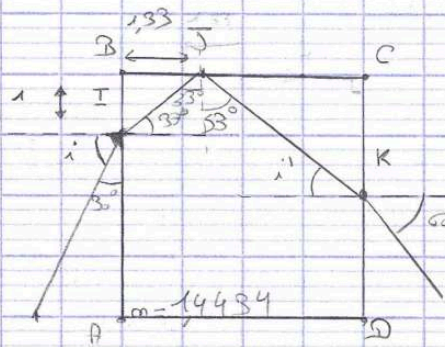


Optique géométrique

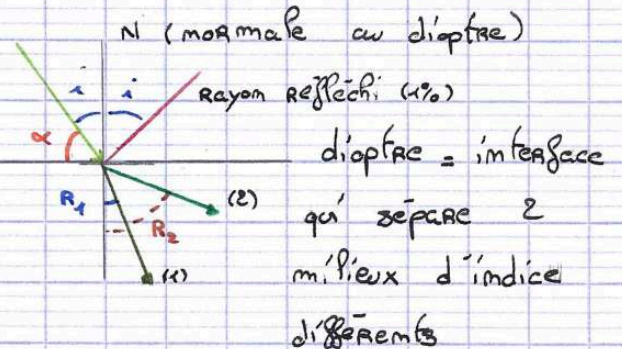
1

I - Réfraction, réflexion, prismes

Exercice 1



Rappels:



$$i = 60^\circ$$

$$\sin i = m \sin R$$

$$R = 38.9^\circ$$

$$\tan R = \frac{IB}{BJ}$$

$$BJ = 1.33 \text{ cm}$$

$$m \sin 53 = \sin R'$$

$$\sin R' = 1.15$$

impossible $\Rightarrow$ pas de réfraction

Loi de Snell:

$$n_1 \sin i_1 = n_2 \sin i_2$$

$$n = \frac{c}{v} \gg 1$$

$$(1) \text{ Si } \frac{n_2}{n_1} \gg 1 \Rightarrow \sin i_1 \gg \sin i_2$$

$$i_1 \gg i_2$$

$$(2) \text{ Si } \frac{n_2}{n_1} \leq 1 \Rightarrow \sin i_1 \leq \sin i_2$$

$$i_2 \geq i_1$$

$\Rightarrow$ i_{lim} incident $i_2 = 90^\circ$
 $\Rightarrow$ Réflexion totale

Angle limite en J

on cherche j_{lim} tel

$$\text{que } R' = 90^\circ$$

$$m \sin j_{\text{lim}} = 1$$

$$j_{\text{lim}} = 43.9^\circ$$

$$R = j > j_{\text{lim}}$$

$\Rightarrow$ réflexion totale en J

Angle d'incidence en K: i'

$$i' = 90 - j = 36.9$$

$$i' < j_{\text{lim}} \Rightarrow \text{réfraction en K}$$

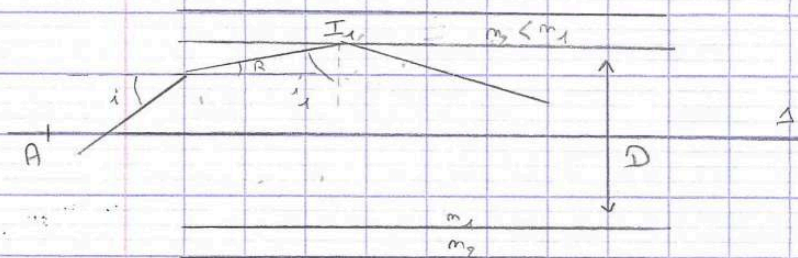
$$m \sin i' = \sin R''$$

$$R'' = 60^\circ$$

$$\tan \frac{JC}{KC}$$

$$KC = 2 \text{ cm}$$

Exercice 2



$$n_1 > 1 \text{ et } \sin i = n \sin R \\ \Rightarrow i > R$$

- 1) On veut une réflexion totale en I
on cherche le $i_{P,m}$ limite tel que $R' = 90^\circ$

$$n_1 \sin i_{P,m} = n_2 \sin R' \\ = n_2 (\text{si } R' = 90^\circ)$$

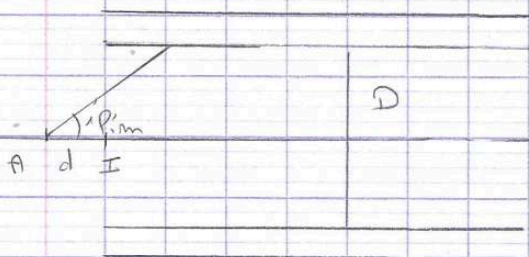
$$\sin i_{P,m} = \frac{n_2}{n_1}$$

- 2) dans propagation guidée quand $i > i_{P,m}$

$$R_{P,m} = \frac{\pi}{2} - i_{P,m} \text{ et } \sin i_{P,m} = n_1 \sin R_{P,m} \\ = n_1 \sin \left(\frac{\pi}{2} - i_{P,m} \right)$$

