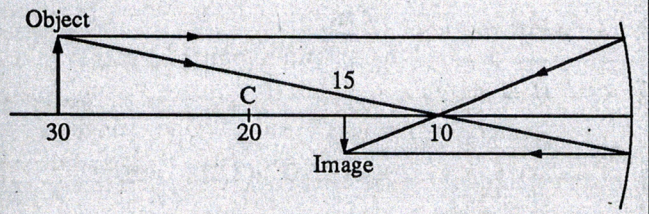
Chapter 18: Mirrors and Lenses

Practice Problems

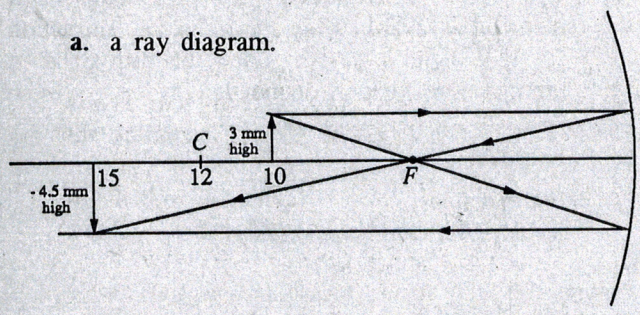
page 374

1. Solve the Example Problem above using a ray diagram.



2. An object 3.0 mm high is 10.0 cm in front of a concave mirror having a 6.0–cm focal length. Find the image by means of

a. a ray diagram.



b. the mirror equation.

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

$d_i = d_o f/(d_o - f)$
$= (10\text{ cm})(6.0\text{ cm})/(10\text{ cm} - 6.0\text{ cm})$
$= 15\text{ cm}$

c. Find the magnification of the mirror.

$m = -d_i/d_o = -(15\text{ cm})/(10.0\text{ cm}) = -1.5$

d. What is the height of the image?

$m = h_i/h_o$, so
$h_i = mh_o = (-1.5)(3.0\text{ mm}) = -4.5\text{ mm}$

3. The image of an object is 30.0 cm from a concave mirror with a 20.0–cm radius of curvature. Locate the object.

$f = r/2 = (20.0\text{ cm})/2 = 10.0\text{ cm}$,
$1/d_o + 1/d_i = 1/f$, so
$d_o = fd_i/(d_i - f)$
$= (10.0\text{ cm})(30.0\text{ cm})/(30.0\text{ cm} - 10.0\text{ cm})$
$= 15.0\text{ cm}$

Practice Problems

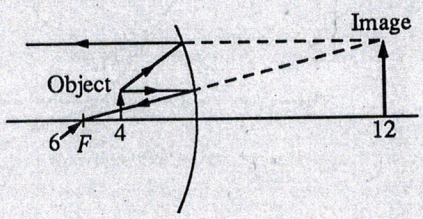
4. An old "magic trick" used a concave mirror to project an image the same size as the object and at the same distance from the mirror. If the object is 25 cm from the mirror, what should be the radius of the curvature of the mirror?

If $d_o = d_i$ then $1/f = 2/d_o$ or $f = \frac{1}{2}d_o$.

Now $r = 2f = d_o = 25\text{ cm}$

page 376

5. An object is 4.0 cm in front of a concave mirror having a 12.0–cm radius. Locate the image using the mirror equation and a ray diagram.



$f = r/2 = (12.0\text{ cm})/2 = 6.0\text{ cm}$,
$1/d_o + 1/d_i = 1/f$, so
$d_i = fd_o/(d_o - f)$
$= (6.0\text{ cm})(4.0\text{ cm})/(4.0\text{ cm} - 6.0\text{ cm})$
$= -12\text{ cm}$

6. A concave mirror has a focal length of 9.0 cm. A 15–mm high object is placed 6.0 cm from the mirror.

a. Find the image using the mirror equation.

