

Curved Mirrors, Ray Diagrams, and Simulations

Background Information

Spherical mirrors may be concave or convex. Concave mirrors have the focal point (f) in front of the mirror, and convex mirrors have the focal point behind the mirror. In this equation, the symbols d_o and d_i represent the distances from the mirror to the object and to the image.

The mirror equation used in this activity: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

The sign convention for mirrors is described below:

d_o positive	when the object is "in front of the mirror"
d_i positive	real images (inverted - "in front of the mirror")
d_i negative	virtual images (upright - "behind the mirror")
f positive	converging (concave) mirrors
f negative	diverging (convex) mirrors

Activity 8 – 1: Focal Length of a Concave Mirror using Parallel Rays - Method I

Objective:

- Determine the focal length of a concave mirror – quickly with a minimum of materials.
- For a spherical concave mirror – parallel rays of light focus to a point. The distance from the mirror to the focused point image is the focal length of the mirror.

Materials Included:

- Economy Optical Bench (Optional)
- 10 cm focal length concave mirror

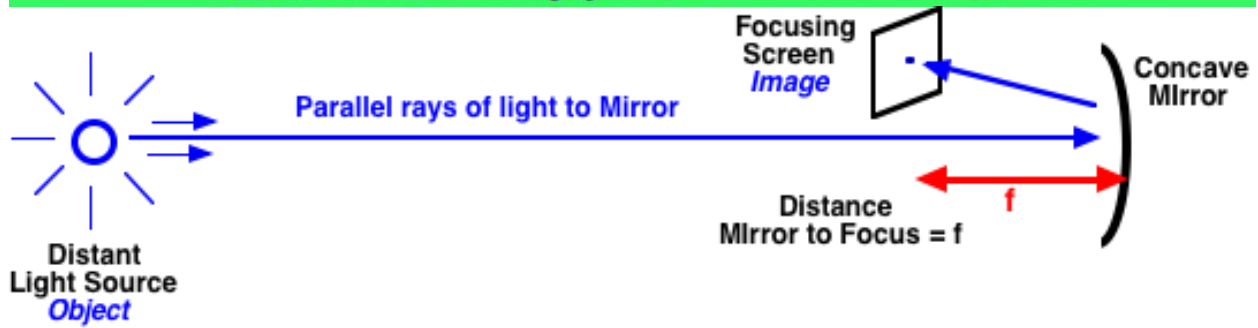
Materials Provided by You:

- Incandescent Frosted 60 Watt bulb with an F drawn on it (Optional)
- A Ruler and a sheet of paper (for focusing screen)
- Permanent ink (Sharpie) Pen

Procedure:

1. Aim your mirror at a distant light source greater than 6 meters away in a darkened room. You can use the sun outdoors or even inside through a window.
2. Place a sheet of paper (focusing screen) between the mirror and light source so that light can strike the mirror and reflect back to the paper (see diagram below).
3. Move the paper toward and away for the mirror to find the position where the reflected light forms the image of a small spot on the paper.
4. Measure the distance between the mirror and the image on the spot with a ruler

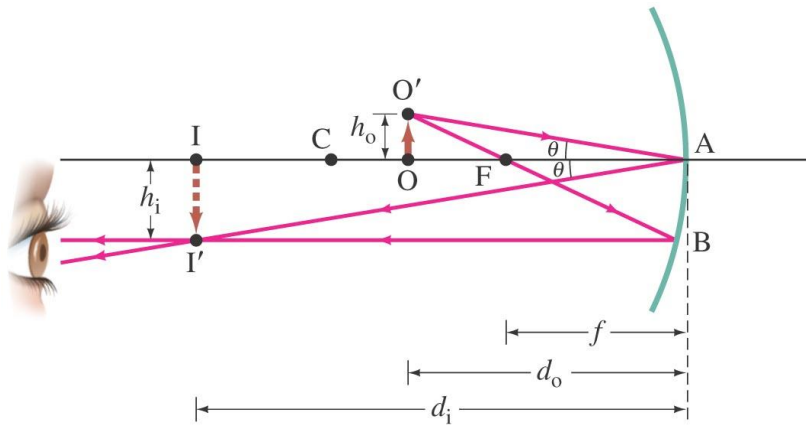
5. Focal Length of Mirror using Method I: _____ cm



