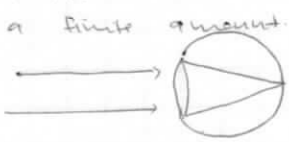
2.710 OPTICS FALL 2004 QUIZ #1

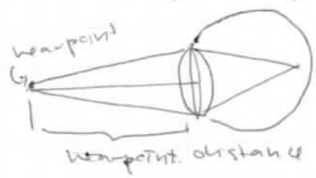
① TRUE or FALSE Questions

a) this question is $\boxed{\text{inappropriately stated}}$ because there are different definitions of a telescope. the most common is an instrument whose purpose is to view very long and remote objects, which inherently requires a magnifying power much greater than one. However, in a more abstract definition (as we saw in class) a telescope is an optical system that receives a plane wave and converts it to another plane wave. [Recall the function of a system that arises when B=0 in the ABCD matrix!]. In this definition, it doesn't matter whether the magnification increases or not.

b) $\boxed{\text{TRUE}}$ In a microscope there are 2 lenses. The first, the objective forms a real magnified intermediate image of the object. The second lens, the eyepiece, forms a magnified virtual image far away from the observer's eye. Therefore, we have a cascade of two lenses, both of which magnify the original object.

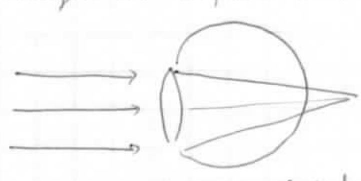
c) $\boxed{\text{FALSE}}$ the human eye can perceive objects with clarity only when they are located within an acceptable range away from the eye. This is because the crystalline lens of the eye can only be flexed a finite amount.



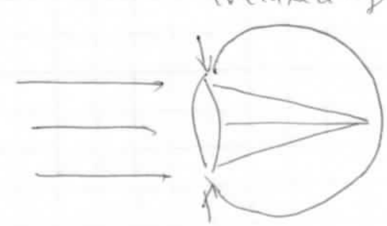


The eye cannot properly focus any object (virtual, or real) that is located closer than the nearpoint.

d) $\boxed{\text{TRUE}}$ Hyperopia = far-sighted. This means that a hyperopic person images an object at infinity at a point behind the retina when the eye is relaxed. However the person can shorten the focal ~~length~~ length of the crystalline lens by contracting the ciliary muscles. therefore, a far-sighted person is generally able to view objects at infinity with some straining.

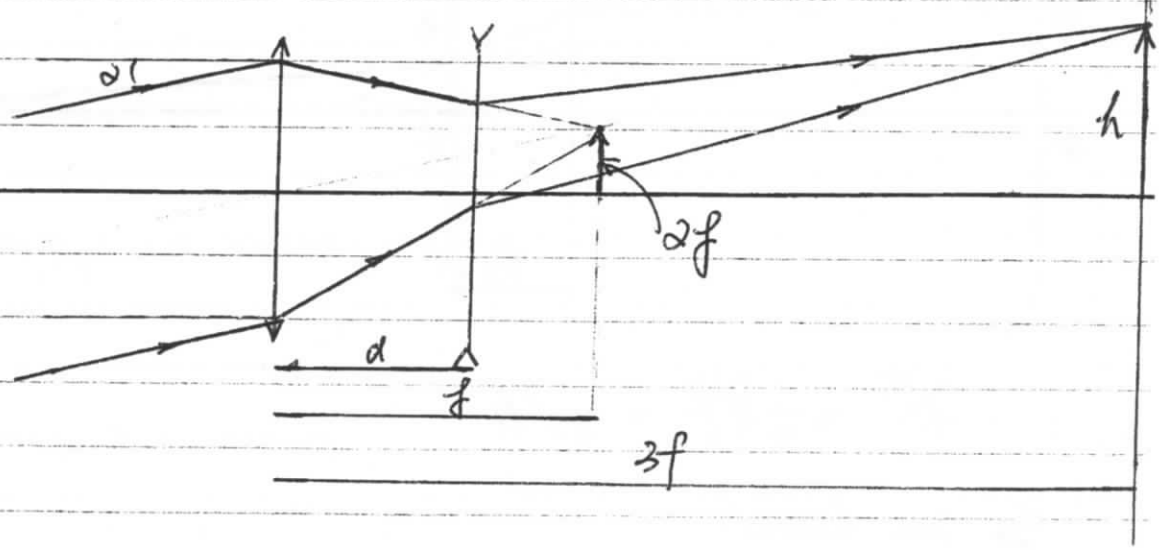


unaccomodated (relaxed eye)



with accomodation (straining)

Problem 2.



a)

