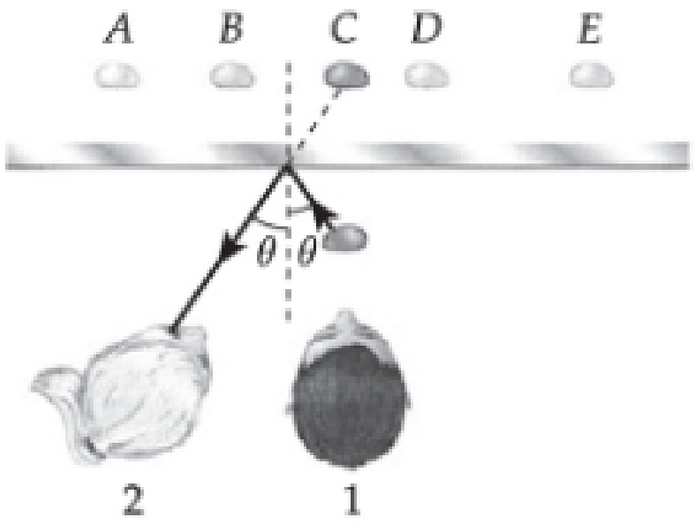
23

Mirrors and Lenses

QUICK QUIZZES

1. At C.



2. (c). Since $n_{water} > n_{air}$, the virtual image of the fish formed by refraction at the flat water surface is closer to the surface than is the fish. See Equation (23.9).

3. **(a)** False. A concave mirror forms an inverted image when the object distance is greater than the focal length.

(b) False. The magnitude of the magnification produced by a concave mirror is greater than 1 if the object distance is less than the radius of curvature.

(c) True.

4. (b). In this case, the index of refraction of the lens material is less than that of the surrounding medium. Under these conditions, a biconvex lens will be divergent.

5. Although a ray diagram only uses 2 or 3 rays (those whose direction is easily determined using only a straight edge), an infinite number of rays leaving the object will always pass through the lens.

6. **(a)** False. A virtual image is formed on the left side of the lens if $p < f$.

(b) True. An upright, virtual image is formed when $p < f$, while an inverted, real image is formed when $p > f$.

(c) False. A magnified, real image is formed if $2f > p > f$, and a magnified, virtual image is formed if $p < f$.

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. The image of a real object formed by a flat mirror is always an upright, virtual image, that is the same size as the object and located as far behind the mirror as the object is in front of the mirror. Thus, statements (b), (c), and (e) are all true, while statements (a) and (d) are false.

2. From the mirror equation, $1/p + 1/q = 2/R = 1/f$, with $f > 0$ since the mirror is concave, the image distance is found to be

$$q = \frac{pf}{p - f} = \frac{(16.0\text{ cm})(6.00\text{ cm})}{16.0\text{ cm} - 6.00\text{ cm}} = +9.60\text{ cm}$$

Since $q > 0$, the image is located 9.60 cm in front of the mirror, and choice (a) is the correct answer.

3. From the mirror equation, $1/p + 1/q = 2/R = 1/f$, with $f < 0$ since the mirror is convex, the image distance is found to be

$$q = \frac{pf}{p - f} = \frac{(16.0\text{ cm})(-6.00\text{ cm})}{16.0\text{ cm} - (-6.00\text{ cm})} = -4.36\text{ cm}$$

Since $q < 0$, the image is virtual and located 4.36 cm behind the mirror. Choice (d) is the correct answer.

4. For a converging lens, the focal length is positive, or $f > 0$. Since the object is virtual, we know that the object distance is negative, or $p < 0$ and $p = -|p|$. Thus, the thin lens equation gives the image distance as

$$q = \frac{pf}{p - f} = \frac{-|p|f}{-|p| - f} = +\left(\frac{|p|}{|p| + f}\right)f$$

Since $|p|$ and f are positive quantities, we see that $q > 0$ and the image is real. Also, since $|p|/(|p| + f) < 1$, we see that $q < f$. Thus, we have shown that choices (a) and (d) are false statements, while choices (b), (c), and (e) are all true.

5. For a convergent lens, $f > 0$, and because the image is real, $q > 0$. The thin lens equation, $1/p + 1/q = 1/f$, then gives

$$p = \frac{qf}{q - f} = \frac{(12.0\text{ cm})(8.00\text{ cm})}{12.0\text{ cm} - (8.00\text{ cm})} = +24.0\text{ cm}$$

Since $p > 0$, the object is in front (in this case, to the left) of the lens, and the correct choice is (c).

6. For a divergent lens, $f < 0$, and because the object is real, $p > 0$. The thin lens equation, $1/p + 1/q = 1/f$, then gives

$$q = \frac{pf}{p - f} = \frac{(10.0\text{ cm})(-16.0\text{ cm})}{10.0\text{ cm} - (-16.0\text{ cm})} = -6.15\text{ cm}$$

Since $q < 0$, the image is in front (in this case, to the left) of the lens, and the correct choice is (b).

7. A concave mirror forms inverted, real images of real objects located outside the focal point ($p > f$), and upright, magnified, virtual images of real objects located inside the focal point ($p < f$) of the mirror. Virtual images, located behind the mirror, have negative image distances by the sign convention of Table 23.1. Choices (d) and (e) are true statements and all other choices are false.

8. With a real object in front of a convex mirror, the image is always upright, virtual, diminished in size, and located between the mirror and the focal point. Thus, of the available choices, only choice (d) is a true statement.

9. A convergent lens forms inverted, real images of real objects located outside the focal point ($p > f$). When $p > 2f$, the real image is diminished in size, and the image is enlarged if $2f > p > f$. For real objects located inside the focal point ($p < f$) of the convergent lens, the image is upright, virtual, and enlarged. In the given case, $p > 2f$, so the image is real, inverted, and diminished in size. Choice (c) is the correct answer.

10. For a real object ($p > 0$) and a diverging lens ($f < 0$), the image distance given by the thin lens equation is

$$q = \frac{pf}{p-f} = \frac{|p|(-|f|)}{|p|-(-|f|)} = -\frac{|p||f|}{|p|+|f|} < 0$$

and the magnification is

$$M = -\frac{q}{p} = -\frac{-|q|}{|p|} > 0$$

Thus, the image is always virtual and upright, meaning that choice (b) is a true statement while all other choices are false.

ANSWERS TO EVEN NUMBERED CONCEPTUAL QUESTIONS

2. Chromatic aberration is produced when light passes *through* a material, as it does when passing through the glass of a lens. A mirror, silvered on its front surface never has light passing through it, so this aberration cannot occur. This is only one of many reasons why large telescopes use mirrors rather than lenses for their primary optical elements.

4. All objects beneath the stream appear to be closer to the surface than they really are because of refraction. Thus, the pebbles on the bottom of the stream appear to be close to the surface of a shallow stream.

6. An effect similar to a mirage is produced except the "mirage" is seen hovering in the air. Ghost lighthouses in the sky have been seen over bodies of water by this effect.

8. Actually no physics is involved here. The design is chosen so your eyelashes will not brush against the glass as you blink. A reason involving a little physics is that with this design, when you direct your gaze near the outer circumference of the lens you receive a ray that has passed through glass with more nearly parallel surfaces of entry and exit. Then the lens minimally distorts the direction to the object you are looking at.

10. Both words are inverted. However, OXIDE looks the same right side up and upside down. LEAD does not.