Activity 8 – 2: Focal Length of a Concave Mirror using Equidistance - Method II

Objective:

- To determine the focal length of a concave mirror.
- $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ if $d_o = d_i \Rightarrow \frac{1}{f} = \frac{2}{d} \Rightarrow f = \frac{d}{2}$ f is half the distance to the mirror



Materials Included:

- Economy Optical Bench
- 10 cm focal length concave mirror

Materials Provided by You:

- Incandescent Frosted 60 Watt bulb with an F drawn on it
- A Ruler and a sheet of paper (for focusing screen)
- Permanent ink (Sharpie) Pen
- Paper clip and scotch tape (Optional)

Procedure:

1. With a Sharpie pen, draw the letter “F” at least 3 cm tall on the bulb facing the direction of the mirror (this will allow you to distinguish up/down or left/right on the image). Place the front of the light source at the zero meter end of the optical bench (as shown below).

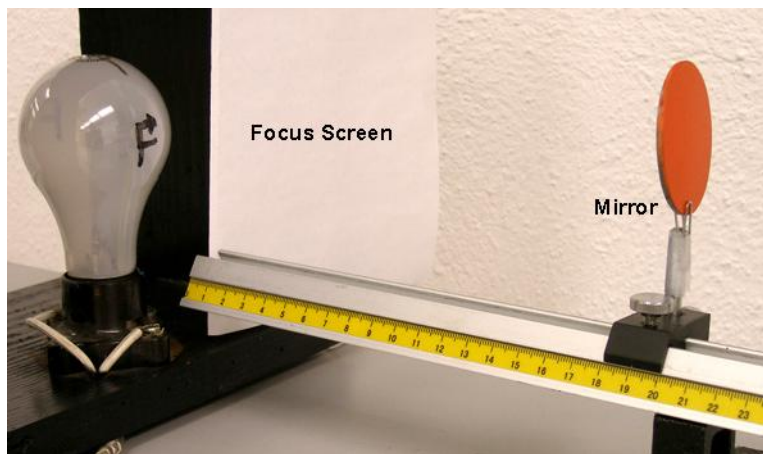


Figure 8 - 1

2. Place a concave mirror facing the bulb in a sliding holder on the optical bench.
3. Fold a sheet of white paper in half to make a focusing screen and place it slightly to the left or right of the light source → so that the front of the bulb and the paper focusing screen are equal distance from the mirror. See Figure 8-1.

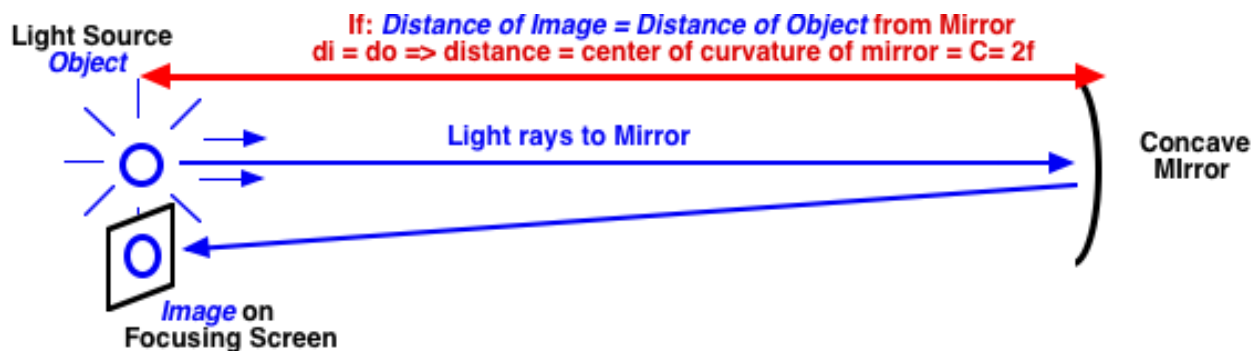


Figure 8-2

4. Adjust the position of the mirror, back and forth, along the bench until you have the clearest image of the “F” (on the bulb) on the focusing screen. You will have to also rotate the mirror slightly to get the image on the paper. Record the location of the mirror along the bench in centimeters:

_____ cm

5. What is the orientation of the image with regards to up/down and left/right compared to the original lamp?

6. How does the size of the image compare to the object?
7. What is the image distance _____ cm?
8. What is the object distance _____ cm?
9. Use the mirror equation to determine the focal length f of the mirror from your information in step 6. Focal length for the concave mirror = _____ cm.
10. Compare your calculated value of f to the suggested value for focal length of the mirror given by the lens company?

Activity 8 – 3: Focal Length of a Concave Mirror using Graphical Analysis-Method III

Objective:

- Accurately determine the focal length of a concave mirror.

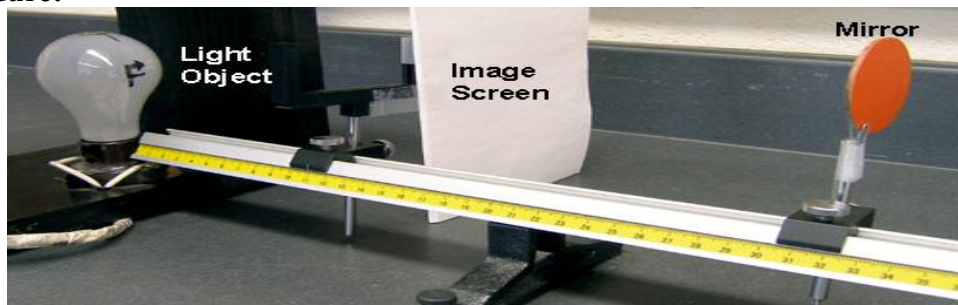
Materials Included:

- Economy Optical Bench
- 10 cm focal length concave mirror

Materials Provided by You:

- Incandescent Frosted 60 Watt bulb with an F drawn on it
- A sheet of paper (for focusing screen)
- Permanent ink (Sharpie) Pen
- Paper clip and scotch tape (Optional)

Procedure:



1. Use the light source and mirror used in activity 8-1. Connect the light source and place the light source at the zero end of the optical bench.
2. Place the mirror at the 80 cm mark on the bench. Put the white focusing screen between the mirror and the light source (slightly to the side). Adjust the location of the screen until you see an image on the screen of your light bulb. You may have to tilt the mirror slightly to form an image on the screen.
3. Record the distance from the lamp to the mirror as d_o , and the distance from the mirror to the screen as d_i . Record these distances to the nearest 0.1 cm in **Table 8-1**.
4. Is the image erect or inverted? Is the image real or virtual? Record this information in **Table 8-1**. (hint: there may not be a clear “real” image at all (d_o) distances.)

Table 8-1
Concave Mirror

Trial #	Light to Mirror d_o (cm)	Image to Mirror d_i (cm)	1/ d_o	1/ d_i	Image Orientation Erect/Inverted	Type of Image (real/virtual/none)	Image height _____ (cm)
1	80	?	?	?	?	?	
2	70	?	?	?	?	?	
3	60	?	?	?	?	?	
4	50	?	?	?	?	?	
5	40	?	?	?	?	?	
6	30	?	?	?	?	?	
7	20	?	?	?	?	?	
	15						
8	10 5	?	?	?	?	?	