$$\Rightarrow i < i_{P,m} \text{ propagation}$$

- 3) Cas optimal



$$\tan i_{P,m} = \frac{D/2}{d} \Leftrightarrow 1/d = \frac{D}{2} \tan i_{P,m}$$

$$i_{P,m} = 31,3$$

$$d = 1,69 \text{ mm}$$

2) (a) $i = 90^\circ$

• en I $\sin 90^\circ = \sqrt{3} \sin R$

$R = \arcsin\left(\frac{1}{\sqrt{3}}\right)$
 $= 35,26^\circ$

• en J : $i' = A \cos R$

$(\sqrt{3} \sin(24,79)) = 46,46^\circ$

$R + R' = A$

$\Rightarrow R' = A - R$

$= 24,79^\circ$

$D = i + i' - A$

$= 76,46^\circ$

(b) On veut maintenant $i' = 90^\circ$

Principe de retour inverse de la lumière

$i = 90^\circ \Rightarrow i' = 46,66^\circ$

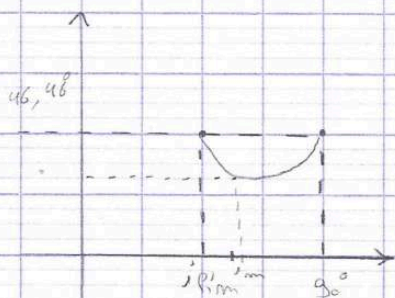
$\Rightarrow i' = 90^\circ \Rightarrow i = 46,66^\circ \Rightarrow D = 76,46^\circ$

2) (c) $i = 45^\circ$?

Si $i = 46,46^\circ \Rightarrow i' = 90^\circ$

Si $i > 46,46^\circ \Rightarrow R > (1) \Rightarrow R' < (3) \Rightarrow i' \nearrow$

Si $i < 46,46^\circ$ il y a réflexion totale en J.



on cherche $\frac{\partial D}{\partial i} = 0$

on constate que $D = D_m$

quand $IJ \parallel$ base

$R = R' \Rightarrow R + R' = A$

$\Rightarrow i = i'$

$D_m = 2 i_m - A$

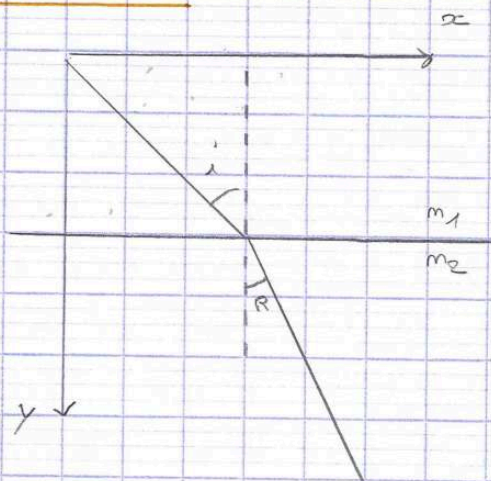
$R = \frac{A}{2} = 30^\circ$

$i_m = \arcsin(\sqrt{3} \sin 30^\circ) = 60^\circ$

$D_m = 60^\circ$

(d) $\sin i_m = n \sin i_R = n \sin \frac{A}{2}$
 $\sin\left(\frac{D_m + A}{2} = i_m\right) = n \sin \frac{A}{2}$

Exercice 6



$$\bullet A \rightarrow I \quad v_1 = c/n_1$$

$$t_{A \rightarrow I} = t_1 = d_{AI} / v_1$$

$$\bullet I \rightarrow B \quad v_2 = c/n_2 \quad \text{donc}$$

$$t_{I \rightarrow B} = t_2 = d_{IB} / v_2$$

$$\text{or } AI^2 = d^2 + x^2 = d_{AI}^2$$

$$IB^2 = (y_B - d)^2 + (x_B - x)^2 = d_{IB}^2$$

$$\text{donc } T_{A \rightarrow B} = t_1 + t_2 = \frac{d_{AI}}{v_1} + \frac{d_{IB}}{v_2} = \frac{n_1}{c} d_{AI} + \frac{n_2}{c} d_{IB}$$

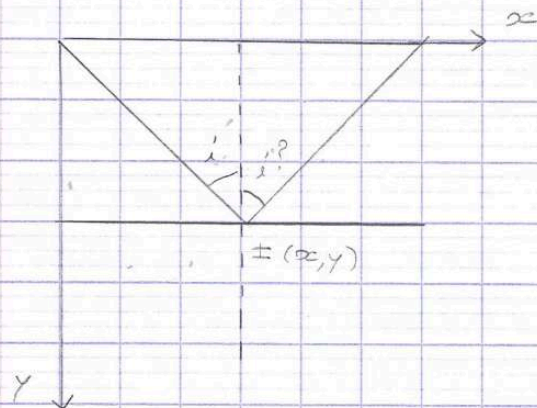
$$= \frac{1}{c} \left[n_1 \sqrt{d^2 + x^2} + n_2 \sqrt{(x_B - x)^2 + (y_B - d)^2} \right]$$

Principe de Fermat $\frac{\partial T(x)}{\partial x} = 0$:

$$\frac{n_1}{c} \frac{x}{\sqrt{x^2 + d^2}} - \frac{n_2}{c} \frac{x_B - x}{\sqrt{(x_B - x)^2 + (y_B - d)^2}} = 0$$

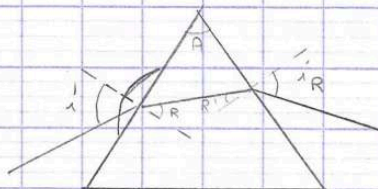
$$\sin i = x / d_{AI} \quad , \quad \sin r = (x_B - x) / d_{IB}$$

$$n_1 \sin i = n_2 \sin r$$



On a $\sin i = \sin i'$
 donc $i = i'$
 ou $i' = \pi - i$ (faux)

