Chapter 34

4. When S is barely able to see B, the light rays from B must reflect to S off the edge of the mirror. The angle of reflection in this case is 45°, since a line drawn from S to the mirror's edge makes a 45° angle relative to the wall. By the law of reflection, we find

$$\frac{x}{d/2} = \tan 45° = 1 \quad \Rightarrow \quad x = \frac{d}{2} = \frac{3.0\,\text{m}}{2} = 1.5\,\text{m}.$$

6. We note from Fig. 34-34 that $m = \frac{1}{2}$ when p = 5 cm. Thus Eq. 34-7 (the magnification equation) gives us i = –10 cm in that case. Then, by Eq. 34-9 (which applies to mirrors and thin lenses) we find the focal length of the mirror is f = 10 cm. Next, the problem asks us to consider p = 14 cm. With the focal length value already determined, then Eq. 34-9 yields i = 35 cm for this new value of object distance. Then, using Eq. 34-7 again, we find $m = i/p = -2.5$.

20. (a) From Eq. 34-7, we get $i = -mp$ = +28 cm, which implies the image is real (R) and on the same side as the object. Since $m < 0$, we know it was inverted (I). From Eq. 34-9, we obtain $f = ip/(i + p)$ = +16 cm, which tells us (among other things) that the mirror is concave.

(b) $f = ip/(i + p)$ = +16 cm.

(c) $r = 2f$ = +32 cm.

(d) p = +40 cm, as given in the table.

(e) $i = -mp$ = +28 cm.

(f) m = –0.70, as given in the table.

(g) The image is real (R).

(h) The image is inverted (I).

(i) A real image is formed on the <u>same</u> side as the object.

43. We solve Eq. 34-9 for the image distance:

$$i = \left(\frac{1}{f} - \frac{1}{p}\right)^{-1} = \frac{fp}{p-f}.$$

The height of the image is thus

$$h_i = mh_p = \left(\frac{i}{p}\right)h_p = \frac{fh_p}{p-f} = \frac{(75\text{ mm})(1.80\text{ m})}{27\text{ m} - 0.075\text{ m}} = 5.0\text{ mm}.$$

46. Since the focal length is a constant for the whole graph, then $1/p + 1/i$ = constant. Consider the value of the graph at p = 20 cm; we estimate its value there to be –10 cm. Therefore, $1/20 + 1/(-10) = 1/70 + 1/i_{\text{new}}$. Thus, $i_{\text{new}} = -16$ cm.

68. (a) A convex (converging) lens, since a real image is formed.

(b) Since $i = d - p$ and $i/p = 1/2$,

$$p = \frac{2d}{3} = \frac{2(40.0\text{ cm})}{3} = 26.7\text{ cm}.$$

(c) The focal length is

$$f = \left(\frac{1}{i} + \frac{1}{p}\right)^{-1} = \left(\frac{1}{d/3} + \frac{1}{2d/3}\right)^{-1} = \frac{2d}{9} = \frac{2(40.0\text{ cm})}{9} = 8.89\text{ cm}.$$

91. (a) When the eye is relaxed, its lens focuses faraway objects on the retina, a distance i behind the lens. We set $p = \infty$ in the thin lens equation to obtain $1/i = 1/f$, where f is the focal length of the relaxed effective lens. Thus, $i = f = 2.50$ cm. When the eye focuses on closer objects, the image distance i remains the same but the object distance and focal length change. If p is the new object distance and f' is the new focal length, then

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f'}.$$

We substitute $i = f$ and solve for f':

$$f' = \frac{pf}{f+p} = \frac{(40.0\text{ cm})(2.50\text{ cm})}{40.0\text{ cm} + 2.50\text{ cm}} = 2.35\text{ cm}.$$

(b) Consider the lens maker's equation

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

where r_1 and r_2 are the radii of curvature of the two surfaces of the lens and n is the index of refraction of the lens material. For the lens pictured in Fig. 34-46, r_1 and r_2 have about the same magnitude, r_1 is positive, and r_2 is negative. Since the focal length decreases, the combination $(1/r_1) - (1/r_2)$ must increase. This can be accomplished by decreasing the magnitudes of both radii.

94. By Eq. 34-9, $1/i + 1/p$ is equal to constant $(1/f)$. Thus,

$$1/(-10) + 1/(15) = 1/i_{\text{new}} + 1/(70).$$

This leads to $i_{\text{new}} = -21$ cm.

112. The water is medium 1, so $n_1 = n_w$, which we simply write as n. The air is medium 2, for which $n_2 \approx 1$. We refer to points where the light rays strike the water surface as A (on the left side of Fig. 34-56) and B (on the right side of the picture). The point midway between A and B (the center point in the picture) is C. The penny P is directly below C, and the location of the "apparent" or virtual penny is V. We note that the angle $\angle CVB$ (the same as $\angle CVA$) is equal to θ_2, and the angle $\angle CPB$ (the same as $\angle CPA$) is equal to θ_1. The triangles CVB and CPB share a common side, the horizontal distance from C to B (which we refer to as x). Therefore,

$$\tan\theta_2 = \frac{x}{d_{\text{a}}} \qquad \text{and} \qquad \tan\theta_1 = \frac{x}{d}.$$

Using the small angle approximation (so a ratio of tangents is nearly equal to a ratio of sines) and the law of refraction, we obtain

$$\frac{\tan\theta_2}{\tan\theta_1} \approx \frac{\sin\theta_2}{\sin\theta_1} \quad \Rightarrow \quad \frac{\frac{x}{d_a}}{\frac{x}{d}} \approx \frac{n_1}{n_2} \quad \Rightarrow \quad \frac{d}{d_{\text{a}}} \approx n$$

which yields the desired relation: $d_{\text{a}} = d/n$.