5. Decrease the distance between the lamp and mirror and record your results in the above data table. Continue to decrease the object distance until you have reached an object distance of 5 cm.
6. Discuss the orientation and height of the various types of images formed in relation to the perceived focal length of the lens (f found in previous activities).
6. We will now determine the focal length of the mirror using two different graphical methods taking advantage of the equation:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \rightarrow \rightarrow \text{using a little algebra}$$

first from: $\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$ we will plot: $\frac{1}{d_o}$ (as x), $\frac{1}{d_i}$ (as y) to find $\frac{1}{f}$, thus f

7. Make a plot of: $\frac{1}{d_o}$ (as x) vs. $\frac{1}{d_i}$ (as y) using the chart option in Excel.

Properly scale and label the axis of the graph. Draw a best-fit straight line using the “trend-line” option under chart (also select to display the equation of the trend-line). The trend-line may not go exactly through all the data points.

[Cut and paste the Excel chart here.](#)

8. If the equation for this graph is: $\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$, how can you determine the value of $\frac{1}{f}$ from the graph? Explain your reasoning here:

The values you determined from your graph:

$$\frac{1}{f} = \underline{\hspace{2cm}} \qquad f = \underline{\hspace{2cm}}$$

9. How do your values of f compare for the same lens? [Fill in the table below.](#)

<u>Methods</u>	<u>f value (cm)</u>
Method Activity I	?
Method Activity II	?
Graphical Method I	?
Manufacture's Value	?

10. State which of the f values you think is most accurate? Justify your reasoning. Briefly explain how you would determine f for this mirror - if accuracy of the f value were very critical.

Activity 8 – 4: Computer Simulation Illustrating Graphical Analysis

Objectives:

- To graphically analyze more difficult optical phenomenon using computer simulations.

Materials Provided by You:

- Internet access

Procedure:

1. We will use the mirror simulation program located at <http://webphysics.davidson.edu/Applets/optics/intro.html>. You will use this applet again later in the course. Bookmark this location.
2. Click your mouse on the “**Mirror**” button. The text becomes colored, showing that it is active. Click on the diagram and you will notice a “+” on the screen. Note that as you move the “+” a small yellow box in the corner of the diagram indicates its x, y position (left edge = $x = 0$, yellow line = $y = 0$).
3. Move your cursor to about 1/4 of the way from the right side, near the yellow line. When you click your mouse, a concave curved mirror appears. The location of the center of the mirror is given on the screen. Move the mirror to a convenient location (such as $x = 4.0$) by dragging the mirror left or right. This is labeled on the screen as “**x**” and is near the center of the mirror. The focal length of the mirror is labeled “**f**”.
4. Click the “**Object**” button. Click about 1/4 of the way from the left side, above the yellow line. An arrow will appear as our object. As object will appears, three light rays come from the point of the arrow to strike the mirror and reflect back. You can change the height of the arrow or its distance from the mirror by putting the hand icon at the top of the arrow and dragging it around the diagram. Note also that the three reflected rays converge to a point on the screen that represents the arrow point of the image.
5. Click on the focal point on the left side of the mirror and slowly drag it to the far left of the screen.
 - What effect does this have on the shape of the mirror?
 - How do the “f” numbers change?
 - What effect does this have on the image arrow?
6. Return the focal point to its original position. Now, click on the left focal point and drag it slowly to the right of the mirror.
 - What effect does this have on the shape of the mirror?
 - How do the “f” numbers change?
 - What effect does this have on the image arrow?
7. Changes can be easily corrected by clicking on the object you want to change then selecting the “**Clear Active**” button. If you want to restart the applet from the beginning, click on the “**Clear All**” button.
8. Select the “**Beam**” button then click on the screen. Describe what this option does.
9. Leave the “**Beam**” on, and now use the “**Aperture**” option. Play with it and describe what this option does.

Practice with the various options until you feel comfortable changing the size and location of the object, changing the location of the mirror, changing the type of mirror, adding and deleting the beam, changing the location of the beam. The more practice you have for this activity, the more time you will save in the later activities.

