OPTIKA

EZ-OHIKORAKO PRESTAKETA

JON ETXEBERRIA

2018-19

3. gaiko ariketak

POLARIZAZIOA

✓x 1/ Kalkulatu $\vec{E} = E_0 [\cos(\omega t - kz)\hat{\imath} + \cos(\omega t - kz - \frac{\pi}{4})\hat{\jmath}]$ uhinaren polarizazio-parametroak, eremu magnetikoa eta fluxu-dentsitatea.

$E_x = E_0 \cos(\omega t - kz)$

$E_y = E_0 \cos(\omega t - kz - \frac{\pi}{4})$

$\boxed{\delta = \delta_y - \delta_x = -\frac{\pi}{4}}$ → $\sin\delta < 0$ denez, lebogiroa da.

$|E_x| = |E_y| \Rightarrow \delta \neq \pm\frac{\pi}{2}$ → Eliptikoa da, $\alpha = \frac{\pi}{4}$

$$\begin{cases} \cos(2\chi)\sin(2\psi) = \cos(-\frac{\pi}{4}) = \frac{\sqrt{2}}{2} & \to \boxed{\chi = \pm\frac{\pi}{4}} \\ \cos(2\chi)\cos(2\psi) = \cos(\frac{\pi}{2}) = 0 & \to \cos(2\psi) = 0 \to \boxed{\psi = \pm\frac{\pi}{4}} \end{cases}$$

STOKESen PARAMETROAK definitu lehenik!!

(I, M, S, C) → $I = \frac{1}{I'}$ normalizatua egonez gero, $I' = 1$

$M = \frac{a_x^2 - a_y^2}{I'}$; $C = \frac{a_x a_y \cos\delta}{I'}$; $S = \frac{a_x a_y \sin\delta}{I'}$ → $\boxed{\delta = -\frac{\pi}{4}}$ dugu!

↳ $\boxed{M = 0}$; $\boxed{I = 1}$; $\boxed{C = \frac{2a_x\sqrt{2}}{2} = a_x\sqrt{2}}$; $\boxed{S = \frac{2\sqrt{2}}{2}a_x = a_x\sqrt{2}}$

↳ $\begin{pmatrix} 1 \\ 0 \\ \frac{\sqrt{2}}{2} \\ \frac{\sqrt{2}}{2} \end{pmatrix}$ → Normalizatuta!

$0 = \cos(2\alpha)$ → $\alpha = \pm\frac{\pi}{4}$

$\frac{1}{\sqrt{2}} = \sin(2\alpha)\frac{1}{\sqrt{2}}$ → $\sin(2\alpha) = 1$ → $\boxed{\alpha = \frac{\pi}{4}}$

$$\begin{cases} 0 = \cos(2\chi)\cos(2\psi) & \to \psi = \pm\frac{\pi}{4} \\ \frac{1}{\sqrt{2}} = \cos(2\chi)\sin(2\psi) & \to \chi = \frac{\pi}{8} \to \psi = \frac{\pi}{4} \\ -\frac{1}{\sqrt{2}} = \sin(2\chi) \end{cases}$$

$\frac{1}{\sqrt{2}} = \frac{1}{\sqrt{2}}\sin 2\psi$ ↳ $\boxed{\psi = \frac{\pi}{4}}$

↳ $\boxed{\chi = -\frac{\pi}{8}}$

$\vec{H} = (\hat{S} \times \vec{E})/z_0$ non $z_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$

$\hat{S} = \hat{k}$ izanik

$$\boxed{\vec{H} = \left\{- E_0 \cos\left(\omega t - kz - \frac{\pi}{4}\right)\hat{\imath} + E_0 \cos(\omega t - kz)\hat{\jmath}\right\}\sqrt{\frac{\mu_0}{\varepsilon_0}}}$$

$S = ?$ $\quad S = c\varepsilon_0 \langle E^2 \rangle$ ~~...~~ $\quad \boxed{S = c\varepsilon_0 E_0^2}$

Klasian proposatu bitan ariketatxo bi/ (polarizazio-parametroak lortzeko)

a) $\begin{bmatrix} 2 \\ i \end{bmatrix} \to \begin{pmatrix} E_x \\ E_y \end{pmatrix} \to$ normalizatu! $\quad \begin{pmatrix} \frac{2}{\sqrt{5}} \\ \frac{i}{\sqrt{5}} \end{pmatrix} = \begin{pmatrix} \cos\alpha \\ \sin\alpha\, e^{-i\delta} \end{pmatrix}$

$\boxed{\alpha = \arccos\left(\frac{2}{\sqrt{5}}\right) = 0{,}4636\,\text{rad}} \to e^{-i\delta} = i \to \boxed{\delta = -\frac{\pi}{2}\,\text{rad}}$

$\tan(2\psi) = \tan(2\alpha)\cos\delta \to \tan(2\psi) = 0 \to \psi = 0$ edo π rad

$\sin(2\chi) = \sin(2\alpha)\sin\delta \to \sin(2\chi) = -\frac{4}{5} \to \boxed{\chi = -0{,}4636\,\text{rad}}$

~~$\cos(2\chi) = \frac{0{,}6}{0{,}6} = 1 \to \chi = 0$ edo $\frac{\pi}{2}$~~ $\quad \psi = 0$ edo $\frac{\pi}{2}$

$\boxed{\psi = 0\,\text{rad}}$

b) ~~$\begin{bmatrix} -1 \\ 2i \end{bmatrix} = \begin{bmatrix} a_x \\ a_y e^{-i\delta} \end{bmatrix} \to \begin{matrix} a_x = 1 \\ a_y = 2 \end{matrix} \quad e^{-i\delta} = i \to \boxed{\delta = -\frac{\pi}{2}\,\text{rad}}$~~

~~$\alpha = \arctan\left(\frac{a_y}{a_x}\right) \to \boxed{\alpha = 1{,}1071\,\text{rad}}$~~

~~$\chi = \frac{1}{2}\arcsin[\sin(2\alpha)\sin\delta] \to \boxed{\chi = -0{,}4636\,\text{rad}}$~~

~~$\boxed{\psi = 1{,}5594\,\text{rad}}$~~

$-1\begin{pmatrix} 1/\sqrt{5} \\ \frac{-2i}{\sqrt{5}} \end{pmatrix} \to \boxed{\begin{matrix} \alpha = 1{,}1071\,\text{rad} \\ \delta = \frac{\pi}{2}\,\text{rad} \end{matrix}}$

$\boxed{\begin{matrix} \chi = 0{,}4636\,\text{rad} \\ \psi = 1{,}5628\,\text{rad} \end{matrix}}$

2/ Lortu ~~Jonesen~~ $|e\rangle = \frac{1}{\sqrt{5}}\begin{pmatrix}2\\-i\end{pmatrix}$ egoeraren Jonesen bektore ortogonala. Kalkulatu bi egoerei dagozkien Stokesen bektoreak eta haien kokapena Poincaré esferan.

$|g\rangle$ ortogonala izan dadin, $\langle g|e\rangle = 0$ izan behar da!

$|g\rangle = (\alpha \;\; \beta)$ definituz.

$\langle g|e\rangle = (\alpha^* \;\; \beta^*)\begin{pmatrix}2/\sqrt{5}\\ -\frac{i}{\sqrt{5}}\end{pmatrix} = 0 = -\frac{\cancel{\beta^*} i}{\sqrt{5}} + \frac{2\cancel{\alpha}^*}{\sqrt{5}}$

eta ondorioz denetan $\alpha \leftrightarrow \beta$ egin behar dira.

↳ $\alpha^* \in \mathbb{C}$ eta $\beta^* \in \mathbb{R}$ → hartuko dut.
edo
$\alpha^* \in \mathbb{R}$ eta $\beta^* \in \mathbb{C}$

$|\alpha|^2 + |\beta|^2 = 1$ bestetik.

$\alpha^* = \frac{2\beta^*}{i} = -2i\beta^* \rightarrow \alpha = 2i\beta$

$4\beta^2 + \beta^2 = 1 \rightarrow \cancel{\alpha} \beta = \frac{1}{\sqrt{5}} \quad \cancel{\beta}\alpha = \frac{2i}{\sqrt{5}}$ → hau hartuz

beste aukera

$\cancel{\alpha} = -\frac{i}{\sqrt{5}} \quad \cancel{\beta} = \frac{2}{\sqrt{5}}$ (bigarren aukerakoa beteko da)

~~$|g\rangle = \frac{1}{\sqrt{5}}\begin{pmatrix}2\\-i\end{pmatrix}$~~ $\quad \boxed{|g\rangle = \frac{1}{\sqrt{5}}\begin{pmatrix}1\\2i\end{pmatrix}}$

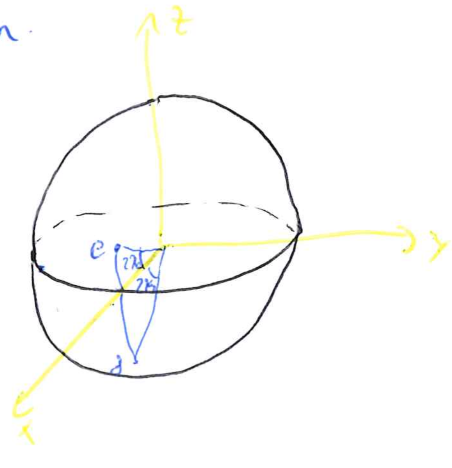
$|e\rangle = \begin{pmatrix}2/\sqrt{5}\\ -i/\sqrt{5}\end{pmatrix} \rightarrow \left[\begin{array}{l}\alpha = 0{,}4636 \text{ rad}\\ \delta = \frac{\pi}{2} \text{ rad}\end{array}\right]$

13,28

$\boxed{\chi = 0{,}4636 \text{ rad}}$

$\boxed{\psi = 0}$ ordea.

$\boxed{S_e = (1 \quad 0{,}6 \quad 0 \quad 0{,}8)}$

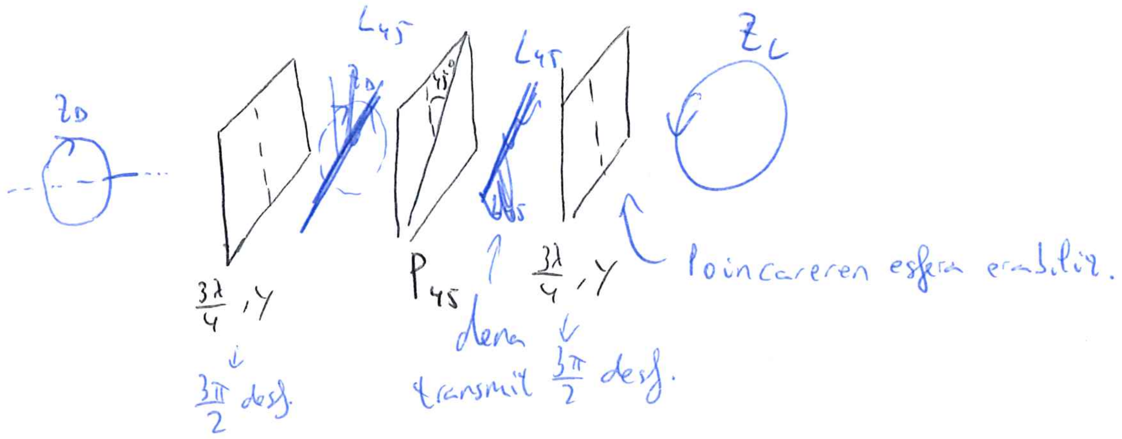


$|g\rangle = \begin{pmatrix}1/\sqrt{5}\\ \frac{2i}{\sqrt{5}}\end{pmatrix} \rightarrow \left[\begin{array}{l}\alpha = 1{,}1071 \text{ rad}\\ \delta = -\frac{\pi}{2} \text{ rad}\end{array}\right]$

$\left[\begin{array}{l}\chi = -1{,}1071 \text{ rad}\\ \psi = ? \text{ rad}\end{array}\right]$ $\quad \boxed{S_g = (1 \quad -0{,}6 \quad 0 \quad -0{,}8)}$

5/ $\frac{3\lambda}{4}$-eko bi xaflak ditugu, bien artean 45°-ra kokaturiko polarizatzaile lineal bat dugularik. Dispositiboa argi zirkular dextrogiroz Z_D argitzen da. Bi desfasatzaileak orientazio berean daude, Y ardatz lasterra izanik.

→ zein da irteerako argiaren egoera?



Irteeran ZLebogiroa izango dugu hasierako intentsitate berdinarekin

Bektoreekin eginez gero, sarreran: $\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-i\end{bmatrix}$

$A_{2,\frac{3}{2}\pi,Y} \cdot P_{45} \cdot A_{1,\frac{3}{2}\pi,Y} \rightarrow P_{45} = \frac{1}{2}\begin{bmatrix}1 & 1\\1 & 1\end{bmatrix} \quad A_{\frac{3}{2}\pi,Y} = \begin{pmatrix}1 & 0\\0 & i\end{pmatrix}$

$\begin{pmatrix}1 & 0\\0 & i\end{pmatrix}\frac{1}{2}\begin{pmatrix}1 & 1\\1 & 1\end{pmatrix}\begin{pmatrix}1 & 0\\0 & i\end{pmatrix} = \frac{1}{2}\begin{pmatrix}1 & 1\\i & i\end{pmatrix}\begin{pmatrix}1 & 0\\0 & i\end{pmatrix} = \frac{1}{2}\begin{pmatrix}1 & i\\i & -1\end{pmatrix}$

$\frac{1}{2\sqrt{2}}\begin{pmatrix}1\\-i\end{pmatrix}\begin{pmatrix}1 & i\\i & -1\end{pmatrix} = \frac{1}{2\sqrt{2}}\begin{pmatrix}2\\2i\end{pmatrix} = \boxed{\frac{1}{\sqrt{2}}\begin{pmatrix}1\\i\end{pmatrix} = Z_L}$

6/ → $\vec{S} = (1 \;\; \frac{1}{2} \;\; 0 \;\; -\frac{3}{4})$ -en polarizazio egoera?

→ Y ardatz lasterreko $\frac{1}{4}$ -ko $\left(\rightarrow \frac{\pi}{2}\right)$ xafla batetik pasaz gero, kalkulatu irteerako uhina Poincaréren esfera erabiliz.

$$\left(\frac{1}{2}\right)^2 + \left(-\frac{3}{4}\right)^2 \overset{?}{=} 1^2$$

$$\frac{1}{4} + \frac{9}{16} = \frac{13}{16} < 1$$ → ez da egongo guztiz polarizatua! (partzialki polarizatua egongo da!)

$$I_{PP} = \frac{\sqrt{13}}{4} \qquad \boxed{V = \frac{\frac{\sqrt{13}}{4}}{1} = \frac{\sqrt{13}}{4} \approx 0,9}$$

Biraketa jasan!

$$\boxed{\vec{S} = 0,1 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0,9 \\ 1/2 \\ 0 \\ -\frac{3}{4} \end{pmatrix}}$$

Kalkuluak eginez: Hasierako angeluak kalkulatu!

$$S_0 = 0,9 \rightarrow \quad \frac{1}{2}\,\frac{1}{0,9} = \cos 2\alpha \rightarrow \boxed{\alpha = 28,12° = 0,49\,rad}$$

$$\cancel{-\frac{4}{3\cdot 2} = -\frac{2}{3} = \sin(2\alpha)\sin\delta \rightarrow \delta = -5}$$

$$\arcsin\left(-\frac{3\cdot}{4\cdot 0,9}\,\frac{1}{\sin(2\alpha)}\right) = \boxed{\delta = -\frac{\pi}{2}} \qquad \boxed{\chi = -28,12 = -0,49\,rad} \qquad \boxed{\psi = 0\,rad}$$

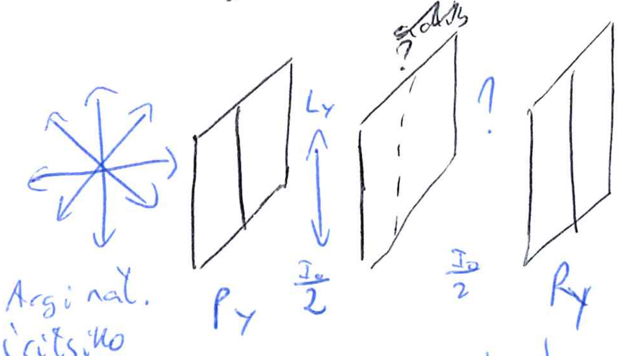
$$\boxed{\vec{S} = \left(1, \frac{1}{2}, \frac{3}{4}, 0\right)}$$

7/ 3 elem.-ko dispositibo optikoa.

→ Orientazio bereko bi P

→ Tartean A bat.

* Argi naturalezko, hasierako egoeran, opakua bada dispositiboa, A 15° biratuz gero zenbatekoa izango litzateke transmitantzia?



ezer ez

$I=0$

→ ondorioz, tartean L_x, $\frac{I_0}{2}$ izango dugu!

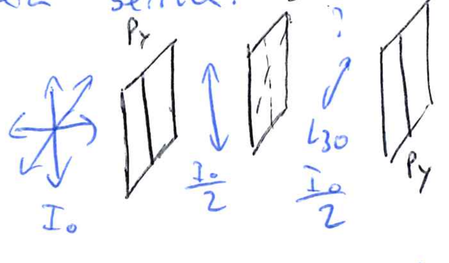
→ =)

↳ nik esleitutako posizioa!

⇒ Hau, $\frac{\lambda}{2}$-ko eta L_x eta L_y ez den edozein ardatz azkarreko desfasatzaile linealak emango digu.

Gaur, adibidez, $A_{45,\pi}$ hartuko dugu.

Egoera berria: 15° biratuta!



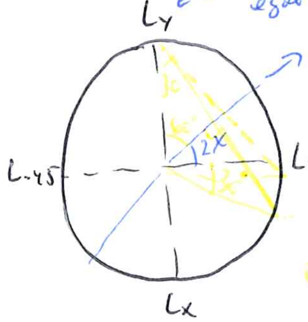
L_Y

$\frac{I_0}{2}\cos^2(60°)$

30° x-erakoa dira!

→ Bukaerako egoera: L_Y, $\frac{1}{8}I_0$

Desfasatzailea 15° biratu badugu ere, bikoitza izango da kalkuluetan erabili beharko duguna.



← sartuko den egoera!

ardatz azkar berria!

2x = 30° = 2·15° dugu

L_{45} → lehenengo ardatz azkarra

(Marrazkia ez dago oso ondo)

9/ a) $\vec{S} = \sqrt{2}\left(1 \quad 0 \quad \frac{1}{2} \quad \frac{1}{2}\right)$ -ren ezaugarriak deskribatu.

~~Lehenik eta behin~~ $1^2 \geq \left(\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2 = \frac{1}{2}$ → Partzialki polarizatua egongo da.

~~$\vec{S} = (\sqrt{2} - V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\0\\\sqrt{2}/2\\\sqrt{2}/2\end{pmatrix}$ dugu. $V = \frac{\sqrt{\left(\frac{1}{4}+\frac{1}{4}\right)2}}{2} = \frac{1}{2}$~~

$$\vec{S} = (\sqrt{2} - 1)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \sqrt{2}\begin{pmatrix}1/\sqrt{2}\\0\\1/2\\1/2\end{pmatrix}$$

$V = \frac{I_{pp}}{I_n + I_{pp}}$

$$\boxed{V = \frac{1}{\sqrt{2} - 1 + 1} = \frac{1}{\sqrt{2}} = 0,707 \text{ da polarizazio-maila.}}$$

~~$(1 \quad 0 \quad \sqrt{2}/2 \quad \sqrt{2}/2)$ dugun non $S_0 = \sqrt{2}$ den.~~

~~$0 = \cos(2\alpha) \to \alpha = \pm\frac{\pi}{4}$~~

~~$\frac{\sqrt{2}}{2} = \sin(2\alpha)\cdot\cos\delta$~~

~~$\frac{1}{2} = \sin(2\alpha)\sin\delta$~~

~~$\frac{1}{2} = \sin(2\chi) \to \chi = 15°$~~

$\left(1/\sqrt{2} \quad 0 \quad \frac{1}{2} \quad \frac{1}{2}\right)$ $\quad s_0 = \frac{1}{\sqrt{2}}$ izango delarik.

$0 = \cos(2\alpha) \to \alpha = \pm\frac{\pi}{4}$

$\frac{1}{2} = \frac{1}{\sqrt{2}}\overbrace{\sin(2\alpha)}^{1 \cdot 0 \cdot 1}\cos(\delta)$

$\frac{1}{2} = \frac{1}{\sqrt{2}}\overbrace{\sin(2\alpha)}^{1 \cdot 0 \cdot 1}\sin\delta$

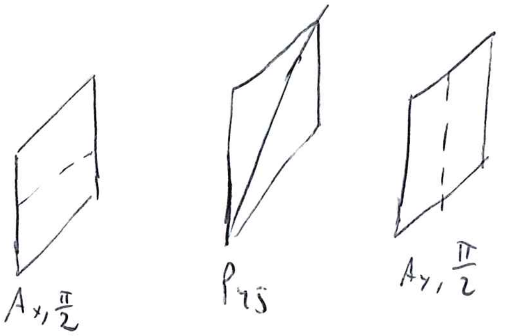
$$\boxed{\alpha = \frac{\pi}{4} \qquad \delta = \frac{\pi}{4}}$$

$0 = \cos(2\chi)\cos(2\psi)$

$\frac{1}{2} = \frac{1}{\sqrt{2}}\cos(2\chi)\sin(2\psi) \to \boxed{\psi = \frac{\pi}{4} \text{ rad}}$

$\frac{1}{2} = \frac{1}{\sqrt{2}}\sin(2\chi) \Rightarrow \boxed{\chi = 22,5° = \frac{\pi}{8} \text{ rad}}$

b) Uhin horrek ondoko dispositiboa zeharkatuko du:



→ Irteerako argiaren intentsitatea eta polarizazio egoera?

→ Zein motatako dispositiboa da?

Genuen uhina (zati polarizatua)

$\vec{S}' = \sqrt{2}\left(\frac{1}{\sqrt{2}}, 0, \frac{1}{2}, \frac{1}{2}\right)$

1. A-k argi ez-polarizatuari ez baitio eragiten!

↳ A_{x_1} ondoren? $A_{x,\frac{\pi}{2}} \to \vec{S}' = \sqrt{2}\left(\frac{1}{\sqrt{2}}, 0, \frac{1}{2}, -\frac{1}{2}\right)$ $\cancel{I_N' = \frac{I_N}{2} = \frac{\sqrt{2}-1}{2}}$

$\chi' = -\chi'''$

P_{45} ondoren:

↳ $P_{45^\circ} = \frac{1}{2}\begin{pmatrix}1 & 1\\ 1 & 1\end{pmatrix}$ Jcda, → Hemendik pasa ondoren: $I_0\begin{pmatrix}1\\0\\1\\0\end{pmatrix}$

non $I_0 = 1\cdot\cos^2\chi = 0{,}8535$ den

$\chi = \frac{\pi}{4}$ rad

↳ polarizazioaren int-en txikitzea.

