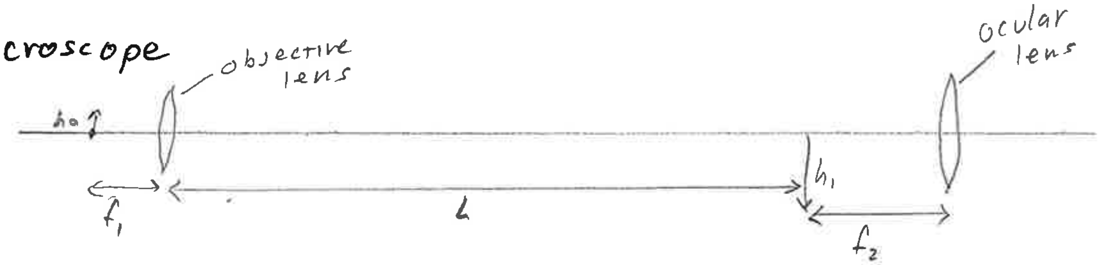
PHYS 1120 Discussion Worksheet 10

Compound Optics

1. Microscope



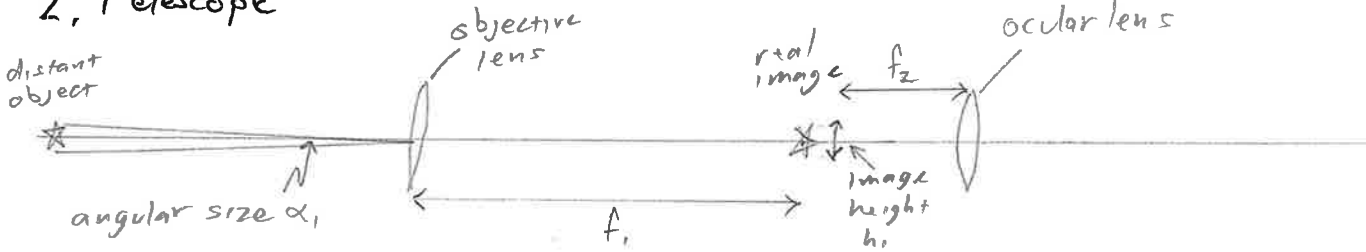
A. $\frac{h_1}{L} = \frac{h_o}{f_1}$ so $h_1 = h_o L / f_1$

B. α_2 = angular size of real image as viewed from ocular lens

$$\alpha_2 = h_1/f_2 = \frac{h_o L}{f_1 f_2}$$

C. Angular magnification $M = \frac{\alpha_2}{\alpha_1} = \frac{h_o L}{f_1 f_2} \Big/ \frac{h_o}{N} = \frac{h_o L N}{f_1 f_2 h_o} = \frac{LN}{f_1 f_2}$

2, Telescope



A. $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$, so $\frac{1}{d_i} = \frac{1}{f_1} - \frac{1}{d_o} = \frac{1}{f_1} - \frac{1}{\infty} = \frac{1}{f_1}$. So $d_o = f_1$, the image is at the focal plane of the objective lens.

B. We know that from the objective lens, the angular size of the image equals the angular size of the object. So $h_1/f_1 = \alpha_1$ solving for h_1 gives $h_1 = f_1 \alpha_1$.

C. $\alpha_2 = \frac{h_1}{f_2} = \frac{f_1 \alpha_1}{f_2}$

D. $M = \alpha_2/\alpha_1 = f_1/f_2$

E. In reverse, $M = \alpha_2/\alpha_1 = f_1/f_2$, the reciprocal of the forward magnification.

3. Correcting myopia

A. An object at the nearpoint ($d_o = N$) gives an image at the retina ($d_i = D$).

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{N} + \frac{1}{D} = \frac{1}{1m} + \frac{1}{0.025m} = \frac{41}{m}$$

so $f = \frac{1}{41} m = 0.02439\ m = 24.39\ mm$.

This is just a little shy of reaching the retina.

B. The image is in front of the eye; it is also in front of the corrective lens. This means it is a virtual image, with a negative image distance. So $d_i = -N$.

C. $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{\infty} + \frac{1}{-N} = -\frac{1}{N}$, so $f = -N = -1$ meter

D. The focal length is negative, so it is a diverging lens

4. Correcting hyperopia

A. Object distance to give image distance of D when $f = D(1+a)$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i},\ \text{so}\ \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{D(1+a)} - \frac{1}{D} = \frac{1}{D(1+a)} - \frac{1+a}{D(1+a)} = \frac{1-1-a}{D(1+a)} = \frac{-a}{D(1+a)}$$

so $d_o = -D\frac{1+a}{a}$

B. This object distance is negative, meaning behind the lens of the eye. Also, because a is small, its absolute value is much greater than D.

C. We want an object at $d_o = \infty$ to produce an image at $D\frac{1+a}{a}$ behind the lens of the eye. This puts the image behind the corrective lens, at a positive image distance, $d_i = +D\frac{1+a}{a}$.

D. $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{\infty} + \frac{a}{D(1+a)} = 0 + \frac{a}{D(1+a)}$, so $f = D\frac{1+a}{a}$.

E. The focal length is positive, so it is a converging lens.

F. To focus on an object at $d_o = N < \infty$, we have

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{N} + \frac{a}{D(1+a)} = \frac{D(1+a) + Na}{ND(1+a)} = \frac{D + Da + Na}{ND(1+a)} =$$

$$f = \frac{ND(1+a)}{D(1+a) + Na} = \frac{D(1+a)}{a + D(1+a)/N}$$

This has the same numerator as the focal length for $d_o = \infty$, but a larger denominator. Thus a shorter focal length.