Activity 8–5: Ray Diagrams for Concave Mirrors

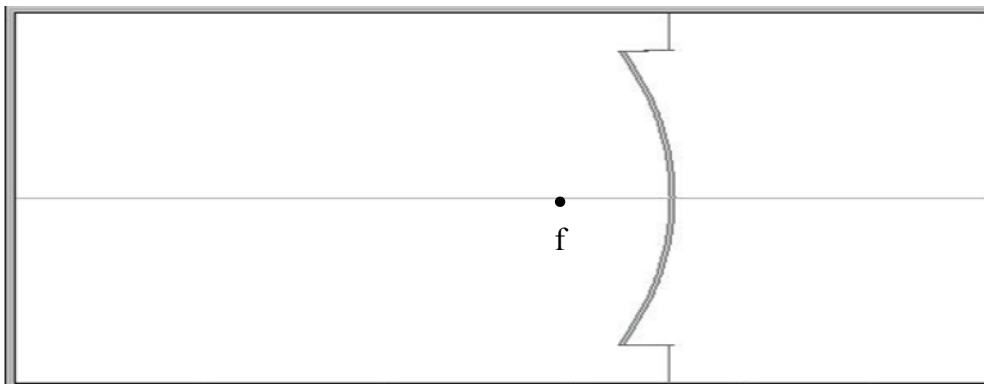
Objective:

- Draw a ray diagrams for a mirror to quickly locate the image.

Materials Provided by You: > Ruler > Paper

Procedure:

1. We will make our ray diagrams by using three rays. Use a vertical arrow for the object. All light rays start at the tip of the arrow. Make an object that is 1 cm high. Locate the object at a distance that is between f and $2f$.
2. One ray goes parallel to the principal axis from the tip of the arrow to the mirror. When it strikes the front of the mirror, it reflects and goes back through the focal point f .
3. One ray goes from the tip of the arrow through f to the mirror. After it strikes the mirror, it is reflected back on the same side of the object parallel to the principal axis.
4. One ray goes to the center of the mirror and is reflected back at the same angle. The three reflected rays should intersect at the same location. Make your rays on the diagram below.



5. Measure d_o , d_i . Measure the height of the image. Record your answers to the nearest 0.1 cm. Record units on your measurements.

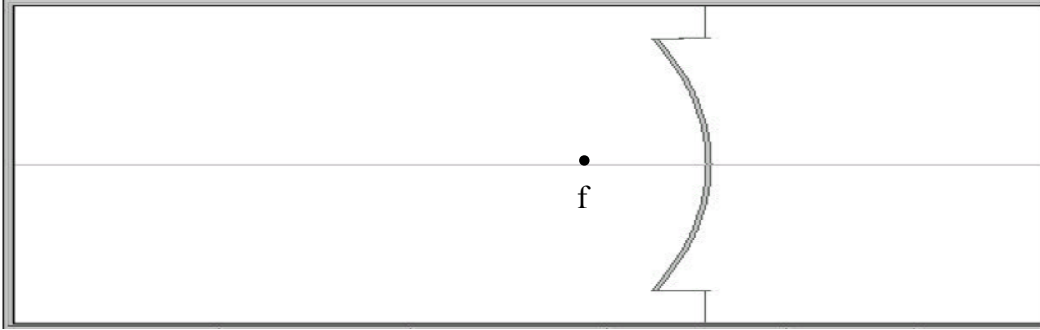
$d_o =$

Height of image =

$d_i =$

Type of image =

6. Place your object at $2f$. Make your ray diagram on the diagram below.



7. Measure d_o , d_i . Measure the height of the image. Record your answers to the nearest 0.1 cm. Record units on your measurements.