Exercice 9



1) en I: $N \sin(i) = m \sin(R_1)$

On a réfraction en I

si $\sin R < 1$ or $\sin i < 1$

$$\Rightarrow \frac{N}{m} < 1$$

(2) $N \sin i = m \sin R$

$$R + R' = A$$

$$m \sin R' = \sin i'$$

$$N \sin i = m \sin (A - R')$$

$$\sin(a+b) = \sin a \cos b + \cos a \sin b$$

$$\cos(a+b) = \cos a \cos b - \sin a \sin b$$

$$\sin(A - R') = (\sin A \cos R' - \cos A \sin R')$$

$$\cos(R') = \sqrt{m^2 - \sin^2(i')} \cdot \frac{1}{m}$$

$$N = \frac{1}{\sin i} (\sin(A) \sqrt{m^2 - \sin^2(i')} - \cos(A) \sin i')$$

(3) Soit $i = 90^\circ$ $i_1' = 26,5^\circ$ (avec N)

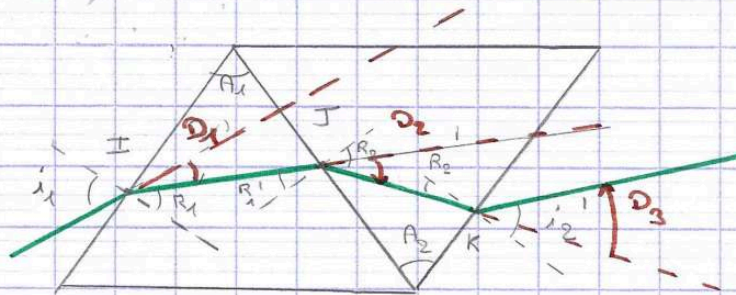
$$i_2' = 42,5^\circ$$

$$1 = \sin A \sqrt{m^2 - \sin^2 i_2'} \Leftrightarrow m = \frac{\sin^2 42,5 + (1 + \cos 60 \sin 45)}{\sin 60}$$

$$m = 1,686, N = 1,185$$

Exercise 12

1



(1) $\vec{L}_m$ I: $2 \sin i_1 = m_1 \sin R_1$

$$R_1 + R_1' = A_1$$

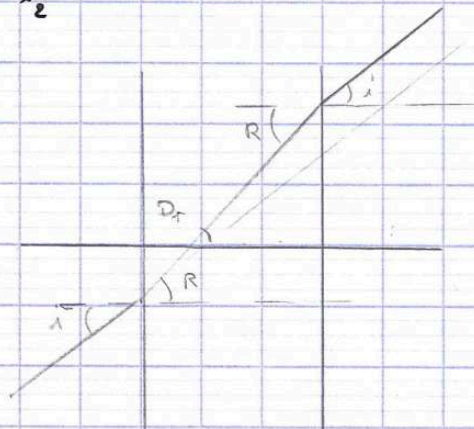
$\vec{L}_m$ J: $m_1 \sin R_1' = m_2 \sin R_2$

$$R_2 + R_2' = A_2$$

$$m_2 \sin R_2' = \sin i_2'$$

(2) $i_1 = m_1 R_1$
 $m_1 R_1' = m_2 R_2$
 $m_2 R_2' = i_2'$

(3)



$$D_1 = i_1 - R_1$$

$$D_2 = -i_1' + R_2$$

$$D = 0$$

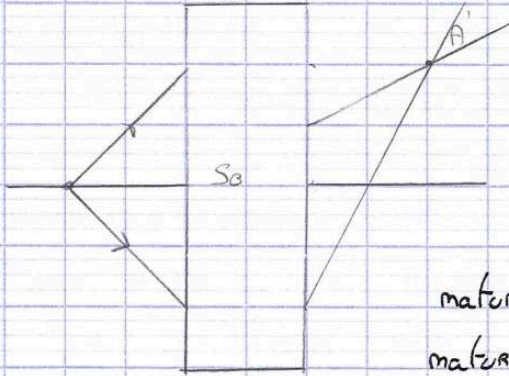
$$\begin{aligned} D = D_1 + D_2 + D_3 &= (i_1 - R_1) + (R_2 - R_1') - (i_2' - R_2') \\ &= m_1 R_1 - R_1 + R_2 - A_1 + R_1 - m_2 R_2' + A_2 - R_2 \\ &= m_1 R_1 - A_1 - m_2 R_2' + A_2 \end{aligned}$$

Exercice 14

II - Miroirs plans

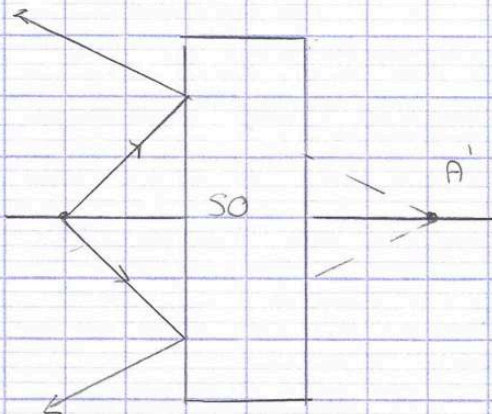
5

Rappel: construction de l'image d'un point en système optiq



Il faut au moins 2 rayons issus de A pour avoir A'

nature de A': réel (on peut visualiser l'objet)
nature de A: réel (lumière émise de A)