$1/d_o + 1/d_i = 1/f$, so
$d_i = fd_o/(d_o - f)$
$= (9.0\text{ cm})(6.0\text{ cm})/(6.0\text{ cm} - 9.0\text{ cm})$
$= -18\text{ cm}$

b. How large is the image?

$m = h_i/h_o = -d_i/d_o = -(-18\text{ cm})/(6.0\text{ cm})$
$= +3.0$, so
$h_i = mh_o = (3.0)(15\text{ mm}) = 45\text{ mm}$

7. A 4.0–cm high candle is placed 10.0 cm from a concave mirror having a focal length of 16.0 cm.

   a. Where is the image located?

$$1/d_o + 1/d_i = 1/f, \text{ so}$$
$$d_i = fd_o/(d_o - f)$$
$$= \frac{(16.0\ \text{cm})(10.0\ \text{cm})}{(10.0\ \text{cm} - 16.0\ \text{cm})}$$
$$= -27\ \text{cm}$$

   b. What is the height of the candle's image?

$$m = h_i/h_o = -d_i/d_o$$
$$= -(-27\ \text{cm})/(10.0\ \text{cm})$$
$$= +2.7, \text{ so}$$
$$h_i = mh_o = (2.7)(4.0\ \text{cm}) = 11\ \text{cm}$$

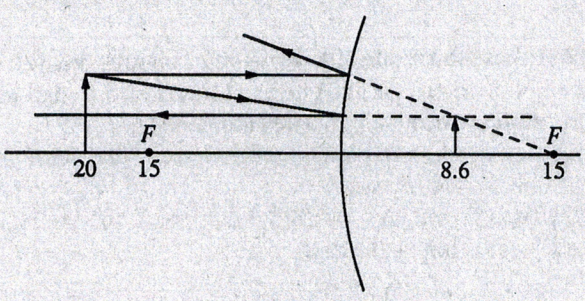
8. What should be the radius of curvature of a concave mirror that magnifies an object placed 25 cm from the mirror by a factor of 3.0?

$$m = -d_i/d_o = 3, \text{ so}$$
$$d_i = -75\ \text{cm}$$
$$1/f = 1/d_o + 1/d_i \text{ so}$$
$$f = d_o d_i/(d_o + d_i)$$
$$= (25\ \text{cm})(-75\ \text{cm})/(25\ \text{cm} + (-75\ \text{cm}))$$
$$= 37.5\ \text{cm and } r = 2f = 75\ \text{cm}$$

page 377

9. An object is 20.0 cm in front of a convex mirror with a −15.0–cm focal length. Find the location of the image using

   a. a ray diagram.



   b. the mirror equation.

$$1/d_o + 1/d_i = 1/f, \text{ so}$$
$$d_i = fd_o/(d_o - f)$$
$$= \frac{(-15.0\ \text{cm})(20.0\ \text{cm})}{(20.0\ \text{cm} - (-15.0\ \text{cm}))}$$
$$= -8.57\ \text{cm}$$

page 378

10. A convex mirror has a focal length of −12 cm. A light bulb with a diameter of 6.0 cm is placed 60.0 cm in front of the mirror.

   a. Where is the image of the light bulb? Use the mirror equation.

$$1/d_o + 1/d_i = 1/f, \text{ so}$$
$$d_i = fd_o/(d_o - f)$$
$$= \frac{(-12\ \text{cm})(60.0\ \text{cm})}{(60.0\ \text{cm} - (-12\ \text{cm}))}$$
$$= -10\ \text{cm}$$

   b. What is the diameter of the image?

$$m = h_i/h_o = -d_i/d_o$$
$$= -(-10\ \text{cm})/(60.0\ \text{cm}) = +0.17, \text{ so}$$
$$h_i = mh_o = (0.17)(6.0\ \text{cm}) = 1.0\ \text{cm}$$

11. In a department store, a mirror used to watch for shoplifters has a focal length of −40.0 cm. A person stands in an aisle 6.0 m from the mirror. Locate the person's image using the mirror equation. Is it erect or inverted? larger or smaller than the object?

$$1/d_o + 1/d_i = 1/f, \text{ so}$$
$$d_i = fd_o/(d_o - f)$$
$$= (-0.40\ \text{m})(6.0\ \text{m})/(6.0\ \text{m} - (-0.40\ \text{m}))$$
$$= -0.38\ \text{m erect, smaller}$$

Practice Problems

12. A convex mirror is needed to produce an image located 24 cm behind a mirror that is 3/4 the size of the object. What focal length should be specified?