Argi naturalaren I erdira jaitsiko da: $I_N' = \frac{I_N}{2} = \frac{\sqrt{2}-1}{2}$

Beraz orain arte dugu:

$$\underbrace{\frac{\sqrt{2}-1}{2}}_{0{,}21}\begin{pmatrix}1\\0\\1\\0\end{pmatrix} + 0{,}8535\begin{pmatrix}1\\0\\1\\0\end{pmatrix} = 1{,}0635\begin{pmatrix}1\\0\\1\\0\end{pmatrix}$$

↳ Azken desfasatzaileak ez du I-n eraginik izango, eta Poincaré-ren esfera erabiliz:

$$1{,}0635\underbrace{\begin{pmatrix}1\\0\\0\\1\end{pmatrix}}_{2_D}$$ izango dugu irteeran

Dispositiboa 2_D polarizatzailea da!

10/ Lor ezazu erradiazio eta maiztasun bereko L_{45} eta L_{-45} uhinen gainezarmen koherentearen emaitza ondoko kasuetan:

a) Biak fasean badaude.

a,b...) edozein kasutan, $|E\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\1\end{bmatrix} + e^{i\delta}\frac{1}{\sqrt{2}}\begin{bmatrix}1\\-1\end{bmatrix}$ izango dugu.

Fasean badaude: $\delta = 0$

$$|E\rangle = \frac{1}{\sqrt{2}}\left\{\begin{pmatrix}1\\1\end{pmatrix}+\begin{pmatrix}1\\-1\end{pmatrix}\right\}$$

$$I = \langle E|E\rangle = \frac{1}{2}\left\{\left[(1\ \ 1)+(1\ \ -1)\right]\left[\begin{pmatrix}1\\1\end{pmatrix}+\begin{pmatrix}1\\-1\end{pmatrix}\right]\right\}$$

$$I = \frac{1}{2}\left[2+0+0+2\right] \rightarrow \boxed{I = 2}$$

b) Kontrafasean badaude: $\delta = \pi$ izango da.

$$|E\rangle = \frac{1}{\sqrt{2}}\left\{\begin{bmatrix}1\\1\end{bmatrix}-\begin{bmatrix}1\\-1\end{bmatrix}\right\}$$

$$I = \langle E|E\rangle = \frac{1}{2}\left\{\left[(1\ \ 1)-(1\ \ -1)\right]\left[\begin{pmatrix}1\\1\end{pmatrix}-\begin{pmatrix}1\\-1\end{pmatrix}\right]\right\} = \frac{1}{2}\left[2-0-0+2\right] = 2$$

c) Koadraturan badaude: $\delta = \frac{\pi}{2}$ bada

$$|E\rangle = \frac{1}{\sqrt{2}}\left\{\begin{bmatrix}1\\1\end{bmatrix}+i\begin{bmatrix}1\\-1\end{bmatrix}\right\}$$

$-i\cdot i + i(-i) = 1+1 = 2$

$$I = \langle E|E\rangle = \frac{1}{2}\left\{\left[(1\ \ 1) - i(1\ \ -1)\right]\left[\begin{pmatrix}1\\1\end{pmatrix}+i\begin{pmatrix}1\\-1\end{pmatrix}\right]\right\} = \frac{1}{2}\left[2-0-0+2\right] = 2$$

d) $\frac{\pi}{3}$-ko desfasearekin

$$|E\rangle = \frac{1}{\sqrt{2}}\left\{\begin{bmatrix}1\\1\end{bmatrix}+e^{i\frac{\pi}{3}}\begin{bmatrix}1\\-1\end{bmatrix}\right\}$$

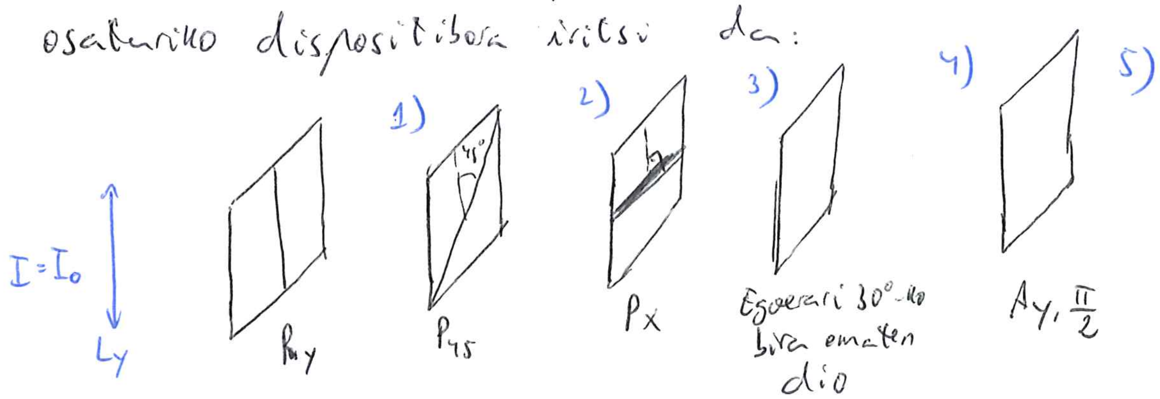
$e^{i\frac{\pi}{3}} = \cos\frac{\pi}{3} + i\sin\frac{\pi}{3} = \frac{1}{2}+\frac{i\sqrt{3}}{2} = \frac{1}{2}(1+i\sqrt{3})$

$$I = \langle E|E\rangle = \frac{1}{2}\left\{\left[\begin{pmatrix}1 & 1\end{pmatrix} + \frac{1}{2}(1-i\sqrt{3})\begin{pmatrix}1 & -1\end{pmatrix}\right]\left[\begin{pmatrix}1\\1\end{pmatrix} + \frac{1}{2}(1+i\sqrt{3})\begin{pmatrix}1\\-1\end{pmatrix}\right]\right\}$$

$$I = \frac{1}{2}\left[2 + \frac{1+i\sqrt{3}}{2} - \frac{1+i\sqrt{3}}{2} + 0 + \frac{2}{4}(1-i\sqrt{3})(1+i\sqrt{3})\right]$$

$$\boxed{I = \frac{1}{2}\left[2 + \frac{1}{2}(1+3)\right] = 2}$$

11/ Argi-sorta bertikalki polarizatu bat (L_y) ondoko elementuez osaturiko dispositibora iritsi da:



→ Polarizazio eta erradiazioa eta~~ka~~n balioitzean?

1. xaflan ez da ezer gertatuko: 1) $\updownarrow L_y$ $I = I_0$

2. xaflan: L_{45} $I = I_0\cos^2(45) = \frac{I_0}{2}$

3. xaflan: $\longleftrightarrow L_x$ $I = \frac{I_0}{4}$

4. xaflan: L_{30} $I = \frac{I_0}{4}$ → $\delta = 0°$ $\psi = 30°$ → $\alpha = 30°$ → $\chi = 0°$

$|e\rangle = \frac{1}{2}\begin{bmatrix}\sqrt{3}\\1\end{bmatrix}\cdot\frac{1}{2}$ → intentsitatea egokia izateko → $\langle e|e\rangle = \frac{1}{4^2}(3+1) = \frac{1}{4}$

$A_{y,\frac{\pi}{2}} = \begin{pmatrix}1 & 0\\0 & -i\end{pmatrix}$

$$\begin{pmatrix}1 & 0\\0 & -i\end{pmatrix}\frac{1}{4}\begin{pmatrix}\sqrt{3}\\1\end{pmatrix} = \frac{1}{4}\begin{pmatrix}\sqrt{3}\\-i\end{pmatrix}$$ → izango dugun bukaerako egoera!

12/ Kalkulatu $\underbrace{\frac{1}{2}\begin{pmatrix}\sqrt{3}\\1\end{pmatrix}}_{a}$ eta $\underbrace{\begin{pmatrix}1\\i\end{pmatrix}}_{b}$ argien gainezarpen inkoerentearen polarizazio-egoera.

Gainezarpen inkoherentea ~~egiteko~~ kalkulatzeko, stokesen bektoreak behar ditugu.

a) $\frac{1}{4}(3+1)=1$ normalizatua dago $\rightarrow \begin{pmatrix}\sqrt{3}/2\\1/2\end{pmatrix}=\begin{pmatrix}\cos\alpha\\ \sin\alpha\, e^{-i\delta}\end{pmatrix}\rightarrow$

$\rightarrow \underline{\alpha=30^\circ \quad \delta=0^\circ} \rightarrow \underline{\psi=30^\circ \text{ eta } \chi=0^\circ}$

$$\boxed{\vec{S}_a=\left(1 \quad \frac{1}{2} \quad \frac{\sqrt{3}}{2} \quad 0\right)}$$

b) $\rightarrow \langle b|b\rangle=2 \rightarrow S_0=2$ izango da kasu honetan

$\begin{pmatrix}1/\sqrt{2}\\ i/\sqrt{2}\end{pmatrix}=\begin{pmatrix}\cos\alpha\\ \sin\alpha\, e^{-i\delta}\end{pmatrix} \rightarrow \left[\alpha=\overset{\pi/4}{45^\circ} \quad \delta=\overset{3\pi/2}{\cancel{2}70^\circ}\right] \rightarrow \left[\psi=0\text{ rad eta } \chi=\frac{\pi}{2}\text{ rad}\right]$

$$\boxed{\vec{S}_b=\left(2 \quad 0 \quad 0 \quad -2\right)}$$

~~Gainezarpena: $\vec{S}_a+\vec{S}_b=\begin{pmatrix}3\\1/2\\ \sqrt{3}/2\\ -2\end{pmatrix} \rightarrow V=\frac{\sqrt{\frac{1}{4}+\frac{3}{4}+4}}{3}=\frac{\sqrt{5}}{3}$~~

~~$\vec{S}=(3-V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix}+\begin{pmatrix}V\\1/2\\ \sqrt{3}/2\\ -2\end{pmatrix}$ izango da~~

~~polarizazio maila ~~V=0,7454~~ izanik.~~

$V=0,7454$

~~Angelnall~~ kalkulatzeko:

$$\vec{S} = \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = (1-V)\begin{pmatrix} S_0 \\ 0 \\ 0 \\ 0 \end{pmatrix} + V \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix}$$

$$\boxed{V = \frac{\sqrt{5}}{3}}$$

$$\vec{S} = (3-V)\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + V \begin{pmatrix} 1 \\ \frac{3}{2\sqrt{5}} \\ \frac{3}{2}\sqrt{\frac{3}{5}} \\ -\frac{6}{\sqrt{5}} \end{pmatrix}$$

$$S_1 = V S_0 \cos(2\alpha) \qquad \frac{3}{2\sqrt{5}} = \cos(2\alpha)$$

$$\boxed{\vec{S} = \begin{pmatrix} 3 \\ 1/2 \\ \sqrt{3}/2 \\ -2 \end{pmatrix} \text{ dugu,}}$$

$3^2 \overset{?}{=} \frac{1}{4} + \frac{3}{4} + 4 = 5$

$9 > 5 \rightarrow$ partzialki polarizatutako argia.

$$\vec{S} = (3-\sqrt{5})\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} \sqrt{5} \\ 1/2 \\ \sqrt{3}/2 \\ -2 \end{pmatrix} \qquad V = \frac{I_{PP}}{I_N + I_{PP}} = \frac{\sqrt{5}}{3-\sqrt{5}+\sqrt{5}} = \frac{\sqrt{5}}{3}$$

$$-2 = \sqrt{5}\sin(2\chi) \rightarrow \boxed{\chi = -31,72^\circ}$$

$$\frac{1}{2} = \sqrt{5}\cdot 0,4472 \cdot \cos(2\psi) \rightarrow \boxed{\psi = 30^\circ}$$

$$\cos(2\alpha) = 0,5 \rightarrow \boxed{\alpha = 38,54^\circ}$$

$$\boxed{\delta = -66,59^\circ}$$

14/ Kalkulatu ($\psi = \frac{\pi}{2}$, $\chi = \arctan(\frac{1}{2})$ $\overset{\text{0,46rad}}{=}$) polarizatzailearen Jones-en matrizea eta polarizatzailearen transmitantzia honako uhin erasotzaile bakoitzerako.

a) ~~Lx~~

Lehenik polarizatzailearen α eta δ kalkulatuko ditut. $\alpha = 1{,}11\ rad$ $\delta = 1{,}52\ rad \approx \frac{\pi}{2} rad$

$$P_{\alpha,\delta} = \begin{pmatrix} 0{,}2 & i0{,}4 \\ -i0{,}4 & 0{,}8 \end{pmatrix}$$ da polarizatzailearen mat.

a) Lx badator. (Suposatuz $I_i = 1$ dela)

$$|e'\rangle = P_{\alpha,\delta}|e\rangle = \begin{pmatrix} 0{,}2 & i0{,}4 \\ -i0{,}4 & 0{,}8 \end{pmatrix}\begin{pmatrix} 1 \\ 0 \end{pmatrix} = \begin{pmatrix} 0{,}2 \\ -i0{,}4 \end{pmatrix} = |e'\rangle$$

$$\mathcal{T} = \frac{(0{,}2)^2 + (0{,}4)^2}{1} \rightarrow \mathcal{T} = 0{,}2$$

b) Ly

$$|e'\rangle = \begin{pmatrix} 0{,}2 & i0{,}4 \\ -i0{,}4 & 0{,}8 \end{pmatrix}\begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{pmatrix} i0{,}4 \\ 0{,}8 \end{pmatrix} = |e'\rangle \qquad \mathcal{T} = 0{,}8$$

c,d) L_{45}, L_{-45} (1 egin)

$$|e'\rangle = \begin{pmatrix} 0{,}2 & i0{,}4 \\ -i0{,}4 & 0{,}8 \end{pmatrix}\underbrace{\frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \end{pmatrix}}_{L_{45}} = \frac{1}{\sqrt{2}}\begin{pmatrix} 0{,}2 + i0{,}4 \\ 0{,}8 - i0{,}4 \end{pmatrix} = |e'\rangle$$

$$\mathcal{T} = \frac{1}{2}\left[(0{,}2)^2 + (0{,}4)^2 + (0{,}8)^2 + (0{,}4)^2\right] = 0{,}5$$

e) λ_D

$$|e'\rangle = \begin{pmatrix} 0,2 & 0,4i \\ -0,4i & 0,8 \end{pmatrix} \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ -i \end{pmatrix} = \boxed{\frac{1}{\sqrt{2}} \begin{pmatrix} 0,6 \\ -1,2i \end{pmatrix} = |e'\rangle}$$

$$\boxed{J = \frac{1}{2}\left(0,6^2 + 1,2^2\right) = 0,9}$$

g) Argi naturala. $\rightarrow \boxed{J = \frac{1}{2}}$

$|e'\rangle$ L_{45}-eko kasuko berdina aterako dena, $|e'\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix} 0,2+i0,4 \\ 0,8-0,4i \end{pmatrix}$

15/

$E_{\alpha,\delta}$ I_0  P_x $\frac{I_0}{2}$ | $E_{\alpha,\delta}$ I_0  $\frac{I_0}{3}$

$$\frac{I_0}{2} = I_0 \cos^2(\alpha)$$

$$\hookrightarrow \cos(\alpha) = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2}$$

$\alpha = \pm\frac{\pi}{4}$ $\rightarrow 0 < \alpha < \frac{\pi}{2} \rightarrow \boxed{\alpha = \frac{\pi}{4}}$

$\hookrightarrow E_{\alpha,\delta} \rightarrow L_{45}$ edo L_{-45} dugu.

$$\begin{pmatrix} \cos\frac{\pi}{4} \\ \sin\frac{\pi}{4} e^{-i\delta} \end{pmatrix} = \frac{\sqrt{2}}{2}\begin{pmatrix} 1 \\ e^{-i\delta} \end{pmatrix} \rightarrow \frac{1}{2}\frac{\sqrt{2}}{2}\begin{pmatrix} 1 & i \\ -i & 1 \end{pmatrix}\begin{pmatrix} 1 \\ e^{-i\delta} \end{pmatrix} =$$

ez egin hau, ez dakit zer/ez λ_D-ko proiekzioa topatu

$$= \frac{\sqrt{2}}{4}\begin{pmatrix} 1 + i e^{-i\delta} \\ -i + e^{-i\delta} \end{pmatrix} = |e'\rangle \quad I = \langle e'|e'\rangle = \frac{1}{8}(1+1+1+1) =$$

$$\left|\frac{\sqrt{2}}{2}\frac{1}{\sqrt{2}}\begin{pmatrix} 1 & -i \end{pmatrix}\begin{pmatrix} 1 \\ e^{-i\delta} \end{pmatrix}\right|^2 = \frac{1}{4}\left|1 - i e^{-i\delta}\right|^2 = \frac{1}{4}(1+1)$$

$\cos\alpha\,(A + iBe^{i\delta})(A + iBe^{-i\delta}) = A^2 + iABe^{-i\delta}$

$\alpha = \frac{\pi}{4}$ izanik

$$\langle t_b | e' \rangle \left| \frac{1}{\sqrt{2}}(1 \quad i)\begin{pmatrix}\cos\alpha \\ \sin\alpha\, e^{-i\delta}\end{pmatrix}\right|^2 = \frac{1}{2}\left|\cos\alpha + i\sin\alpha\, e^{-i\delta}\right|^2 = \frac{1}{3}$$

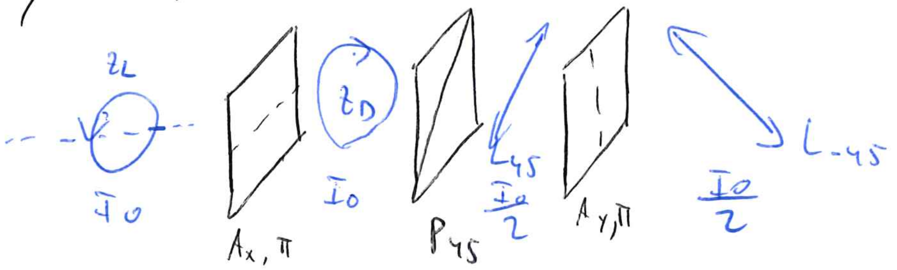
$$\frac{2}{3} = \cos^2\alpha + \sin^2\alpha + i\left(\cos\alpha\sin\alpha\, e^{-i\delta} - \cos\alpha\sin\alpha\, e^{i\delta}\right)$$

$$+\frac{1}{3} = +\frac{1}{2}\cdot\sin(\delta) \to -\frac{1}{3} = \sin\delta \to \underline{\delta = -19{,}47^\circ \text{ edo } 199{,}47^\circ}$$

Nola aurkitu zeinugabetasuna?

↳ P_{lin} biratu intentsitatearen aldaketak neurtzeko.

16/ z_L (polarizatuak) beheko dispositiboa gurutzatzen du:



Polarizatzaile lineal batek zirkularrari intentsitatea erdira jaisten baitio!

a) Jonesen bektoreak erabiliz bukaerako int. eta pol.-egoera kalkulatu.

Lehenik Poincaré-ren esferarekin egingo ditut kalkuluak, gero konparatzeko.

$$A_{x,\pi} = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \qquad A_{y,\pi} = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \qquad P_{45} = \frac{1}{2}\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$$

$$|e\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ +i \end{pmatrix} \qquad |e'\rangle = A_{y,\pi}\, P_{45}\, A_{x,\pi}|e\rangle$$

$$|e'\rangle = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}\begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}\frac{1}{2\sqrt{2}}\begin{pmatrix} 1 \\ i \end{pmatrix} = \begin{pmatrix} -1 & -1 \\ 1 & 1 \end{pmatrix}\begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}\frac{1}{2\sqrt{2}}\begin{pmatrix} 1 \\ i \end{pmatrix}$$

$$|e'\rangle = \begin{pmatrix} 1 & -1 \\ -1 & 1 \end{pmatrix}\frac{1}{2\sqrt{2}}\begin{pmatrix} 1 \\ i \end{pmatrix} = \frac{1}{2\sqrt{2}}\begin{pmatrix} 1-i \\ -1+i \end{pmatrix} = \frac{\sqrt{2}}{2\sqrt{2}}\begin{pmatrix} e^{-i\frac{\pi}{4}} \\ e^{+i\frac{3\pi}{4}} \end{pmatrix} = \frac{e^{-i\frac{\pi}{4}}}{2}\begin{pmatrix} 1 \\ e^{i\pi} \end{pmatrix} = \underbrace{\boxed{\frac{e^{-i\frac{\pi}{4}}}{2}\begin{pmatrix} 1 \\ -1 \end{pmatrix}}}_{L_{-45}}$$

b) a) atalean lortutako argiaren eta int. bikoitza duen Z_D-ren argiaren gainezarpen inkoherentearen egoera?

$$|e_a\rangle = \frac{e^{-i\frac{\pi}{2}}}{2}\begin{pmatrix}1\\-1\end{pmatrix} \overset{\text{fase is.}}{\doteq} \frac{1}{2}\begin{pmatrix}1\\-1\end{pmatrix} \rightarrow \frac{1}{4}+\frac{1}{4}=\frac{1}{2} \rightarrow I \rightarrow \text{bestean } 1 \text{ anp.}$$

$$|e_b\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\-i\end{pmatrix} \rightarrow Z_D \text{ eta } I \text{ bikoitza.}$$

$$\left[|e_a\rangle \Rightarrow \delta_a = 0 \text{ rad } \psi = -\pi/4 \quad \alpha = -\frac{\pi}{4} \quad \chi = 0 \text{ rad}\right]$$

$$S_0 = \frac{1}{2} \rightarrow \boxed{\vec{S}_a = \begin{pmatrix}\frac{1}{2} & 0 & -\frac{1}{2} & 0\end{pmatrix}}$$

$$|e_b\rangle \Rightarrow \delta = \frac{\pi}{2} \text{ rad} \quad \alpha = \frac{\pi}{4} \text{ rad} \quad \chi = \frac{\pi}{4} \text{ rad} \quad \psi = 0 \text{ rad}$$

$$\boxed{\vec{S}_b = \begin{pmatrix}1 & 0 & 0 & 1\end{pmatrix}}$$

$$\boxed{\vec{S} = \begin{pmatrix}\frac{3}{2} & 0 & -\frac{1}{2} & 1\end{pmatrix}} \qquad \frac{9}{4} > \frac{1}{4} + 1 = \frac{5}{4}$$

$$\boxed{\vec{S} = \left(\frac{3}{2} - \frac{\sqrt{5}}{2}\right)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}\sqrt{5}/2\\0\\-\frac{1}{2}\\1\end{pmatrix}} \qquad \boxed{V = \frac{\sqrt{5}/2}{\frac{3}{2} - \frac{\sqrt{5}}{2} + \frac{\sqrt{5}}{2}} = \frac{\sqrt{5}}{3}}$$

$$\delta = 116{,}56° \text{ edo}$$

$$0 = \cos(2\alpha) = \cos(2\chi)\cos(2\psi)$$

$$-\frac{1}{2} = \frac{\sqrt{5}}{2}\sin(2\alpha)\cos\delta = \frac{\sqrt{5}}{2}\cos(2\chi)\sin(2\psi) \qquad \boxed{\psi = -45°}$$

$$1 = \frac{\sqrt{5}}{2}\sin(2\alpha)\sin\delta = \frac{\sqrt{5}}{2}\sin(2\chi) \rightarrow \boxed{\chi = 31{,}72°}$$

$$\alpha = \pm 45° \qquad -\frac{1}{2} = \frac{1}{\tan(\delta)} \rightarrow \arctan(-2) = \boxed{\delta = -63{,}43° \quad \alpha = -45°}$$

c) b) atalean lorturiko argiaren intentsitatea eta ezaugarriak, iragazki lineal bat zeharkatu ondoren.

