PHYS143
Physics for Engineers
Tutorial - Chapter 36 – Solutions

Question 1

An object is placed 50.0 cm from a concave spherical mirror with focal length of magnitude 20.0 cm. (a) Find the location of the image. (b) What is the magnification of the image? (c) Is the image real or virtual? (d) Is the image upright or inverted?

(a) A concave mirror is a converging mirror, so the focal length $f = +20.0$ cm. Then, $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$ gives

$$\frac{1}{50.0\text{ cm}}+\frac{1}{q}=\frac{1}{20.0\text{ cm}} \quad \rightarrow \quad q=+33.3\text{ cm}$$

Since $q > 0$, the image is located $\boxed{\text{33.3 cm in front of the mirror}}$.

(b) $M=-\frac{q}{p}=-\frac{(33.3\text{ cm})}{50.0\text{ cm}}=\boxed{-0.666}$

(c) The image distance is positive, so the image is $\boxed{\text{real}}$.

(d) The magnification is negative, so the image is $\boxed{\text{inverted}}$.

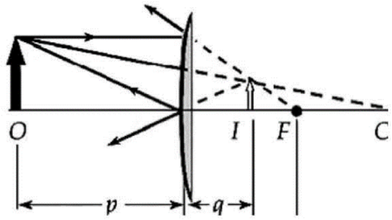
Question 2

A convex spherical mirror has a radius of curvature of magnitude 40.0 cm. Determine the position of the virtual image and the magnification for object distances of (a) 30.0 cm and (b) 60.0 cm. (c) Are the images in parts (a) and (b) upright or inverted?

The convex mirror is described by

$$f=\frac{R}{2}=\frac{-40.0\text{ cm}}{2}=-20.0\text{ cm}$$

ANS. FIG. shows the ray diagram for this situation.



ANS. FIG.

(a) Then $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$ gives

$$q=\frac{1}{1/f-1/p}=\frac{1}{1/(-20.0\text{ cm})-1/(30.0\text{ cm})}=\boxed{-12.0\text{ cm}}$$

The magnification factor is

$$M=-\frac{q}{p}=-\left(\frac{-12.0\text{ cm}}{30.0\text{ cm}}\right)=\boxed{+0.400}$$

The image is behind the mirror, upright, virtual, and diminished.

(b) Following the same steps,

$$q=\frac{1}{1/f-1/p}=\frac{1}{1/(-20.0\text{ cm})-1/(60.0\text{ cm})}=\boxed{-15.0\text{ cm}}$$

and $M=\frac{-q}{p}=-\left(\frac{-15.0\text{ cm}}{60.0\text{ cm}}\right)=\boxed{+0.250}$.

(c) Since $M>0$, the images are $\boxed{\text{both upright}}$.

Question 3

(a) A concave spherical mirror forms an inverted image 4.00 times larger than the object. Assuming the distance between object and image is 0.600 m, find the focal length of the mirror. (b) What If? Suppose the mirror is convex. The distance between the image and the object is the same as in part (a), but the image is 0.500 the size of the object. Determine the focal length of the mirror.

(a) The image is inverted and 4.00 times larger, so the magnification is

$$M=-4.00=-\frac{q}{p}\quad\rightarrow\quad q=4.00p$$

Thus the image is farther from the mirror than the object.

The object and images distances are related by

$$q-p=0.600\text{ m}=4.00p-p=3.00p\quad\rightarrow\quad p=0.200\text{ m},$$

and $q=0.800$ m.