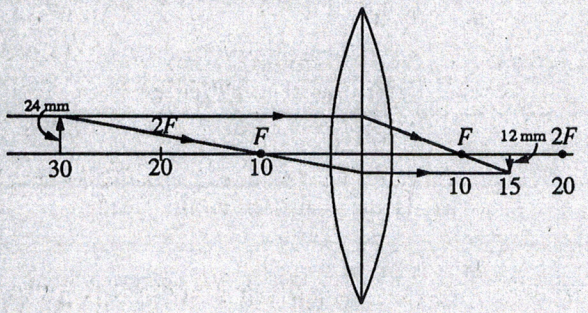
$1/f = 1/d_o + 1/d_i$ so $f = d_o d_i/(d_o + d_i)$ and
$m = -d_i/d_o$ so $d_o = -d_i/m$.
Since $d_i = -24$ cm and $m = 0.75$,

$$d_o = \frac{-(-24\text{ cm})}{0.75} = 32\text{ cm and}$$

$$f = \frac{(32\text{ cm})(-24\text{ cm})}{32\text{ cm} + (-24\text{ cm})} = -96\text{ cm}.$$

page 381

13. Use a ray diagram to find the image position of an object 30 cm to the left of a convex lens with a +10–cm focal length. (Let 1 cm on the drawing represent 20 cm.)



14. An object 2.25 mm high is 8.5 cm to the left of a convex lens of 5.5–cm focal length. Find the image distance and height.

$1/d_o + 1/d_i = 1/f$, so
$d_i = fd_o/(d_o - f)$
$= (5.5\text{ cm})(8.5\text{ cm})/(8.5\text{ cm} - 5.5\text{ cm})$
$= 16$ cm
$h_i = -d_i h_o/d_o = -(16\text{ cm})(2.25\text{ mm})/(8.5\text{ cm})$
$= -4.2$ mm

15. An object is placed to the left of a 25–mm focal length convex lens so that its image is the same size as the object. What are the image and object distances?

$1/d_o + 1/d_i = 1/f$ with $d_o = d_i$ since
$m = -d_i/d_o$ and $m = -1$. Therefore,
$2/d_o = 1/f$, $d_o = d_i = 2f = 50$ mm

Practice Problems

16. A lens is needed to create an inverted image twice as large as the object when the object is 7.0 cm from the lens. What focal length lens is needed?

$m = -d_i/d_o$
so $d_i = -md_o = -(-2)(7.0\text{ cm}) = 14$ cm.
$1/f = 1/d_o + 1/d_i$ so
$f = d_o d_i/(d_o + d_i)$
$= (7.0\text{ cm})(14\text{ cm})/(7.0\text{ cm} + 14\text{ cm})$
$= 4.7$ cm

page 383

17. A newspaper is held 6.0 cm from a convex lens of 20.0–cm focal length. Find the image distance of the newsprint image.

$1/d_o + 1/d_i = 1/f$, so
$d_i = fd_o/(d_o - f)$
$= (20.0\text{ cm})(6.0\text{ cm})/(6.0\text{ cm} - 20.0\text{ cm})$
$= -8.6$ cm

18. A magnifying glass has a focal length of 12.0 cm. A coin, 2.0 cm in diameter, is placed 3.4 cm from the lens.

a. Locate the image of the coin.

$1/d_o + 1/d_i = 1/f$, so
$d_i = fd_o/(d_o - f)$
$= (12\text{ cm})(3.4\text{ cm})/(3.4\text{ cm} - 12\text{ cm})$
$= -4.7$ cm

b. What is the diameter of the image?