Iragazkiaren norabide gardena 30°-ra dago.

$I_N'' = \frac{3-\sqrt{5}}{2} \Rightarrow \boxed{I_N' = \frac{3-\sqrt{5}}{4}} \approx 0,19$

~~$I_p = \frac{\sqrt{5}}{2} \rightarrow I_p' = \frac{\sqrt{5}}{2}\cos^2(30) = \frac{3\sqrt{5}}{8} = I_p'$~~

~~$I_T = \frac{6+\sqrt{5}}{8} \approx$~~

$I_p = \frac{\sqrt{5}}{2} \rightarrow I_p' = \frac{\sqrt{5}}{2} \cdot \frac{\sqrt{5}}{4} = \frac{5}{8} \approx 0,625$

Hau tela da??

$\hookrightarrow s_0 = \frac{\sqrt{5}}{2} = a_x^2 + a_y^2$

$s_1 = 0 = a_x^2 - a_y^2 \rightarrow a_x = a_y$

$\hookrightarrow \frac{\sqrt{5}}{2} = 2a_x^2 \rightarrow a_x = \sqrt{\frac{\sqrt{5}}{4}} = \frac{\sqrt[4]{5}}{2}$

$I_T = 0,82\, I = 0,55\, I_0$

$0,82\, \frac{I_0}{\frac{3}{2}\left(1+\frac{1}{2}\right)}$

Transmititzen dena: $I_0\left[(a^2 - b^2)\cos^2\alpha + b^2\right] = I_0\, b^2 = \frac{5}{8}$

(a^2-b^2): berdinak izatean, 0

$b^2 = a_y^2 = \frac{\sqrt{5}}{4}$, $\frac{\sqrt{5}}{2}$

17/ $L_x \underset{\text{inkoh.}}{+} Z_L$ → polarizatzaile lineal baten aztertu da.

↳ Honen orientazioa aldatuz, transmititutako intentsitate maximoa I_{max} da.

Posizio horretatik P 45° biratuz, $\frac{3}{4} I_{max}$ lortzen da.

a) Kalkulatu bi osagaien intentsitatean, gainezarpenaren polarizazio maila eta polarizazio egoera.

$L_x = \begin{pmatrix}1\\0\end{pmatrix} \cdot a$ ↳ $I_1 = a^2$ $Z_L = \frac{1}{\sqrt{2}}\begin{pmatrix}1\\ i\end{pmatrix} b$

$\vec{S}_1 = (a \quad a \quad 0 \quad 0)$ $\vec{S}_2 = (b \quad 0 \quad 0 \quad -b)$

$\vec{S} = (a+b \quad a \quad 0 \quad -b)$ $(a+b)^2 = a^2+b^2+2ab > a^2+b^2$

$$\vec{S} = \left(a+b-\sqrt{a^2+b^2}\right)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}\sqrt{a^2+b^2}\\ a\\ 0\\ -b\end{pmatrix}$$

~~I_{max} → naturala erdira eta bestea berdin mantenduz~~

$$\underbrace{\frac{a+b-\sqrt{a^2+b^2}}{2}}_{\text{naturala}} + \sqrt{a^2+b^2} = \boxed{\frac{a+b+\sqrt{a^2+b^2}}{2} = I_{max}}$$

Gaizki, independenteki jarraituko balute bezala kalkulatu I_{max} hasieran, a eta b lortzeko.

Z_L → beti erdira. → $I_2 = \frac{b^2}{2}$

Suposatuko dugu I_{max} P_x-an lortzen dela.

$L_x \nearrow \overset{P_x}{I_{max}} \to a^2$

$\searrow I_{P_{45}} = \frac{a^2}{2}$

$I_{max} = \frac{b^2+2a^2}{2}$

$\frac{3}{4} I_{max} = \frac{a^2+b^2}{2}$

$\frac{I_{max}}{4} = \frac{a^2}{2}$

↳ $a^2 = \frac{I_{max}}{2}$ →

~~$b^2 = 3 I_{max}$~~

→ $\boxed{2a^2 = I_{max}}$

$\boxed{b^2 = I_{max}}$

$$\vec{S} = \frac{I_{max}}{2}\begin{pmatrix}1\\1\\0\\0\end{pmatrix} + I_{max}\begin{pmatrix}1\\0\\0\\-1\end{pmatrix} = I_{max}\begin{pmatrix}3/2\\1/2\\0\\-1\end{pmatrix}$$

$$\frac{9}{4} > \frac{5}{4} \qquad \cancel{\vec{S} = \left(\frac{3}{2} - \ldots\right)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}1/\sqrt{2}\\1/2\\0\\-1/2\end{pmatrix}}$$

$$\boxed{\vec{S} = I\left(\frac{3}{2} - \frac{\sqrt{5}}{2}\right)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}\sqrt{5}/2\\1/2\\0\\-1\end{pmatrix} I_{max}} \qquad \boxed{V = \frac{\sqrt{5}/2}{3/2} = \frac{\sqrt{5}}{3}}$$

$$S_0 = \frac{\sqrt{5}}{2} \qquad \frac{1}{2} = \frac{\sqrt{5}}{2}\cos(2\alpha) \rightarrow \boxed{\alpha = 31,72^\circ}$$

$$-1 = \frac{\sqrt{5}}{2}\sin(2\chi) \rightarrow \boxed{\chi = -31,72^\circ}$$ edo bestea agian!

$$\boxed{\delta = -90^\circ} \qquad \boxed{\psi = 0^\circ}$$

b) Hasierako gainezarpena koherentea eta fasean eginez gero, uhin anplitudeak eta gainezarpenaren pol.-egoera kalkulatu

a(I_{max}) eta b(I_{max}) berriro kalkulatu behar dira!

$$\cancel{|a\rangle = \frac{I_{max}}{2}\begin{bmatrix}1\\0\end{bmatrix}} \qquad |b\rangle = \frac{I_{max}}{\sqrt{2}}\begin{bmatrix}1\\+i\end{bmatrix}$$

$$\cancel{|E\rangle = \frac{I_{max}}{2}\left(\begin{bmatrix}1\\0\end{bmatrix} + \sqrt{2}\begin{bmatrix}1\\i\end{bmatrix}\right) = \frac{I_{max}}{2}\begin{bmatrix}1+\sqrt{2}\\ \sqrt{2}\, i\end{bmatrix}}$$

$$|1\rangle = a\begin{bmatrix}1\\0\end{bmatrix} \quad |2\rangle = \frac{b}{\sqrt{2}}\begin{bmatrix}1\\i\end{bmatrix} \Rightarrow |E\rangle = a\begin{bmatrix}1\\0\end{bmatrix} + \frac{b}{\sqrt{2}}\begin{bmatrix}1\\i\end{bmatrix} = \begin{bmatrix}a + b/\sqrt{2}\\ bi/\sqrt{2}\end{bmatrix}$$

$P_\alpha = \begin{bmatrix}\cos\alpha\\ \sin\alpha\end{bmatrix}$ izango dugu $\quad |E'\rangle = \begin{bmatrix}\left(a + \frac{b}{\sqrt{2}}\right)\cos\alpha \\ \frac{b i \sin\alpha}{\sqrt{2}}\end{bmatrix}$

$$I = \langle E' | E' \rangle = \left[\left(a+\frac{b}{\sqrt{2}}\right)\cos\alpha \quad -\frac{b\,i\sin\alpha}{\sqrt{2}} \right] \begin{bmatrix} \left(a+\frac{b}{\sqrt{2}}\right)\cos\alpha \\ \frac{b\,i\sin\alpha}{\sqrt{2}} \end{bmatrix}$$

$$I = \left(a+\frac{b}{\sqrt{2}}\right)^2\cos^2\alpha + \frac{b^2\sin^2\alpha}{2}$$

↳ I_{max} $\alpha = ?$

$$\frac{dI}{d\alpha} = 0 = -2\left(a+\frac{b}{\sqrt{2}}\right)^2\cos\alpha\sin\alpha + b^2\sin\alpha\cos\alpha$$

$$0 = \left[b^2 - 2\left(a+\frac{b}{\sqrt{2}}\right)^2\right]\sin\alpha\cos\alpha \quad \to \left.\begin{matrix}\alpha = 0^\circ \\ \alpha = 90^\circ\end{matrix}\right\} \text{a dib.}$$

~~dA~~ 2. Deribatua kalkulatu baino, goian ordezkatu (berez metodo praktikoa xamarra da, azterketan bai deribatua kalkulatu).

$\alpha = 0$-rekin lortzen da maximoa!

$$I_{max} = \left(a+\frac{b}{\sqrt{2}}\right)^2 = a^2 + \frac{2ab}{\sqrt{2}} + \frac{b^2}{2}$$

$$\frac{3}{4}I_{max} = \left(a+\frac{b}{\sqrt{2}}\right)^2\frac{1}{2} + \frac{b^2}{4} = \frac{a^2}{2} + \frac{ab}{\sqrt{2}} + \frac{b^2}{4} + \frac{b^2}{4} = \frac{a^2}{2} + \frac{b^2}{2} + \frac{ab}{\sqrt{2}}$$

↳ $I_{max}\frac{1}{2} + \frac{b^2}{4} = \frac{3}{4}I_{max} \to \frac{b^2}{\cancel{4}} = \frac{I_{max}}{\cancel{4}} \to \to \boxed{b = \sqrt{I_{max}}}$

$\sqrt{I_{max}} = a + \sqrt{\frac{I_{max}}{2}}$

↳ $\boxed{a = \sqrt{I_{max}}\left(1 - \frac{1}{\sqrt{2}}\right)}$

$$|E'\rangle = \begin{bmatrix} \sqrt{I_{max}}\left[1 - \frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right]\cos\alpha \\ \frac{\sqrt{I_{max}}}{\sqrt{2}}\,i\sin\alpha \end{bmatrix}$$

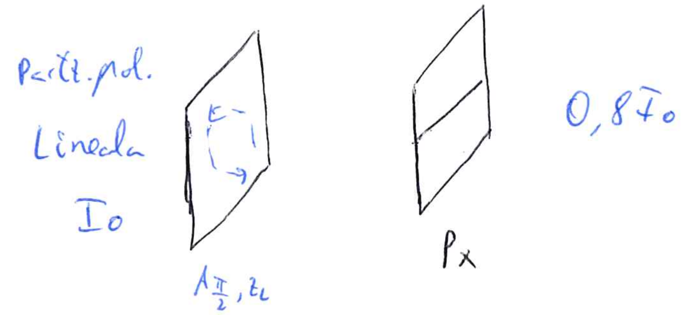
$$|E'\rangle = \sqrt{I_{max}}\begin{bmatrix} \cos\alpha \\ \frac{i\sin\alpha}{\sqrt{2}} \end{bmatrix}$$

18/ • I_0 intentsitateko partzialki polarizatutako argi linealak, desfasatzaile zirkular lebogiro bat ($A_{\frac{\pi}{2}}, z_L$) eta P_x bat zeharkatu ondoren, $0{,}8 I_0$ genuen bukaeran.

• $A \longleftrightarrow P$ lekualdatu gero, $0{,}5 I_0$ lortu da amaieran.

→ Hasierako argiaren polarizazio maila eta polarizazio egoera?

a)



$$\vec{S} = (I_0 - V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\a\\b\\c\end{pmatrix}$$

→ Lineala denez, zati polarizatuan $\delta = m\pi$ izango dugu

↳ $c = 0$

↳ $\boxed{\chi = 0}$

↳ $\boxed{\begin{matrix} a = \cos(2\psi) \\ b = \sin(2\psi) \end{matrix}}$

Beraz, oraingoz duguna:

$$\vec{S} = (I_0 - V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\a\\b\\0\end{pmatrix}$$

Ezezagunak: V, a, b.

a) Lehenik desfasatzaileak ez du eraginik intentsitatean,

$$\vec{S} = (I_0 - V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\\cos(2\psi)\\\sin(2\psi)\\0\end{pmatrix}$$ → desfasatzailetik pasatzean →

→ $\cos\left[2\left(\psi + \frac{\pi}{2}\right)\right] = -\cos(2\psi)$

$\sin\left[2\left(\psi + \frac{\pi}{2}\right)\right] =$

$$\vec{S} = (I_0 - V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\\cos(2\psi + \frac{\pi}{2})\\\sin(2\psi + \frac{\pi}{2})\\0\end{pmatrix}$$

$\cos\left[2\psi + \frac{\pi}{2}\right] = -\sin(2\psi)$

$\sin\left[2\psi + \frac{\pi}{2}\right] = \cos(2\psi)$

$$\vec{S} = (I_0 - V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\-\sin(2\psi)\\\cos(2\psi)\\0\end{pmatrix}$$

Kasu honetan, polarizatzailetik pasatzean: $\psi = \alpha$ izanik

$$\boxed{I_0 \cdot 0{,}8 = \frac{I_0 - V}{2} + I_0 \cos^2(\psi)}$$

$\psi = 22{,}5$ $\quad \psi' = 67{,}5$

$2\psi = 45$

$2\psi' = 135$

$\frac{\psi'}{\psi} = \frac{135}{45} \rightarrow \psi' = 3\psi$

$\psi' = 3\psi$

Bestea kortzeko:

$$\vec{S}_0 = (1-V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\\cos(2\psi)\\\sin(2\psi)\\0\end{pmatrix}$$

P_x pasatzean $\frac{1-V}{2}$

$$\vec{S}_0 = (1-V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\\cos(2\psi)\\\sin(2\psi)\\0\end{pmatrix}$$ dugu hasieran.

a) Kasuan $A_{\frac{\pi}{2}, z_c}$-tik pasatzean:

$$\vec{S}_a' = (\cancel{I_0}-V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\\cos[2\psi+\frac{\pi}{2}]\\\sin[2\psi+\frac{\pi}{2}]\\0\end{pmatrix} = (1-V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\-\sin(2\psi)\\\cos(2\psi)\\0\end{pmatrix}$$

$2\psi' = 2\psi + \frac{\pi}{2}$

P_x-tik pasatzean

$$\vec{S}_a'' = \left(\frac{I_0 - V}{2}\right)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \cos^2(2\psi')\begin{pmatrix}V\\1\\0\\0\end{pmatrix} \rightarrow I_0 \cdot 0{,}8 = \frac{I_0 - V}{2} + V\cos^2(2\psi')$$

$$I_0 \cdot 0{,}8 = \frac{I_0 - V}{2} + V\cos^2\left(2\psi + \frac{\pi}{2}\right)$$

b) Kasuan.

$$\vec{S}_b' = \frac{I_0 - V}{2}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \cos^2(2\psi)\begin{pmatrix}V\\1\\0\\0\end{pmatrix}$$

~~$\vec{S}_b'' = \frac{I_0 - V}{2}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \cos^2(2\psi)\begin{pmatrix}V\\0\\1\\0\end{pmatrix}$~~

$$I_0 \cdot 0{,}8 = \frac{I_0 - V}{2} + V\underbrace{\sin^2(2\psi)}_{\text{zati hauek}}$$

$$I_0 \cdot 0{,}8 = \frac{I_0 - V}{2} + V\underbrace{\cos^2(2\psi)}$$ gaizki daude!

$\cancel{1,3 I_0 = I_0 - V + V}$ $\qquad \cancel{I_0 \cdot 0,8 = 0,5 I_0 + 0,5 V - V \sin^2(2\psi)}$

$\cancel{0,3 I_0 = V \sin^2} \quad \cancel{\frac{1}{2} \arcsin\left(\sqrt{0,3\frac{I_0}{V} + 0,5}\right) = \psi}$

$\frac{1}{2} = \cos^2(2\psi)$

$\frac{1}{4} = \cos(2\psi)$

I_0

$\cancel{\vec{S}_b'' = \frac{I_0 - V}{2}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \cos 2\psi}$ $= \sin^2\left(\frac{\pi}{4} - \psi\right)$ $\qquad \psi' = \psi + \frac{\pi}{4}$ izanik.

$\cos^2\left(\psi + \frac{\pi}{4}\right)$

$$\vec{S}_a'' = \frac{I_0 - V}{2}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \overbrace{\cos^2(\psi')}^{=}\begin{pmatrix}V\\1\\0\\0\end{pmatrix}$$

$$\vec{S}_b'' = \frac{I_0 - V}{2}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \cos^2(\psi)\begin{pmatrix}V\\0\\1\\0\end{pmatrix}$$

$$\vec{S}_a'' = \frac{I_0 - V}{2}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \sin^2\left(\frac{\pi}{4} - \psi\right)\begin{pmatrix}V\\0\\1\\0\end{pmatrix}$$

$$I_0 \cdot 0,5 = \frac{I_0 - V}{2} + \cos^2(\psi) V$$

$$I_0 \cdot 0,8 = \frac{I_0 - V}{2} + \sin^2\left(\frac{\pi}{4} - \psi\right) V$$

→ Balio ezberdinak probatuz.

↳ $\cancel{I_0 \cdot 0,3 = \left[\cos^2(\psi) - \sin^2\left(\frac{\pi}{4} - \psi\right)\right] V}$

$$I_0 \cdot 0,3 = V\left[\cos^2(\psi) + \sin^2\left(\frac{\pi}{4} - \psi\right)\right]$$ → $I_0 = 1$ hartuz balioak probatuz.

↓

azkenean,

$V = 0,6 \quad \psi = -\frac{\pi}{4}$ lortuko da!

19/ • Polarizazio ezezaguneko argi-sorta batek P_{lineal} bat argiztatzen du.

• $I_t = I_A\left[1+2\cos^2(\psi-\frac{\pi}{4})\right]$ da neurtzen den intentsitatea,

$\psi=\psi(t)$ izanik.

a) U-Erasoztailea guztiz polarizatua dagoenean → pol.-egoera eta Intentsitatea kalkulatu.

$I_{t\,max} = 3I_A$ $\psi = \frac{\pi}{4}$ edo $\frac{5}{4}\pi$ denean.

$I_{t\,min} = I_A$ $\psi = \frac{3\pi}{4}$ edo $\frac{7\pi}{4}$ denean

Maximoa 45°-n minimoa 135°-gradun

$I = 3I_A$ eta L_{45} izango da. Gezurra! bestean 0 ez baita! Max $3I_A$ da eta min I_A

$I = 4I_A$ izango L_{45} ($\psi = 45°$) eta $\alpha = 45°$ X:

Beste era batera!

$\psi = \frac{\pi}{4} \to 3I_A$ $\psi = \frac{\pi}{2} \to 2I_A$ $\psi = 0 \to 2I_A$

$\psi = 0\ \alpha \to I_t = \left|\begin{pmatrix}1 & 0\end{pmatrix}\begin{bmatrix}\cos\alpha \\ \sin\alpha\, e^{-i\delta}\end{bmatrix}\sqrt{I_0}\right|^2 = 2I_A$

X-n egongo baita

$\boxed{\cos^2\alpha\ I_0 = 2I_A}$

$\psi = 45° \to I_t = \left|\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\end{bmatrix}\begin{bmatrix}\cos\alpha \\ \sin\alpha\, e^{-i\delta}\end{bmatrix}\sqrt{I_0}\right|^2 = 3I_A$

$\frac{1}{2}\underbrace{\left[\cos^2\alpha + \sin^2\alpha\right]}_{1} \cdot I_0 = 3I_A \to \boxed{I_0 = 6I_A}$

$\psi = 90° \to I_t = \left|\begin{bmatrix}0 & 1\end{bmatrix}\begin{bmatrix}\cos\alpha \\ \sin\alpha\, e^{-i\delta}\end{bmatrix}\sqrt{I_0}\right|^2 = 2I_A \to \sin^2\alpha \cdot I_0 = 2I_A$

$\sin^2\alpha \cdot 6I_A = 2I_A$ $\frac{1}{3}$

(19/segida)

$$|E\rangle = \sqrt{I}\begin{pmatrix}\cos\alpha \\ \sin\alpha\, e^{-i\delta}\end{pmatrix} \qquad P = \begin{bmatrix}\cos^2\varphi & \cos\varphi\sin\varphi \\ \cos\varphi\sin\varphi & \sin^2\varphi\end{bmatrix}$$

$\sqrt{I} \downarrow ?$

$I_{t\,max} = 3I_A \quad \varphi = \frac{\pi}{4}$; $I_{min} = I_A \quad \varphi = \frac{3\pi}{4}$ denean.

Argia guzti polarizatua dagoenez eta $min \neq 0$ $\neq max$ denez, argia eliptikoki polarizatua dago!

$3I_A = a^2 \rightarrow \chi = 2\arctan\left(\frac{b}{a}\right) \rightarrow \boxed{\chi = \pm\frac{\pi}{6}}$

$I_A = b^2$

Intentsitatea: $a^2 + b^2 = 4I_A$

b) U-eras. partzialki pol. badago (zati p. linealki p. egonik) zenbatekoa da V?

$V = ?$ $\quad I_{max} = 3I_A \quad \varphi = \frac{\pi}{4}$ denean $\quad I_{min} = I_A \Rightarrow \frac{3}{4}\pi = \varphi$ denean.

Naturala beti erdira gaitsi!

