P36.2 The virtual image is as far behind the mirror as the choir is in front of the mirror. Thus, the image is 5.30 m behind the mirror. The image of the choir is $0.800\text{ m} + 5.30\text{ m} = 6.10\text{ m}$ from the organist. Using similar triangles:

$$\frac{h'}{0.600\text{ m}} = \frac{6.10\text{ m}}{0.800\text{ m}}$$

or $$h' = (0.600\text{ m})\left(\frac{6.10\text{ m}}{0.800\text{ m}}\right) = \boxed{4.58\text{ m}}.$$

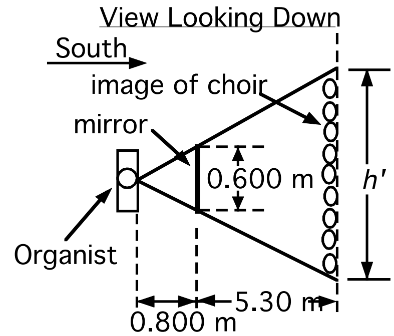


FIG. P36.2

P36.12 For a concave mirror, R and f are positive. Also, for an erect image, M is positive. Therefore, $M = -\frac{q}{p} = 4$ and $q = -4p$.

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} \text{ becomes } \frac{1}{40.0\text{ cm}} = \frac{1}{p} - \frac{1}{4p} = \frac{3}{4p}\text{; from which, } p = \boxed{30.0\text{ cm}}.$$

P36.18 Assume that the object distance is the same in both cases (i.e., her face is the same distance from the hubcap regardless of which way it is turned). Also realize that the near image ($q = -10.0\text{ cm}$) occurs when using the convex side of the hubcap. Applying the mirror equation to both cases gives:

(concave side: $R = |R|$, $q = -30.0\text{ cm}$)

$$\frac{1}{p} - \frac{1}{30.0} = \frac{2}{|R|}$$

or

$$\frac{2}{|R|} = \frac{30.0\text{ cm} - p}{(30.0\text{ cm})p} \qquad (1)$$

(convex side: $R = -|R|$, $q = -10.0\text{ cm}$)

$$\frac{1}{p} - \frac{1}{10.0} = -\frac{2}{|R|}$$

or

$$\frac{2}{|R|} = \frac{p - 10.0\text{ cm}}{(10.0\text{ cm})p}. \qquad (2)$$

(a) Equating Equations (1) and (2) gives:

$$\frac{30.0\text{ cm} - p}{3.00} = p - 10.0\text{ cm}$$

or $$p = 15.0\text{ cm}.$$

Thus, her face is $\boxed{15.0\text{ cm}}$ from the hubcap.

(b) Using the above result ($p = 15.0\text{ cm}$) in Equation (1) gives:

$$\frac{2}{|R|} = \frac{30.0\text{ cm} - 15.0\text{ cm}}{(30.0\text{ cm})(15.0\text{ cm})}$$

or $$\frac{2}{|R|} = \frac{1}{30.0\text{ cm}}$$

and $$|R| = 60.0\text{ cm}.$$

The radius of the hubcap is $\boxed{60.0\text{ cm}}$.

P36.27 For a plane surface, $\frac{n_1}{p}+\frac{n_2}{q}=\frac{n_2-n_1}{R}$ becomes $q=-\frac{n_2 p}{n_1}$.

Thus, the magnitudes of the rate of change in the image and object positions are related by

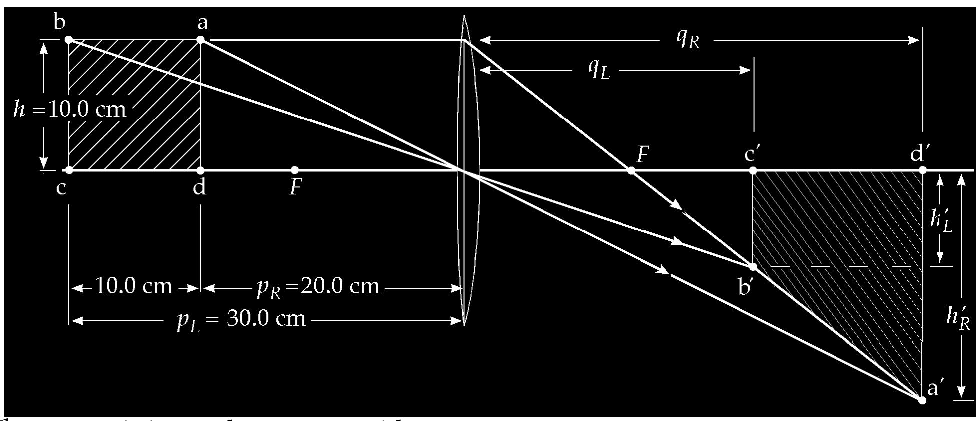
$$\left|\frac{dq}{dt}\right|=\frac{n_2}{n_1}\left|\frac{dp}{dt}\right|.$$

If the fish swims toward the wall with a speed of 2.00 cm/s, the speed of the image is given by

$$v_{\text{image}}=\left|\frac{dq}{dt}\right|=\frac{1.00}{1.33}(2.00\ \text{cm/s})=\boxed{1.50\ \text{cm/s}}.$$

P36.40 (a) $\frac{1}{f}=(n-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]=(1.50-1)\left[\frac{1}{15.0\ \text{cm}}-\frac{1}{(-12.0\ \text{cm})}\right]$ or $\boxed{f=13.3\ \text{cm}}$

(b)



The square is imaged as a trapezoid.