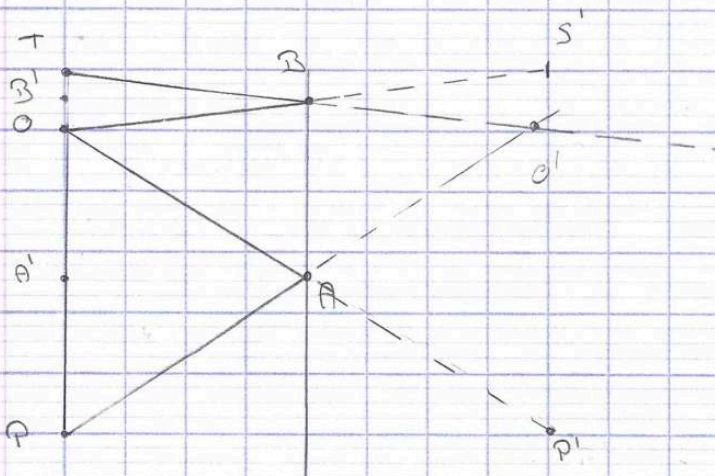
propriété du miroir:

$$i = i'$$

$$AH = HA'$$

$$\overrightarrow{AH} = \overrightarrow{HA'} = -\overrightarrow{AH}$$

A, H, A' tous alignés



Théorème des miroirs

$$TP = 2AB$$

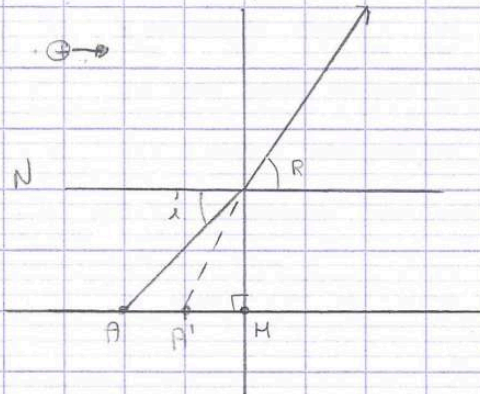
$$\Rightarrow AB_{\min} = TP/2 = 90 \text{ cm}$$

$$AH = AP = \frac{1}{2} P_0 = 85 \text{ cm}$$

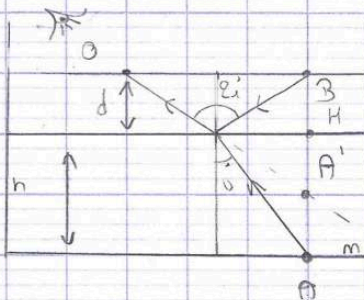
Exercice 16

Dioptre plans

Rappel:



$$\frac{HA}{n_1} = \frac{HA'}{n_2} \quad \text{dans les conditions de Gauss} \left\{ \begin{array}{l} \text{petit angles} \\ \text{proche de la normale} \end{array} \right.$$



$$\text{En C'm I: } n_3 \sin j = n_1 \sin i$$

$$\tan i = \frac{OB}{2d}$$

$$\tan j = \frac{OB}{2h}$$

$$i' = 60^\circ$$

$$\Rightarrow n = 1,33$$

$$j' = 40^\circ$$

$$\vec{B'A'} \quad \tan(n/2 - i) = \frac{A'B'}{OB/2}$$

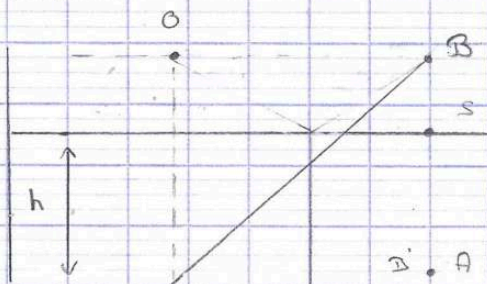
$$A'B' = 17 \cdot \tan(30 - 59,5)$$

$$= 10 \text{ cm}$$

$$(2) \text{ forme du dioptre: } \frac{B'A'}{3} = B'A' = 15 \text{ cm} \quad \Delta \text{ gauss}$$

Exercice 16

6

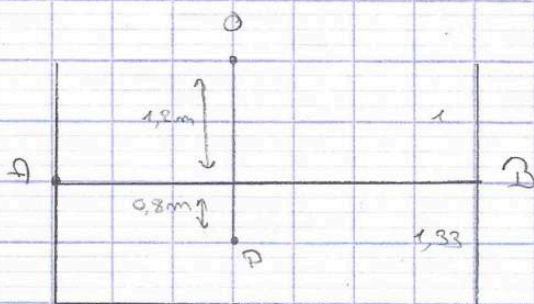


$$\frac{1}{sB} = \frac{m}{sB'}$$

$$\frac{1,33}{sA} = \frac{1}{sA'}$$

$$sA' = 15 \text{ cm}$$

Exercice 17



Exercice 20

- Analyse pb :
- lentille conv $\overline{OF'} > 0$
 - objet réel $\overline{OA} < 0$
 - $\Rightarrow \overline{OA} = -20 \text{ cm}$
 - image virtuelle : $\overline{OA'} < 0$
 - $|\gamma| = 3$

$$1 - \frac{\overline{OA'}}{\overline{OA}} = 1 - \alpha$$

$$\overline{OA'} = \alpha \overline{OA}$$

-60

$$\frac{-60}{\overline{OF'}} = 1 - \alpha$$

$$\overline{OF'} = \frac{-60}{1 - \alpha}$$

$$\frac{1}{\overline{OF'}} = \frac{1}{\overline{OA'}} - \frac{1}{\overline{OA}}$$

$$\frac{\overline{OA'}}{\overline{OF'}} = 1 - \frac{\overline{OA'}}{\overline{OA}} = 1 - \gamma$$

