Curved Mirrors and Images

INTRODUCTION

While we all feel familiar with the images we see in plane mirrors, our experiences with their curved counterparts might be limited to cosmetic mirrors or the side view mirrors on automobiles. In this experiment, you will explore the characteristics of the real and virtual images formed by curved mirrors. Then you will develop a mathematical relationship describing the relationship between the positions of the object and the real image formed by concave mirrors.

OBJECTIVES

In this experiment, you will

- Use curved mirrors to produce real and virtual images.
- Explore how the position of the object affects the appearance, orientation, and size of real images produced by concave mirrors.
- Explore how mirror characteristics and the position of the object affect the appearance, orientation, and size of virtual images produced by concave and convex mirrors.
- Determine the relationship between object distance, image distance, focal length, and magnification in real images produced by concave mirrors.

MATERIALS

Graphical Analysis Pro
Vernier Combination Dynamics Track/Options Bench
Vernier Optics Expansion Kit
Vernier Mirror Set
small plane mirror
3" × 5" index card

PRE-LAB INVESTIGATION

1. Place the convex mirror at one end of the track. Position your eye at the other end of the track and examine the image of yourself. In what way does the image of yourself differ from that which you would see if you were looking into a plane mirror? How does the image change when you move the mirror closer to you?

2. Replace the convex mirror with the concave one and move it to the end of the track. As you did before, position your eye at the other end of the track and examine the image of yourself. In what ways does the image of yourself differ from that which you observed with the convex mirror? What happens to the image when you move your head slightly from side to side?

3. Gradually move the concave mirror closer to you. How does this affect the image you observe? What happens to the image when the mirror is approximately 20 cm from your eye?

In your class discussion, you will learn how the use of ray diagrams can help you to determine how and where light from a particular point on an object converges to form an image.

PROCEDURE

Part 1 Concave mirror and real images

1. Set up the light source and concave mirror to project a clear image on the half screen.
   a. Attach the light source assembly from the Optics Expansion Kit to the track. Position it so that the pointer in the base is at the 10 cm mark and the light source faces the other end of the track (see Figure 1).
   b. Place the concave mirror near the other end of the track so that it faces the light source. Attach the half screen to the track between the light source and the mirror.
   c. Turn the light source wheel until the number "4" is visible in the opening. This will be your "object" for this investigation.
   d. Adjust the position of the screen until the image of the "4" on the screen is in focus. You may need to adjust the angle of the mirror in its holder so that the image projected by the mirror shows on the screen. One approach to obtain the sharpest image, once you think you have it, is to move the screen in either direction until the image begins to blur, then move it back until it again appears sharp.

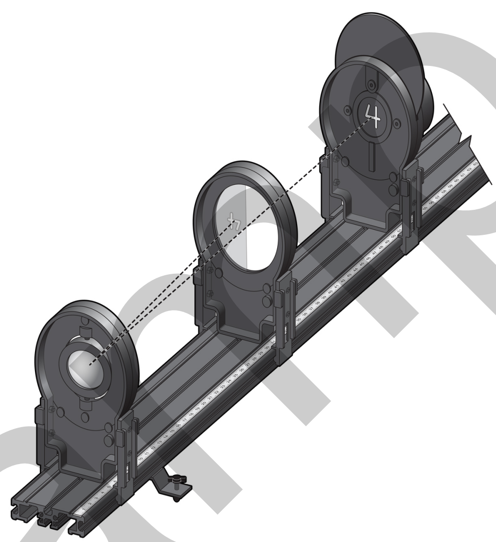

Figure 1

2. Describe the size, shape, and orientation of the image.

3. Now, move the mirror to the 100 cm mark, then move the screen toward the mirror until you can see a sharp image of the "4" on the half screen. Record the distance between the light source and the mirror as "object distance" and the distance between the mirror and the screen as "image distance" in your lab notebook.

4. Obtain object distance and image distance data for four more points, moving the mirror 10 cm closer each time. Note what happens to the size of the image as the object distance decreases.

5. Move the mirror to the 50 cm mark, leaving the light source at 10 cm. Note that you cannot obtain a sharp image on the screen. If you remove the screen and rotate the mirror slightly, you can observe a sharp image of the "4" on the light source assembly itself. Compare the size of the image to that of the object.

6. It is possible to obtain another data point for which the mirror is even closer to the light source. To do so, move the light source to the middle of the track and the mirror 30 cm away. Hold the screen off to the side *behind* the light source and rotate the mirror until you can observe the projected image on the screen. Make your best estimate of the image distance.

Part 2 Convex mirror and virtual images

Locating a virtual image is more difficult because it cannot be projected onto a screen, like a real image. The technique described below involves the use of parallax to determine the position of the virtual image.

7. Draw a vertical line on a 3″ × 5″ index card; place this card in the slot on the full viewing screen. This screen is your image position marker. Place the half screen (which serves as the object), convex mirror, and full screen on the track as shown in Figure 2.

