OPTICAL INSTRUMENTS HMWK SOLUTIONS

1) We want the object distance p. From the image and object sizes we can get the ratio of p to q

$$M = -\frac{q}{p} = \frac{h_i}{h_o} = \frac{-2.4 \text{ cm}}{170 \text{ cm}}$$

($h_i = -2.4$ because the image will be inverted)

Then we have

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q} = \frac{1}{p}\left[1 + \frac{p}{q}\right] = \frac{1}{p}\left[1 + \frac{170}{2.4}\right]$$

$$p = f \times \left(1 + \frac{170}{2.4}\right) = (5 \text{ cm})\left(1 + \frac{170}{2.4}\right) = 359 \text{ cm} = \boxed{3.59 \text{ m}}$$

2) So $q = 2.5$ cm and $\frac{1}{f} = \frac{1}{q} + \frac{1}{p}$

$p = 3$ m $\qquad \frac{1}{f} = \frac{1}{2.5 \text{cm}} + \frac{1}{300 \text{ cm}} \qquad \boxed{f = 24.8 \text{ mm}}$

$p = 30$ cm $\qquad \frac{1}{f} = \frac{1}{2.5 \text{cm}} + \frac{1}{30 \text{ cm}} \qquad \boxed{f = 23.1 \text{ mm}}$

3) The object is at 25cm and $f = 50$ cm so the image location is

$$\frac{1}{q} = \frac{1}{f} - \frac{1}{p} = \frac{1}{50} - \frac{1}{25} \quad \Rightarrow \quad \boxed{q = -50 \text{cm}}$$

Presumably the lenses are putting the image at the near point, so the conclusion is

$$\boxed{X_n = 50 \text{ cm}}$$

4) (a) For distant objects p is large ⇒ take $p \to \infty$ ⇒ $\frac{1}{p} = 0$
Then $\frac{1}{f} = \frac{1}{q}$ ⇒ $f = q$. We want to put the image at the person's far point ⇒ we want $q = -125$ cm so

$$\boxed{f = -125 \text{ cm}}$$

(b) What object distance will now give an image at the person's near point. $X_n = 15$ cm so the image will be at $q = -15$ cm

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

$$\frac{1}{p} = \frac{1}{f} - \frac{1}{q} = \frac{1}{-125cm} - \frac{1}{-15cm} = \frac{1}{15} - \frac{1}{125}$$

$P = 17.0$ cm. The person will be unable to focus on objects closer than this, so the new near point is

$$\boxed{X_n = 17.0 \text{ cm}}$$

5) The magnifying power is given by

$$m = X_n \left[\frac{1}{f} + \frac{1}{x} \right]$$

(a) Virtual image at infinity $\Rightarrow X = \infty$

$$m = X_n/f = 25/5 \qquad \Rightarrow \qquad \boxed{m = 5}$$

(b) For $X = X_n$ the answer is

$$m = 25 \left(\frac{1}{5} + \frac{1}{25} \right) \qquad \Rightarrow \qquad \boxed{m = 6}$$

6) (a) $\quad m = X_n/f = 50/5 \qquad \Rightarrow \qquad \boxed{m = 10}$

The magnifying power is greater for the second person.

(b) From the notes, the angular size of the image formed by the magnifying glass is

$$\alpha = h \left[\frac{1}{f} + \frac{1}{x} \right]$$

If both people focus to put the image at ∞ then $\frac{1}{x} = 0$ and $\alpha = h/f$. Since α determines the size on the retina, he will be the **same for both.** The magnifying power is greater for the second person because m is the ratio of the image size with the lens to the image size without the lens. Because the second person can't focus with the object as close, he without the lens will be smaller

7)
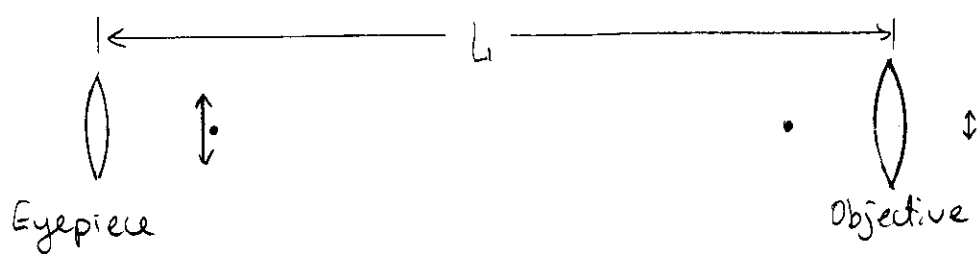
In general the magnifying power is

$$m = -\frac{X_n(L - f_0 - f_e)}{f_0 \cdot f_e}$$

The image forms close to the focal point of the eyepiece, so

$$L \simeq q + f_e$$

and

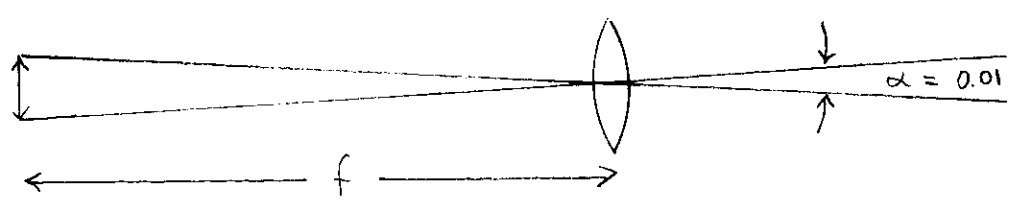$$L - f_0 - f_e = q - f_0 = 16cm - 1cm$$

Then

$$m = -\frac{(25)(15)}{(1)(3)} = \boxed{-125}$$

8)(a) For a telescope

$$m = -\frac{f_0}{f_e} = -\frac{100}{3} \qquad \boxed{m = -33.3}$$

(b)

Because the moon is far away $q \simeq f = 100cm$, and so the image size is

$$h = f \cdot \alpha = (100cm) \cdot (0.01) \Rightarrow \boxed{h = 1 cm}$$

(c) The magnifying power is just the ratio of the angular size of the final image to the angular size of object. So

$$\alpha = (33.3) \cdot (0.01 \, rad) \qquad \boxed{\alpha = 0.333 \, radians}$$