$$\text{si } \gamma = +3, \quad \overline{OF'} = 30 \text{ cm (1)}$$

$$\gamma = -3, \quad \overline{OF'} = 15 \text{ cm (2)}$$

$$\gamma = \frac{\overline{OA'}}{\overline{OA}}$$

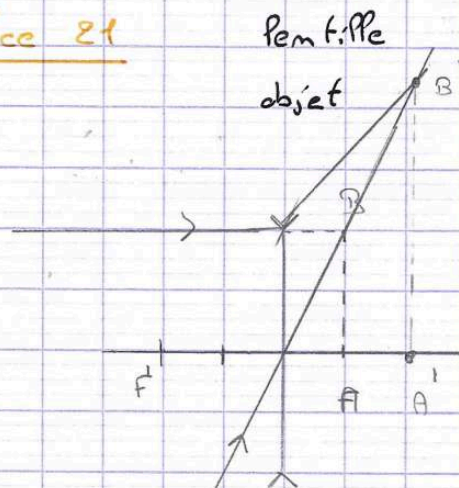
$$\frac{1}{\overline{OA'}} = \frac{1}{\overline{OA}} + \frac{1}{\overline{OF'}}$$

$$\Rightarrow \overline{OA'} = \frac{\overline{OF'} \times \overline{OA}}{\overline{OF'} + \overline{OA}}$$

$$\Rightarrow (1) : \overline{OA'} = -60 \text{ cm} \quad \text{virtuelle}$$

$$(2) : \overline{OA'} = 60 \text{ cm} \quad \text{réelle}$$

Exercice 21



lentille divergente $\Rightarrow \overline{OF'} < 0$

lentille divergente $\Rightarrow \overline{OF'} < 0$

objet virtuel $\Rightarrow \overline{OA} > 0$

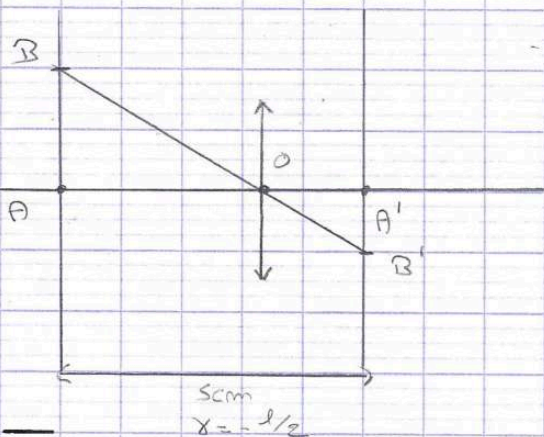
$$\overline{OF'} = -15 \text{ cm}$$

$$\overline{OA} = 10 \text{ cm}$$

$$\frac{1}{\overline{OF'}} = \frac{1}{\overline{OA'}} - \frac{1}{\overline{OA}} \quad (\Rightarrow) \quad \overline{OA'} = \frac{\overline{OA} \overline{OF'}}{\overline{OF'} + \overline{OA}}$$

AN $\overline{OA'} = 30 \text{ cm}$
 $\gamma = 3$

Exercice 22



A réel
 A' réel

$$\gamma = -\frac{1}{2} = \frac{\overline{A'B'}}{\overline{AB}} \Rightarrow \overline{A'B'} = \frac{1}{2} \overline{AB}$$

$$-\gamma = \frac{\overline{OA'}}{\overline{OA}} = \frac{\overline{A'B'}}{\overline{AB}} = \frac{1}{2}$$

$$\overline{AA'} = 45 \text{ cm} = -\overline{OA} + \overline{OA'}$$

$$\Rightarrow \overline{OA'} = 15 \text{ cm}$$

$$\overline{OA} = -30 \text{ cm}$$

$$\Rightarrow \frac{1}{\overline{OF'}} = \frac{1}{\overline{OA'}} - \frac{1}{\overline{OA}}$$

$$\Rightarrow \overline{OF'} = 10 \text{ cm}$$

Exercice 24

L_1 lentille convergente

7

$$\overline{OF_1} = +5 \text{ cm}$$

$\overline{A_1B_1}$ sur un film photo $\Rightarrow A_1B_1$ réelle

$\overline{AB}$ réel

$$\overline{AB} = 10 \text{ cm}$$

$$\overline{OA} = -100 \text{ cm}$$

$$\frac{1}{\overline{OF_1'}} = \frac{1}{\overline{OA_1}} - \frac{1}{\overline{OA}} \Rightarrow \overline{OA'} = \frac{\overline{OF_1'} \cdot \overline{OA}}{\overline{OF_1'} + \overline{OA}} \approx 5,26 \text{ cm}$$

$$\overline{A'B'} = \gamma \overline{AB} = -\frac{10}{19}$$

A_2B_2 virtuel (objet de L_2 divergente)

$$\overline{O_2A_2} > 0$$

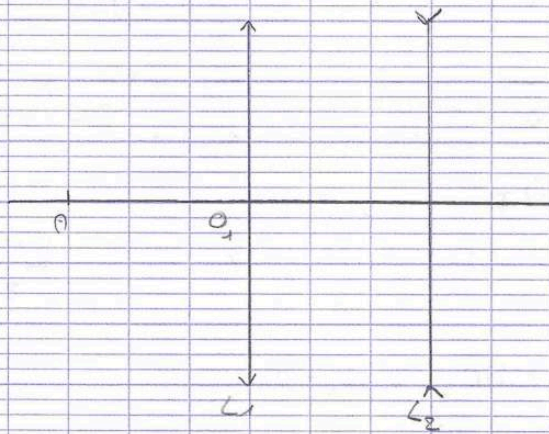
$$\overline{O_2A_2} = 2 \text{ cm}$$

$$\overline{O_2F_2'} = -4 \text{ cm}$$

$$A_2 \xrightarrow{L_2} A'$$

$$\overline{O_2A'} = \frac{\overline{O_2A_2} \cdot \overline{O_2F_2'}}{\overline{O_2F_2'} + \overline{O_2A_2}} = 4 \text{ cm}$$