$h_i = -h_o d_i/d_o$
$= -(2.0\text{ cm})(-4.7\text{ cm})/(3.4\text{ cm})$
$= 2.8$ cm

19. A stamp collector wants to magnify images by 4.0 when the object is 3.5 cm from the lens. What focal length lens is needed?

$m = -d_i/d_o$ so
$d_i = -md_o = -(4.0)(3.5\text{ cm}) = -14$ cm.
$1/f = 1/d_o + 1/d_i$ so
$f = d_o d_i/(d_o + d_i)$
$= (3.5\text{ cm})(-14\text{ cm})/(3.5\text{ cm} + (-14\text{ cm}))$
$= 4.7$ cm

Practice Problems

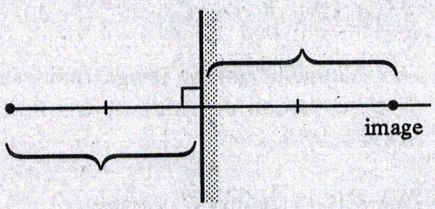
20. Suppose you are looking at a stamp through a magnifying glass and want to increase the size of the image. Should you move the glass closer to the stamp or farther away? Explain and indicate the maximum distance you should move it.

    From Figure (18–17), you can increase image size by making $(d_o - f)$ as small as possible. Thus, increase d_o until it is almost f, which is the limit.

Chapter Review Problems

pages 388–389

1. Find the image of the object in Figure 18–25.



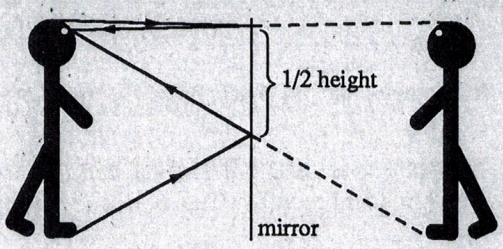
2. Penny wishes to take a picture of her image in a plane mirror. If the camera is 1.2 m in front of the mirror, at what distance should the camera lens be focused?

    The image is 1.2 m behind the mirror, so the camera lens should be set to 2.4 m.

3. Draw a ray diagram of a plane mirror to show that if you want to see yourself from your feet to the top of your head, the mirror must be at least half your height.

    The ray from top of head hits mirror halfway between eyes and top of head. Ray from feet hits mirror halfway between eyes and feet. Distance between the point the two rays hit the mirror is half the total height.

Chapter Review Problems



4. A concave mirror has a focal length of 10.0 cm. What is its radius of curvature?

    $c = 2f = 2(10.0\text{ cm}) = 20.0\text{ cm}$

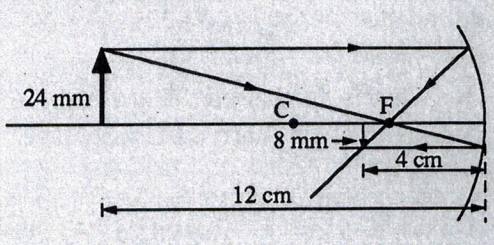
5. Light from a distant star is collected by a concave mirror. How far from the mirror is the image of the star if the radius of curvature is 150 cm?

    Stars are far enough away that the light coming into the mirror can be considered to be parallel and parallel light will converge at the focal point. Since $c = 2f$, $f = \frac{c}{2} = \frac{150\text{ cm}}{2} = 75.0$ cm

6. The sun falls on a concave mirror and forms an image 3.0 cm from the mirror. If an object 24 mm high is placed 12.0 cm from the mirror, where will its image be formed?

    The focal length of the mirror is 3.0 cm since that is the location of the image of the sun.

    a. Use a ray diagram.



    b. Use the mirror equation.

