light bulb or a candle as a light source, which will be called the “object.” Carefully mount your mirror so it is at the same height as the light source. Place a light bulb about a meter away from the mirror. Put the bulb slightly off the center line, as shown, so that an index card will not block the light from hitting the mirror.

9. Try to find the image of the object on an index card. Move the card back and forth until the image is sharp. The image you found is called a real image because you are able to project it on a card.

1. a) Record the distance of the bulb from the mirror and of the image on the file card from the mirror. Put your results in the first line of a table like the one below.

<table>
<thead>
<tr>
<th>Distance of bulb from mirror</th>
<th>Distance of image from mirror</th>
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<tr>
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10. Carefully move the mirror closer to the object. Find the sharp image, as before, by moving the index card back and forth.
   a) Record the image and object distances in your table.
   b) Repeat the measurement for at least six object locations.
   c) Draw a graph of the image distance (y-axis) versus the object distance (x-axis).
   d) Write a sentence that describes the relationship between the image distance and the object distance.

11. A mathematical relation that describes concave mirrors is

\[
\frac{1}{f} = \frac{1}{D_o} + \frac{1}{D_i}
\]

where

- \( f \) is the focal length of that particular mirror
- \( D_o \) is the object distance
- \( D_i \) is the image distance

You have measured \( D_o \) and \( D_i \). Calculate \( \frac{1}{D_o} \) and \( \frac{1}{D_i} \). Find their sum for each pair of data.
   a) Record your calculations in your log.
   b) Are your sums approximately equal? If so, you have mathematically found the value of \( \frac{1}{f} \) for the mirror you used.

12. A convex mirror cannot form a real image that can be projected onto a screen. It can form an image behind the mirror, like a plane mirror.
   a) Record in your log descriptions of the image in a convex mirror when the mirror is held close and when the mirror is held far from the object.
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PHYSICS TALK

Making Real Images

To find how a concave mirror makes a real image, you can view a few rays of light. Each ray of light obeys the relation you found for plane mirrors (angle of incidence = angle of reflection). In this case, you choose two easily drawn rays.

Look at the drawing. It shows rays coming into a concave mirror from a point on a light bulb. One ray comes in parallel to the dotted line, which is the axis of the mirror. This ray reflects through the focus. The other ray hits the center of the mirror. This ray reflects and makes the same angle with the mirror axis going out as it did coming in. Where these rays meet is the image of the top of the light bulb.

The next drawing shows the same mirror, but with the object much further from the mirror. Notice how the image in this second drawing is much smaller and much closer to the focus.

As you have seen, the position of the object and image are described by the equation below.

$$\frac{1}{f} = \frac{1}{D_o} + \frac{1}{D_i}$$

Look at the graph of this equation at left. Notice that as the object distance decreases, the image distance becomes very large. As the object distance increases, the image distance moves towards the focal length (f). Also notice that neither the object distance nor the image distance can be less than the focal length.
Reflecting on the Activity and the Challenge

You have observed how rays of light are reflected by a curved mirror. You have seen that a concave mirror can make an upside-down real image (an image on a screen). You have also seen that the image and object distances are described by a simple mathematical relationship. In addition, you have seen that there is no real image in a convex mirror, and the image is always smaller than the object.

You may want to use a curved mirror in your sound and light show. You may want to project an image on a screen or produce a reflection that the audience can see in the mirror. What you have learned will help you explain how these images are made.

Since the image changes with distance, you may try to find a way to have a moving object so that the image will automatically move and change size. A ball suspended by a string in front of a mirror may produce an interesting effect. You may also wish to combine convex and concave mirrors so that some parts of the object are larger and others are smaller. Convex and concave mirrors could be shaped to make some kind of fun-house mirror.

Remember that your light show will be judged partly on creativity and partly on the application of physics principles. This activity has provided you with some useful principles that can help with both criteria.

Physics To Go

1. a) Make a drawing of parallel laser beams aimed at a convex mirror.
   b) Draw lines to show how the beams reflect from the mirror.

2. a) Make a drawing of parallel laser beams aimed at a concave mirror.
   b) Draw lines to show how the beams reflect from the mirror.

3. a) Look at the back of a spoon. What do you see?
   b) Look at the inside of a spoon. What do you see?
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4. a) If you were designing a shaving mirror, would you make it concave or convex? Explain your answer.
   b) Why do some makeup mirrors have two sides? What do the different sides do? How does each side produce its own special view?
   c) How does a curved side mirror on a car produce a useful view? How can this view sometimes be dangerous?
   d) Why does a dentist use a curved mirror?

5. a) A student found the real image of a light bulb in a concave mirror. The student moved the light bulb to different positions. At each position, the student measured the position of the image and the light bulb. The results are shown in the table on the left. Draw a graph of this data.
   b) Make a general statement to summarize how the image distance changes as the object distance changes.
   c) If the object were twice as far away as the greatest object distance in the data, estimate where the image would be.
   d) If the object were only half as far from the mirror as the smallest object distance in the data, estimate what would happen to the image.

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<thead>
<tr>
<th>$D_o$ (cm)</th>
<th>$D_i$ (cm)</th>
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<tr>
<td>549</td>
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6. A ball is hung on a string in front of a flat mirror. The ball swings toward the mirror and back. How would the image of the ball in the mirror change as the ball swings back and forth?

7. a) A ball is hung on a string in front of a concave mirror. The ball swings toward the mirror and back. How would the image of the ball in the mirror change as the ball swings back and forth?
   b) How could you use this swinging ball in your light show?

8. Outdoors at night, you use a large concave mirror to make an image on a card of distant auto headlights. You make the image on a card. What happens to the image as the car gradually comes closer?
9. The diagram shows a light ray $R$ parallel to the principal axis of a spherical concave (converging) mirror. Point $F$ is the focal point and $C$ is the center of curvature. Draw the reflected light ray.

10. The diagram shows a curved mirror surface and a light bulb and its image. In relation to the focal point of the mirror, where is the light bulb (object) most likely located?

11. A candle is located beyond the center of curvature, $C$, of a concave spherical mirror having a principal focus, $F$, as shown in the diagram. Sketch the image of the candle.
12. The diagram shows four rays of light from object $AB$ incident on a spherical mirror with a focal length of 0.04 m. Point $F$ is the principal focus of the mirror, point $C$ is the center of curvature, and point $O$ is located on the principal axis.

a) Which ray of light will pass through $F$ after it is reflected from the mirror?

b) As object $AB$ is moved from its position toward the left, what will happen to the size of the image produced?