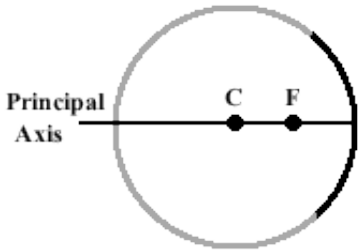
Concave Mirrors

A group of students are studying the images that are produced by a concave spherical mirror. The anatomy of a concave mirror is shown in **Figure 1**. There is a focal point (**F**) and a center of curvature (**C**) positioned along an imaginary line known as the principal axis.

Figure 1



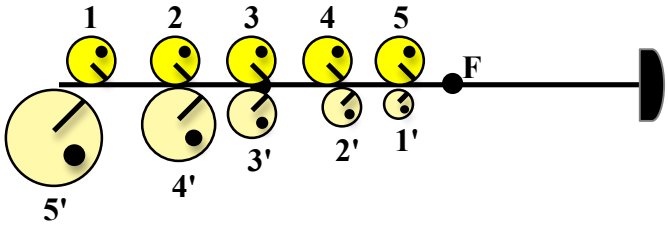
Experiment 1

The students take their mirror outside and point it towards the sun. They reflect sunlight off the mirror onto a note card. An image of the sun – a bright dot – forms on the note card. They measure the distance from the mirror to the note card to be 14.9 cm. This distance is the **focal length** – the distance from focal point to the mirror.

Experiment 2

In **Experiment 2**, the students take the same mirror and mount it in putty on a lab table. They place a small piece of tape on the table and label it **F** for focal point. They position a small night light bulb on the table and inscribe a smiley face on the front of the bulb. Light from the bulb reflects off the mirror and converges to form an image. They project the image on a note card and observe its characteristics. They find that the location of the object bulb affects the characteristics of the image. For instance, when the light bulb is at position **1**, they find the image (at position **1'**) is smaller in size (*reduced*) and upside down (*inverted*). In contrast, when the object bulb is at position **4**, the image (at position **4'**) is larger in size (*magnified*) but still inverted. **Figure 2** summarizes their findings.

Figure 2



Experiment 3

In **Experiment 3**, the students use the same set up and a similar method that was used in **Experiment 2**. But this time they make measurements of the distance from object to mirror (known as the object distance) and of the distance from the image to the mirror (known as the image distance). They also measure the diameter of the image for each image that is formed. The bulb's actual diameter is 4.1 cm. All measurements are shown in **Table 1**.

Table 1

Object Distance (cm)	Image Distance (cm)	Image Diameter (cm)
80.0	18.2	1.0
70.0	18.8	1.1
60.0	19.6	1.4
50.0	21.0	1.8
45.0	22.1	2.1
40.0	23.5	2.5
37.0	24.7	2.8
35.0	25.6	3.1
32.0	27.5	3.6
30.0	29.2	4.1
28.0	31.4	4.7
26.0	34.4	5.6
24.0	38.6	6.8
22.0	45.2	8.6

Questions:

1. Which characteristic of an image is observed for all five locations in **Figure 2**?
   a. The image is larger than the bulb.
   b. The image is smaller than the bulb.
   c. The image is inverted or turned upside down.
   d. The image is further from the mirror than the bulb is from the mirror;

2. For which bulb positions shown in **Experiment 2** is the image reduced in size?
   a. Positions 1 and 2
   b. Positions 3 and 4
   c. Positions 3, 4, and 5
   d. All five positions.

3. For which bulb position in **Figure 2** is the diameter of the image two times the size as the diameter of the bulb.
   a. Position 1
   b. Position 2
   c. Position 3
   d. Position 4
   e. Position 5

4. For which bulb position in **Figure 2** is the corresponding image the smallest?
   a. Position 1
   b. Position 2
   c. Position 3
   d. Position 4
   e. Position 5

5. Which statement describes the changes that are observed in the image diameter as the distance from the bulb to the mirror is increased?
   a. The image diameter increases as the object distance increases.
   b. The image diameter decreases as the object distance increases.
   c. The image diameter is not affected by changes in the object distance.
   d. The image diameter first decreases and then increases as object distance increases.

6. Which one of the following conclusions can be drawn from the results in **Experiment 3**?
   a. Images appear largest when the objects are furthest from the mirror surface.
   b. A large object distance results in small image distance and a small image diameter.
   c. A 10-cm change in the object distance results in a 0.6-cm change in the image distance.
   d. The accompanying data do not reveal any pattern from which predictions can be made.

7. The students determined the focal length in **Experiment 1**. Which statement describes the image when the object was placed a distance of approximately 3•f (three focal lengths) from the mirror in **Experiment 3**?
   a. The image distance is three times the focal length.
   b. The image distance is about one-third the object distance.
   c. The image diameter is about one-half of the object diameter.
   d. The image diameter is four times larger than the focal length.

8. Consider the following statement:

> When an object is far from a concave mirror, the image of the object will be reduced in size.

Which experiment(s) provides evidence to support this statement?

a. Experiment 1 only.
b. Experiment 2 only.
c. Experiments 2 and 3.
d. All three experiments.

9. The center of curvature is located twice as far from the mirror as the focal point is. Use **Table 1** to determine the approximate image diameter when the object is placed at the center of curvature.

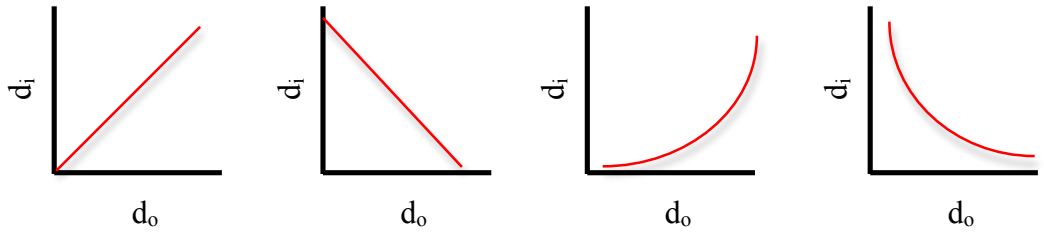
a. Approximately 2.0 cm
b. Approximately 4.1 cm
c. Approximately 8.2 cm
d. Approximately 29.8 cm

10. Which range of object distances in **Experiment 3** would correspond to the most significant changes in the image distance?

a. From 22 cm to 26 cm.
b. From 26 cm to 35 cm.
c. From 35 cm to 50 cm.
d. From 60 cm to 80 cm.

11. Which graph best represents the relationship between object distance (d_o) and image distance (d_i) as found in **Experiment 3**?

a. b. c. d.



12. Use **Table 1** to predict the image distance (d_i) and the diameter (D) that would result when the object is located 55 cm from the surface of the mirror.

a. d_i = 19.6 cm; D = 1.4 cm
b. d_i = 20.2 cm; D = 1.6 cm
c. d_i = 21.0 cm; D = 1.8 cm
d. d_i = 21.5 cm; D = 1.9 cm

13. Use **Table 1** to predict the image distance (d_i) and the diameter (D) that would result when the object is located 90 cm from the surface of the mirror.

a. d_i = 8.2 cm; D = 0.5 cm
b. d_i = 17.2 cm; D = 0.9 cm
c. d_i = 17.7 cm; D = 0.9 cm
d. d_i = 18.5 cm; D = 1.2 cm

14. Which position in **Figure 2** most closely corresponds to the row in **Table 1** that has an object distance of 22.0 cm?

a. Position 2
b. Position 3
c. Position 4
d. There is no way to tell.