By the mirror equation,

$$\frac{1}{f}=\frac{1}{p}+\frac{1}{q}=\frac{1}{0.200\text{ m}}+\frac{1}{0.800\text{ m}}\quad\rightarrow\quad f=\boxed{0.160\text{ m}}$$

(b) A convex (diverging) mirror forms an upright, virtual image, so the magnification is

$$M=+0.500=-\frac{q}{p}\quad\rightarrow\quad q=-0.500p$$

The image is virtual, so it is behind the mirror, and the image distance is negative. The object and images distances are related by

$$|q| + p = 0.600\text{ m} = -q + p = -(-0.500p) + p = 1.50p$$

$$p = 0.400\text{ m} \quad \rightarrow \quad q = -0.200\text{ m}$$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} = \frac{1}{0.400\text{ m}} + \frac{1}{-0.200\text{ m}} \quad \rightarrow \quad f = \boxed{-0.400\text{ m}}$$

Question 4

An object located 32.0 cm in front of a lens forms an image on a screen 8.00 cm behind the lens. (a) Find the focal length of the lens. (b) Determine the magnification. (c) Is the lens converging or diverging?

(a) From the mirror-and-lens equation,

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}: \qquad \frac{1}{32.0\text{ cm}} + \frac{1}{8.00\text{ cm}} = \frac{1}{f}$$

so $\boxed{f = 6.40\text{ cm}}$.

(b) $M = -\frac{q}{p} = -\frac{8.00\text{ cm}}{32.0\text{ cm}} = \boxed{-0.250}$

(c) Since $f > 0$, the lens is $\boxed{\text{converging}}$.

Question 5

An object is located 20.0 cm to the left of a diverging lens having a focal length $f = -32.0$ cm. Determine (a) the location and (b) the magnification of the image. (c) real or virtual and (d) upright or inverted.

(a) From the mirror-and-lens equation, $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$:

$$\frac{1}{20.0\text{ cm}} + \frac{1}{q} = \frac{1}{(-32.0\text{ cm})}$$

$$\rightarrow \quad q = -\left(\frac{1}{20.0} + \frac{1}{32.0}\right)^{-1} = -12.3\text{ cm}$$

The image forms $\boxed{\text{12.3 cm in front of the lens}}$.

(b) $M = -\frac{q}{p} = -\frac{(-12.3\text{ cm})}{20.0\text{ cm}} = \boxed{0.615}$

(c) The object distance is negative, so the image is $\boxed{\text{virtual}}$.

(d) The magnification is positive, so the image is $\boxed{\text{upright}}$.

Question 6

A 1.00-cm-high object is placed 4.00 cm to the left of a converging lens of focal length 8.00 cm. A diverging lens of focal length -16.00 cm is 6.00 cm to the right of the converging lens. Find the position and height of the final image. Is the image inverted or upright? Real or virtual?

From the thin lens equation, $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$, we obtain

$$q_1=\frac{p_1 f_1}{p_1-f_1}=\frac{(4.00\text{ cm})(8.00\text{ cm})}{4.00\text{ cm}-8.00\text{ cm}}=-8.00\text{ cm}$$

The magnification by the first lens is

$$M_1=-\frac{q_1}{p_1}=-\frac{(-8.00\text{ cm})}{4.00\text{ cm}}=+2.00$$

The virtual image formed by the first lens is the object for the second lens, so

$$p_2=6.00\text{ cm}+|q_1|=6.00\text{ cm}+8.00\text{ cm}=+14.00\text{ cm}$$

and the thin lens equation gives

$$q_2=\frac{p_2 f_2}{p_2-f_2}=\frac{(14.0\text{ cm})(-16.0\text{ cm})}{14.0\text{ cm}-(-16.0\text{ cm})}=-7.47\text{ cm}$$

The magnification by the second lens is

$$M_2=-\frac{q_2}{p_2}=-\frac{(-7.47\text{ cm})}{14.0\text{ cm}}=+0.533$$

so the overall magnification is

$$M=M_1M_2=(+2.00)(+0.533)=+1.07$$

The position of the final image is $\boxed{\text{7.47 cm in front of the second lens}}$, and its height is

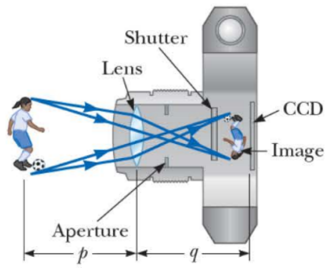
$$h'=Mh=M_1M_2=(+1.07)(1.00\text{ cm})=\boxed{1.07\text{ cm}}$$

Since $M>0$, the final image is $\boxed{\text{upright}}$, and since $q_2<0$, this image is $\boxed{\text{virtual}}$.