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

$$d_i = \frac{fd_o}{(d_o - f)} = \frac{(3.0\text{ cm})(12.0\text{ cm})}{12.0\text{ cm} - 3.0\text{ cm}}$$

$$= 4.0\text{ cm}$$

c. How high is the image?

$$m = \frac{-d_i}{d_o} = \frac{-4.0\text{ cm}}{12.0\text{ cm}} = -0.33$$

$$h_i = mh_o = (-0.33)(24\text{ mm}) = -8.0\text{ mm}$$

7. An object is 30.0 cm from a concave mirror of 15–cm focal length. The object is 1.8 cm high.

a. Locate the image, using the mirror equation.

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(30.0\text{ cm})(15\text{ cm})}{30.0\text{ cm} - 15\text{ cm}}$$

$$= 30\text{ cm}$$

b. How high is the image?

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

$$h_i = \frac{-d_i h_o}{d_o} = \frac{-(30\text{ cm})(1.8\text{ cm})}{30.0\text{ cm}}$$

$$= -1.8\text{ cm}$$

8. A jeweler inspects a watch, with a diameter of 3.0 cm, by placing it 8.0 cm in front of a concave mirror of 12.0–cm focal length.

a. Where will the image of the watch appear?

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(8.0\text{ cm})(12\text{ cm})}{8.0\text{ cm} - 12.0\text{ cm}}$$

$$= -24\text{ cm}$$

b. What is the diameter of the image?

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

$$h_i = \frac{-d_i h_o}{d_o} = \frac{-(-24\text{ cm})(3.0\text{ cm})}{8.0\text{ cm}}$$

$$= +9.0\text{ cm}$$

Chapter Review Problems

9. A dentist uses a small mirror of radius 40 mm to locate a cavity in a patient's tooth. If the mirror is concave and held 16 mm from the tooth, what is its magnification of the resulting image?

$$f = \frac{c}{2} = \frac{40\text{ mm}}{2} = 20\text{ mm}$$

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(16\text{ mm})(20\text{ mm})}{16\text{ mm} - 20\text{ mm}}$$

$$= -80\text{ mm}$$

$$m = \frac{-d_i}{d_o} = \frac{-(-80\text{ mm})}{16\text{ mm}} = 5.0$$

10. A production line inspector wants a mirror that produces an upright image with magnification 7.5 when it is located 14.0 mm from a machine part.

a. What kind of mirror would do this job?

An enlarged, upright image only results from a concave mirror, with object inside of the focal length.

b. What is its radius of curvature?

$m = \frac{-d_i}{d_o}$, so

$$d_i = -md_o = -(7.5)(14.0\text{ mm})$$

$$= -105\text{ mm}$$

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

$$f = \frac{d_o d_i}{(d_i - d_o)} = \frac{(14.0\text{ mm})(-105\text{ mm})}{14.0\text{ mm} - 105\text{ mm}}$$

$$= 16.2\text{ mm}$$

radius of curvature $= 2f = (2)(16.2\text{ mm})$

$$= 32.4\text{ mm}$$

11. Shiny lawn spheres placed on pedestals are convex mirrors. One such sphere has a diameter of 40 cm. A 12-cm robin sits in a tree 1.5 m from the sphere.

a. Where is the image of the robin?

$r = 20$ cm, $f = -10$ cm

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

$$d_i = \frac{fd_o}{(d_o - f)} = \frac{(-10.0\text{ cm})(1.5\text{ m})}{1.5\text{ m} - (-10.0\text{ cm})}$$

$$= -9.4\text{ cm}$$

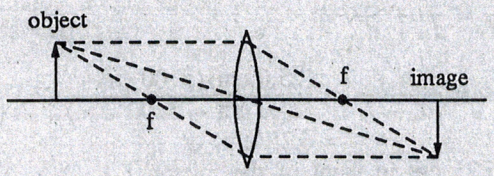
b. How long is the robin's image?

$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o} = \frac{-(-9.4\text{ cm})}{150\text{ cm}}$$

$$= +0.063$$

$$h_i = mh_o = (0.063)(12\text{ cm}) = 0.75\text{ cm}$$

12. The focal length of a convex lens is 17 cm. A candle is placed 34 cm in front of the lens. Make a ray diagram to find the location of the image.