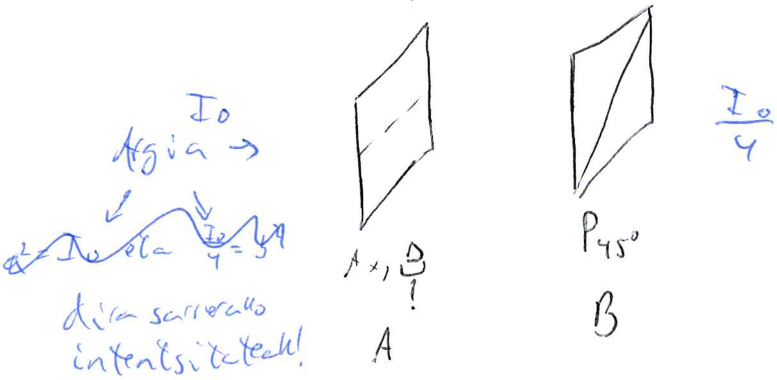
$I_t = \frac{I_o}{2} + I_o\cos^2(\varphi - \frac{\pi}{4})$ izango dugu orain.

$3I_A = \frac{I_N}{2} + I_P \rightarrow 3I_A = I_A + I_P \rightarrow \boxed{I_P = 2I_A}$

$I_A = \frac{I_N}{2} \rightarrow \boxed{I_N = 2I_A}$ $\qquad V = \frac{2I_A}{2I_A \cdot 2} \rightarrow \boxed{V = \frac{1}{2}}$

20/ · Guztiz polarizatutako argia: $\alpha = 45°$, $\delta = 30°$ → $\psi = 20,45°$ $\chi = 15°$

$V = 1$ duen eliptikoki polarizatutako argia dugu.



Desfasatzailearen desfasea?

$$P_{45} = \frac{1}{2}\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix} \qquad A_{x,\delta} = \begin{bmatrix} e^{-i\delta} & 0 \\ 0 & 1 \end{bmatrix}$$

$$|E\rangle = \cancel{\cos\alpha} \qquad \cos\alpha = \frac{\sqrt{2}}{2} \quad \sin\alpha = \frac{\sqrt{2}}{2} \qquad \delta = 30° = \frac{\pi}{6}\,\text{rad}.$$

$$|E\rangle = \frac{\sqrt{2}}{2}\sqrt{I_0}\begin{bmatrix} 1 \\ e^{-i\pi/6} \end{bmatrix}$$

$$|E'\rangle = P_{45} A_{x,\delta} |E\rangle = \frac{1}{2}\frac{\sqrt{2}}{2}\sqrt{I_0}\begin{pmatrix} e^{-i\delta} & 1 \\ e^{-i\delta} & 1 \end{pmatrix}\begin{pmatrix} 1 \\ e^{-i\frac{\pi}{6}} \end{pmatrix} = \frac{\sqrt{2}}{4}\sqrt{I_0}\begin{pmatrix} e^{-i\delta} + e^{-i\frac{\pi}{6}} \\ e^{-i\delta} + e^{-i\frac{\pi}{6}} \end{pmatrix}$$

$$I' = \langle E'|E'\rangle = \frac{1}{8} I_0 \left[(e^{i\delta} + e^{i\frac{\pi}{6}}) \quad (e^{i\delta} + e^{i\frac{\pi}{6}}) \right] \begin{bmatrix} e^{-i\delta} + e^{-i\frac{\pi}{6}} \\ e^{-i\delta} + e^{-i\frac{\pi}{6}} \end{bmatrix}$$

$$I' = \frac{I_0}{\cancel{8}4}\left[1 + e^{i(\delta - \frac{\pi}{6})} + e^{-i(\delta - \frac{\pi}{6})} + 1 \right]\cdot \cancel{2} = \frac{I_0}{4}\left[2 + 2\cos(\delta - \tfrac{\pi}{6})\right]$$

$$I' = \frac{I_0}{4} = \frac{I_0}{4}\underbrace{\left[2 + 2\cos(\delta - \tfrac{\pi}{6})\right]}_{1} \Rightarrow 1 = 2\left[1 + \cos(\delta - \tfrac{\pi}{6})\right] \rightarrow$$

edo $-\delta + \frac{\pi}{6} = \frac{2}{3}\pi \rightarrow \delta = -\frac{\pi}{2}\,\text{rad} = -90°$

$$\rightarrow \frac{1}{2} - 1 = \cos(\delta - \tfrac{\pi}{6}) = -\frac{1}{2} \rightarrow \delta - \frac{\pi}{6} = \frac{2\pi}{3} \rightarrow \delta = \frac{4\pi + \pi}{6}$$

$\delta = \frac{5\pi}{6}$ da desfasea $= 150°$

22/ • $v = 1$ eta Z_D dugu $I_{Z_D} = I_0$ izanik.

$$Z_D \rightarrow A_{x,\frac{\pi}{2}} \xrightarrow[I_0]{L_{45}} P_{45} \xrightarrow[I_0]{L_{45}} A_{y,\frac{\pi}{2}} \quad \begin{matrix} Z_D \\ I_0 \end{matrix}$$

a) Jonesen algebra erabiliz, irteerako int + pol. eg. kalkulatu.

1. Poincaré-rekin egingo dut, gero emaitza kontrastatzeko.

$$|E\rangle = \sqrt{I_0}\,\frac{1}{\sqrt{2}}\begin{pmatrix}1\\-i\end{pmatrix} \qquad A_{y,\frac{\pi}{2}} = \begin{pmatrix}1 & 0\\0 & -i\end{pmatrix} \qquad A_{x,\frac{\pi}{2}} = \begin{pmatrix}-i & 0\\0 & 1\end{pmatrix} \qquad P_{45} = \frac{1}{2}\begin{pmatrix}1 & 1\\1 & 1\end{pmatrix}$$

$$|E'\rangle = A_{y,\frac{\pi}{2}} P_{45} A_{x,\frac{\pi}{2}} |E\rangle = \frac{1}{2}\begin{pmatrix}1 & 1\\-i & -i\end{pmatrix}\begin{pmatrix}-i & 0\\0 & 1\end{pmatrix}\sqrt{\frac{I_0}{2}}\begin{pmatrix}1\\-i\end{pmatrix}$$

$$|E'\rangle = \frac{1}{2}\sqrt{\frac{I_0}{2}}\begin{pmatrix}-i & 1\\-1 & -i\end{pmatrix}\begin{pmatrix}1\\-i\end{pmatrix} = \frac{1}{2}\sqrt{\frac{I_0}{2}}\begin{pmatrix}+2i\\-2i\end{pmatrix} = \frac{\sqrt{I_0}}{\sqrt{2}}\begin{pmatrix}1\\-i\end{pmatrix}$$

$|E'\rangle \rightarrow I_0$ intentsitateko Z_D dugu

b) Kalkulatu irteerako argiaren eta zirkularki polarizatutako argi lebogiroaren ($I_{ZL} = I_0$) gainezarpen inkoherentearen egoera.

$$\vec{S}_a = (1 \quad 0 \quad 0 \quad 1) \qquad \vec{S}_b = (1 \quad 0 \quad 0 \quad -1)$$

$\vec{S} = (2 \quad 0 \quad 0 \quad 0) \rightarrow I = 2I_0$-ko argi aleatorioa

c) P_{30} zeharkatzean, b) -ko argiak ematen duen I eta argi mota?

$I = I_0$ -ko ~~...~~ L_{30} argi guztiz polarizatua izango dugu.

2 4/5

• PP argi lineala: $I = I_0$, $V = V_0$ $\quad z_L$ da!

$$V_0 = \frac{I_0}{I_N + I_0}$$

$$\hookrightarrow I_N = \frac{I_0}{V_0} - I_0$$

$$\boxed{I_N = I_0\left(\frac{1}{V_0} - 1\right)}$$

$$\xrightarrow{z_L} \overset{A}{P_{z_D}} \xrightarrow[\theta]{z_D} \overset{B}{A}, \frac{\pi}{2} \longrightarrow \overset{C}{P_{\frac{\pi}{4}}}, \text{lineala} \rightarrow$$

↳ Sfitik naturala pasatzen da!

Itsatsita, 1. aren egoera lasterra bigarrenaren Lineala gardena izan dadin.

Irteerako argiaren I azken bien orientazioaren arabera?

~~$I_N = I_0\left(\frac{1}{V_0} - 1\right)$~~ $I_N = (1 - V_0) I_0$

~~B~~ A ondoren $\quad I_N = \frac{1 - V_0}{2} I_0$ eta z_D

↳ B C → $I_N = \frac{1 - V_0}{4} I_0$ izango da edozein orientaziotan B-k, egoera lineal batera pasatzen baitu eta ~~edozein~~ C-n erdia kentzen ~~baitzaio~~ zaio, ortogonala ez den (edo berdina) orientazio izango baitu.

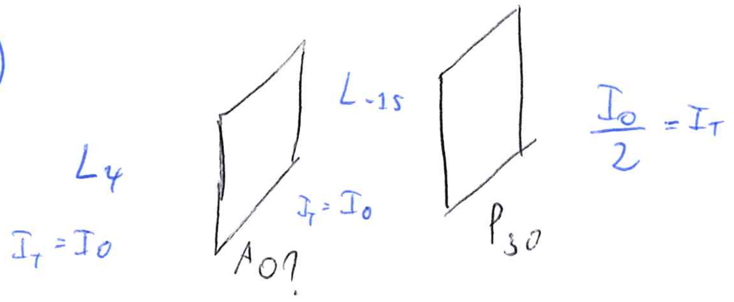
24/ • PP argi linealal! $I = I_0$, $V = 0,6$ dugu → $A_{??}$ bat eta P_{30} bat zeharkatu.

↳ $I' = \frac{I_0}{2}$ dugu.

• Dispositiboak errotatuz, $I = 0,35 I_0$ dugu.

• Sarrerako argiaren polarizazioa eta A-ren ezaugarriak?

a)



$I_N' = \frac{I_N}{2} = 0,2 I_0$

$I_T = \underbrace{I_0 \cdot 0,4}_{I_N} + \underbrace{I_0\, 0,6}_{I_P} = I_0$

$I_p' = ?$

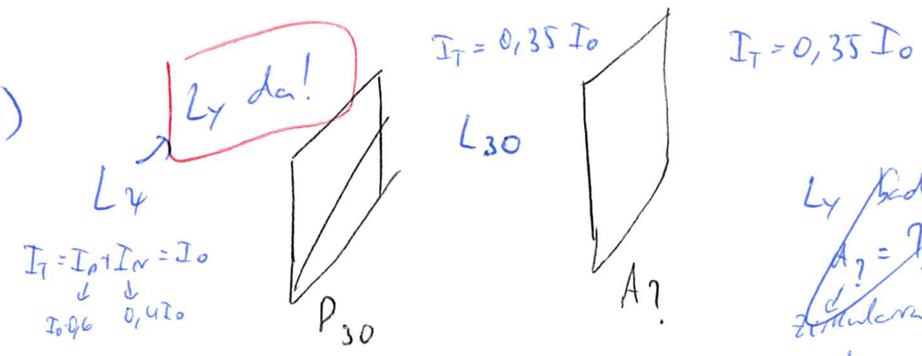
$I_N' + I_p' = I_0 \cdot 0,5 = 0,2 I_0 + I_p'$ → $I_p' = 0,3 I_0$

$I_p' = 0,3 I_0 = I_p \cdot \cos^2(\gamma) = I_0 \cdot 0,6 \cdot \cos^2(\gamma)$ → $\frac{1}{2} = \cos^2(\gamma)$

↳ $\gamma = 45$ izanik →

→ L_{-15} izango da tartean!

b)



L_Y bada sarrerakoa, $A_? = ?$ → L_{-15} atera dadin? zirkularra da!

↳ L_{-15} hola da?

$I_N' = 0,2 I_0$

$I_p' = 0,35 I_0 - 0,2 I_0 = 0,15 I_0 = I_p \cos^2(\gamma)$

$0,15 I_0 = 0,6 I_0 \cos^2(\gamma)$ → L_Y da sarrerakoa! → edo L_{-30} !

↳ $\gamma = 60°$

Sarreran: L_y Irteeran: L_{-15} Desfasatzailea biraketarra.

~~Irten~~ $A = ?$ $L_{-15} = ?$

$\hookrightarrow \delta = m\pi$; $\chi = 0 \Rightarrow \psi = \alpha = -15^\circ$

$\psi = -15^\circ$

$\sin(2\psi) = \sin(2\alpha)$

$\cos(2\psi) = \cos(2\alpha)$

$$L_{-15} = \begin{bmatrix} \cos 15 \\ -\sin(15) \end{bmatrix}$$

$A \Rightarrow$ A_{z_L} aukeratuko dut,

$$\begin{bmatrix} \cos 15 \\ -\sin 15 \end{bmatrix} = \begin{pmatrix} \cos\frac{\Delta}{2} & -\sin\frac{\Delta}{2} \\ \sin\frac{\Delta}{2} & \cos\frac{\Delta}{2} \end{pmatrix} \begin{pmatrix} 0 \\ 1 \end{pmatrix} = \begin{matrix} -\sin\left(\frac{\Delta}{2}\right) \\ \cos\left(\frac{\Delta}{2}\right) \end{matrix} \Rightarrow$$

$\Rightarrow \Delta = -150^\circ$

Sarreran: L_{-30} Irteeran, L_{-15} Desf.?

$\downarrow$

$\delta = m\pi$ $\chi = 0$

$\psi = \alpha = -30$

$\downarrow$

$$\begin{pmatrix} \cos 15 \\ -\sin(15) \end{pmatrix} = \begin{pmatrix} \cos\frac{\Delta}{2} & -\sin\frac{\Delta}{2} \\ \sin\frac{\Delta}{2} & \cos\frac{\Delta}{2} \end{pmatrix} \begin{pmatrix} \cos 30 \\ -\sin 30 \end{pmatrix} \rightarrow \text{Zailagoa da!}$$

Islapena eta Errefrakzioa

X1/ Lortu Brewsterren erasorako islapen- eta transmisio-faktoreak, eta egiaztatu ondorengo erlazioa betetzen dela:

$$T_\perp + R_\perp = T_\parallel + R_\parallel = 1$$

$$r_\perp = -\frac{\sin(\theta_i-\theta_t)}{\sin(\theta_i+\theta_t)} = -\sin(\theta_i-\theta_t) = \cancel{-\sin(\theta_B - 2\theta_t) = -\sin\left(\tfrac{\pi}{2}\right)\cos(2\theta_t) + \sin(2\theta_t)\cos\left(\tfrac{\pi}{2}\right)}$$

Brewsterren $\theta_i + \theta_t = \frac{\pi}{2}$

$$= -\sin\Big(2\theta_i - \underbrace{\tfrac{\pi}{2}}_{(\theta_i+\theta_t)}\Big)$$

$$\cancel{r_\perp = -\cos(2\theta_t)}$$

$$r_\perp = -\sin(2\theta_i)\underbrace{\cos\left(\tfrac{\pi}{2}\right)}_{0} + \cos(2\theta_i)\sin\left(\tfrac{\pi}{2}\right) \rightarrow r_\perp = \cos 2\theta_i = \cos^{\pi}(2\theta_B)$$

$$R_\perp = \cos^2(2\theta_B)$$

$$r_\parallel = \frac{\tan(\theta_i-\theta_t)}{\underbrace{\tan(\underbrace{\theta_i+\theta_t}_{90})}_{\infty}} = 0 \rightarrow \boxed{r_\parallel = R_\parallel = 0}$$

$$t_\perp = \frac{2\sin\theta_t\cos\theta_i}{\sin(\theta_i+\theta_t)} = 2\sin\theta_t\cos\left(\tfrac{\pi}{2}-\theta_t\right) = 2\sin^2\theta_t$$

$$= 2\sin\left(\tfrac{\pi}{2}-\theta_i\right)\cos\theta_i = 2\cos^2\theta_i = 2\cos^2\theta_B$$

$$t_\perp = 2\cos^2\theta_B \qquad \cancel{T_\perp = 4\cos^2\theta_B}$$

T-en kasuan ez da kalkulatu!

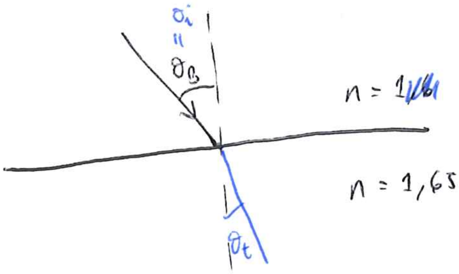
$$t_\parallel = \frac{2\sin\theta_t\cos\theta_i}{\cos(\theta_i-\theta_t)} = \frac{2\sin\theta_t\cos\theta_i}{\cos\left(\frac{\pi}{2}-2\theta_t\right)} = \frac{2\sin\theta_t\cos\theta_i}{\sin 2\theta_t} =$$

$$t_\parallel = \frac{\cos\theta_i}{\sin\theta_t} \overset{?}{=} \frac{\cos\theta_B}{\sin\theta_B} = \frac{1}{\tan\theta_B} = \frac{n_1}{n_2}$$

$\theta_i = \theta_t = \theta_B$

EZ DIOT SEGI FROGAPEN TEORIKOA DELAKO.

2/



→ Transmitantzia?

→ Trans.-tako argiaren pol. egoera?

$\mathcal{T}$? V?

Brewster erasoan: $\theta_i + \theta_t = \frac{\pi}{2}$ $\quad \tan\theta_B = \frac{n_2}{n_1} \Rightarrow \boxed{\theta_B = 58{,}78^\circ}$

Eraso angelu hau erabiliz, argi naturaletik argi ~~pa~~ guztiz polarizatua lor daiteke (islatutako zatian).

$\boxed{\theta_t = 31{,}22^\circ}$ $\quad \boxed{\mathcal{T}_\perp} = \frac{\sin(2\theta_B)\sin(2\theta_t)}{\sin^2(\theta_i+\theta_t)} = \boxed{0{,}786}$

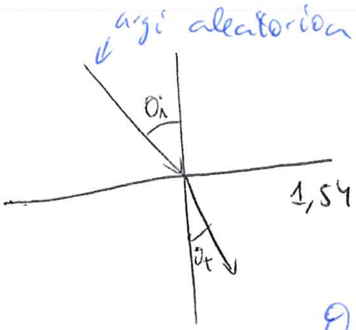
$\boxed{\mathcal{T}_\parallel = 1}$ $\quad \boxed{\mathcal{T} = \frac{1}{2}\left(\mathcal{T}_\perp + \mathcal{T}_\parallel\right) \text{ argi naturalean!}}$

$\boxed{\mathcal{T} = 0{,}893}$

$R_\parallel = 0$ izango da, islatutakoa guztiz polarizatua egongo delarik

$V = \left|\frac{\mathcal{T}_\perp - \mathcal{T}_\parallel}{\mathcal{T}_\perp + \mathcal{T}_\parallel}\right| \rightarrow$ V = 0,12 da polarizazio maila, $\mathcal{T}_\perp \neq \mathcal{T}_\parallel$ izanik, argia partzialki polarizatutako lineala izango delarik.

4/



→ Islagarritasuna, transmitantzia, eta islatu eta transmitituaren egoerak, θ_i ezberdinetarako?

$$\theta_B = \arctan(1,54) = 57^\circ$$

a) $\theta_i = 30^\circ \rightarrow \theta_t = 18,95^\circ$

$R_\perp = 0,06$ $\qquad R_\parallel = 0,03$

$T_\perp = 0,94$ $\qquad T_\parallel = 0,971$

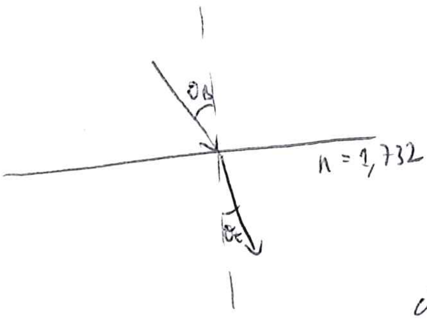
$$\boxed{R = \frac{1}{2}(R_\perp + R_\parallel) = 0,045 \qquad T = \frac{1}{2}(T_\perp + T_\parallel) = 0,9555}$$

Islatuan $V = \left| \frac{R_\perp - R_\parallel}{R_\perp + R_\parallel} \right| \rightarrow \boxed{V = \frac{1}{3}}$ Argia p.p. argi lineala ⊥

Transmitituan $V = \left| \frac{T_\perp - T_\parallel}{T_\perp + T_\parallel} \right| = \boxed{0,02 = V}$ argia p.p. argi lineala ∥

b) eta c) jarraitzeko egitea litzateke.

5/ Lortu, Brewsterren erasorako, islagarritasuna eta arg. isl.-ren egoera:



~~Egoera~~ Eraso ezberdinetarako

~~a)~~ ~~Arg~~ $\arctan(1,732) = \boxed{\theta_B = 60^\circ \quad \theta_t = 30^\circ}$

a) Argi aleatoriorako

erl. betetzen dira!

$R_\perp = 0,25$

$R_\parallel = 0$

$T_\perp = 0,75$

$T_\parallel = 1$ ⇐ ez dira Kalkulatu ber!

→ $\boxed{R = 0,125 \rightarrow V = 1}$ Argia guztiz linealki pol. (⊥)

$T = 0,875 \rightarrow V = \frac{1}{7}$ Argia p.p. linealki pol (∥)

b) L_{45} ~~k~~ c) τ_D d) Eliptikoki pol. ($\alpha=45°$)

¿ ~~a)~~ Zatiko berdina prozedura bera delako.

$\underbrace{R_{\parallel}=0}_{\text{Brewster baita!}}$, $R_{\perp}=0{,}25$ $\quad R = R_{\perp}\underbrace{\cos^2(\alpha_i)}_{\frac{1}{2}} + \underbrace{R_{\parallel}}_{0}\sin^2(\alpha_i)$ $\quad \alpha_i = 45$

a) eta c) -ko bera emango du!

6/ Aurreko arilketakoa, transmititzeko.