Question 7

Figure diagrams a cross section of a camera. It has a single lens of focal length 65.0 mm, which is to form an image on the CCD at the back of the camera.

a) What should be the distance between the lens and the CCD to form a sharp image of a distant object?
b) Assume that the distant object is brought closer to the camera, such that the distance between the object and the camera is now 2.00 m. How far and in what direction must the lens be moved to form a sharp image of the object?



a) For a distant object, $p = \infty$, therefore,

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{65} - \frac{1}{\infty} = \frac{1}{65} - 0 = \frac{1}{65}$$

$$q = 65\ mm$$

Thus, the distance between the lens and the CCD should be 65 mm.

b) Now, $p = 2.00$ m, therefore,

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{65} - \frac{1}{2000}$$

$$q = 67.18\ mm$$

Thus, the distance between the lens and the CCD should be 67.18 mm to form the image on the CCD. Since the current distance (from part a) between the lens and the CCD is 65 mm, this means that we need to move the lens to the left (away from the CCD) by 67.18 – 65 = 2.18 mm.

Question 8

A nearsighted person cannot see objects clearly beyond 25.0 cm (her far point). If she has no astigmatism and contact lenses are prescribed for her, what (a) power and (b) type of lens are required to correct her vision?

The lens should take parallel light rays from a very distant object ($p = \infty$) and make them diverge from a virtual image at the woman's far point, which is 25.0 cm beyond the lens, at $q = -25.0$ cm.

(a) $P = \frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{\infty} - \frac{1}{0.250\text{ m}} = \boxed{-4.00\text{ diopters}}$

(b) The power is negative: a $\boxed{\text{diverging lens}}$.

Question 9

A lens that has a focal length of 5.00 cm is used as a magnifying glass. (a) To obtain maximum magnification and an image that can be seen clearly by a normal eye, where should the object be placed? (b) What is the magnification?

(a) Angular magnification is a maximum when the image is at the near point of the eye: $q = 25.0$ cm. From the thin lens equation:

$$\frac{1}{p} + \frac{1}{(-25.0\text{ cm})} = \frac{1}{5.00\text{ cm}} \quad \text{or} \quad p = \boxed{4.17\text{ cm}}$$

(b) From

$$M = -\frac{q}{p} = 1 + \frac{25.0\text{ cm}}{f} = 1 + \frac{25.0\text{ cm}}{5.00\text{ cm}} = \boxed{6.00}$$

Question 10

The distance between the eyepiece and the objective lens in a certain compound microscope is 23.0 cm. The focal length of the eyepiece is 2.50 cm and that of the objective is 0.400 cm. What is the overall magnification of the microscope?

Using

$$M \approx -\left(\frac{L}{f_o}\right)\left(\frac{25.0\text{ cm}}{f_e}\right) = -\left(\frac{23.0\text{ cm}}{0.400\text{ cm}}\right)\left(\frac{25.0\text{ cm}}{2.50\text{ cm}}\right) = \boxed{-575}$$

Question 11

The refracting telescope at the Yerkes Observatory has a 1.00-m diameter objective lens of focal length 20.0 m. Assume it is used with an eyepiece of focal length 2.50 cm. (a) Determine the magnification of Mars as seen through this telescope. (b) Are the Martian polar caps right side up or upside down?

$f_o = 20.0$ m, $f_e = 0.025\,0$ m

(a) The angular magnification produced by this telescope is

$$m = -\frac{f_o}{f_e} = \boxed{-800}$$

(b) Since $m < 0$, the image is $\boxed{\text{inverted}}$.