From requirements (i), (ii)

$$h = 5\alpha f$$

the magnification is

$$-\frac{S_i}{S_o} = -\frac{3f-d}{d-f} = \frac{h}{\alpha f} \Rightarrow \frac{3f-d}{f-d} = 5$$

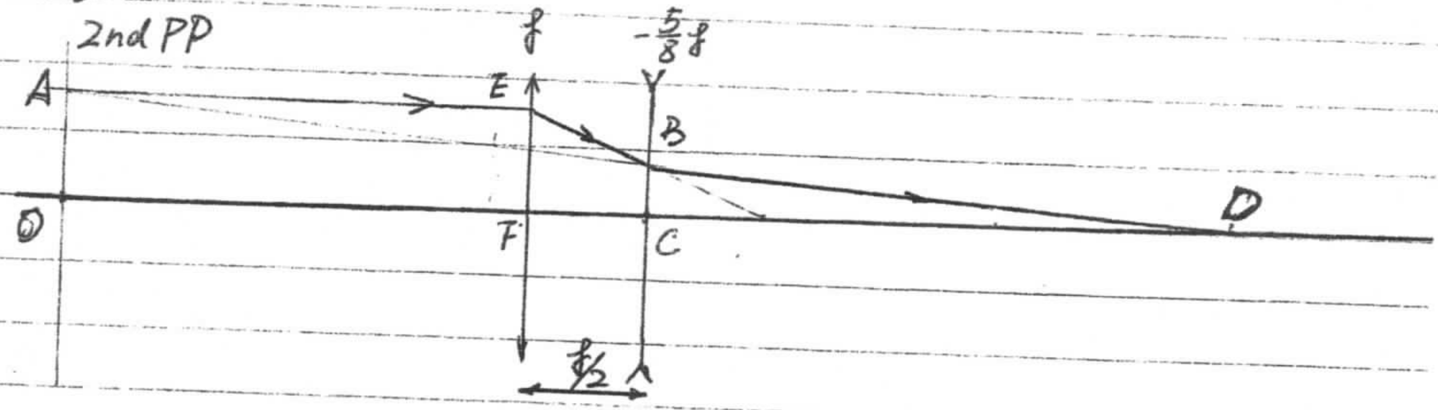
$$\Rightarrow d = \frac{f}{2}$$

So we have the imaging condition as

$$S_o = d - f = -\frac{f}{2} \qquad S_i = 3f - d = \frac{5}{2} f$$

$$\frac{1}{f_o} = \frac{1}{S_o} + \frac{1}{S_i} \Rightarrow f_o = -\frac{5}{8} f$$

b>



$\overline{BC} = \frac{1}{2}\overline{EF} = \frac{1}{2}\overline{AO}$

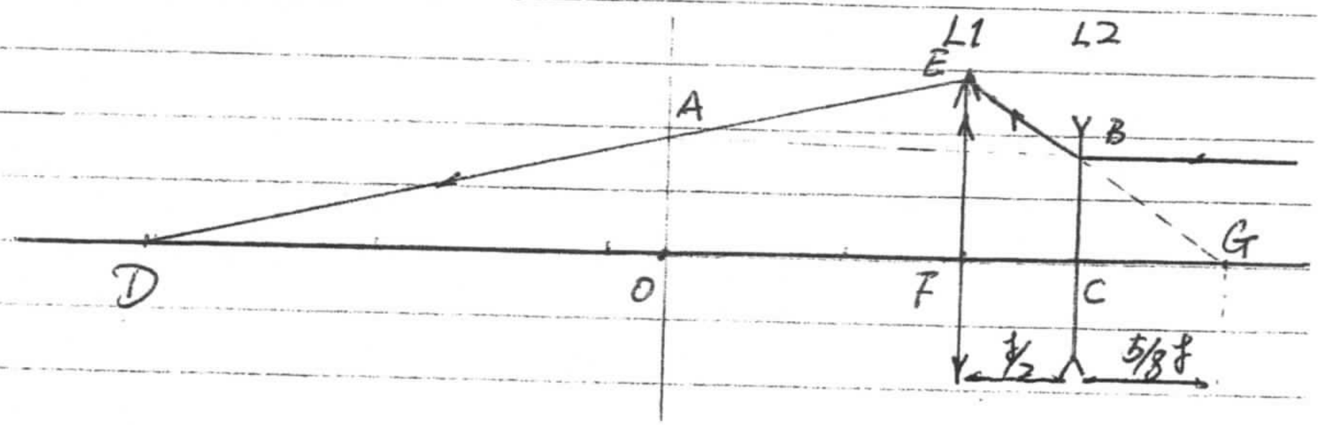
So we have

$\overline{OD} = 2\,\overline{CD} = 2\cdot(3f - \frac{f}{2}) = 5f$

$\overline{OF} = 5f - 3f = 2f.$

2nd PP is located to the left of L1 at distan[ce] 2f.