Beti: $T_{\perp}=0{,}75$ $\quad T_{\parallel}=1$

a) Argi naturalerako: $V=\frac{1}{7}$ $\quad T=0{,}875$ $\quad$ a p.p. lineala da ($\parallel$)

b) L_{45} c) τ_D d) ~~Elip.~~ pol. ($\alpha=45°$)

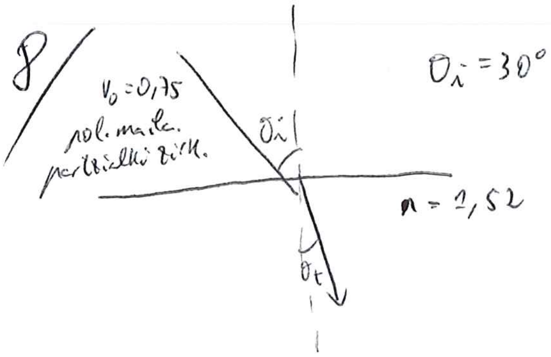
$$\frac{R_{\parallel}}{R_{\perp}} = \tan\alpha_r \, e^{-i\delta_r} = -\frac{\cos(\theta_i+\theta_t)}{\cos(\theta_i-\theta_t)}\tan(\alpha_i)\, e^{-i\delta_i} = 0$$

~~$\frac{T_{\parallel}}{T_{\perp}} = \frac{4}{3}$~~ $\quad \frac{T_{\parallel}}{T_{\perp}} =$ ~~$\frac{2\sin\theta_t A_{\parallel}}{A_{\perp}} \frac{\cos(\theta_i+\theta_t) A_{\parallel}}{\sin(\theta_i+\theta_t)\cos(\theta_i-\theta_t) A_{\perp}}$~~ $=$

$$\frac{T_{\parallel}}{T_{\perp}} = \frac{4}{3} = \tan(\alpha_t)\, e^{-i\delta_t} \rightarrow \alpha_t = 53{,}13°$$

Nola dakigu guztiz polarizatua dela?

8



Islageritasuna eta argi islatuaren polarizazio egoera?

$$\boxed{\theta_r = \theta_i = 30°}$$

$$\boxed{\theta_t = 19{,}20°}$$

$$R_\perp = \frac{\sin^2(\theta_i - \theta_t)}{\sin^2(\theta_i + \theta_t)} = 0{,}061$$

$$R_\parallel = 0{,}0327$$

$$\boxed{R_p = R_N = \frac{1}{2}\left(R_\perp + R_\parallel\right) = 0{,}044}$$

$$\vec{S} = 0{,}25 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0{,}75 \\ 0 \\ 0 \\ 1 \end{pmatrix}$$

$$\boxed{R = (1-V)\, R_N + V R_p = 0{,}044}$$

Argi ~~is~~ islatuaren polarizazio egoera:

- Naturaletik datorrena:

$$V = \left| \frac{R_\perp - R_\parallel}{R_\perp + R_\parallel} \right| = 0{,}39 \rightarrow$$

~~Alde~~ partzialki polarizatutako argi lineala $(\perp)$

- Uhin-erasotzaile polarizatutik datorrena:

$$\tan(\alpha_r)\, e^{-i\delta_r} = -\frac{\cos(\theta_i + \theta_t)}{\cos(\theta_i - \theta_t)} \tan(\alpha_i)\, e^{-i\delta_i}$$

Datorrena zirkularra izanik, $\boxed{\delta_i = \pm\frac{\pi}{2} \qquad \alpha_i = 45°}$

$$\tan(\alpha_r)\, e^{-i\delta_r} = -0{,}6652\, e^{\mp i \frac{\pi}{2}} = 0{,}6652\, e^{\pm i \frac{\pi}{2}}$$

$$\boxed{\alpha_r = 33{,}63° \qquad \delta_r = \mp \frac{\pi}{2}\ \text{rad}}$$

$V' = 0,4 \rightarrow$ baina zergatik posizio horretan?

$$\dot{V}_0 R_P \begin{pmatrix} 1 \\ 0,39 \\ 0 \\ \mp 0,92 \end{pmatrix} + (1 - V_0) R_N \begin{pmatrix} 1 \\ V' \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0,044 \\ 0,017 \\ 0 \\ \mp 0,03 \end{pmatrix} \rightarrow \boxed{V = \frac{\sqrt{0,017^2 + 0,03^2}}{0,044} = 0,783}$$

$\cos(2\alpha_r) = 0,39$

$\sin(2\alpha_r)\sin(\delta) = \mp 0,92$

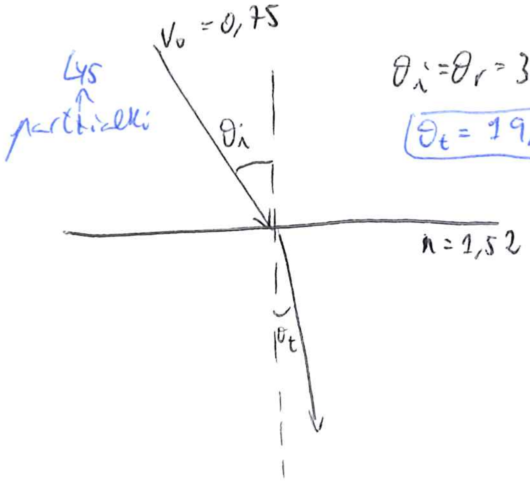
$$0,044 \begin{pmatrix} 1 \\ 0,386 \\ 0 \\ \mp 0,68 \end{pmatrix} = 0,044 \left[\begin{pmatrix} 0,75 \\ 0,318 \\ 0 \\ \mp 0,68 \end{pmatrix} + 0,25 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} \right]$$

$0,318 = 0,75 \cdot \cos(2\alpha) \quad = 0,75 \cdot \cos(2\chi)\cos(2\psi)$

$0 = \cos(2\chi)\sin(2\psi) \rightarrow \boxed{\psi = 0}$

$\mp 0,68 = \overset{0,75}{1} \sin(2\chi) \rightarrow \boxed{\chi = \mp 32,52^\circ}$

4/ Errepikatu ariketa argi erasotzailea 45°-rako partzialki lineala denean.



$\theta_i = \theta_r = 30°$

$\boxed{\theta_t = 19,2°}$

$$\left.\begin{array}{ll} R_\perp = 0,061 & R_\parallel = 0,027 \end{array}\right\} \text{lehenokoak}$$

$$R = R_p V_0 + (1 - V_0) R_N$$

$$R_N = \frac{1}{2}(R_\perp + R_\parallel) = 0,044135 = R_p$$

$L_{45} \to \alpha = 45°$ denez

$\cancel{R = 0,044135}$

$$\boxed{R = 0,044135}$$

Polarizazio egoera

- Aleatorioan

$$\boxed{V = 0,\ [illegible]386}$$

$$R_N(1 - V_0)\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

- L_{45} p.p.-an

$\alpha = 45 = \psi$, $\chi = 0$ $\quad \delta = 0$

$$-\tan(45)\, e^{i\cdot 0}\, \frac{\cos(49,2°)}{\cos(10,8°)} = -0,66520 = +\tan(\alpha_r)\, e^{i\delta_r} \to$$

$$\to \boxed{\alpha_r = 33,63° \quad \delta_r = \pi \text{ rad}}$$

$$\boxed{V = 0,7925}$$

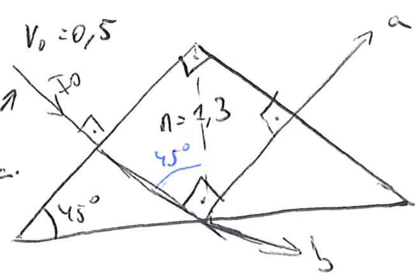
$$R_p V_0 \begin{pmatrix} 1 \\ 0,395 \\ -0,919 \\ 0 \end{pmatrix} + R_N(1 - V_0)\begin{pmatrix} 1 \\ V' \\ 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0,044135 \\ 0,0173 \\ -0,0304 \\ 0 \end{pmatrix}$$

$$0{,}044135\begin{pmatrix}1\\0{,}392\\-0{,}689\\0\end{pmatrix} = 0{,}044135\left[(1-V)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}V\\0{,}392\\-0{,}689\\0\end{pmatrix}\right]$$

$\alpha = 30{,}17^\circ$ $\delta = 0$ ~~aldatu~~

$\chi = 0^\circ$ $\psi = -30{,}17^\circ$

10/



1. argi lineala

bere bektoreak $\psi = 45^\circ$-ko angelua osatu irudiaren planoarekin

a) a-ren I, pol. egoera eta pol. maila?

Eraso perpendikularra: $R_\perp = R_\parallel$

$\theta_i = 0 = \theta_r$

$\theta_t = 0$

$\cancel{\gamma_\perp =}$ $\cancel{\gamma_\parallel =}$ $\gamma = \dfrac{4 n_1 n_2}{(n_1+n_2)^2}$

$\downarrow$

$\boxed{\gamma_1 = 0{,}983}$

$$\vec{S}_0 = I_0\, 0{,}5\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \begin{pmatrix}0{,}5\\0\\1\\0\end{pmatrix} I_0$$

$$\hookrightarrow \vec{S}_1 = I_0\, 0{,}5\,\gamma_1\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + I_0\, 0{,}5\,\gamma_1\begin{pmatrix}1\\0\\1\\0\end{pmatrix}$$

Orain $\theta_i = 45^\circ = \theta_r$ $\longrightarrow$ $R_\perp = 0{,}1603$ $\rightarrow$ $\left[R_N = \overset{R_2}{\overset{\parallel}{R_p}} = \dfrac{R_\perp + R_\parallel}{2} = 0{,}093\right]$

$\theta_t = 66{,}82^\circ$ $R_\parallel = 0{,}0257$

$\vec{S}_1 \to$ zati polarizatuna ea aldatu den ikusi behar da.

$\boxed{\begin{matrix}\alpha_i = 45^\circ\\ \delta_i = 0\,\text{rad}\end{matrix}}$ $0{,}4\,e^{i\cdot 0} = \tan(\alpha_r)\,e^{i\delta_r} \rightarrow \boxed{\begin{matrix}\delta_r = 0\\ \alpha_r = 21{,}8^\circ\end{matrix}}$

$$\vec{S}_2 = I_0 \cdot 0{,}5 \cdot \Upsilon_1 \cdot R_{N_2} \begin{pmatrix} 1 \\ V \\ 0 \\ 0 \end{pmatrix} + I_0 \; 0{,}5 \, \Upsilon_1 R_2 \begin{pmatrix} 1 \\ 0{,}724 \\ 0{,}690 \\ 0 \end{pmatrix}$$

$$V = \left| \frac{R_\perp - R_\parallel}{R_\perp + R_\parallel} \right| = 0{,}72365$$

$$\vec{S}_3 = I_0 \Upsilon_1^2 R_2 \left[\begin{pmatrix} 1 \\ V \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 1 \\ 0{,}724 \\ 0{,}690 \\ 0 \end{pmatrix} \right] 0{,}5$$

Υ_1

izango denez berriz

$$\vec{S}_3 = \frac{I_0 \Upsilon_1^2 R_2}{2} \begin{pmatrix} 2 \\ 1{,}44 \\ 0{,}69 \\ 0 \end{pmatrix} = I_0 \begin{pmatrix} 0{,}089 \\ 0{,}0647 \\ 0{,}031 \\ 0 \end{pmatrix} = 0{,}089 I_0 \begin{pmatrix} 1 \\ 0{,}727 \\ 0{,}348 \\ 0 \end{pmatrix}$$

$$V_3 = \frac{\sqrt{0{,}0647^2 + 0{,}031^2}}{0{,}089} \rightarrow \boxed{V_3 = 0{,}806}$$

$$\boxed{I_{bul} = 0{,}089 I_0}$$

$$\vec{S}_3 = I_0 (1 - V_3) \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + I_0 \begin{pmatrix} V_3 \\ 0{,}0647 \\ 0{,}031 \\ 0 \end{pmatrix}$$

$$0{,}0647 = 0{,}806 \cdot \cos(2\alpha) = 0{,}0806 \cos(2\chi) \cos(2\psi)$$

$$\boxed{\alpha = 42{,}698^\circ} \qquad \boxed{\chi = 0^\circ \qquad \psi = \alpha}$$

$$\boxed{\delta = \cancel{64{,}35^\circ}}$$

Han galdetu!! tela da $\cos(2\alpha) = 0{,}727$ eta ez $0{,}806 \cos(2\alpha) = 0{,}0647$

~~Hail Satan~~

$$\vec{S}_3 = 0{,}089 I_0 \left[(1 - V_3) \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} V_3 \\ 0{,}727 \\ 0{,}348 \\ 0 \end{pmatrix} \right]$$

$$a\cos(0{,}727) \cdot \frac{1}{2} = \boxed{\begin{matrix} \alpha = 12{,}79^\circ = \psi \\ \delta = 0^\circ \\ \chi = 0^\circ \end{matrix}}$$

b) Uhin-erasotzaileeren V_0 mantenduz, kalkulatu bere polarizatio egoera b argi sortzen atal polarizatuaren orientazioa 45°-koa izandadin!

$$\boxed{\theta_i = 45° \quad \theta_t = 66{,}82°}$$

$\gamma_1 = 0{,}983$

$$\vec{S}_0 = I_0 \cdot 0{,}5 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + I_0 \begin{pmatrix} 0{,}5 \\ \cos(2\alpha) \\ \sin(2\alpha)\cos\delta \\ \sin(2\alpha)\sin\delta \end{pmatrix}$$

$$\vec{S}_1 = I_0\, 0{,}5\, \gamma_1 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + I_0 \gamma_1 \begin{pmatrix} 0{,}5 \\ \cos(2\alpha_i) \\ \sin(2\alpha_i)\cos\delta \\ \sin(2\alpha_i)\sin\delta \end{pmatrix}$$

$\gamma_\perp = 0{,}8397$ $\qquad \gamma_{2n}^{ideat} = 0{,}907$

$\gamma_\parallel = 0{,}9743$

$$\gamma_{2n} = \gamma_\perp \cos^2\alpha_i + \gamma_\parallel \sin^2\alpha_i$$

$$1{,}0772 \tan\alpha_i\, e^{-i\delta_i} = \tan(45)\, e^{-i\overset{0}{\delta_t}}$$

$$\cancel{\vec{S}_2 = I_0\, 0{,}5\, \gamma_1 \gamma_{2n} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + I_0 \gamma}$$

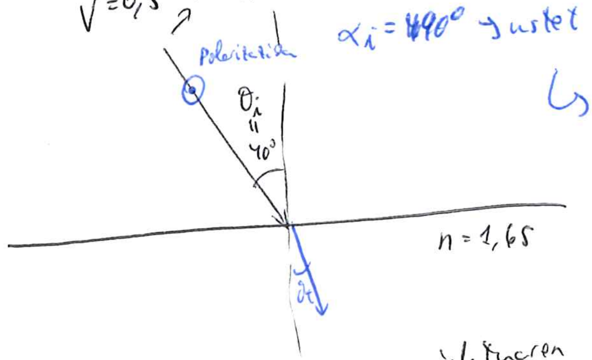
$\alpha_i = 42{,}87°$

$\delta_i = 0°$

$\tan(42{,}87)$

11/

$V=0{,}5$ → Ni. sorta lineala.



$\alpha_i = 90°$ justet enao seguru.

↳ Bai! $\cancel{\boxed{\alpha_i = 90°}}$

$\alpha_i = 0°$ da!

a) Islagarritasuna, argi islatuaren pol maila eta honen pol. egoera.

$\theta_B = 58{,}78°$ $\boxed{\theta_t = 22{,}93°}$

$\boxed{R_\perp = 0{,}109}$ $\boxed{R_\parallel = 0{,}025}$

$$R_N = \frac{1}{2}(R_\perp + R_\parallel) = 0{,}067$$

$$R_p = R_\perp \cdot \cos^2(\alpha_i) + R_\parallel \sin^2(\alpha_i) = R_\parallel = \cancel{0{,}025}\ 0{,}109$$

$$R = R_N \cdot 0{,}5 + R_p \cdot 0{,}5 \rightarrow \boxed{R = 0{,}088}$$

$$\tan(\alpha_t) e^{i\delta_t} = \overset{0}{\tan(\alpha_i)} e^{i\delta_i} \frac{(-)\cos(\theta_i+\theta_t)}{\cos(\theta_i-\theta_t)}$$

$$\downarrow$$

$$\delta_t = \alpha_t = 0$$

$$V' = \left| \frac{R_\perp - R_\parallel}{R_\perp + R_\parallel} \right| = 0{,}627$$

$$\vec{S}_0 = 0{,}5 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0{,}5 \\ 0{,}5 \\ 0 \\ 0 \end{pmatrix} \rightarrow \vec{S}_1 = 0{,}5 R_N \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + R_p \begin{pmatrix} 0{,}5 \\ 0{,}5 \\ 0 \\ 0 \end{pmatrix}$$

$$\vec{S}_1 = \begin{pmatrix} 0{,}088 \\ 0{,}076 \\ 0 \\ 0 \end{pmatrix} \qquad V = \frac{0{,}076}{0{,}088} \rightarrow \boxed{V = 0{,}86}$$

$\alpha = 0$ partz. pol. lineala $\perp$

$\cancel{0{,}076 = 0{,}088 \cdot \cos(2\alpha) \rightarrow}$ $\alpha = 15{,}136°$

$$\cancel{\vec{S}_{N_1} = I_0 \begin{pmatrix} \frac{R_\perp + R_\parallel}{2} \\ \frac{R_\perp - R_\parallel}{2} \\ 0 \\ 0 \end{pmatrix} = \vec{S}_{N_1} = I_0 \begin{pmatrix} 0{,}067 \\ 0{,}042 \\ 0 \\ 0 \end{pmatrix} = 0{,}067 \cdot 1}$$

b) Argi erasoitzaileen atal pol-en pol. egoera eraso planoaren paralelo bada, ($\alpha_i = 90°$) kalkulatu zein erasoitzaileen pol-maila, argi islatua aleatorioa izan dadin.

$R_\perp = 0{,}109$ $R_{\parallel} = 0{,}025$

$R_N = 0{,}067$ $R_p = 0{,}0025$ $V' = 0{,}627$

$\tan(\alpha_r)\, e^{-i\delta_r} = \infty \rightarrow \alpha_r = 90°$ $\delta_r = 0°$

$$(1-V) R_N \begin{pmatrix} 1 \\ V' \\ 0 \\ 0 \end{pmatrix} + V R_p \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix}$$

$(1-V) R_N V' - V R_p = 0$

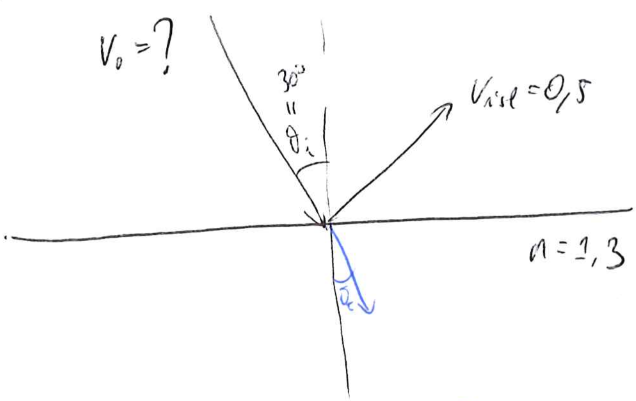
~~$R_N V' = V(R_p + R_N)$~~ $\rightarrow V = \frac{R_N V'}{R_p + R_N} \rightarrow V = 0{,}457$

$R_N V' = V(R_p + R_N V')$

$\rightarrow V = \frac{R_N V'}{R_N V' + R_p} \rightarrow V = 0{,}627$

12/

$V_0 = ?$



$$\boxed{\begin{aligned}\alpha_i &= +45^\circ \\ \delta_i &= -90^\circ\end{aligned}}$$

$$\boxed{\theta_t = 22{,}62^\circ}$$

$R_\perp = 0{,}026 \qquad R_\parallel = 0{,}0098$

$$\boxed{R_P = R_N = \frac{R_\perp + R_\parallel}{2} = 0{,}0179}$$

$$\tan(\alpha_r)\, e^{-i\delta_r} = -0{,}612 \cdot e^{+i\cdot 90} = 0{,}612\, e^{-i 90}$$

$$\vec{S_0} = (1 - V_0)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + V_0 \begin{pmatrix}1\\0\\0\\-1\end{pmatrix}$$

$$\boxed{\begin{aligned}\delta_r &= 90^\circ \\ \alpha_r &= 31{,}47^\circ\end{aligned}}$$

$V' = 0{,}453$

$$\vec{S_1} = (1 - V_0) R_N \begin{pmatrix}1\\V'\\0\\0\end{pmatrix} + V_0 R_P \begin{pmatrix}1\\0{,}455\\0\\0{,}891\end{pmatrix}$$

$$\cancel{\vec{S_1} = \begin{pmatrix}(1-V_0)R_N + V_0 R_P \\ (1-V_0)R_N V' + 0{,}455\, V_0 R_P \\ V_0 R_P 0{,}891 \\ 0\end{pmatrix}} \qquad \cancel{V_{ísl} = 0{,}5 = \sqrt{((1-V_0)R_N}}$$

$$\vec{S_1} = \begin{pmatrix}R_N \\ (1-V_0)R_N V' + V_0 R_P\, 0{,}455 \\ 0 \\ V_0 R_P \cdot 0{,}891\end{pmatrix} \qquad \cancel{\to 0{,}5 = \sqrt{1^2 +}}$$

$$\cancel{0{,}5 = \sqrt{1^2 + V_0^2 R_P^2\, 0{,}891^2}}$$

$V' \approx 0{,}455 \quad \hookrightarrow \quad \vec{S_1} = \begin{pmatrix}R_N \\ 1 R_N V' \\ 0 \\ V_0 R_P 0{,}891\end{pmatrix}$

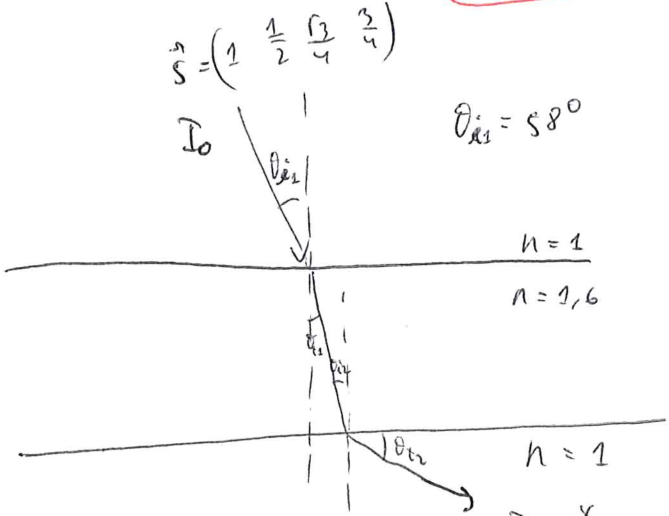
$$\cancel{R_N 0{,}5 = \sqrt{R_N^2 + 0{,}000254\, V_0^2}}$$

$$\cancel{V_0 = 0{,}075}$$

$$\vec{S} = R_V \begin{pmatrix} 1 \\ V' \\ 0 \\ V_0 \cdot 0{,}891 \end{pmatrix} \qquad 0{,}5 = \sqrt{V'^2 + V_0^2\, 0{,}891^2}$$

$$\boxed{V_0 = 0{,}238}$$

13/



$\theta_{i1} = 58^0$

→ I eta polarizazio egoera?