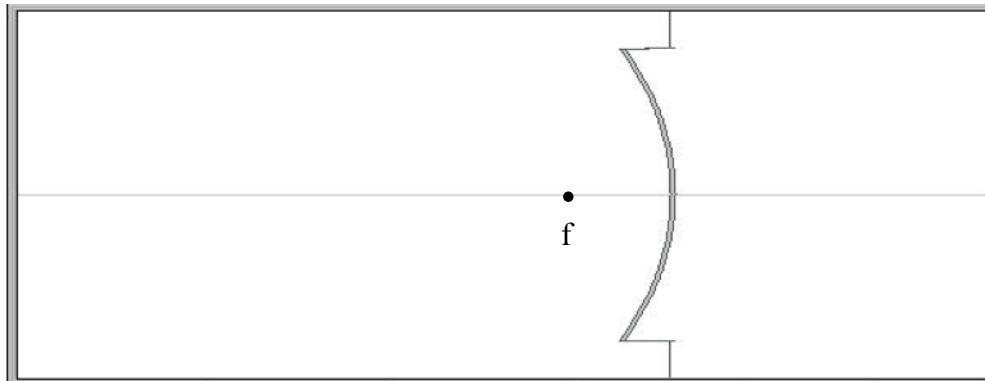
$d_o =$

$d_i =$

Height of image =

Type of image =

8. Place your object at a distance that is greater than $2f$. Make your ray diagram on the diagram below.



9. Measure d_o , d_i . Measure the height of the image. Record your answers to the nearest 0.1 cm. Record units on your measurements.

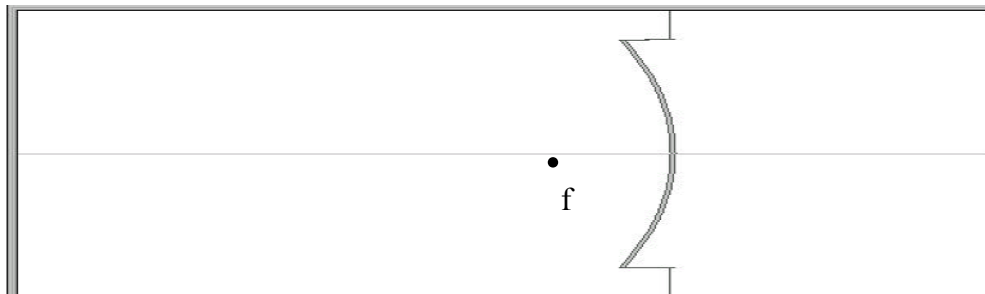
$d_o =$

$d_i =$

Height of image =

Type of image =

10. Place your object at a distance that is at $0.5f$. Make your ray diagram on the diagram below.



11. Did your rays intersect on the left side of the mirror? If not, extend the reflected rays. Make them dashed when you extend the lines.
12. Measure d_o , d_i . Measure the height of the image. Record your answers to the nearest 0.1 cm. Record units on your measurements.

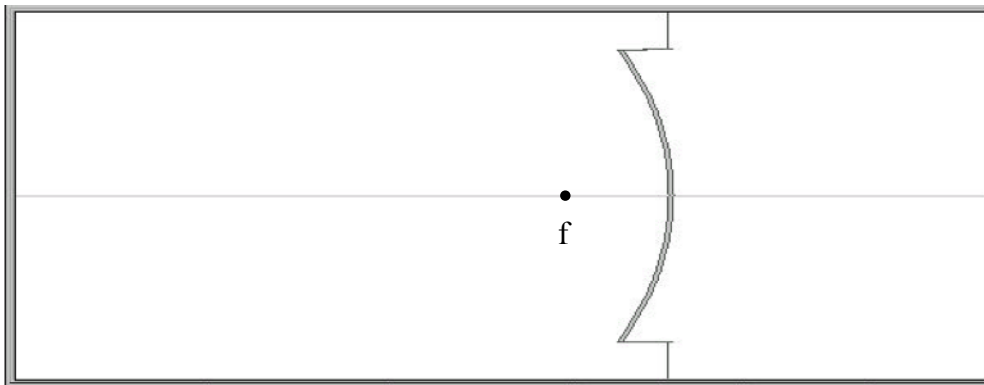
$d_o =$

$d_i =$

Height of image =

Type of image =

13. Place your object at a distance that is equal to f . Make your ray diagram on the diagram below.



14. Did your rays intersect on the left side of the mirror? If not, extend the reflected rays. Make them dashed when you extend the lines.
15. Measure d_o , d_i . Measure the height of the image. Record your answers to the nearest 0.1 cm. Record units on your measurements.

$d_o =$

$d_i =$

Height of image =

Type of image =

16. Summarize your ray diagrams for a concave mirrors.