13. The convex lens of a copy machine has a focal length of 25.0 cm. A letter to be copied is placed 40.0 cm from the lens.

a. How far from the lens is the copy paper located?

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(40.0\text{ cm})(25.0\text{ cm})}{40.0\text{ cm} - 25.0\text{ cm}}$$

$$= 66.7\text{ cm}$$

b. The machine was adjusted to give an enlarged copy of the letter. How much larger will the copy be?

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

$$h_i = \frac{d_i h_o}{d_o} = \frac{(66.7\text{ cm})(h_o)}{40.0\text{ cm}} = 1.67\ h_o$$

Chapter Review Problems

14. Camera lenses are described in terms of their focal length. A 50.0 mm lens has a focal length of 50.0 mm.

a. A camera is focused on an object 3.0 m away using a 50.0 mm lens. Locate the position of the image.

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(3.0 \times 10^3\text{ mm})(50.0\text{ mm})}{3.0 \times 10^3\text{ mm} - 50.0\text{ mm}}$$

$$= 51\text{ mm}$$

b. A 1.00×10^3 mm lens is focused on an object 125 m away. Locate the position of the image.

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(125\text{ m})(1.00\text{ m})}{125\text{ m} - 1.00\text{ m}}$$

$$= 1.01\text{ m}$$

$$= 1.01 \times 10^3\text{ mm}$$

15. Solve Problem 10 using a lens rather than a mirror.

An enlarged, upright image requires a convex lens with the object inside the focal length.

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

$$d_i = -md_o = -(7.5)(14.0\text{ mm}) = -105\text{ mm}$$

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

$$f = \frac{d_o d_i}{(d_i + d_o)} = \frac{(14.0\text{ mm})(-105\text{ mm})}{14.0\text{ mm} - 105\text{ mm}}$$

$$= 16.2\text{ mm}$$

16. A convex lens is needed to produce an image located 24 cm behind the lens that is 0.75 the size of the object. What focal length should be specified?

$d_i = 0.75d_o$, so $d_o = \dfrac{d_i}{0.75} = \dfrac{24\text{ cm}}{0.75} = 32\text{ cm}$

$\dfrac{1}{f} = \dfrac{1}{d_i} + \dfrac{1}{d_o}$, so

$$f = \frac{d_o d_i}{d_o + d_i} = \frac{(32\text{ cm})(24\text{ cm})}{32\text{ cm} + 24\text{ cm}} = 14\text{ cm}$$

Chapter Review Problems

17. A microscope slide with an onion cell is placed 12 mm from the objective lens of a microscope. The focal length of the objective lens is 10.0 mm.

a. How far from the lens is the image formed?

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(12.0\text{ mm})(10.0\text{ mm})}{12.0\text{ mm} - 10.0\text{ mm}}$$

$$= 60.0\text{ mm}$$

b. What is the magnification of this image?

$$m_o = \frac{-d_i}{d_o} = \frac{-60.0\text{ mm}}{12.0\text{ mm}} = -5.0$$

c. The real image formed is located 10.0 mm beneath the eyepiece lens of the microscope. If the focal length of the eyepiece is 20.0 mm, where does the final image appear?

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(10.0\text{ mm})(20.0\text{ mm})}{10.0\text{ mm} - 20.0\text{ mm}}$$

$$= -20.0\text{ mm}$$

d. What is the final magnification of this compound system?

$$m_e = \frac{-d_i}{d_o} = \frac{-(-20.0\text{ mm})}{10.0\text{ mm}} = 2.00$$

$$m_{total} = (m_o)(m_e) = (-5.0)(2.00) = -10.0$$

18. In order to clearly read a book at 25 cm away, a farsighted person needs an image distance of −45 cm. What focal length is needed?

