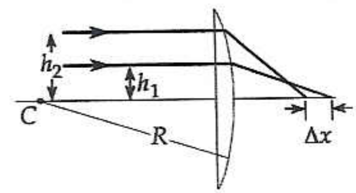
36.43 Ray h_1 is undeviated at the plane surface and strikes the second surface at angle of incidence given by

$$\theta_1 = \sin^{-1}\left(\frac{h_1}{R}\right) = \sin^{-1}\left(\frac{0.500 \text{ cm}}{20.0 \text{ cm}}\right) = 1.43°$$

Then, $(1.00)\sin\theta_2 = (1.60)\sin\theta_1 = (1.60)\left(\frac{0.500}{20.0 \text{ cm}}\right)$ so $\theta_2 = 2.29°$

The angle this emerging ray makes with the horizontal is



$$\theta_2 - \theta_1 = 0.860°$$

It crosses the axis at a point farther out by f_1 where

$$f_1 = \frac{h_1}{\tan(\theta_2 - \theta_1)} = \frac{0.500 \text{ cm}}{\tan(0.860°)} = 33.3 \text{ cm}$$

The point of exit for this ray is distant axially from the lens vertex by

$$20.0 \text{ cm} - \sqrt{(20.0 \text{ cm})^2 - (0.500 \text{ cm})^2} = 0.00625 \text{ cm}$$

so ray h_1 crosses the axis at this distance from the vertex:

$$x_1 = 33.3 \text{ cm} - 0.00625 \text{ cm} = 33.3 \text{ cm}$$

Now we repeat this calculation for ray h_2: $\theta_1 = \sin^{-1}\left(\frac{12.0 \text{ cm}}{20.0 \text{ cm}}\right) = 36.9°$

$$(1.00)\sin\theta_2 = (1.60)\sin\theta_1 = (1.60)\left(\frac{12.00}{20.0}\right) \qquad \theta_2 = 73.7°$$

$$f_2 = \frac{h_2}{\tan(\theta_2 - \theta_1)} = \frac{12.0 \text{ cm}}{\tan(36.8°)} = 16.0 \text{ cm}$$

$$x_2 = (16.0 \text{ cm})\left(20.0 \text{ cm} - \sqrt{(20.0 \text{ cm})^2 - (12.0 \text{ cm})^2}\right) = 12.0 \text{ cm}$$

Now $\Delta x = 33.3 \text{ cm} - 12.0 \text{ cm} = \boxed{21.3 \text{ cm}}$

36.45 $P = \frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{\infty} - \frac{1}{0.250\text{ m}} = -4.00\text{ diopters} = \boxed{-4.00\text{ diopters, a diverging lens}}$

36.46 Consider an object at infinity, imaged at the person's far point:

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \qquad \frac{1}{\infty} + \frac{1}{q} = -4.00\text{ m}^{-1} \qquad q = -25.0\text{ cm}$$

The person's far point is $25.0\text{ cm} + 2.00\text{ cm} = 27.0\text{ cm}$ from his eyes. For the contact lenses we want

$$\frac{1}{\infty} + \frac{1}{(-0.270\text{ m})} = \frac{1}{f} = \boxed{-3.70\text{ diopters}}$$

*36.52 (a) The lensmaker's equation $\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$

gives $q = \frac{1}{1/f - 1/p} = \frac{1}{\left(\frac{p-f}{fp}\right)} = \frac{fp}{p-f}$

Then, $M = \frac{h'}{h} = -\frac{q}{p} = -\frac{f}{p-f}$

gives $\boxed{h' = \frac{hf}{f-p}}$

(b) For $p >> f, \quad f - p \approx -p$. Then, $h' = \boxed{-\frac{hf}{p}}$.

(c) Suppose the telescope observes the space station at the zenith:

$$h' = -\frac{hf}{p} = -\frac{(108.6\text{ m})(4.00\text{ m})}{407 \times 10^3\text{ m}} = \boxed{-1.07\text{ mm}}$$

*36.64 (a) For the light the mirror intercepts, $\mathcal{P} = I_0 A = I_0 \pi R_a^2$

$350\text{ W} = (1000\text{ W/m}^2)\pi R_a^2$ and $R_a = \boxed{0.334\text{ m or larger}}$

(b) In $\frac{1}{p} + \frac{1}{q} = \frac{1}{f} = \frac{2}{R}$ we have $p \to \infty$ so $q = \frac{R}{2}$.

$M = \frac{h'}{h} = -\frac{q}{p}$, so $h' = -q(h/p) = -\left(\frac{R}{2}\right)\left[0.533° \left(\frac{\pi\text{ rad}}{180°}\right)\right] = -\left(\frac{R}{2}\right)(9.30\text{ m rad})$

where h/p is the angle the Sun subtends. The intensity at the image is then

$$I = \frac{\mathcal{P}}{\pi h'^2/4} = \frac{4I_0 \pi R_a^2}{\pi h'^2} = \frac{4I_0 R_a^2}{(R/2)^2 (9.30 \times 10^{-3}\text{ rad})^2}$$

$120 \times 10^3\text{ W/m}^2 = \frac{16(1000\text{ W/m}^2)R_a^2}{R^2 (9.30 \times 10^{-3}\text{ rad})^2}$ so $\boxed{\frac{R_a}{R} = 0.0255\text{ or larger}}$