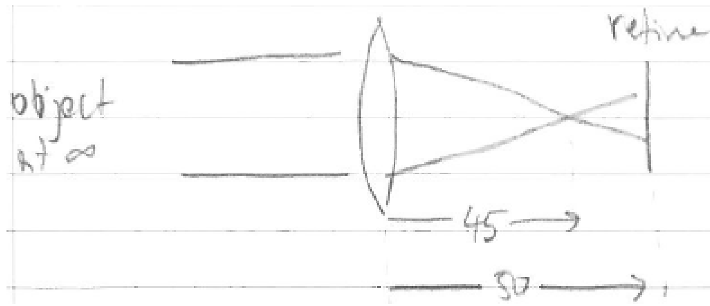
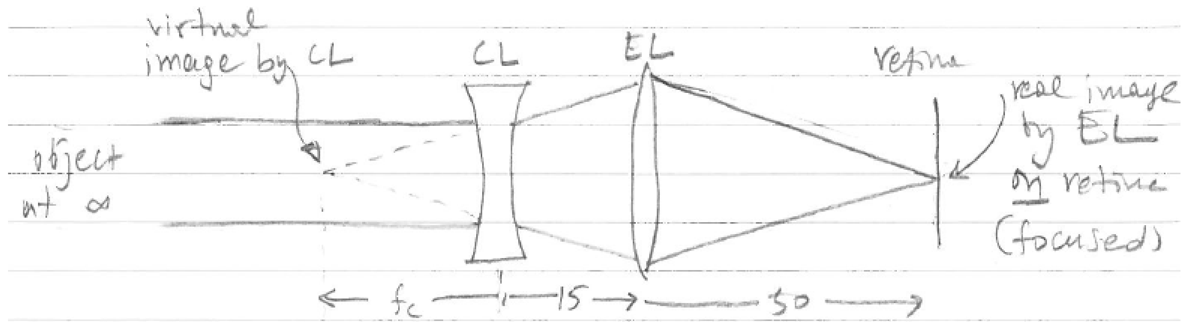
1. (a) Without correction, the focus is before the retina, leading to blurred vision:

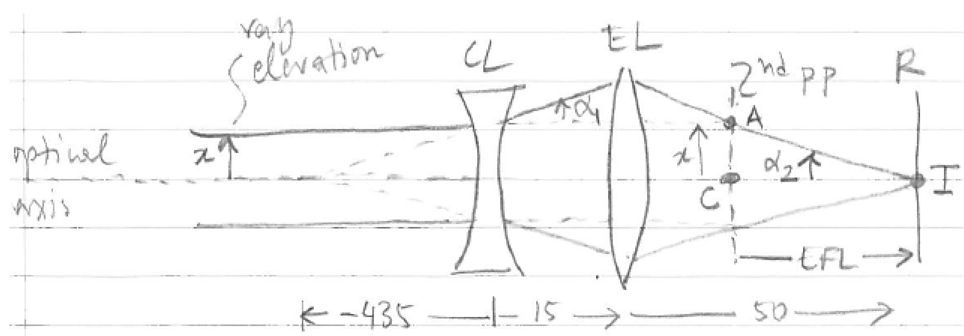


With correction, the image forms (focused) on the retina:



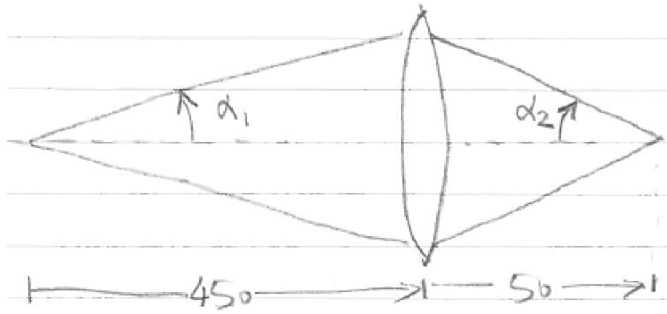
$$\frac{1}{-f_c+15}+\frac{1}{50}=\frac{1}{45}\Rightarrow\frac{1}{-f_c+15}=\frac{1}{45}-\frac{1}{50}=\frac{50-45}{50\times 45}=\frac{5}{50\times 45}$$
$$-f_c+15=\frac{50\times 45}{5}=450\Rightarrow f_c=-435 \quad (P_c\approx -2.3D)$$

(b) Draw again the ray-tracing diagram for the object at ∞:



$$\alpha_1=-\frac{x}{f_c}=-\frac{x}{-435}=\frac{x}{435}$$

Draw the imaging system formed by EL above, with object = the virtual image found by CL.



