Exercise 1 — total (8,5)

1) $\frac{1}{f'} = \frac{1}{f'_1} + \frac{1}{f'_2}$ (1)

2) $\frac{1}{f'_1} = (n_1 - 1) \times \frac{2}{R}$ (0,5)

3) $\frac{1}{f'_2} = (n_2 - 1)\left(\frac{-1}{R} - \frac{1}{R'}\right)$ (0,5)

4) For BK7 : $\Delta n = n_{Blue} - n_{Red} = 81 \cdot 10^{-4} \rightarrow \underline{\nu_1 = 63,8}$ (0,5)

For SF6 : $\Delta n = 316 \cdot 10^{-4} \rightarrow \underline{\nu_2 = 25,5}$ (0,5)

$n(\lambda)$ varies faster for SF6

5) f'_1 and f'_2 vary when λ varies because n_1 and n_2 depend on λ (0,5)

6) $-\frac{\Delta f'_1}{f'_1} = \frac{\Delta(n_1 - 1)}{n_1 - 1} = \frac{1}{\nu_1} \Rightarrow \Delta f'_1 = -\frac{f'_1}{\nu_1}$ (1)

In the same way, $\Delta f'_2 = -\frac{f'_2}{\nu_2}$

7) Using question 1), $\frac{\Delta f'}{f'^2} = \frac{\Delta f'_1}{f'^2_1} + \frac{\Delta f'_2}{f'^2_2}$ (1)

$\Delta f' = 0 \Leftrightarrow \frac{1}{f'_1 \nu_1} + \frac{1}{f'_2 \nu_2} = 0$ (condition for achromatism) (0,5)

8) Solve $\begin{cases} \frac{1}{f'_1} + \frac{1}{f'_2} = \frac{1}{f'} \\ \frac{1}{f'_1 \nu_1} + \frac{1}{f'_2 \nu_2} = 0 \end{cases} \Leftrightarrow \begin{cases} f'_1 = f' \cdot \frac{\nu_1 - \nu_2}{\nu_1} \\ f'_2 = f' \cdot \frac{\nu_2 - \nu_1}{\nu_2} \end{cases}$ (0,75)

$f' = 150$ mm, $\nu_1 = 63,8$, $\nu_2 = 25,5$ $\rightarrow$

$\boxed{f'_1 = 90 \text{ mm} \quad f'_2 = -225,3 \text{ mm}}$ (0,75)

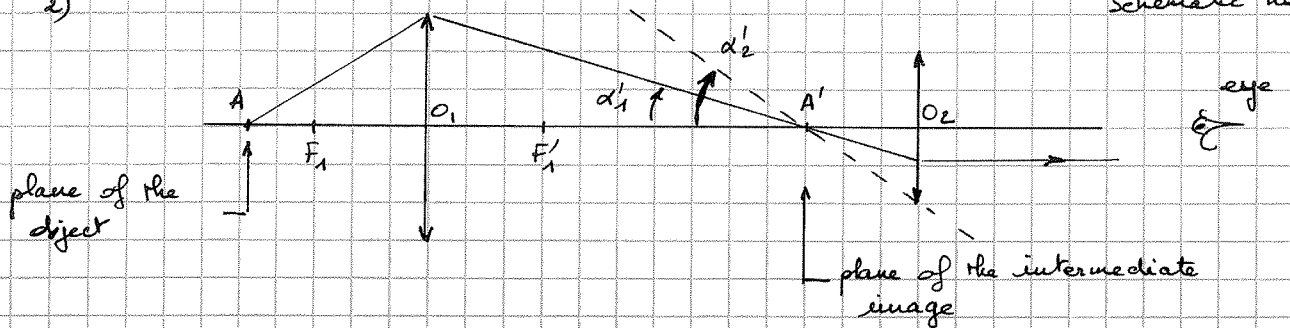
9) Using 2), $R = 2(n_1 - 1) f'_1 = \underline{93 \text{ mm}}$ (0,5)

Using 3), $R' = \left[-\frac{1}{R} - \frac{1}{(n_2 - 1) f'_2}\right]^{-1} = \underline{-190,8 \text{ mm}}$ (0,5)

Exercise 2 Total: (9)

1) $G_{i,c} = \frac{250\,mm}{f_2'} = \underline{12,5}$ (0,5)

2) Schematic not to scale.



Draw a ray coming from an object on axis, through the edge of (L_1).

Does it emerge through (L_2) ?

To answer the question, evaluate $|\alpha_1'| = \frac{\Phi_{1/2}}{O_1A'}$ and $|\alpha_2'| = \frac{\Phi_{2/2}}{O_2A'}$

Here, $\overline{O_1A'} = \overline{O_1F_1'} + \overline{F_1'A'} = f_1' - f_1' \underbrace{g_y}_{-2} = 3f_1'$

$\underline{\overline{O_1A'} = 120\ mm}$

$\Rightarrow |\alpha_1'| = \frac{1}{40} = 0,025\ rad$ (2)

Also, $\overline{O_2A'} = -f_2' \Rightarrow |\alpha_2'| = \frac{1}{10} = 0,1\ rad$

$|\alpha_1'| < |\alpha_2'| \Rightarrow$ <u>The objective is the pupil</u> of the system, i.e. it limits the rays coming an object on axis

3) $L = \overline{O_1A'} + \overline{A'O_2} = 3f_1' + f_2' = \underline{140\ mm}$ (0,5)

4) See next page. Note that $\overline{O_1A'} / \overline{O_1A} = g_y = -2 \Rightarrow \overline{O_1A} = -60\ mm$ (1)

5) Exit pupil : image of the pupil through (L_2) (0,5)

$\frac{1}{\overline{O_2O_1'}} - \frac{1}{\overline{O_2O_1}} = \frac{1}{f_2'} \Rightarrow \overline{O_2O_1'} = \left(\frac{1}{20} - \frac{1}{140}\right)^{-1} = \underline{23,3\ mm}$

Size of exit pupil : $\Phi_1' = \Phi_1 \times \left|\frac{-f_2}{\overline{F_2O_1}}\right| = 6\,mm \times \frac{20}{120} = \underline{1\ mm}$ (0,5)

in agreement with ray construction (0,5)

6) See next page (1)

7) In the intermediate space, $\frac{\phi_{1/2} + |y'_i|}{\overline{O_1 A'}} = \frac{\phi_{1/2} + \phi_{2/2}}{\overline{O_1 O_2}}$ (1)

$$\Rightarrow |y'_i| = 5\ mm \times \frac{120}{140} - 3\ mm$$

$$|y'_i| = \underline{1,28\ mm}$$

In the object space, $|y| = \frac{|y'_i|}{|(g_y)|} = \underline{0,64\ mm}$ (0,5) at the edge of the bright field of view

8) In the eye space, the angular separation of 2 graduations is

$$\Delta\theta = \frac{100\ \mu m}{f'_2} = 5 \cdot 10^{-3}\ rad = 17' > 2'$$ (1)

So, the eye can resolve 2 graduations