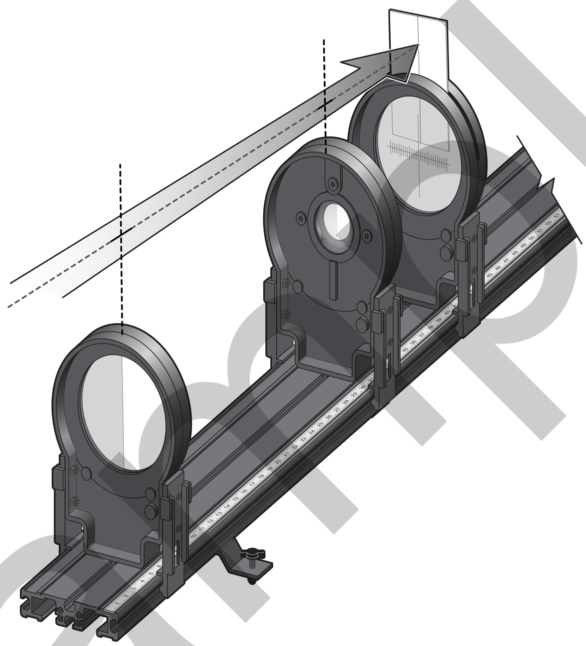

Figure 2

8. Move the convex mirror to a position 40 to 50 cm from the half screen. Record this as the object distance. Stand at the end of the track near the half screen so that you can view both the virtual image of the half screen and the index card attached to the full screen.

9. Place the index card and screen serving as the position marker just behind the convex mirror. Position your head directly behind and above the half screen. As you look over the top of the half screen toward the mirror, you can view the half screen in the mirror. Move your head so that the line on the marker and the edge of the half screen are aligned.

10. Move your head to the right of the half screen. Note that the edge of the screen in the image appears to the right of the line on the marker. When you move your head to the left of the half screen you should note that the edge in the image shifts to the left of the marker line (see Figure 3). This difference in relative positions is called parallax.

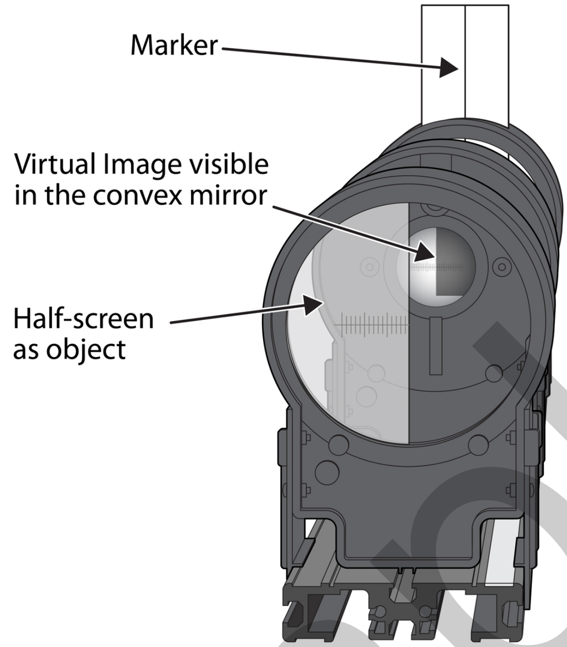

Figure 3

11. Move the marker 5 cm farther from the mirror, and repeat Step 4. When you are further from the mirror, the parallax is reduced. Gradually move the marker farther from the mirror and check the alignment of the edge of the half screen and the line on the marker until there is no parallax. Record this distance as the distance of the virtual image. If you go beyond the no-parallax point, the image and the object will move in opposite directions.

EVALUATION OF DATA

1. Launch Graphical Analysis and select Manual Entry. Use Column Options, ⋯, to rename the X and Y data columns to **d-o** (for the object distance) and **d-i** (for the image distance). Enter your data in the data table to produce a graph of image distance *vs*. object distance.

2. Examine your graph of image distance *vs*. object distance. What relationship appears to exist between these variables? Click or tap Column Options, ⋯, and choose Add Calculated Column to modify a column so as to produce a linear relationship. You may find it necessary to modify the variables on *both* axes to linearize the graph.

   When you have a linear graph, click or tap Graph Tools, , and choose Apply Curve Fit to find the best fit equation for your linearized graph. Record the equation of the best-fit line.

3. Examine the value and the units of the slope. Discuss with your instructor what the ideal value of the slope might be.

4. Examine the value and units of the vertical intercept. In view of the modifications you made to the object distance and image distance in order to produce a linear graph, draw a conclusion about the physical significance of the intercept.

5. Write a general equation of your best-fit line in terms of d_i, d_o, and f, and then rearrange the equation so that d_i and d_o are on the same side. Compare your results to the spherical mirror equation in your text or a web-based resource.

6. The magnification, m, of an image is the ratio of the image height, i, to the object height, o. Using similar triangles, one can show that it is also equal to the ratio of the image distance to the object distance.

$$m = \frac{i}{o} = -\frac{d_i}{d_o}$$

   Note: The negative sign is included as part of the convention to indicate that the real image is inverted.

   Find a configuration of the mirror and the screen that produces an image of the "4" used as the object that measures 10 mm across. Measure d_i and d_o and compare the agreement between the two ratios. Repeat this process for an image that is half as large. The "4" on the light source is 20 mm across.

7. In the sign convention used for spherical mirrors, both the focal length of a convex mirror and the image distance for a virtual image have negative values. The focal length of the convex mirror in the mirror set is –20 cm. Use the spherical mirror equation to calculate the expected distance for the virtual image. How does this compare to the value you obtained from your observations?

EXTENSIONS

1. Suppose you had used a 15 cm concave mirror in your experiment. Predict the slope and intercept of the graph of $1/d_i$ *vs*. $1/d_o$.

2. In what ways are the virtual images one can see with both convex and concave mirrors the same? How are they different?

3. Determine the virtual image distance for at least five more positions of the half screen serving as the object as you did in Part 2. Click or tap Data Set Options, ⋯, and choose Add New Data Set to create a new Data Set in your file. Enter the values for the object and image distances. Use the vertical- and horizontal-axis labels to plot a graph of $1/d_i$ *vs*. $1/d_o$. Click or tap Graph Tools, , and choose Apply Curve Fit to apply a linear fit as before, and determine the agreement between your data and the spherical mirror equation.