A' image réelle



$$\overline{O_1A_1} = 5,26$$

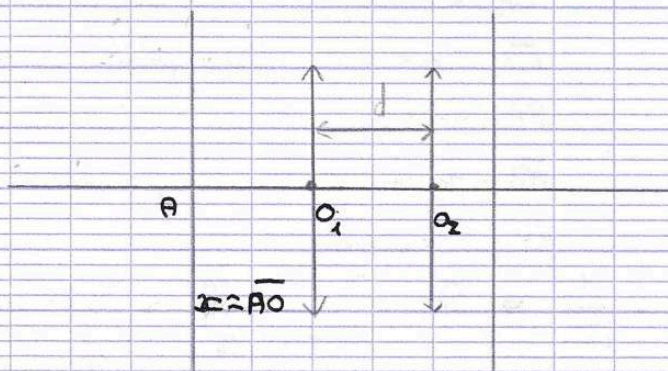
$$A \xrightarrow{L_1} A_1 \xrightarrow{L_2} A'$$

$$\overline{O_1A_1} = 5,26 \text{ cm}$$

$$\overline{O_2A_1} = 2 \text{ cm}$$

$$\text{et } \overline{O_2A'} = 4 \text{ cm}$$

Exercice 25



Plan objet
P. (Réel)

L'écram L'
(Réelle)

Relation de conjugaison: $\frac{1}{\overline{OA'}} - \frac{1}{\overline{OA}} = \frac{1}{\overline{OF'}}$

$$x = \overline{AO}$$

$$D = \overline{AA'} \Rightarrow D = \overline{AO} + \overline{OA'} = x + \overline{OA'}$$

$$\overline{OA'} = D - x$$

$$\frac{1}{D-x} + \frac{1}{x} = \frac{1}{f'}$$

$$\frac{x + (D-x)}{x(D-x)} = \frac{1}{f'}$$

$$Df' = -x^2 + Dx$$

$$x^2 - Dx + Df' = 0$$

$$\Delta = D^2 - 4Df' = D(D - 4f')$$

$$> 0 \Rightarrow D > 4f'$$

2 solutions $\Rightarrow$ 2 images

$$\text{Si } \Delta = 0 \Rightarrow D = 4f'$$

$$x_1 = \frac{D - \sqrt{D(D-4f')}}{2}$$

$$x_2 = \frac{D + \sqrt{D(D-4f')}}{2}$$

$$d = \overline{O_1O_2} = \overline{O_1A} + \overline{AO_2} = x_2 - x_1$$

$$d = \sqrt{D(D-4f')}$$

$$\Rightarrow f' = \frac{D^2 - d^2}{4D}$$

Exercice 26

2 lentilles convergentes L_1 et L_2
de foyer $f'_1 = 3 \text{ cm}$ et $\overline{O_1 O_2} = 2 \text{ cm}$

$$\overline{FA} = \overline{FO} + \overline{OA} = f'_1 + \overline{OA}$$

$$\overline{FA'} = \overline{FO'} + \overline{OA'} = -f'_1 + \overline{OA'}$$

$$\text{et } \frac{1}{OA'} - \frac{1}{OA} = \frac{1}{f'_1}$$

$$\frac{OA - OA'}{OA' OA} = \frac{1}{f'_1}$$

$$f'_1 = \frac{OA - OA'}{OA' OA}$$

$$f'_1 = \frac{OA OA'}{OA - OA'}$$

$$(f'_1 + OA)(-f'_1 + OA')$$

$$-f'^2_1 - f'_1 OA + f'_1 OA' + OA OA'$$

$$-f'^2_1 + f'_1(OA' - OA) + OA OA'$$

$$-f'^2_1 + f'_1 \left(\frac{OA' OA}{f'_1} \right) + OA OA'$$

$$\overline{F_1 F} \times \overline{F_1' F_2} = f'^2_1$$

$$\overline{F_1' F_2} = \overline{F_1' O_1} + \overline{O_1 O_2} + \overline{O_2 F_2} = -f'_1 + \overline{O_1 O_2} - f'_2$$

$$= -4 \text{ cm}$$

$$F_1 F = + \frac{9}{4} \text{ cm} = 2,25$$

$$\infty \xrightarrow{L_1} F_1' \xrightarrow{L_2} F_2' \quad \overline{F_2' F_1'} \cdot \overline{F_2' F_1} = -f'^2_2$$

$$\overline{F_2' F_1'} = \overline{F_2' O_2} + \overline{O_2 O_1} + \overline{O_1 F_1'} = f'_2 - \overline{O_1 O_2} + f'_1 = -\frac{9}{4} = -2,25 \text{ cm}$$

L'œil et la vision

9

Exercice 31

- PP à 10 cm pointum proximum
- $\Delta C = 8 \text{ D}$ amplitude dioptrique.

Image nette si elle se forme sur la rétine
et $\frac{1}{OA'} - \frac{1}{OA} = \frac{1}{g'} = C$

on pose $K = \frac{1}{OA} = C_0$

$\frac{1}{OA}$ varie tout le temps $\Rightarrow g'$ s'ajuste en permanence

Pour un œil au repos (observation à P'_∞)
on pose $D_{PR} = \frac{1}{AO} > 0$, $C_0 - \frac{1}{D_{PR}} = K$