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}, \text{ so}$$

$$f = \frac{d_o d_i}{(d_o - d_i)} = \frac{(25\text{ cm})(-45\text{ cm})}{25\text{ cm} + (-45\text{ cm})}$$

$$= 56\text{ cm}$$

Supplemental Problems (Appendix B)

1. Sally's face is 75 cm in front of a plane mirror. Where is the image of Sally's face?

75 cm behind the mirror

2. A concave mirror has a focal length of 10.0 cm. What is its radius of curvature?

$r = 2f = 2(10.0\text{ cm}) = 20.0\text{ cm}$

3. Light from a distant star is collected by a concave mirror that has a radius of curvature of 150 cm. How far from the mirror is the image of the star?

$$f = \frac{r}{2} = \frac{150\text{ cm}}{2} = 75.0\text{ cm}$$

$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$, but d_o is extremely large, so

$\frac{1}{f} = \frac{1}{d_i}$, or $d_i f = 75.0\text{ cm}$

4. An object is placed 25.0 cm away from a concave mirror that has a focal length of 5.00 cm. Where is the image located?

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

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(25.0\text{ cm})(5.00\text{ cm})}{(25.0\text{ cm} - 5.00\text{ cm})}$$

$= 6.25$ cm, or

6.25 cm in front of the mirror

5. An object and its image as seen in a concave mirror are the same height when the object is 48.4 cm from the mirror. What is the focal length of the mirror?

For a concave mirror, an object and its image have the same height when the object is two focal lengths from the mirror. Therefore,
48.4 cm = $2f$, or f = 48.4 cm/2 = 24.2 cm

6. An object placed 50.0 cm from a concave mirror gives a real image 33.3 cm from the mirror. If the image is 28.4 cm high, what is the height of the object?

$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o} = \frac{-33.3\text{ cm}}{50.0\text{ cm}} = -0.666, \text{ so}$$

$$h_o = \frac{h_i}{m} = \frac{-28.4\text{ cm}}{(-0.666)} = 42.6\text{ cm}$$

m is negative, so the image is inverted and h_i is negative.

7. An object 15.8 cm high is located 87.6 cm from a concave mirror that has a focal length of 17.0 cm.

a. Where is the image located?

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ so}$$

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(87.6\text{ cm})(17.0\text{ cm})}{(87.6\text{ cm} - 17.0\text{ cm})}$$

$$= 21.1\text{ cm}$$

b. How high is the image?

$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o} = \frac{(-21.1\text{ cm})}{(86.7\text{ cm})} = -0.241, \text{ so}$$

$$h_i = mh_o = (-0.241)(15.8\text{ cm})$$
$$= -3.81\text{ cm; inverted}$$

The negative sign indicates an inverted image.

8. The image of the moon is formed by a concave mirror whose radius of curvature is 4.20 m at a time when the moon's distance is 3.80×10^5 km. What is the diameter of the image of the moon if the diameter of the moon is 3480 km?

$$f = \frac{r}{2} = \frac{4.20\text{ m}}{2} = 2.10\text{ m}$$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ but } d_o \text{ is extremely large, so}$$

$$\frac{1}{f} = \frac{1}{d_i}, \text{ or } d_i = f = 2.10\text{ m} = 2.10 \times 10^{-3}\text{ km}$$

$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o} = \frac{-(2.10 \times 10^{-3}\text{ km})}{(3.80 \times 10^5\text{ km})}$$

$$= -5.53 \times 10^{-9}, \text{ so}$$

$$h_i = mh_o = (-5.53 \times 10^{-9})(3480\text{ km})$$
$$= -1.92 \times 10^{-5}\text{ km}$$
$$= -1.92\text{ cm; inverted}$$

The negative sign indicates an inverted image.

Supplemental Problems

9. A shaving mirror has a radius of curvature of 30.0 cm. When a face is 10.0 cm away from the mirror, what is the magnification of the mirror?

A shaving mirror is concave.

$$f = \frac{r}{2} = \frac{30.0\text{ cm}}{2} = 15.0\text{ cm}$$

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ so}$$

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(10.0\text{ cm})(15.0\text{ cm})}{(10.0\text{ cm} - 15.0\text{ cm})}$$

$$= -30\text{ cm}$$

$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o} = \frac{-(-30\text{ cm})}{(10.0\text{ cm})} = 3.0$$

m is positive, so the image is erect.