$$\boxed{\theta_{t_1} = \theta_{i_2} = 32^0}$$

$$\boxed{\theta_{t_2} = 58 = \theta_0}$$

$$\vec{S}_0 = \left(1 \;\; \frac{1}{2} \;\; \frac{\sqrt{3}}{4} \;\; \frac{3}{4}\right) \rightarrow \quad 1^2 = \frac{1}{4} + \frac{3}{16} + \frac{9}{16} = \frac{16}{16}$$

↳ Guztiz polarizatua dago!

$$\vec{S_0} = I_0 \begin{pmatrix} 1 \\ 1/2 \\ \sqrt{3}/4 \\ 3/4 \end{pmatrix} \qquad \mathcal{T}_{\perp_1} = 0{,}808 \qquad \mathcal{T}_{\parallel_2} = 1$$

$$\frac{1}{2} = \cos(2\alpha_0) \rightarrow \boxed{\alpha_0 = 30^0} \qquad \boxed{\delta_0 = 60^0}$$

$$\mathcal{T}_{p_1} = \mathcal{T}_{\perp_1} \cos^2(\alpha_0) + \mathcal{T}_{\parallel_1} \sin^2(\alpha_0)$$

$$\boxed{\mathcal{T}_{p_1} = 0{,}856}$$

$$\tan(\alpha_t)\, e^{-i\delta_t} = 0{,}642\, e^{-i60^0} \rightarrow \boxed{\delta_t = 60^0} \rightarrow \boxed{\alpha_t = 32{,}7^0}$$

$$\boxed{\vec{S_1} = I_0\, \mathcal{T}_{p_1} \begin{pmatrix} 1 \\ 0{,}416 \\ 0{,}455 \\ 0{,}787 \end{pmatrix}}$$

$\tau_{\perp_2} = 0{,}808$

$\rightarrow \tau_{P_2} = \tau_{\perp_2} \cos^2(\alpha_t) + \tau_{\parallel_2} \sin^2(\alpha_t)$

$\tau_{\parallel_2} = \underline{1}$

$\tau_{P_2} = 0{,}864$

$\tan(\alpha_t')\, e^{-i\delta_t'} = 0{,}714 \cdot e^{-i \cdot 60^\circ}$

$\delta_t' = 60^\circ$ $\quad$ $\alpha_t' = 35{,}527^\circ$

$$\vec{S}_F = I_0 \, \tau_{P_3} \tau_{P_2} \begin{pmatrix} 1 \\ 0{,}325 \\ 0{,}473 \\ 0{,}819 \end{pmatrix} = I_0 \cdot 0{,}7396 \begin{pmatrix} 1 \\ 0{,}325 \\ 0{,}473 \\ 0{,}819 \end{pmatrix}$$

$\dfrac{0{,}325}{0{,}573}$

$I' = 0{,}7396\, I_0$

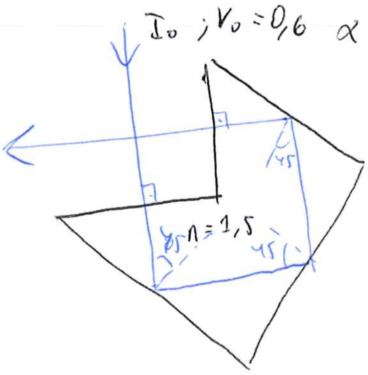
$\alpha = 35{,}53^\circ$ $\quad$ $\chi = 27{,}50^\circ$

$\delta = 60^\circ$ $\quad$ $\psi = 27{,}77^\circ$

GUZIJA POLARIZATUA.

$\sqrt{}_X$ 14/

I_0 ; $V_0 = 0{,}6$ $\alpha = 30^\circ$ → Argi lineala!



→ Irteerako uhinaren intentsitatea eta polarizazioaren ezaugarriak?

$$\vec{S}_0 = I_0(1-V_0)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + I_0 V_0 \begin{pmatrix}1\\1/2\\\sqrt{3}/2\\0\end{pmatrix}$$ → Dena ezaguna!

1. erasoa 1

$n_1 \sin(\theta_i) = n_2 \sin(\theta_t)$

$$\cancel{R_{A1}}\ T_1 = \frac{4n_1n_2}{(n_1+n_2)^2} = 0{,}96$$

$$\vec{S}_1 = I_0(1-V_0)T_1\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + I_0V_0T_1\begin{pmatrix}1\\1/2\\\sqrt{3}/2\\0\end{pmatrix}$$

$\boxed{\alpha = 30 \quad \delta = 0}$

Islapen osoa denez, $\alpha_i = \alpha_r$

$$tg\left(\frac{\delta'}{2}\right) = \frac{\cos(45)\sqrt{\sin^2(45) - \cancel{(1)}n^2}}{\cancel{\cos}\sin^2(45)}$$

non $n = \left(\frac{1}{1{,}5}\right)$

2. erasoa (eta 3 eta 4)

$\theta_i = 45^\circ$ $\quad \theta_t = 90^\circ$

~~$\alpha = 30$~~

~~$\delta = 0$~~

$\delta' = 36{,}87^\circ$

↳ Ko desfasea sartu barne islapen bakoitzean

$\cancel{R_\perp = 1}$ $\quad \cancel{R_\parallel = 1}$

Mantendu!

5. erasoa!

3 barne islapen ondoren: $\delta' = 110{,}61^\circ$

$$\vec{S}_{F\theta} = I_0 T_1 \left[(1-V_0)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + V_0\begin{pmatrix}1\\1/2\\-0{,}3\\0{,}81\end{pmatrix}\right]$$

$T_1 = T_2$

$$\vec{S}_F = I_0 T_1^2\left[(1-V_0)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + V_0\begin{pmatrix}1\\1/2\\-0{,}3\\0{,}81\end{pmatrix}\right]$$

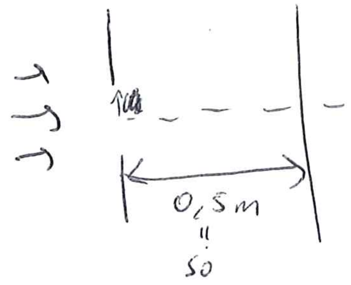
$$\cancel{\vec{S}_F = I_0 \cdot 0{,}9216\begin{pmatrix}1\\0{,}3\\0{,}520\\0\end{pmatrix}}$$

$$\vec{S}_F = 0{,}9216 I_0 \begin{pmatrix}1\\0{,}3\\-0{,}18\\0{,}486\end{pmatrix}$$

2. Gaiko ariketak.

Difrakzioa

1/ $\lambda = 632{,}8\,nm$



a) Lehen 7 zona erdiperiodikoen erradioak?

~~$\rho_j = \sqrt{j\lambda S_0}$ izanik~~ $\rho_j = \sqrt{j\lambda S_0}$ izanik, $j = 1, \ldots 7$-ra ordezkatu.

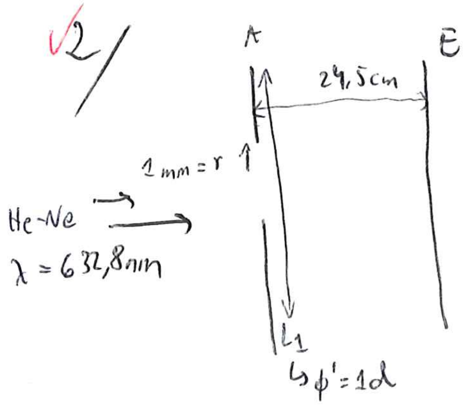
b) Diafragmaren erradioa 1mm bada, aurkitu ardatzeko maximo eta minimoen posizioak.

$S_0 = \dfrac{\rho_j^2}{j\lambda}$ → ~~maximoak~~ minimoak bikoitiak → $j = (2n)$ denean

~~minimoak~~ maximoak bakoitiak → $j = (2n-1)$ denean

→ 0,79m
→ 0,40m
→ ... → $\dfrac{1{,}58}{j}$
→ 1,58m
→ 0,53m
→ ... → $\dfrac{1{,}58}{j}$

2/



a) Pantailan jasotako irudia?

$\dfrac{1}{a'} - \dfrac{1}{a} = \dfrac{1}{f'}$ $\qquad \dfrac{1}{f'} = \phi' \to f' = 1m$

$\to a = \underline{0{,}325m = S_0}$ erreala

$\underline{\beta' = 0{,}75}$

$\dfrac{\rho_j^2}{S_0\lambda} = j \simeq 5$ zona erdiperiodiko → erdian argia → argi eraztunak inguruan,

$S_0\lambda$
||
4,86

b) L_1-en ordez L_2 ($\phi' = -1d$) jarriz gero, $a' = ?$ irudia aurrekoaren antzekoa izan dadin? Bi irudien neurrien arteko erlazioa lortu.

So mantendu, $a' = \dfrac{1}{\frac{1}{a} + \frac{1}{f'}}$ → $\underline{a' = 0{,}481m\text{-ra jarri behar da!}}$

$a = S_0$, $f' = -1$

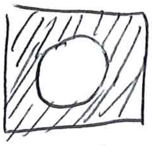
$\underline{\beta'_2 = 1{,}481}$

$\dfrac{\beta'_2}{\beta'_1} = 1{,}92 \simeq 2$ aldiz handiagoa da bigarren irudia.

3/ Irudiko bi irekidurak $\lambda = 632{,}8\,nm$-ko uhin-lau batez perpendikularki erasota daude.

→ Kalkulatu kasu bakoitzean irekiduratik 40cm-ra (S_0) "ardatzeko" puntuan neurtuko genukeen intentsitatea.

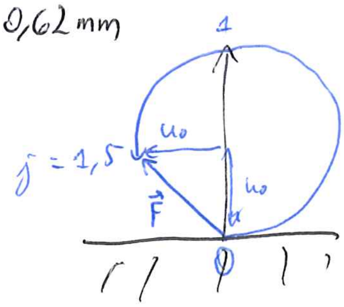
a)



$r = 0{,}62\,mm$

λ eta $\rho = r$ ~~ezaga~~ eta S_0 ezagunak ditugu.

$\frac{\rho^2}{\lambda S_0} = j = 1{,}52$ erdi-periodo izango ditugu.



$\vec{F} = \rho e^{i\varphi}$

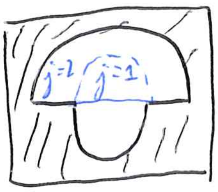
$|\vec{F}|^2 = \rho^2$

Zirkunferentziatzat har dezakegunez,

$\rho^2 = 2u_0^2 \rightarrow \rho = \sqrt{2}\, u_0$

Intentsitatea $I = \rho^2$ izanik, $I = 2I_0$

b)



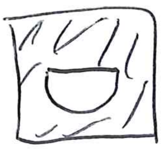
$r_1 = 0{,}5\,mm$

$r_2 = 0{,}71\,mm$

$j_1 = 0{,}98 \simeq 1$ zona erdip.

$j_2 = 1{,}99 \simeq 2$ zona erdip.

Irudiaren goiko erdiak, elkarri anulatuz, ekarpen nulua egingo digu.



$r_1 = 0{,}5\,mm$

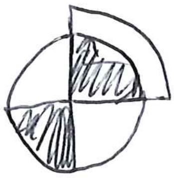
→ aztertu behar da $j = 1$ izanik.

$U_F = \frac{U_1}{2} = \frac{2U_0}{2} = U_0$

Ondorioz, $I = I_0$

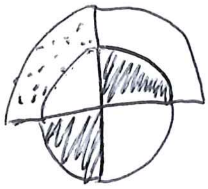
4/ $r_1 = 1{,}7mm$ eta $r_2 = 2{,}08mm$ izanik, $\lambda = 632{,}8nm$-ko argiaz, $s_0 = 2{,}28m$ izanik. Kalkulatu intentsitatea zentroan ∴-k $\pi/2$-ko atzerapena eragiten badu.

Kasu denetarako $\left\{ \begin{array}{l} r_1 \to 2 \text{ zona erdi} \\ r_2 \to 3 \text{ " " } \end{array} \right\}$

a) 

$$\frac{U_1+U_2}{2} = 0$$

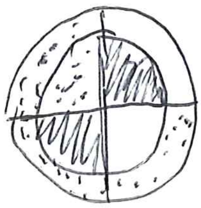
$$U = \cancel{\frac{U_1}{2}} + \frac{U_2}{4} = \cancel{\frac{2U_0}{2}}^{\,0} - \frac{2U_0}{4} = -\frac{U_0}{2} \to \boxed{I = \frac{I_0}{4}}$$

b) 

$$U = \overbrace{\frac{U_1}{2} + \frac{U_2}{2}}^{0} + \frac{U_3}{4} + \frac{U_3}{4} e^{i\frac{\pi}{2}}$$

$$U = \frac{U_3}{4}\left(1 + e^{i\frac{\pi}{2}}\right) = \frac{e^{i\frac{\pi}{4}}}{2} U_0 \cancel{2} \left(e^{-\frac{\pi}{4}i} + e^{\frac{\pi}{4}i}\right)$$

$$U = \cancel{\tfrac{2}{2}} U_0 e^{i\frac{\pi}{4}} \cos\left(\frac{\pi}{4}\right) = \frac{\sqrt{2}}{2} U_0 e^{i\frac{\pi}{4}} \to \boxed{I = I_0/2}$$

c) 

$$U = \underbrace{\frac{U_1}{4} + \frac{U_2}{4}}_{0} + \underbrace{\left(\frac{U_1}{4} + \frac{U_2}{4}\right)}_{0} e^{i\frac{\pi}{2}} + \frac{U_3}{4} + \frac{3}{4} U_3 e^{i\frac{\pi}{2}}$$

$$U = \frac{1}{4} 2U_0 \left(1 + 3e^{i\frac{\pi}{2}}\right) \to I = \frac{1}{4} I_0 \left(1 + 3e^{-i\frac{\pi}{2}}\right)\left(1 + 3e^{+i\frac{\pi}{2}}\right)$$

$$I = \frac{I_0}{4}\left[10 + 3\left(e^{i\frac{\pi}{2}} + e^{-i\frac{\pi}{2}}\right)\right] = \frac{I_0}{4}\left[10 + 6\cancel{\cos\left(\frac{\pi}{2}\right)}^{\,0}\right]$$

$$\boxed{I = \frac{5}{2} I_0}$$

5/  → Fraunhoferren difrakzio-irudiak gurutze baten antza du.

→ Kalkulatu $\frac{I}{I_0}$ erlazioa maximo hauetan:

a) $v=0,\ u=0$

↳ $I(0,0)=c^2\varsigma^2=I_0 \rightarrow \frac{I}{I_0}=1$

b) $v=\pm 1,3\pi,\ u=0$

↳ $I(v,0)=I_0\cdot 0,00304 \rightarrow \frac{I}{I_0}=\cancel{0,00304}\ \cancel{0,039}\ 0,047$

c) $v=\pm 2,46\pi,\ u=0$

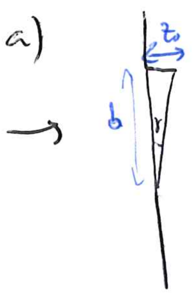
$\frac{I(v,0)}{I_0}=\cancel{0,00302}\ 0,016$

d) $v=\pm 2,43\pi,\ u=\pm 1,43\pi$

$\frac{I(v,u)}{I_0}=\cancel{9,25\cdot 10^{-9}}\ \cancel{0,0015}\ 0,002$

6/ Kalkulatu ~~Fraunh~~ Fraunhoferren difrakzioaren arabera, zirrikitu baten emandako intentsitate diferentzia kasu hauetan:

a) $\gamma \ll 1$ izanik



~~Bat~~ Beirak Δ-ko atzerapena eragingo dio.

~~Funtzioa~~ $I(p,0)=I_0\left(\frac{\sin v}{v}\right)^2$ non $v=\frac{1}{2}kpb$ den.

Hala ere, beira bat izatean integrala egin behar da berriro!

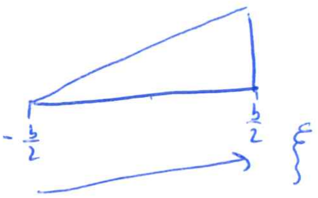
~~$\tan\gamma=\frac{2}{b}$ ... $\tan\gamma$~~ lortzeko

lodiera max

$b\cdot\tan\gamma=D \Rightarrow \gamma\ll$ denez $\rightarrow \boxed{D\approx\gamma b}$

~~$\xi_0 \Rightarrow$ lodiera max!~~

→ lodiera(ℓ) ξ-ren funtzioan lortu!



$\ell(\xi)=\alpha+\beta\xi \rightarrow \ell(-\frac{b}{2})=0=a-\frac{\beta b}{2}\quad a=\frac{\beta b}{2}$

$\ell(\frac{b}{2})=\gamma b=a+\frac{\beta b}{2}=\beta b$

$\boxed{\ell(\xi)=\frac{\gamma b}{2}+\gamma\xi}$

↳ $\beta=\gamma$, $a=\frac{\gamma b}{2}$

$$U(p) = C\int_{-\frac{b}{2}}^{\frac{b}{2}} e^{-ik_0 p \xi}\, e^{ik_0(n-1)d}\, d\xi$$

lodiera!

$$U(p) = C\int_{-\frac{b}{2}}^{\frac{b}{2}} e^{-ik_0 p \xi}\, e^{ik_0(n-1)\gamma\left(\frac{b}{2}+\xi\right)}\, d\xi$$

$$U(p) = C\,\underbrace{e^{ik_0(n-1)\frac{\gamma b}{2}}}_{\text{intentsitatean arbuiatu.}}\int_{-\frac{b}{2}}^{\frac{b}{2}} e^{-ik_0\overbrace{\left[p-(n-1)\gamma\right]}^{p'=p-(n-1)\gamma}\xi}\, d\xi$$

$$U(p) \approx C\left[\frac{e^{-ik_0 p' \xi}}{+ik_0 p'}\right]_{\frac{b}{2}}^{-\frac{b}{2}} = \frac{C}{ik_0 p'}\left(e^{i\frac{k_0 p b}{2}} - e^{-i\frac{k_0 p b}{2}}\right)$$

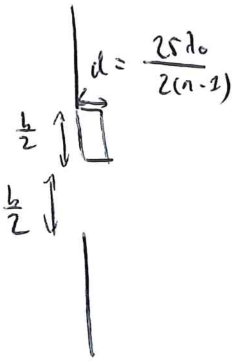
$$\boxed{U(p) \approx \frac{C}{\frac{1}{2}k_0 p'}\sin\left(\frac{1}{2}k_0 p b\right) = \frac{\overbrace{Cb}^{\sqrt{I_0}}}{\frac{1}{2}k_0 p' b}\sin\left(\frac{1}{2}k_0 p b\right)}$$

$$\boxed{I = I_0\left[\frac{\sin\left(\frac{1}{2}k_0 p' b\right)}{\frac{1}{2}k_0 p' b}\right]^2}$$

maximoa sinuaren angelua 0 denean →

→ $\frac{1}{2}k_0 b\left[p-(n-1)\gamma\right] = 0$ → $p = (n-1)\gamma$ norabideen egongo da intentsitatearen maximoa.

b)



$$U(P) = C\left[\int_{-\frac{b}{2}}^{0} e^{-ik_0\rho\xi}\,d\xi + \int_0^{b/2} e^{-ik_0\rho\xi}\, e^{\frac{ik_0\cancel{(n-1)}\,25\lambda_0}{2\cancel{(n-1)}}}\,d\xi\right]$$

$$k_0 = \frac{2\pi}{\lambda_0} \qquad U(P) = C\left\{\left[\frac{e^{-ik_0\rho\xi}}{+ik\rho}\right]_0^{-\frac{b}{2}} + \underbrace{e^{i\frac{2\pi}{\cancel{\lambda_0}}\frac{25\cancel{\lambda_0}}{2}}}_{\underbrace{e^{i25\pi}}_{-1}} \int_0^{b/2} e^{-ik_0\rho\xi}\,d\xi\right\}$$

$$U(P) = C\left[\frac{1}{ik_0\rho}\left(e^{ik_0\rho\frac{b}{2}} - 1\right) + \frac{e^{-ik_0\rho\frac{b}{2}} - 1}{ik\rho}\right]$$

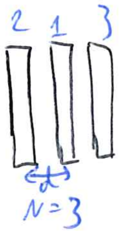
$$U(P) = C\,\frac{1}{ik_0\rho}\left[2\cos\left(\frac{k_0\rho b}{2}\right) - 2\right] = \frac{-2C}{ik_0\rho}\left[1 - \cos\left(\frac{k_0\rho b}{2}\right)\right]$$

$$U(P) = \frac{-2\overbrace{Cb}^{S}}{ik_0\rho b}\,2\sin^2\left(\frac{k_0\rho b}{4}\right)$$

$$I = \frac{C^2S^2}{\frac{1}{16}k_0^2\rho^2b^2}\sin^4\left(\frac{k_0\rho b}{4}\right) \qquad V' = \frac{k_0\rho b}{4}$$

$$I = C^2S^2\left[\frac{\sin(V')}{V'}\right]^2 \sin^2(V')$$

8



3 zirrikitu ditugu.

difrakzio-

→ Horrela emandako Fraunhoferren irudia zein da, kasu bakoitzean?

a) Hirurek amplitude bera transmititzen badute:

non $V = \frac{1}{2} k p d$ den

$$U_1(P) = \underbrace{\overbrace{Cb}^{\sqrt{I_0}} \frac{\sin V}{V}}_{U_0}$$

$$U_1(P) \neq U_2(P) = U_3(P)$$

beren pareko zentruetan.

$$U_{TOT}(P) = U_0\left(1 + e^{ikpd} + e^{-ikpd}\right) \cancel{\frac{\sin V}{V}}$$

$$= U_0\left[1 + 2\cos(kpd)\right] \cancel{\frac{\sin V}{V}}$$

$$\cancel{U_{TOT}(P) = U_0\left[1 + 2\cos(2V)\right]} \frac{\sin V}{V}$$

$$I = \underbrace{I_0}_{U_0 \frac{\sin V}{V}}\left(1 + 4\cos(kpd) + 4\cos^2(kpd)\right)$$

b) Erdikoak amplitude bikoitza transmititzen badu.