Pour un œil accommodant

$$C_0 + \Delta C - \frac{1}{D_{PP}} = K$$

donc au final : $C_0 - \frac{1}{D_{PR}} = C_0 + \Delta C - \frac{1}{D_{PP}}$

$$\Rightarrow \Delta C = \frac{1}{D_{PR}} - \frac{1}{D_{PP}}$$

œil emmetrope : $D_{PR} \rightarrow \infty$ et $D_{PP} \sim 25 \text{ cm} = \frac{1}{4} \text{ m}$
 $\Rightarrow \Delta C = 4 \text{ D}$

$$(1) \Delta C = \frac{1}{D_{PP}} - \frac{1}{D_{PR}} \Rightarrow \frac{1}{D_{PR}} = \frac{1}{0,1} - 8$$

$$\Rightarrow \frac{1}{D_{PR}} = 25 \Rightarrow D_{PR} = 50 \text{ cm}$$

(2) Nature de la lentille par un PR à l' ∞
sans correction : $C - \frac{1}{D_{PR}} = K$

une correction : $C_0 + C - \frac{1}{D_{PR}^C} = K$ on veut $D_{PR}^C \rightarrow \infty$

$$\Rightarrow C_0 + C = C_0 - \frac{1}{D_{PR}} \quad \text{ou} \quad C = -\frac{1}{D_{PR}} = -2 \delta$$

$C < 0 \Rightarrow$ lentille divergente

$$C = \frac{1}{f_c} \Rightarrow f_c' = -50 \text{ cm}$$

œil avec PR à l' ∞ et $\Delta C = 8 \delta$ et on cherche le PP

$$\Delta C = \frac{1}{D_{PP}^C} - \frac{1}{D_{PR}^C}$$

$$\Delta C = 8 \delta$$

$$\Rightarrow D_{PP}^C = 12,5 \text{ cm}$$

et un œil avec PR à l' ∞ et $\Delta C = 8 \delta$ et tel que

$$\Delta C = \frac{1}{D_{PP}} - \frac{1}{D_{PR}} \Rightarrow D_{PP} = 12,5 \text{ cm}$$

$\Rightarrow$ la correction corrige aussi le PP !

(3) Lentille correctrice

$$C = (n-1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

Rayon de l'œil : $R = 8 \text{ mm}$, indice du verre : 1,5

$$\Rightarrow R_2 = \overline{S_2 C_2} = 8 \text{ mm} \quad \text{et} \quad C = -2 \delta$$

$$\Rightarrow -2 = (1,5 - 1) \left(\frac{1}{R_1} - \frac{1}{8 \cdot 10^{-3}} \right)$$

$$\Rightarrow -4 + \frac{1}{8 \cdot 10^{-3}} = \frac{1}{R_1}$$

$$R_1 = 8,265 \text{ mm}$$

$$= \overline{S_1 C_1}$$

Exercice 32

$$PP = 1 \text{ m}$$

PR virtuel $\Rightarrow$ il accomode tout le temps

$$(1) \text{ Avec accommodation } C_0 + \Delta C - \frac{1}{D_{PP}} = K$$

$$\text{avec correction } C_0 + \Delta C + C - \frac{1}{D_{PP}^c} = K$$

$$C_0 + \Delta C - \frac{1}{D_{PP}} = C_0 + \Delta C + C - \frac{1}{D_{PP}^c}$$

$$\Rightarrow C = \frac{1}{D_{PP}^c} - \frac{1}{D_{PP}} \quad g_c = 33 \text{ cm}$$

$$C = \frac{1}{9,25} - 1 = 3 \delta$$

$C > 0 \Rightarrow$ lentille convergente

$$\Delta C = \frac{1}{D_{PP}^c} - \frac{1}{D_{PR}^c} \quad \Rightarrow \quad 4 \delta = \frac{1}{\frac{1}{4} \text{ m}} - \frac{1}{D_{PR}^c}$$

$$\Rightarrow D_{PR}^c \rightarrow \infty$$

La lentille converge change aussi le PR.

A TRAVERS la Pape : $G_c = 12,5$

$$\Rightarrow \varepsilon_p = \frac{E}{G_c} \Rightarrow \varepsilon_p = 3,2 \times 10^{-5}$$

$$\Rightarrow R_p = 8 \mu m$$

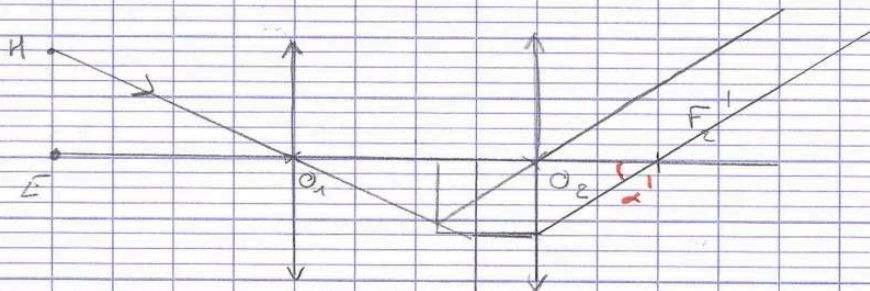
EXERCICE 39

$$L_1 : f_1' = 1m$$

$$L_2 : C = 60\delta$$

(1)

distance angulaire $\varepsilon, H = 20''$



Pas d'accommodation :