10. A convex mirror has a focal length of -16 cm. How far behind the mirror does the image of a person 3.0 m away appear?

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ so}$$

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(3.0\text{ m})(-0.16\text{ m})}{(3.0\text{ m} - (-0.16\text{ m}))}$$

$$= -0.15\text{ m, or}$$

15 cm behind the mirror.

11. How far behind the surface of a convex mirror, focal length of -6.0 cm, does a car 10.0 m from the mirror appear?

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ so}$$

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(10.0\text{ m})(-0.060\text{ m})}{(10.0\text{ m} - (-0.060\text{ m}))}$$

$$= -0.060\text{ m}$$

or 6.0 cm behind the mirror.

12. A converging lens has a focal length of 25.5 cm. If it is placed 72.5 cm from an object, what distance from the lens will the image be?

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ so}$$

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(72.5\text{ cm})(25.5\text{ cm})}{(72.5\text{ cm} - 25.5\text{ cm})}$$

$$= 39.3\text{ cm}$$

13. If an object is 10.0 cm from a converging lens that has a focal length of 5.00 cm, how far from the lens will the image be?

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ so}$$

$$d_i = \frac{d_o f}{(d_o - f)} = \frac{(10.0\text{ cm})(5.00\text{ cm})}{(10.0\text{ cm} - 5.00\text{ cm})}$$

$$= 10\text{ cm}$$

14. The focal length of a lens in a box camera is 10.0 cm. The fixed distance between the lens and the film is 11.0 cm. If an object is clearly focused on the film, how far must the object be from the lens?

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ so}$$

$$d_o = \frac{df}{(d_i - f)} = \frac{(11.0\text{ cm})(10.0\text{ cm})}{(11.0\text{ cm} - 10.0\text{ cm})}$$

$$= 1.1 \times 10^2\text{ cm}$$

15. An object 3.0 cm tall is placed 22 cm in front of a converging lens. A real image is formed 11 cm from the lens. What is the size of the image?

$$m = \frac{h_i}{h_o} = \frac{-d_i}{d_o} = \frac{-(11\text{ cm})}{(22\text{ cm})} = -0.50, \text{ so}$$

$$h_i = mh_o = (-0.50)(3.0\text{ cm})$$

$$= -1.5\text{ cm; inverted}$$

The negative sign indicates an inverted image.

16. An object 3.0 cm tall is placed 20 cm in front of a converging lens. A real image is formed 10 cm from the lens. What is the focal length of the lens?

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{(10\text{ cm})} + \frac{1}{(20\text{ cm})} = \frac{3}{(20\text{ cm})},$$

$$\text{so } f = \frac{20\text{ cm}}{3} = 6.7\text{ cm}$$

Supplemental Problems

17. What is the focal length of the lens in your eye when you read a book that is 35.0 cm from your eye? The distance from the lens to the retina is 0.19 mm.

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}, \text{ so}$$

$$f = (d_i d_o)/(d_i + d_o) = = \frac{(0.19\text{ mm})(350\text{ mm})}{(0.19\text{ mm} + 350\text{ mm})}$$

$$= 0.19\text{ mm}$$

18. When an object 5.0 cm tall is placed 12 cm from a converging lens, an image is formed on the same side of the lens as the object but the image is 61 cm away from the lens.

a. What is the focal length of the lens?

$$f = \frac{d_i d_o}{d_i + d_o} = \frac{(-61\text{ cm})(12\text{ cm})}{-61\text{ cm} + 12\text{ cm}}$$

$$= 14.9\text{ cm}$$

b. What is the size of the image?

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

$$h_i = h_o\left[\frac{-d_i}{d_o}\right] = 5.0\text{ cm}\left[-\frac{-61}{12}\right] = 25.4\text{ cm};$$

image is erect.