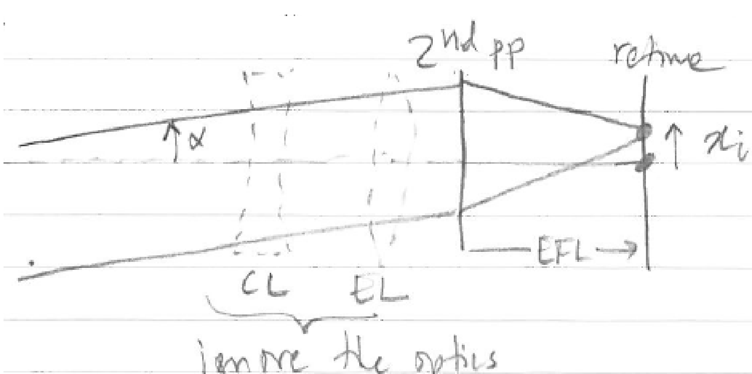
Angular magnification $M_A = -\dfrac{450}{50} = -9$

$$\Rightarrow \alpha_2 = -9 \cdot \alpha_1 = -\frac{9x}{435} = -\frac{x}{48\frac{1}{3}}$$

From $\triangle$ICA (see diagram on previous page),

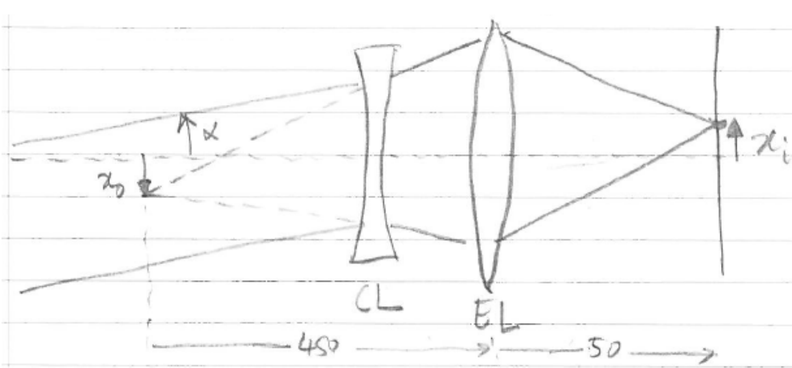
$$\begin{aligned} \frac{x}{\text{EFL}} &= \tan\alpha_2 = \alpha_2 \quad \text{(paraxial approximation)} \\ &= \frac{x}{48\frac{1}{3}} \Rightarrow \text{EFL} = 48\frac{1}{3} \end{aligned}$$

(c) <u>1st method:</u> Using the 2nd PP and EFL



$$x_i = \alpha \cdot (\text{EFL}) = 48\frac{1}{3}\alpha$$

<u>2nd method:</u> Using the imaging condition

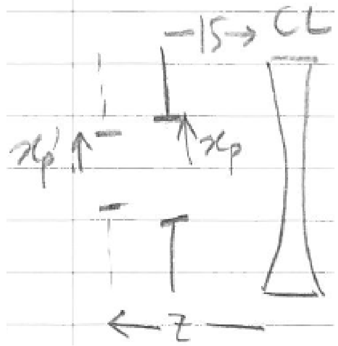


$$x_0 = \alpha f_c = -435\alpha$$

The lateral magnification of EL's imaging system (with the virtual image formed by CL as the object and real image formed on the retina) is given by:

$$M_L = -\frac{50}{450} = -\frac{1}{9} \Rightarrow x_i = M_L x_0 = -\frac{1}{9}\cdot(-435\alpha)$$
$$=\frac{435}{9}\alpha = 48\frac{1}{3}\alpha \Rightarrow \text{Image is } \underline{\text{erect.}}$$

(d) Use the eye's pupil as the object and flip the optical system for proper ray-tracing.



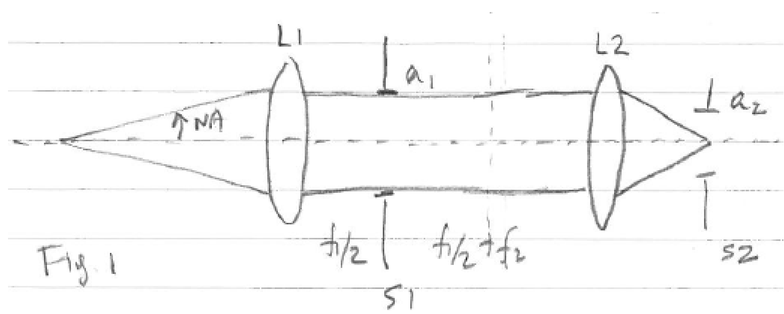
$$\frac{1}{15} + \frac{1}{z} = \frac{1}{-435} \Rightarrow z = -\frac{15\times 435}{450}$$