• image finale à l' ∞

• image intermédiaire au foyer objet de L_2

$$C_2 = \frac{1}{f_2'} = 60 \Rightarrow f_2' = 2cm$$

$$G = \frac{\alpha'}{\alpha}$$

$$\alpha' = \frac{O_1 H_1}{O_2 F_2'}$$

$$\alpha = \frac{O_1 H_1}{O_1 F_c} \Rightarrow$$

$$G = -\frac{1}{f_2'} \times f_1' = -60$$

$$(2) \quad \alpha' = \alpha G \Rightarrow \alpha' = -60 \times 20''$$

$$= -20''$$

$$(3) \quad C = 1'$$

$\Rightarrow$ on ne peut pas résoudre les 2 étoiles

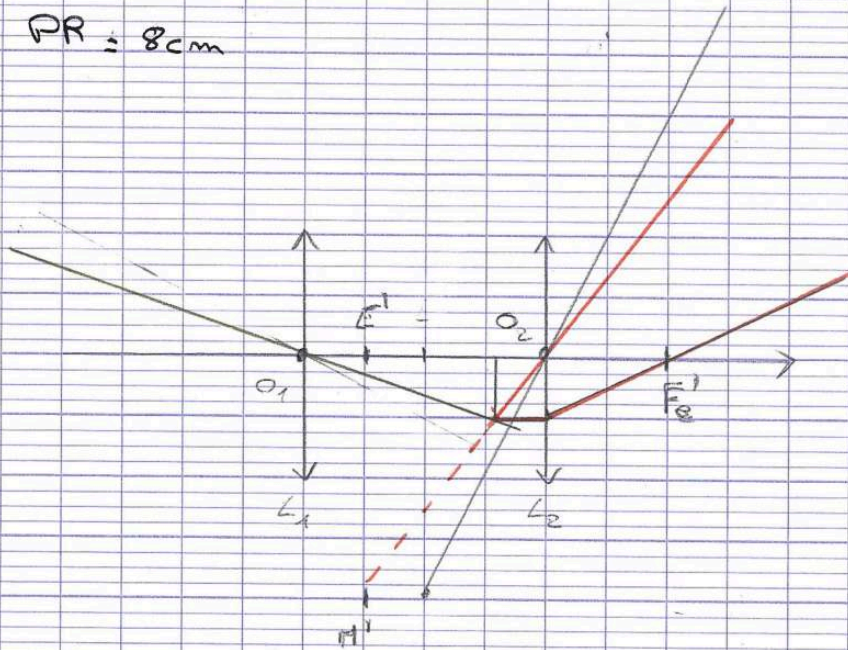
$\Rightarrow$ on voit 2 étoiles à travers la lunette

On cherche α_{min} sachant que $c = 1'$

$$Q = \frac{P}{\alpha_{\min}} \Rightarrow \alpha_{\min} = \frac{P}{Q} = \frac{11}{60}$$

$$A_{\min} = -1$$

(4) $PR = 8 \text{ cm}$



$$\begin{aligned}\overline{O_1 O_2} &= \overline{O_1 C_1} + \overline{C_1 F_2} + \overline{F_2 O_2} \\ &= g_1' + \overline{C_1 F_2} + g_2'\end{aligned}$$

OR $\overline{L_1 F_2} \cdot \overline{L_1 F_1'} = -f_e'^2$
 $\overline{L_1 F_2} = -\frac{82}{\overline{L_1 F_1'}} = -\frac{(1/60)^2}{0.08} = 3.97 \cdot 10^{-3} \text{ m}$

$$r_{O_2} = 1,03 \text{ m}$$

$$G = x|x' = g_1' C_e$$

Exercice 39

$$g_1' = 100 \text{ mm} \quad \text{objectif}$$

$$g_2' = 300 \text{ mm} \quad \text{oculaire}$$

$$\overline{O_1 O_2} = 50 \text{ cm}$$

$$\overline{AB} = 2,5 \text{ cm}$$

$$\overline{O_1 A} = -15 \text{ cm}$$

$$\frac{1}{\overline{A_1 B_1}} = \frac{1}{\overline{O_1 A_1}} - \frac{1}{\overline{O_1 A}} = \frac{1}{g_1'} \Rightarrow \overline{O_1 A_1} = \frac{g_1' \times \overline{O_1 A}}{g_1' + \overline{O_1 A}} = 30 \text{ cm}$$

$$\overline{O_1 O_2} = \overline{O_1 A_1} + \overline{A_1 O_2} \Rightarrow \overline{A_1 O_2} = 20 \text{ cm}$$

$$\frac{1}{\overline{O_2 A_1}} - \frac{1}{\overline{O_2 A_1'}} = \frac{1}{g_2'} \Rightarrow \overline{O_2 A_1'} = \frac{g_2' \times \overline{O_2 A_1}}{g_2' + \overline{O_2 A_1}} = -60 \text{ cm}$$

$$\gamma_1 = \frac{\overline{O_1 A_1}}{\overline{O_1 A}} = -2 \Rightarrow \overline{A_1 B_1} = -5 \text{ cm}$$

$$\gamma_2 = \frac{\overline{O_2 A_1'}}{\overline{O_2 A_1}} = 3 \Rightarrow \overline{A_1' B'} = 3\overline{AB} - \overline{AB} = 15 \text{ cm}$$

$$\overline{O_1 A_1} = \overline{O_1 O_2} + \overline{O_2 A_1} = \overline{O_1 O_2} + \overline{O_2 F_2}$$

$$\overline{O_1 A} = 15 \text{ cm} \Rightarrow l' \text{ image } g' \text{ male } A' \text{ à } 90 \text{ cm de } l' \text{ ce } l' \text{ image } g' \text{ male à } l' \infty \text{ (PR)} \Rightarrow \overline{O_1 A} = -20 \text{ cm}$$

$$(2) \quad g_1' = 5 \text{ mm} \quad \gamma_1 = 40 \quad \Delta = \overline{F_1' F_2} = 20 \text{ cm}$$

$$g_2' = 25 \text{ cm} \quad \gamma_2 = 10 \quad \overline{AB} = 1 \mu\text{m}$$

$$A' \text{ à } l' \infty \Rightarrow A_1 \text{ en } F_2 \quad \overline{O_1 A_1} ?$$

Figure ex 37