FIG. P36.40(b)

(c) To find the area, first find q_R and q_L, along with the heights h'_R and h'_L, using the thin lens equation.

$\frac{1}{p_R}+\frac{1}{q_R}=\frac{1}{f}$ becomes $\frac{1}{20.0\ \text{cm}}+\frac{1}{q_R}=\frac{1}{13.3\ \text{cm}}$ or $q_R=40.0\ \text{cm}$

$$h'_R=hM_R=h\left(\frac{-q_R}{p_R}\right)=(10.0\ \text{cm})(-2.00)=-20.0\ \text{cm}$$

$\frac{1}{30.0\ \text{cm}}+\frac{1}{q_L}=\frac{1}{13.3\ \text{cm}}$ or $q_L=24.0\ \text{cm}$

$$h'_L=hM_L=(10.0\ \text{cm})(-0.800)=-8.00\ \text{cm}$$

Thus, the area of the image is: $\text{Area}=|q_R-q_L||h'_L|+\frac{1}{2}|q_R-q_L||h'_R-h'_L|=\boxed{224\ \text{cm}^2}$.

P36.34 (a) $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$: $\frac{1}{p}+\frac{1}{-30.0\ \text{cm}}=\frac{1}{12.5\ \text{cm}}$

$p=8.82\ \text{cm}$ $M=-\frac{q}{p}=-\frac{(-30.0)}{8.82}=\boxed{3.40,\ \text{upright}}$

(b) See the figure to the right.

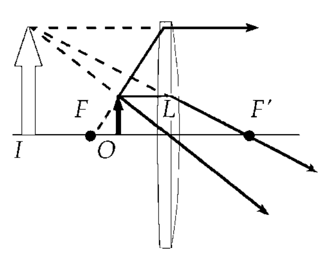


FIG. P36.34(b)

P36.48 For starlight going through Nick's glasses,

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$$

$$\frac{1}{\infty}+\frac{1}{(-0.800\text{ m})}=\frac{1}{f}=-1.25\text{ diopters}.$$

For a nearby object, $\dfrac{1}{p}+\dfrac{1}{(-0.180\text{ m})}=-1.25\text{ m}^{-1}$, so

$p=\boxed{23.2\text{ cm}}$.

P36.51 Using Equation 36.24, $M\approx-\left(\dfrac{L}{f_o}\right)\left(\dfrac{25.0\text{ cm}}{f_e}\right)=-\left(\dfrac{23.0\text{ cm}}{0.400\text{ cm}}\right)\left(\dfrac{25.0\text{ cm}}{2.50\text{ cm}}\right)=\boxed{-575}$.

P36.56 Let I_0 represent the intensity of the light from the nebula and θ_0 its angular diameter. With the first telescope, the image diameter h' on the film is given by $\theta_o=-\dfrac{h'}{f_o}$ as $h'=-\theta_o(2\,000\text{ mm})$.

The light power captured by the telescope aperture is , and the light energy

focused on the film during the exposure is .

Likewise, the light power captured by the aperture of the second telescope is

and the light energy is $E_2=I_0\left[\dfrac{\pi(60.0\text{ mm})^2}{4}\right]\Delta t_2$. Therefore, to have the same light energy per unit area, it is necessary that

$$\frac{I_0\left[\pi(60.0\text{ mm})^2/4\right]\Delta t_2}{\pi\left[\theta_o(900\text{ mm})^2/4\right]}=\frac{I_0\left[\pi(200\text{ mm})^2/4\right](1.50\text{ min})}{\pi\left[\theta_o(2\,000\text{ mm})^2/4\right]}.$$

The required exposure time with the second telescope is

$$\Delta t_2=\frac{(200\text{ mm})^2(900\text{ mm})^2}{(60.0\text{ mm})^2(2\,000\text{ mm})^2}(1.50\text{ min})=\boxed{3.38\text{ min}}.$$

P36.75 (a) $P=\dfrac{1}{f}=\dfrac{1}{p}+\dfrac{1}{q}=\dfrac{1}{(0.022\,4\text{ m})}+\dfrac{1}{\infty}=\boxed{44.6\text{ diopters}}$

(b) $P=\dfrac{1}{f}=\dfrac{1}{p}+\dfrac{1}{q}=\dfrac{1}{(0.330\text{ m})}+\dfrac{1}{\infty}=\boxed{3.03\text{ diopters}}$