$\therefore$ virtual image created as shown

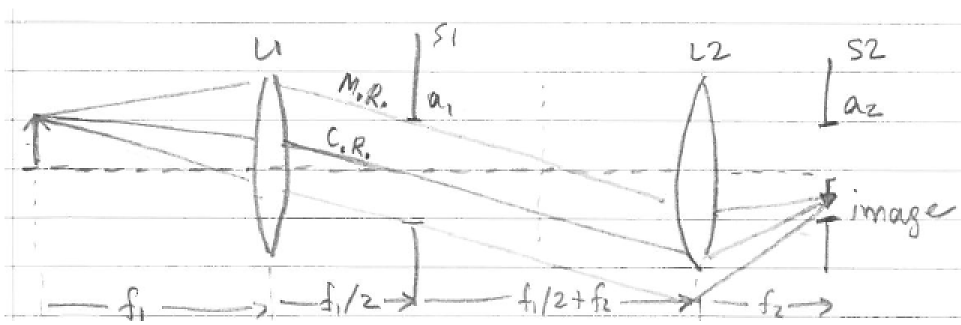
$$\frac{x_p'}{x_p} = M_L = -\frac{z}{15} = \frac{435}{450} = \frac{87}{90}$$

The myopic person's eyes appear smaller and erect.

2. (a) First consider an on-axis point at the object plane.

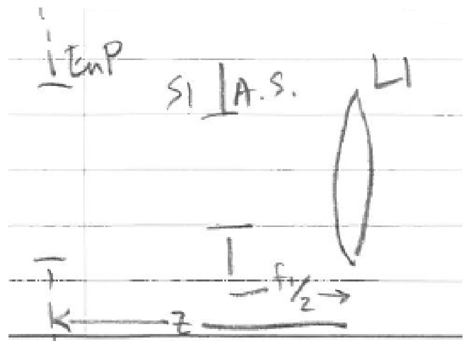


Clearly, S1 limits the angle of acceptance, so S1 is the Aperture Stop. Now consider an off-axis point object. The chief ray goes through the center of the Aperture Stop:



Clearly, S2 limits the angle of acceptance of the chief ray, so S2 is the Field Stop.

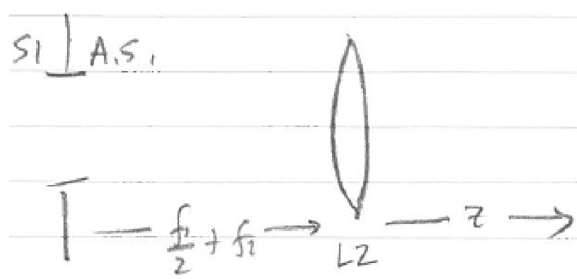
(b) To find the Entrance Pupil, image S1 (the Aperture Stop) through L1 (<u>flip</u> for proper use of the sign conventions):



$$\frac{1}{f_1/2} + \frac{1}{z} = \frac{1}{f_1} \Rightarrow \frac{1}{z} = \frac{1}{f_1} - \frac{2}{f_1} = -\frac{1}{f_1} \Rightarrow z = -f_1$$

The virtual image is formed (to the left) as shown.

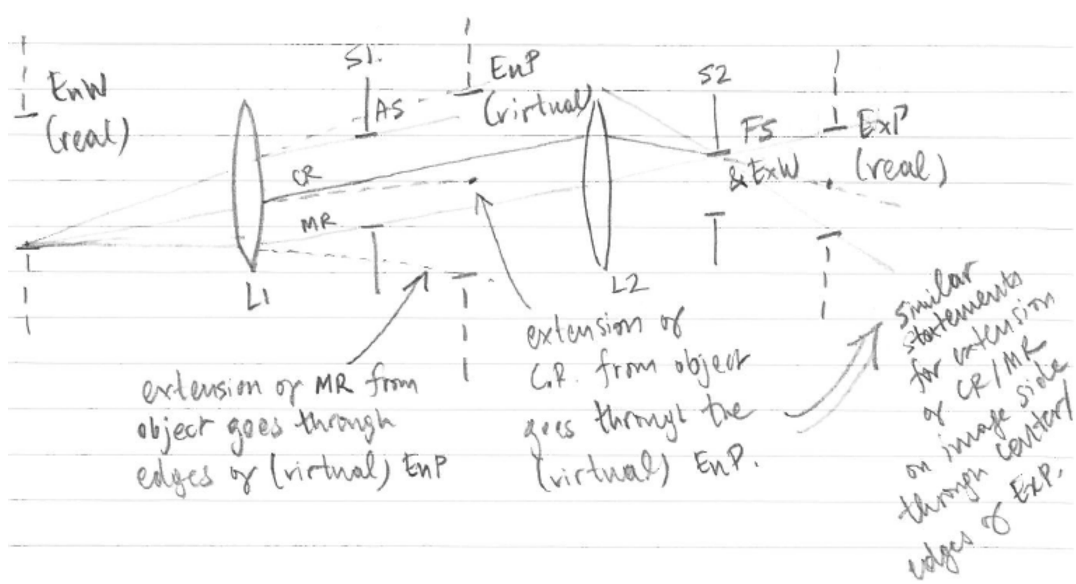
To find the Exit Pupil, image S1 through S2:



$$\frac{1}{\frac{f_1}{2}+f_2} + \frac{1}{z} = \frac{1}{f_2} \Rightarrow \frac{1}{z} = \frac{1}{f_2} - \frac{1}{\frac{f_1}{2}+f_2} = \frac{\frac{f_1}{2} + \cancel{f_2} - \cancel{f_2}}{f_2(\frac{f_1}{2}+f_2)} = \frac{\frac{f_1}{2}}{f_2\left(\frac{f_1+2f_2}{2}\right)} \Rightarrow z = f_2\left(1 + 2\frac{f_2}{f_1}\right) > 0$$

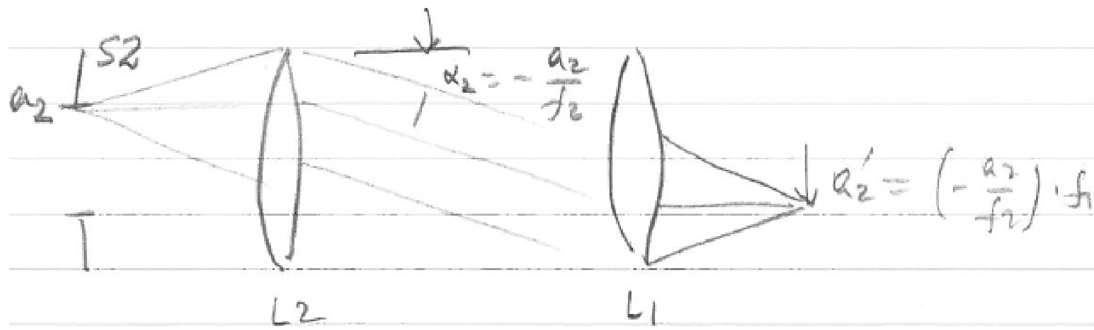
The image is real (to the right) as shown.

S2 is the Field Stop and also the Exit Window. S2 is imaged onto the object plane, where the Entrance Window is located. So the completely annotated system is:

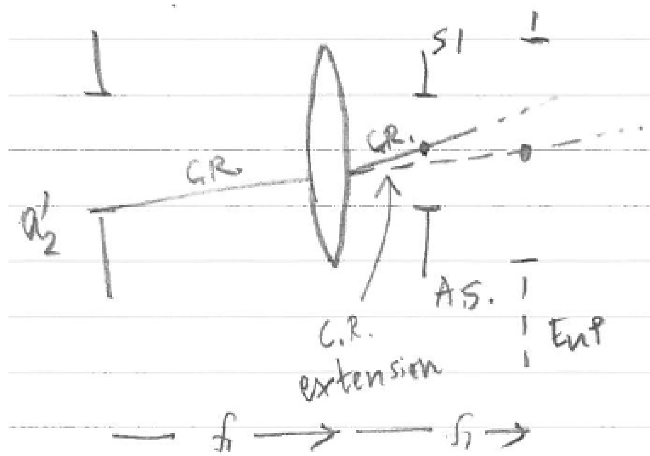


(c) From Fig. 1, NA $= \dfrac{a_1}{f_1}$ is the angle of acceptance. For the FoV, there are two considerations:

i. Size of Exit Window. S2 is imaged onto the object plane. Flipping for proper sign conventions, we find the lateral magnification as $|a_2'| = \frac{f_1}{f_2} a_2$:



ii. Angle of Chief Ray. For this we reconsider the object plane and the Entrance Pupil:



We can see that FoV $= \dfrac{a_2'}{2f_1} = \dfrac{1}{2f_1}\left(\dfrac{f_1}{f_2} a_2\right) = \dfrac{1}{2}\dfrac{a_2}{f_2}$.

(d) Even though S2 is the Field Stop, the location of S1 has the unfortunate consequence of limiting the FoV because of the bending of the chief ray as we saw in the previous question.

We can see easily that if we move S1 to the right, the CR to the left of L1 becomes closer to horizontal and the FoV increases. Its maximum value will be a_2/f_2 when S1 is located symmetrically f_1 to the right of L1. (The EnP, ExP are then at ∞. See the solutions for the 2.71 exam for more details.) Moving the Aperture Stop (i.e. S1) further to the right again reduces the FoV.

The symmetric placement of the AS (f_1 to the right of L1, f_2 to the left of L2) also has some desirable aberration reduction effects, e.g. it reduces distortion.

2.71 / 2.710 Optics
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