Now continue with the 1st PP.



The parallel rays from left will have a virtual fo
point at G after passing through Lens L2.

Use lens law, we know that the ~~front~~ focal point (Fi
of this telephoto system is

$$\frac{1}{S_o} + \frac{1}{S_i} = \frac{1}{f}$$

where $S_o = \frac{1}{2}f + \frac{5}{8}f = \frac{9}{8}f$.

$\Rightarrow S_i = 9f$. to the left of Lens L1

$$\frac{\overline{BC}}{\overline{EF}} = \frac{\frac{5}{8}f}{\frac{9}{8}f} = \frac{5}{9} = \frac{\overline{AO}}{\overline{EF}}$$

$$\Rightarrow \frac{\overline{DO}}{\overline{DF}} = \frac{5}{9} \quad \Rightarrow \overline{DO} = 5f$$

$$\Rightarrow \overline{OF} = 4f.$$

1st PP is located to the left of Lens L2
at distance 4f.

c) From part (b), we know

$$EFL = \overline{DO} = 5f.$$

Or even from the problem we can know the EFL without any calculation:

Because the parallel rays bundle with angle α passing through the system will focus at the focal plane with height $h = 5\alpha f$, so the effective focal length is equal to

$$(EFL) = \frac{h}{\alpha} = 5f.$$

which is consistent with the results we got from ray tracing.

d) $S_o = 24f - 4f = 20f$

$$\frac{1}{S_o} + \frac{1}{S_i} = \frac{1}{5f} \Rightarrow S_i = \frac{20}{3}f.$$

The image plane is to the right of Lens L1 at distance $\frac{20}{3}f - 2f = \frac{14}{3}f$.

Matrix method (complicated):

$$\begin{bmatrix} \alpha_{out} \\ x_{out} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 3f-d & 1 \end{bmatrix} \begin{bmatrix} 1 & -\frac{1}{f_0} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ d & 1 \end{bmatrix} \begin{bmatrix} 1 & -\frac{1}{f} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha_{in} \\ x_{in} \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 \\ 3f-d & 1 \end{bmatrix} \begin{bmatrix} 1-\frac{d}{f_0} & -\left(\frac{1}{f}+\frac{1}{f_0}-\frac{d}{ff_0}\right) \\ d & 1-\frac{d}{f} \end{bmatrix} \begin{bmatrix} \alpha_{in} \\ x_{in} \end{bmatrix}$$

$$= \begin{bmatrix} 1-\frac{d}{f_0}, & -\left(\frac{1}{f}+\frac{1}{f_0}-\frac{d}{ff_0}\right) \\ (3f-d)\left(1-\frac{d}{f_0}\right)+d, & -(3f-d)\left(\frac{1}{f}+\frac{1}{f_0}-\frac{d}{ff_0}\right)+\left(1-\frac{d}{f}\right) \end{bmatrix} \begin{bmatrix} \alpha_{in} \\ x_{in} \end{bmatrix}$$

$$x_{out} = \left[(3f-d)\left(1-\frac{d}{f_0}\right)+d\right]\alpha_{in} + \left[-(3f-d)\left(\frac{1}{f}+\frac{1}{f_0}-\frac{d}{ff_0}\right)+\left(1-\frac{d}{f}\right)\right]x_{in}$$

Because all the parallel rays with angle α will focus at the point at the image plane with $h = 5\alpha f$, So we have

x_{out} is independent of x_{in}. $\quad x_{out} = h = 5\alpha f$.

$$\begin{cases} (3f-d)\left(1-\frac{d}{f_0}\right)+d = 5f & (1) \\ -(3f-d)\left(\frac{1}{f}+\frac{1}{f_0}-\frac{d}{ff_0}\right)+\left(1-\frac{d}{f}\right) = 0 & (2) \end{cases}$$

From Equation (1), we have

$$\frac{1}{f_0} = \left(1 - \frac{5f-d}{3f-d}\right) \cdot \frac{1}{d}$$

Substitute it into (2).

$$-(3f-d)\left(\frac{1}{f} + \left(1-\frac{5f-d}{3f-d}\right) \cdot \frac{1}{d}\left(1-\frac{d}{f}\right)\right) + \left(1-\frac{d}{f}\right) = 0$$

$$\Rightarrow -3 + \frac{d}{f} + 2\frac{f}{d}\left(1-\frac{d}{f}\right) + \left(1-\frac{d}{f}\right) = 0$$

$$\Rightarrow 2\frac{f}{d} - 4 = 0 \Rightarrow \frac{f}{d} = 2$$

$$\Rightarrow d = \frac{f}{2}.$$

which is consistent with the result that I got before.