14. We remark that the sign convention for r (for these refracting surfaces) is the opposite of what was used for mirrors. This point is discussed in §35-5.

(a) We use Eq. 35-8:

$$i = n_2 \left(\frac{n_2 - n_1}{r} - \frac{n_1}{p} \right)^{-1} = 1.5 \left(\frac{1.5 - 1.0}{30\,\text{cm}} - \frac{1.0}{10\,\text{cm}} \right)^{-1} = -18 \text{ cm} .$$

The image is virtual and upright. The ray diagram would be similar to Fig. 35-10(c) in the textbook.

(b) We manipulate Eq. 35-8 to find r:

$$r = (n_2 - n_1) \left(\frac{n_1}{p} + \frac{n_2}{i} \right)^{-1} = (1.5 - 1.0) \left(\frac{1.0}{10} + \frac{1.5}{-13} \right)^{-1} = -32.5 \text{ cm}$$

which should be rounded to two significant figures. The image is virtual and upright. The ray diagram would be similar to Fig. 35-10(e) in the textbook, but with the object and the image placed closer to the surface.

(c) We manipulate Eq. 35-8 to find p:

$$p = \frac{n_1}{\frac{n_2 - n_1}{r} - \frac{n_2}{i}} = \frac{1.0}{\frac{1.5-1.0}{30} - \frac{1.5}{600}} = 71 \text{ cm} .$$

The image is real and inverted. The ray diagram would be similar to Fig. 35-10(a) in the textbook.

(d) We manipulate Eq. 35-8 to separate the indices:

$$\begin{aligned} n_2 \left(\frac{1}{r} - \frac{1}{i} \right) &= \left(\frac{n_1}{p} + \frac{n_1}{r} \right) \\ n_2 \left(\frac{1}{-20} - \frac{1}{-20} \right) &= \left(\frac{1.0}{20} + \frac{1.0}{-20} \right) \\ n_2(0) &= 0 \end{aligned}$$

which is identically satisfied for any choice of n_2. The ray diagram would be similar to Fig. 35-10(d) in the textbook, but with C, O and I together at the same point. The image is virtual and upright.

(e) We manipulate Eq. 35-8 to find r:

$$r = (n_2 - n_1) \left(\frac{n_1}{p} + \frac{n_2}{i} \right)^{-1} = (1.0 - 1.5) \left(\frac{1.5}{10} + \frac{1.0}{-6.0} \right)^{-1} = 30 \text{ cm} .$$

The image is virtual and upright. The ray diagram would be similar to Fig. 35-10(f) in the textbook, but with the object and the image located closer to the surface.

(f) We manipulate Eq. 35-8 to find p:

$$p = \frac{n_1}{\frac{n_2 - n_1}{r} - \frac{n_2}{i}} = \frac{1.5}{\frac{1.0-1.5}{-30} - \frac{1.0}{-7.5}} = 10 \text{ cm} .$$

The image is virtual and upright. The ray diagram would be similar to Fig. 35-10(d) in the textbook.

(g) We manipulate Eq. 35-8 to find the image distance:

$$i = n_2 \left(\frac{n_2 - n_1}{r} - \frac{n_1}{p} \right)^{-1} = 1.0 \left(\frac{1.0 - 1.5}{30\,\text{cm}} - \frac{1.5}{70\,\text{cm}} \right)^{-1} = -26 \text{ cm} .$$

The image is virtual and upright. The ray diagram would be similar to Fig. 35-10(f) in the textbook.