Beren zentroetan ixtiinetakoak: $\frac{cb}{\frac{1}{2}kpb}\sin\left(\frac{1}{2}kpb\right) = U(P_i)$

Zentrokoan: $U(P_j) = \frac{cb}{kpb}$ bikoitza izango da!

$$I = I_0\left[2 + 2\cos(kpd)\right]^2 = I_0 \cdot 4 \cdot 4 \cos^4\left(\frac{kpd}{2}\right)$$

$$I = 16 I_0 \cos^4\left(\frac{kpd}{2}\right)$$

c) Erdiko zirrikituan φ desfasea sartzean ($\varphi = 0$, $\pi/2$, π

a kasua

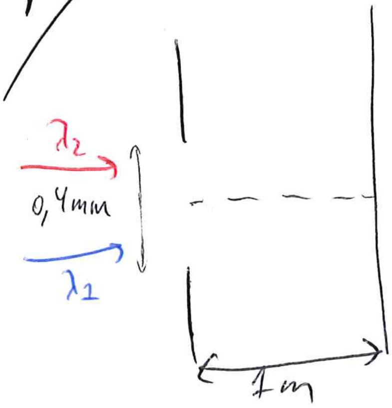
c.2) $I = I_0\left|i + 2\cos(kpd)\right|^2 = I_0\left[-i + 2\cos(kpd)\right]\left[i + 2\cos(kpd)\right]$

$$I = I_0\left[1 + 4\cos^2(kpd)\right]$$

c.3) $I = I_0\left[-1 + 2\cos(kpd)\right]^2$

$$I = I_0\left[1 - 4\cos(kpd) + 4\cos^2(kpd)\right]$$

~~SOTH~~ 9



$\phi' = 1d$-ko lente baten plano fokalean ezarten da.
is $f' = 1m \rightarrow$ 1m-ra sortatuko da!

- λ_1 eta λ_2-k eraso perpendikularra egiten dute.

λ_1-en osagaiaren 4. minimoa
λ_2-en 5. minimoa
} ardatzetik 5mm-ra gainezarri dira.

$\sin\theta_0 = 0$ eraso normala! uhin lateralekin lotua; zirrik. zabalera.

$p = \sin\theta$ $\quad V = \frac{1}{2}kpD = \frac{1}{\cancel{2}}\frac{\cancel{2}\pi}{\lambda}\sin\theta\, D \rightarrow$ hau baca ez da behar.

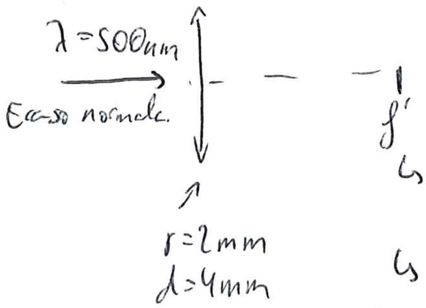
minimoak $\quad \sin\theta = \pm n\frac{\lambda_i}{D}$

$\sin\theta$, bi kasuetan. $\quad$ ~~sin~~ $\tan\theta = \frac{5mm}{1m} \rightarrow \theta = 0,286^\circ \rightarrow \underline{\sin\theta = 0,005}$

$\lambda_1 \rightarrow \quad 0,005 = 4\frac{\lambda_1}{D} \rightarrow \quad \lambda_1 = 500nm$

$\lambda_2 \rightarrow \quad 0,005 = 5\frac{\lambda_2}{D} \rightarrow \quad \lambda_2 = 400nm$

11/



↳ Plano fokalean eratzen sistema ikus daiteke.

↳ Intentsitate min. edo 1. eraztunaren diametroa 7,6 μm bada, zein da f'?

$\rho_j^2 = \sin j\lambda s_0 = j\lambda f'$

$j=1$ hartuz, eta $\rho_j = \frac{7{,}6}{2}\,\mu m$

$f' =$

Ez da Fresnelen difrakzioa, Fraunhoferena baizik!

Suposatuko dugu lentea zirkularra dela.

Teorian dugun bezala, lehen minimoa $x = 1{,}22\pi$ dugunean da.

$$1{,}22\pi = ka\,w = ka\sin\theta = \frac{2\pi}{\lambda}\cdot\frac{d}{2}\sin\theta = \frac{\pi d}{\lambda}\sin\theta$$

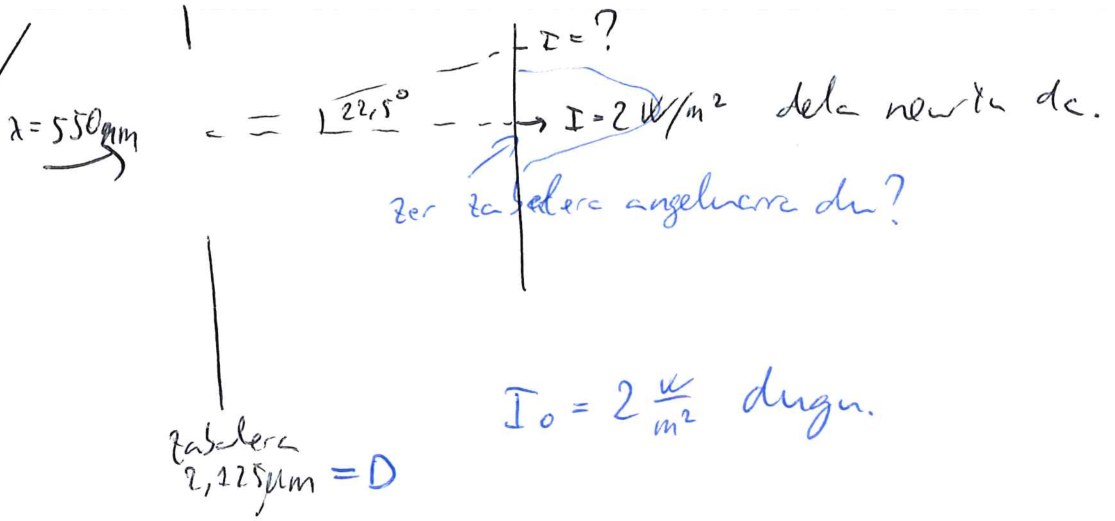
$$w = \sin\theta = \frac{1{,}22\cancel{\pi}\lambda}{\cancel{\pi} d}$$

θ txikia izanik, $\sin\theta \approx \tan\theta$ →

$$\rightarrow \tan\theta = \frac{\frac{7{,}6}{2}\,\mu m}{f'} \rightarrow f' = \frac{\frac{7{,}6}{2}\,\mu m}{1{,}22\lambda}\,d$$

$f' = 2{,}5\,cm$

12/



$$I_0 = 2\,\frac{W}{m^2} \text{ dugn.}$$

$$\sin\theta \rightarrow \sin(22{,}5) = 0{,}383 = \rho$$

$$\boxed{V = \frac{1}{2} k \rho D = \frac{1}{\cancel{2}} \frac{\cancel{2}\pi}{\lambda} \rho D = 4{,}645}$$

dolžina radianetan sartu!

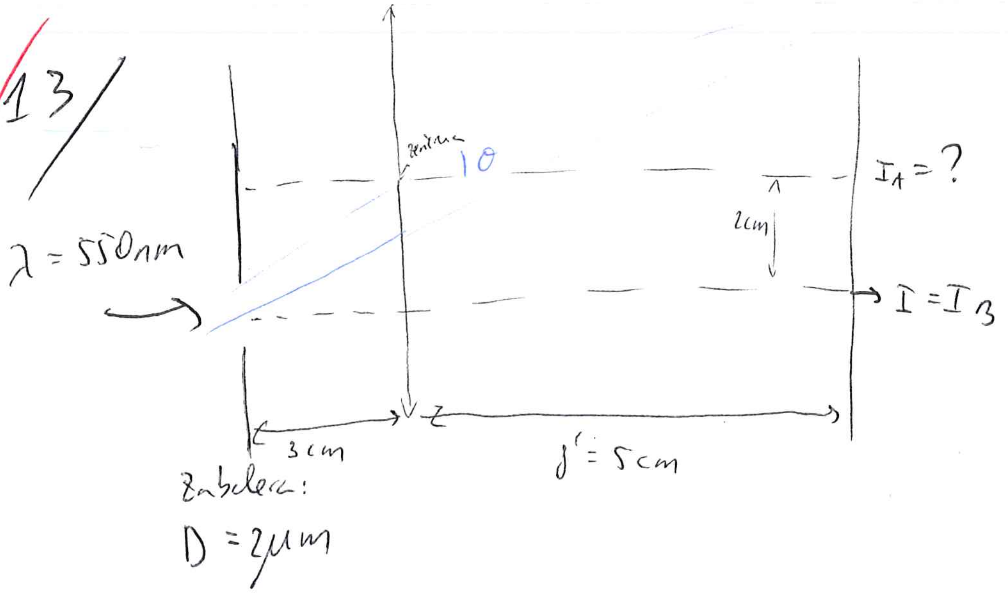
$$I = I_0 \cdot \left(\frac{\sin V}{V}\right)^2 \rightarrow I(\theta = 22{,}5^\circ) = \cancel{6{,}079 \cdot 10^{-4}\,\frac{W}{m^2} = 0{,}00061\,\frac{W}{m^2}}$$

$$= 0{,}0922\,\frac{W}{m^2}$$

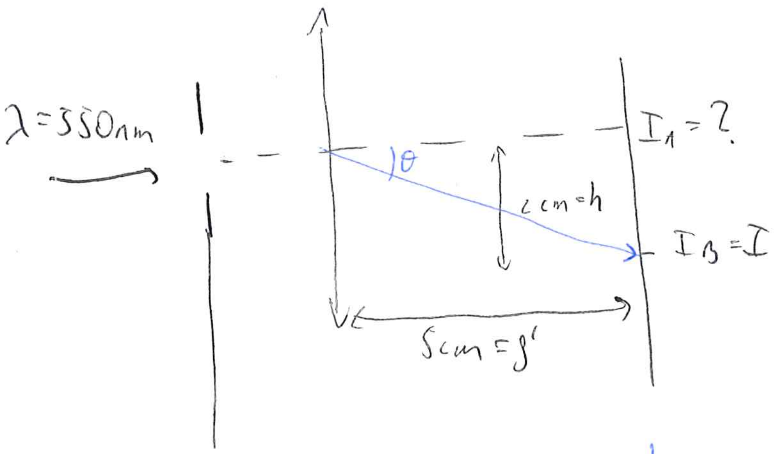
1\. minimoa. $\sin\theta = \frac{\lambda}{D} \rightarrow \Delta\theta = 2\arcsin\left(\frac{\lambda}{D}\right)$

$$\Delta\theta = 30^\circ$$

13/



Zirrikitua lekuz mugituz gero planoan, difrakzio irudia ez da aldatzen



$$V = \frac{1}{2} k \sin\theta D$$

$$\theta = \arctan \frac{h}{g'} \rightarrow \sin(\theta_B) = 0{,}371$$

$$V_B = \frac{1}{2} \frac{2\pi}{\lambda} 0{,}371 \cdot D = 4{,}243$$

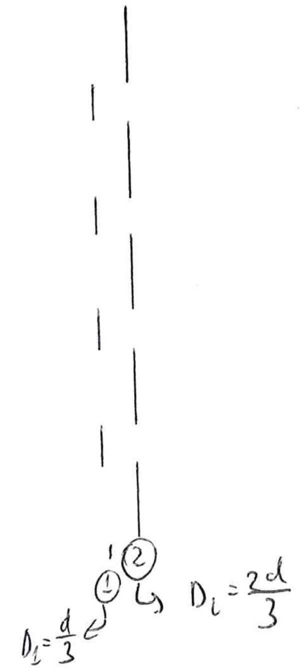
I_A-n, zentruan egonik, intentsitate maximoa egongo da, I_0

$$I_B = I_0 \cdot \left(\frac{\sin V_B}{V_B}\right)^2 = I_0 \cdot 0{,}0441$$

$$I_A = I_0 \quad \rightarrow I_A = \frac{I_B}{0{,}0441} \rightarrow I_A = 22{,}63 I_B$$

Difrakzio Sareak.

1/ Bi sare ditugu elkarren osagarriak direnak.



Irudian d=1,5cm

$$I_1(\rho) = I_{1,1}(\rho)\left[\frac{\sin(N\varphi_1)}{\sin \varphi_1}\right]^2$$

$$I_2(\rho) = I_{2,1}(\rho)\left[\frac{\sin(N\varphi_2)}{\sin(\varphi_2)}\right]^2$$

$N\varphi \overset{?}{=} 0$

$$\boxed{\text{Minimo nuluak.} \quad \rho = \frac{m\lambda}{Nd}}$$

$\hookrightarrow m$

$\varphi_1 = \frac{k\rho d}{2} = \varphi_2$ izango dugu.

Diferentzia $I_{i,1}(\rho)$-n dago.

$$I_{1,1}(\rho) = I_0\left(\frac{\sin V_1}{V_1}\right)^2 \; ; \; I_{2,1}(\rho) = I_0\left(\frac{\sin V_2}{V_2}\right)^2$$

$$\boxed{V_1 = \frac{1}{2}k\rho D_1 = \frac{1}{2}\frac{k\rho d}{3}} \qquad \boxed{V_2 = \frac{1}{2}k\rho D_2 = \frac{k\rho d}{3}}$$

Hori dela eta, esandakoa frogatzeko, $I_{i,1}(\rho)$-ak konparatu behar ditugu:

- $\rho = 0$-n ezberdinak:

$$\frac{\sin V_1}{V_1}$$

$$\frac{\sin V_2}{V_2} = \frac{\sin 2V_1}{2V_1} = \frac{\sin V_1 \cos V_1}{V_1} \rightarrow$$

$$\boxed{I_{1,1}\cdot\cos^2(V_1) = I_{21} \text{ da } \rho=0 \text{ norabidean.}}$$

- Beste ~~ρ-etan~~ (maximoak direnetan): $\boxed{\rho = m\frac{\lambda}{d} \text{ izango da!}}$

$V_1 = \frac{1}{2}\frac{2\pi}{\lambda} m\frac{\lambda}{d}\frac{d}{3} = \frac{m\pi}{3} \rightarrow \frac{d}{D_1} = \frac{m}{n} \Rightarrow 3n = m \rightarrow$ betetzean ordena galdua izango dugu!

$V_2 = \frac{1}{2}\frac{2\pi}{\lambda} m\frac{\lambda}{d}\frac{2d}{3} = \frac{2\pi}{3}m \rightarrow \frac{d}{D_2} = \frac{m}{n} \Rightarrow$ ~~3n~~

① → $I_0 \left[\frac{\sin\left(\frac{k_p d}{2\cdot 3}\right)}{\left(\frac{k_p d}{2\cdot 3}\right)}\right]^2 \cdot \left[\frac{\sin\left(\frac{N k_p d}{2}\right)}{\sin\left(\frac{k_p d}{2}\right)}\right]^2$

② → $I_0 \left[\frac{\sin\left(\frac{k_p d}{2\cdot 3}\right)}{\left(\frac{k_p d}{2\cdot 3}\right)}\right]^2$

• Beste p-tan (p maximoak: $p = m\frac{\lambda}{d}$)

$v_1 = \frac{1}{\cancel{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}} m \frac{\cancel{\lambda}}{\cancel{d}}\frac{\cancel{d}}{3} = \boxed{\frac{m\pi}{3} = v_1}$

$\forall m \in \mathbb{N} \Rightarrow \cos^2(v_1) = \frac{1}{2}$ beteko da eta bigarren zatiarena berdina denez, bai izango direla berdinak euren amplitude, eta ondorioz, intentsitateak.

Agian ez dago %100 ondo.

2/ $1200 \frac{\text{lerro}}{mm}$ 1. ordenako autokolimaziorako erabiltzen da.

$\lambda = 500 nm$

→ zenbat ordena topa daiteke? zein angelu dagozkie?

$d = \frac{1}{1200} mm$ $\theta_0 \neq 0$

$-2 \sin\gamma = m\frac{\lambda}{d} = 0{,}6m$ → $\sin\gamma = -0{,}3m$ → $m = 1$ → $\boxed{\gamma = \theta_0 = -17{,}46°}$

$\sin\theta_m = \frac{m\lambda}{d} + \sin\theta_0$

$\sin\theta_m = \underbrace{0{,}6m - 0{,}3}_{-1 \leq x \leq 1}$ →

$\theta_{m=-1} = -64{,}16°$

$\theta_{m=0} = -17{,}46$

$\theta_{m=1} = 17{,}46°$

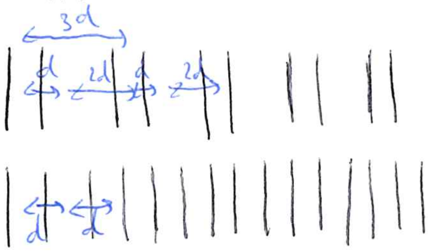
$\theta_{m=2} = 64{,}16°$

3/ • Difr. sare baten bidez eta soilik 1. ordena erabiliz lanpara espektral baten argi monokr. baten λ neurtu da.

↳ λ = 197nm (UV atera zaie)

↳ Sareak akatsa zuen, 3 lerrotik 1 falta zaio:

AKASTUNA



→ Honekin berdin egin?

ZUZENA

ez!

a) Nola da posible emaitza zuzena lortzea, ~~akats~~ akatsa zuela jakinda?

Beraiek p norabidean ~~d~~ periodoa = d-rekin egin dute kalkulua. Guk egin dezakeguna da sarea 3d-ko tartetan ~~hartu~~ hartu segidan orokortzeko sare osora

$$p = \underset{\downarrow \atop 1}{m}\frac{\lambda}{d} \Rightarrow \frac{\lambda_{UV}}{d} = \frac{\lambda_{zuz}}{3d} \rightarrow \boxed{\lambda_{zuz} = 591nm}$$

b) Marren arteko distantzia marren zabalera baino askoz handiagoa izanik: $d \gg D$, kalkulatu $m=0$ eta $m=1$ ordenei dagokien $\frac{I_{m=1}}{I_{m=0}}$ erlazioa.

$\varphi = \frac{kpd}{2}$ ~~→ 3d da gure kasuan! edo $\varphi = \frac{kpd}{2}$ definitzeko 3φ idatzi~~

SARE ZUZENEAN

$$I_i(p) = I_{i,1}(p)\left[\frac{\sin(N\varphi)}{\sin\varphi}\right]^2 = I_0\left(\frac{\sin v}{v}\right)^2\left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2$$

$v = \frac{1}{2}kpD$ izanik.

$$I_i(\rho) = I_0 \left[\frac{\sin\left(\frac{1}{2}k\rho D\right)}{\frac{1}{2}k\rho D}\right]^2 \left[\frac{\sin\left(N\frac{1}{2}k\rho d\right)}{\sin\left(\frac{1}{2}k\rho d\right)}\right]^2$$

$$\rho = m\frac{\lambda}{d}$$

m = 0 denean

$$I_{m=0} = I_0 \cdot 1 \cdot N^2$$

m = 1 deneen

$$I_{m=1} = I_0 \left[\frac{\sin\left(\frac{1}{\cancel{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}\frac{\cancel{\lambda}}{d}D\right)}{\frac{1}{\cancel{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}\frac{\cancel{\lambda}}{d}D}\right]^2 \left(\frac{\sin\left(N\frac{1}{\cancel{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}\frac{\cancel{\lambda}}{\cancel{d}}\cancel{d}\right)}{\sin\left(\frac{1}{\cancel{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}\frac{\cancel{\lambda}}{\cancel{d}}\cancel{d}\right)}\right)^2$$

$$\sin\left(\frac{\pi D}{d}\right) \approx \frac{\pi D}{d} \qquad D \ll d \text{ baita.}$$

$$I_{m=1} = I_0 \cdot 1 \cdot \left(\frac{\sin(N\pi)}{\sin(\pi)}\right)^2 = I_0 \left(\frac{N\pi}{\pi}\right)^2 = I_0 N^2$$

$\frac{I_{m=1}}{I_{m=0}} = 1$ da sare zuzenean

Sare akastunean

$$I(\rho) = I_1(\rho)\left(\frac{\sin\left(\frac{N}{3}\varphi\right)}{\sin\varphi}\right)^2$$ → 3 nakalen hartzean, N 3 aldiz txikiagoa izango baita! $\varphi = \frac{1}{2}\frac{2\pi}{\lambda}m\frac{\lambda}{d}d \Rightarrow \boxed{\varphi = \pi m}$

$I_1(\rho)$ aztertuz: $I_1(\rho) = I_0 \cdot \left(\overbrace{\frac{\sin v}{v}}^{\text{1 beti begiako maxetan}}\right)^2 \left(\frac{\sin(2\varphi')}{\sin\varphi'}\right)^2$ → bi zirrikitako sistema bat baita!

$$\varphi' = \frac{1}{2}\frac{2\pi}{\lambda}m\frac{\lambda}{3d}d = \frac{m\pi}{3} = \varphi'$$

$$I_1(\rho) = I_0 \cdot 1 \cdot 4\cos^2\left(\underbrace{\frac{m\pi}{3}}_{\varphi'}\right)\left(\frac{\sin\left(\frac{N}{3}\pi m\right)}{\sin(\pi m)}\right)^2$$

Beraz, intentsitateak:

$$I(p) = I_0 \, 4\cos^2\left(\frac{m\pi}{3}\right)\left[\frac{\sin\left(\frac{N}{3}\pi m\right)}{\sin(\pi m)}\right]^2$$

$$\left.\begin{aligned} I_{m=0}(p) &= 4I_0 \cdot \frac{N^2}{3^2} \\ I_{m=1}(p) &= I_0 \cdot \frac{N^2}{3^2} \end{aligned}\right\} \quad \frac{I_{m=1}}{I_{m=0}} = \frac{1}{4}$$

4/

$\lambda = 580 nm$

$\hookrightarrow m=1 \rightarrow 15^\circ = \theta_{m=1}$

$\hookrightarrow m=-2 \rightarrow \theta_{m=-2} = -45^\circ$

→ zenbatekoa da sarearen periodoa? zenbat ordena ikusiko dira?

$$\cancel{p = m\frac{\lambda}{d} = \sin\theta \rightarrow \left\{\begin{aligned} \frac{\lambda}{\sin(15)} &= d \\ \frac{-2\lambda}{\sin(-45)} &= d \end{aligned}\right\} = d =}$$

ez digute esan erasoa normala denik!

$p = \sin\theta - \sin\theta_0$

$$\left.\begin{aligned} \frac{\lambda}{d} &= \sin(15) - \sin\theta_0 \\ \frac{-2\lambda}{d} &= \sin(-45) - \sin\theta_0 \end{aligned}\right\} \quad +\frac{3\lambda}{d} = \sin(15) + \sin(45)$$

$\hookrightarrow$ ~~d = 1,2 µm~~ $d = 1,8\,\mu m$

$\theta_0 = -3,64^\circ$

$\sin(90) - \sin(3,64^\circ) = m\frac{\lambda}{d} \rightarrow m = 2,9 \rightarrow m_{max} = 2$

$\sin(-90) - \sin(3,64^\circ) = m\frac{\lambda}{d} \rightarrow m = -3,3 \rightarrow m_{min} = -3$

6 ordena

5/ $\lambda_1 = ?$, $\lambda_2 = 620nm$ -ekin $d = \frac{1}{600}$ mm -eko difrakzio-sare ~~bat~~ eraso normalean argiztatuz, $m=2$-n $\theta_2 - \theta_1 = 12°$ dela ikusi da.

a) $\lambda_1 = ?$

$$\rho = \sin\theta - \underbrace{\sin\theta_0}_{0 \to \text{eraso normala}}$$

$$\sin\theta = \pm m\frac{\lambda}{d} \to 2\frac{\lambda_2}{d} = \sin\theta_2 \to \theta_2 = 48{,}07°$$

$$\sin\theta_1 = 2\frac{\lambda_1}{d} \to \cancel{\theta_1 = \arcsin\frac{\lambda}{d}}$$

$$\lambda_1 = \frac{d\sin\theta_1}{2} = d\sin(\theta_2 - 12°)\cdot\frac{1}{2}$$

$\cancel{\lambda_1 = 981{,}29nm}$ $\to \boxed{\lambda_1 = 490{,}64nm}$

b) Zenbat ordena ikusiko dira?

λ_1-erako $\to$ $1 = m\frac{\lambda_1}{d} \to m = 3{,}397 \to m_{max} = 3$

$-1 = m\frac{\lambda_1}{d} \to m = -3{,}397 \to m_{min} = -3$ } 7 ordena

λ_2-rako $\to$ $m = \pm 2{,}69 \to m_{min} = -2$, $m_{max} = 2$ } 5 ordena

c) Sarearen luzera minimoa zenbatekoa da gutxienez bi uhin-luzeretarako 0,1nm-ko bereizmena lortzeko?

$$R = \frac{\lambda_i}{\underset{0{,}1nm}{\Delta\lambda}}$$

$R_1 = 4910$

$R_2 = 6200$

$d = 1{,}67\ \mu m$

$\frac{R_1}{m_{1max}} = N = 1637$

$\frac{R_2}{m_{2max}} = N = 3100 \to$ $L = N\cdot d \to \boxed{L = 5{,}17mm}$

6/ • Maximo nagusi bat ikusten dekerik

↳ zirrikitu bakoitiak (edo bikoitiak) estali dira.

Beraurrekoen posizioa aldatu gabe, nola aldatuko ~~[illegible]~~ dira bereizmen ahalmena eta tarte askea.

$$N' \to \frac{N}{2} \text{ dugu orain} \qquad d' \to 2d$$

$p = m \frac{\lambda}{d} \to p$ & λ kte.

$d' = 2d$ bada, $m' = 2m$

$$R' = m'N' = \frac{N}{2} 2m = Nm$$

Bereizmena ez da aldatuko.

$$\Delta\lambda' = \frac{\lambda}{m'} = \frac{\lambda}{2m}$$ Tarte askea erdira txikitu

7/ Irudiko kerraturen herena $e = \frac{5\lambda}{2(n-1)}$ lodierako xafla garden batez estali da. Kalkulatu eta irudikatu difrakzio-irudiaren minimo nuloen kokapenak.

Horretarako, lehenik, intentsitatearen adierazpena behar da.

$$I(p) = I_1(p) \cancel{[\ldots]} = I_0 \left(\frac{\sin v}{v}\right)^2 \cancel{[\ldots]}$$ → Baina hau tarteko zatiak eragingo duen desfasea kontuan hartu gabe izango litzateke.

$$e^{i5\pi} = -1$$

$$U(p) = C \int_0^{3a} \left[\int_{-\frac{3a}{2}}^{-\frac{a}{2}} e^{-ikp\xi} d\xi + \int_{-\frac{a}{2}}^{\frac{a}{2}} e^{-ikp\xi} e^{ik(n-1)\frac{5\lambda\pi}{2(n-1)}} d\xi + \int_{\frac{a}{2}}^{\frac{3a}{2}} e^{-ikp\xi} d\xi \right] e^{-ikq\eta} d\eta$$

$$U(p) = C \cdot \left[\frac{e^{-ikq\eta}}{ikq}\right]_{3a}^{0} \cdot \left\{ \left[\frac{e^{-ikp\xi}}{ikp}\right]_{-\frac{a}{2}}^{-\frac{3a}{2}} + \left[\frac{e^{-ikp\xi}}{ikp}\right]_{\frac{3a}{2}}^{\frac{a}{2}} + \left[\frac{e^{-ikp\xi}}{ikp}\right]_{-\frac{a}{2}}^{\frac{a}{2}} \right\}$$

$$U(p) = C\,\frac{1-e^{-3iakq}}{ikq}\cdot\frac{e^{\frac{3}{2}iakp}-e^{\frac{1}{2}iakp}+e^{-\frac{1}{2}iakp}-e^{-\frac{3}{2}iakp}+e^{-\frac{1}{2}iakp}-e^{\frac{1}{2}iakp}}{ikp}$$

$$U(p) = C\cdot\frac{1}{ikq}\,e^{-\frac{3}{2}iakq}\left(e^{\frac{3}{2}iakq}-e^{-\frac{3}{2}iakq}\right)\cdot\frac{1}{ikp}$$

Kalkuluak errazago egiteko, zatizka egin:

Erdikoa:

$$U_E(p) = C\cdot \underset{3a}{\overset{}{\underset{\parallel}{b}}}\,\frac{\sin u}{u}\int_{-\frac{a}{2}}^{\frac{a}{2}} e^{-ikp\xi}\,e^{ik(n-1)\frac{s1}{2(n-1)}}\,d\xi$$

non $u=\frac{1}{2}kq3a$ den

$$U_E(p) = C\cdot \underset{3a^2}{\underset{\parallel}{S}}\,\frac{\sin u}{u}\cdot\frac{\sin v}{v}\,\underbrace{e^{i\pi s}}_{-1} \qquad v=\frac{1}{2}kpa$$

$$I_E(p) = \underset{C^2S^2}{\underset{\parallel}{I_0}}\left(\frac{\sin u}{u}\right)^2\left(\frac{\sin v}{v}\right)^2$$

Ixkinakoen ekarpena, ohikoa + beraien zentrotik 0,0-rak distantzia desfasean

$$U_i(p) = CS\left[-1+e^{ipka}+e^{-ipka}\right] = CS\left[2\cos(kpa)-1\right]$$

$$I(p) = \underset{C^2S^2}{\underset{\parallel}{I_0}}\left[1-2\cos(kpa)+4\cos^2(kpa)\right]$$

minimoak (eraso normala bada) $p=\sin\theta=\pm n\frac{\lambda}{a}$, $n\neq 0$ $\quad n\in\mathbb{Z}-\{0\}$

$q=\pm m\frac{\lambda}{3a}$ $\quad m\in\mathbb{Z}-\{0\}$

$1 = 2\cos kpa$

$\pm\frac{\pi}{3}+2\pi k=\frac{2\pi}{\lambda}pa$

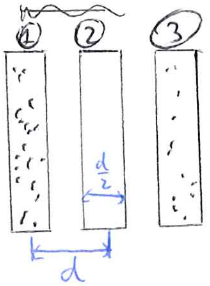
$$p=\frac{\lambda}{2\pi a}\left(\pm\frac{\pi}{3}+2\pi k\right)$$

$$\hookrightarrow\; p=\frac{\lambda}{6a}(6k\pm 1)\quad k\in\mathbb{Z}$$

8/ · 3 zirrikituz osatutako sare bat dugu. (d_π, $D=\frac{d}{2}$ izanik)

· Ixkinako bietan beira garden bana jarri da desfasea sortuko dutelarik.

→ Desfase honi esker, $p=0$ eta $p=\pm\frac{\lambda}{2d}$ -n intentsitate berdinak jaso dira.



$$U_T(p) = U_1(p)\left[e^{ikpd}e^{i\delta}+1+e^{-ikpd}\cdot e^{i\delta}\right]$$

$$U_T(p) = U_1(p)\left[1+2e^{i\delta}\cos(kpd)\right]$$

$$I_T = \underbrace{|U_1(p)|^2}_{\text{bietan berdina}}\left(1+4\cos^2(kpd)+2\cos(kpd)(e^{i\delta}+e^{-i\delta})\right)$$

$$I_T(p) = \underset{A}{|U_1(p)|^2}\left[1+4\cos^2(kpd)+4\cos(kpd)\cos(\delta)\right]$$

$$\boxed{I_T(0) = I_0\left[1+4+4\cos(\delta)\right]} = I_0\left[5+4\cos(\delta)\right]$$

$$\cancel{I_T\left(\pm\frac{\lambda}{2d}\right) = A\cdot\left[\frac{\sin\left(\pm\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{2d}d\right)}{\left(\pm\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{2d}d\right)}\right]^2\left[1+4\cos^2\left(\frac{2\pi}{\lambda}\frac{\lambda}{2d}d\right)+4\cos\left(\frac{2\pi}{\lambda}\frac{\lambda}{2d}d\right)\cos(\delta)\right]}$$

$$\cancel{= A\cdot 1\cdot\left(1+4\cdot(-1)^2-4\cos(\delta)\right) = A\left[5-4\cos(\delta)\right]}$$

$$I_T\left(\pm\frac{\lambda}{2d}\right) = I_0\left[\frac{\sin\left(\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{2d}\frac{d}{2}\right)}{\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{2d}\frac{d}{2}}\right]^2\left[5-4\cos(\delta)\right]$$

$$= I_0\frac{\left(\frac{\sqrt{2}}{2}\right)^2}{\pi^2\left(\frac{1}{4}\right)^2}\left[5-4\cos(\delta)\right] = I_0\frac{2\cdot16}{4\pi^2}\left[5-4\cos(\delta)\right] = I_0\frac{8}{\pi^2}\left[5-4\cos(\delta)\right]$$

Berdintza betetzeko: $\left[5+4\cos(\delta)\right] = \frac{8}{\pi^2}\left[5-4\cos(\delta)\right]$

$$\frac{40}{\pi^2} - 5 = 4\cos(\delta) + \frac{32}{\pi^2}\cos(\delta)$$

$$\frac{\frac{40}{\pi^2} - 5}{4 + \frac{32}{\pi^2}} = \cos(\delta) \rightarrow \cos(\delta) \approx -0,1308$$

$$\boxed{\begin{array}{l} \delta \approx 97,51^\circ + 2\pi n \\ \delta \approx 262,49^\circ + 2\pi n \end{array}}$$

ZAILA!

9/ • Irudian: zirrikituak eta haien kopuruak berdinak dira.

• $D \ll d$ dugu.

a) Alderatu bi sareek emandako intentsitateak, bigarren sareari dagozkion maximo nagusien kokapenetan.

B sarearen I kalkulatzen hasiko naiz. Horretarako, Beraz, sarea 2 ~~tartekoa~~ aztertuko dut.

$$I_B(\rho) = I_2(\rho)\left[\frac{\sin\left(\frac{N}{2}\varphi'\right)}{\sin\varphi'}\right]^2$$

kontuan izan N=2-ko sarea dela!

non N A sareko zirrikitu kopurua den

$$\boxed{\begin{array}{l} \varphi' = \frac{1}{2}k\rho 2d = k\rho d \\ \cancel{\varphi = \frac{1}{2}k\rho d} \end{array}} \quad \cancel{\varphi' = 2\varphi}$$

$$\cancel{I_B(\rho) = I_0\left(\frac{\sin v}{v}\right)^2\left[\frac{\sin(2\varphi)}{\sin(\varphi)}\right]^2\left[\frac{\sin(N\varphi)}{\sin(2\varphi)}\right]^2} \quad \cancel{\boxed{v = \frac{1}{2}k\rho D}}$$

$$I_B(\rho) = I_0\left[\frac{\sin(v)}{v}\right]^2 \cancel{4}\cancel{\cos^2(\varphi)}\frac{\sin^2(N\varphi)}{\cancel{4}\sin^2(\varphi)\cancel{\cos^2(\varphi)}}$$

$$I_B(\rho) = I_0\left[\frac{\sin(V)}{V}\right]^2\left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2$$

$v' = \frac{1}{2} k \rho$

$$I_B(\rho) = I_0 \left[\frac{\sin(v')}{v'}\right]^2 \left[\frac{\sin(2\varphi'')}{\sin(\varphi'')}\right]^2 \left[\frac{\sin\left(\frac{N}{2}\varphi'\right)}{\sin(\varphi')}\right]^2$$

Aurretik definituta $\boxed{\varphi' = k\rho d}$

Bestetik: $\boxed{\varphi'' = \frac{1}{2} k \rho (d-\Delta)}$

A sarekoa definitzat: $\boxed{\varphi = \frac{1}{2} k\rho d} = \frac{1}{2}\frac{2\pi}{\lambda}\rho d$

$$I_A(\rho) = I_0 \left[\frac{\sin(V)}{V}\right]^2 \left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2$$

$\varphi'' = \frac{1}{2}\frac{2\pi}{\lambda}\rho(d-\Delta)$

$\varphi' = 2\varphi =$

Bi kasuetan, $V = V'$ izateaz gain, $\Delta << d$ denez,

$\frac{\sin(V)}{V} = 1$ izango dugu.

Bestetik, bi adierazpenak txukundut eta dena aldagai berdinen arabera idatzi:

$$\left\{\begin{aligned} I_A(\rho) &= I_0 \cdot 1 \cdot \left[\frac{\sin\left(N\frac{\pi}{\lambda}\rho d\right)}{\sin\left(\frac{\pi}{\lambda}\rho d\right)}\right]^2 \\ I_B(\rho) &= I_0 \cdot 1 \cdot 4 \cdot \cos^2\left[\frac{\pi}{\lambda}\rho(d-\Delta)\right] \cdot \left[\frac{\sin\left(N\frac{\pi}{\lambda}\rho d\right)}{\sin\left(\frac{2\pi}{\lambda}\rho d\right)}\right]^2 \end{aligned}\right\}$$

B-ren maximo nagusiak: $\rho = m\frac{\lambda}{2d}$ denean izango dira, ahaztu gabe 2d dela!

$$I_A\left(\frac{m\lambda}{2d}\right) = I_0 \cdot \left[\frac{\sin\left(N\frac{\cancel{\pi}}{\cancel{\lambda}}\frac{m\cancel{\lambda}}{2\cancel{d}}\cancel{d}\right)}{\sin\left(\frac{\pi}{\cancel{\lambda}}\frac{m\cancel{\lambda}}{2\cancel{d}}\cancel{d}\right)}\right]^2 = I_0 \left[\frac{\sin\left(\frac{m\pi N}{2}\right)}{\sin\left(\frac{m\pi}{2}\right)}\right]^2 \quad m \in \mathbb{Z} \text{ izanik.}$$

$$I_B\left(\frac{m\lambda}{2d}\right) = I_0 \cdot 4 \cdot \cos^2\left[\frac{m\pi}{2d}(d-\Delta)\right] \left[\frac{\sin\left(\frac{m\pi N}{2}\right)}{\sin(m\pi)}\right]^2$$

~~m bikoitia bada:~~ $m=2n$

$$I_B = I_0 \cdot 4 \cdot \cos^2\left[\frac{n\pi}{d}(d-\Delta)\right]\left[\frac{\sin(n\pi N)}{\sin(2n\pi)}\right]^2 \qquad n=1,2,3$$

$$I_B = 4I_0 \cos^2\left[\frac{n\pi}{d}(d-\Delta)\right]\cdot\frac{N^2}{4} = I_0 \cos^2\left[\frac{n\pi}{d}(d-\Delta)\right] N^2$$

$$I_A = I_0\left[\frac{\sin(n\pi N)}{\sin(n\pi)}\right]^2 = I_0 N^2$$

Beraz, m bikoitietan: $\frac{I_B}{I_A} = \cos^2\left[\frac{n\pi}{d}(d-\Delta)\right]$

$$\frac{I_B}{I_A} = \cos^2\left[\frac{m\pi}{2d}(d-\Delta)\right] = \frac{1}{2}\left[1+\cos\left(\frac{m\pi}{d}(d\right.\right.$$

m bik/bak-ekin hasi aurretik, emaitza orokorra lortuko dugu (maximoetarako)

$$\frac{I_B}{I_A} = 4\cos^2\left[\frac{m\pi}{2d}(d-\Delta)\right]\frac{\sin^2(m\pi/2)}{\sin^2(m\pi)}$$

$$\frac{m\pi}{2} - \frac{m\pi}{2d}\Delta$$

$$\frac{I_B}{I_A} = \cancel{4}\cos^2\left[\frac{m\pi}{2d}(d-\Delta)\right]\frac{1}{\cancel{4}\cos^2\left(\frac{m\pi}{2}\right)}$$

$$\boxed{\frac{I_B}{I_A} = \frac{\left[\cos\left(\frac{m\pi}{2}\right)\cos\left(\frac{m\pi}{2d}\Delta\right)+\sin\left(\frac{m\pi}{2}\right)\sin\left(\frac{m\pi}{2d}\Delta\right)\right]^2}{\cos^2\left(\frac{m\pi}{2}\right)}}$$

$\cos n\pi$

m bikoitietarako: $m=2n$

$$\frac{I_B}{I_A} = \frac{\left[\cos(n\pi)\cdot\cos\left(\frac{n\pi}{d}\Delta\right)+\sin 0\cdot \ldots\right]^2}{1} = \overbrace{\cos^2(n\pi)}^{1}\cos^2\left(\frac{n\pi\Delta}{d}\right)$$

$$\boxed{\frac{I_B}{I_A} = \cos^2\left(\frac{m\pi\Delta}{2d}\right) = \frac{1}{2}\left[1+\cos\left(\frac{m\pi\Delta}{d}\right)\right]}$$ m bikoitia denean!

m bakoitia denean:

↳ izen-daltzaileak 0 emango du!

$$\frac{I_B}{I_A} = \frac{\left[0 \cdot m + (\pm 1) \cdot \sin \frac{m\pi}{2d} \Delta)\right]^2}{0} = \sin^2\left(\frac{m\pi}{2d}\Delta\right)$$

Zer egin? intentsitate bakoitza aztertu!

$$I_A = I_0 \cdot \left[\frac{\sin\left(\frac{m\pi N}{2}\right)}{\sin \frac{m\pi}{2}}\right]^2$$

Kontuan izan kasu honetan N kopurua bikoitia dela!

↳ Honegatik, $\sin\left(\frac{m\pi N}{2}\right) = 0 \Rightarrow I_A = 0$ ~~mak~~ m bak.

$$I_B = 4 I_0 \cos^2\left[\frac{m\pi}{2d}(d-\Delta)\right] \cdot \left[\frac{\sin\left(\frac{m\pi N}{2}\right)}{\sin(m\pi)}\right]^2$$

↳ bi terminoek zerora, indet!

↳ $\left(\frac{N}{2}\right)^2$

kosinuaren batuean aurreko erlazioa erabili:

↓

$$I_B = I_0 N^2 \sin^2\left(\frac{m\pi}{2d}\Delta\right)$$ m bakoitientzat

$$I_B = \frac{I_0 N^2}{2}\left[\frac{1}{2} - \cos\left(\frac{m\pi}{d}\Delta\right)\right]$$

5) Ikusi ea $\Delta \to 0$ kasuan bi sareentzat emaitza berdinak lortzen diren:

m bak

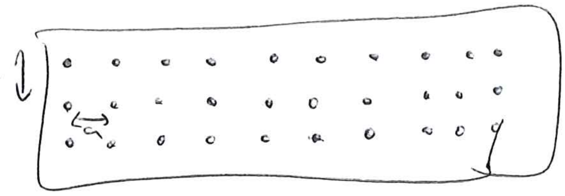
↳ $I_A = 0$, $I_B = 0$

m bik

↳ $\frac{I_B}{I_A} = \frac{1}{2}\left[1+1\right] = 1$

bi kasuetan betetzen da! ✓

10/

a) 

- a, eta b periodoak.
- Maximo nagusiak $p = \frac{m\lambda}{a}$ eta $q = \frac{m\lambda}{b}$ -tan daude.

1) Erdiko lerroa $\frac{a}{3}$ eskuinera mugitu ta gero, nola aldatuko lirateke intentsitateak hasierako sarearekin konparatuz?

Lehenik, hasierako sarearen I_A kalkulatuko dut.

$$\cancel{I_A = I_1 \cdot \left(\frac{\sin(10\varphi)}{\sin(\varphi)}\right)^2}$$

$$\boxed{\varphi = \frac{1}{2}kpa} \qquad \boxed{\alpha = \frac{1}{2}kqb}$$

$$I_A = I_0 \left(\frac{\sin v_a}{v_a}\right)^2 \cdot \left(\frac{\sin(3\alpha)}{\sin(\alpha)}\right)^2 \left[\frac{\sin(10\varphi)}{\sin(\varphi)}\right]^2$$

$$\cancel{v_a = \frac{1}{2}k\frac{2\pi}{\lambda}q}$$

$$\boxed{10 = N}$$

$\cancel{I_A =}$

Hobe amplitudeekin eginez gero,

Zut: bakoitzean: $U_i(p) = U_0\left[1 + e^{-ikqb} + e^{ikqb}\right] = U_0\left[1 + 2\cos(kqb)\right]$

$$I_i(p) = I_0\left[1 + 2\cos(kqb)\right]^2$$

$$\boxed{I_A = I_0\left[1 + 2\cos(kqb)\right]^2 \left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2} \qquad N = 10 \quad \varphi = \frac{1}{2}kpa$$

B kasuan

$$U_i(p) = U_0\left[e^{-i\frac{kpa}{3}} + 2\cos(kqb)\right]$$

$$I_i(p) = I_0\left[1 + 4\cos^2(kqb) + 4\cos(kqb)\cos\left(\frac{kpa}{3}\right)\right]$$

$$I_B = I_0\left[1 + 4\cos^2(kqb) + 4\cos(kqb)\cos\left(\frac{kpa}{3}\right)\right]\left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2$$

Norabide maxetan

$$\boxed{I_{A_{max}} = I_0\left(1 + 2\cos\left(\frac{2\pi}{\lambda}\frac{m\lambda}{b}b\right)\right)^2 N^2 = 9 I_0 N^2}$$

$$I_3 = I_0 \left[1 + 4\cos^2\left(\frac{2\pi}{\cancel{\lambda}}\frac{n\cancel{\lambda}}{\cancel{y}}\cancel{y}\right) + 4\cos\left(\frac{2\pi}{\cancel{\lambda}}\frac{n\cancel{\lambda}}{\cancel{y}}\cancel{y}\right)\cos\left(\frac{2\pi}{\cancel{\lambda}}\frac{m\cancel{\lambda}}{3\cancel{a}}\cancel{a}\right)\right] N^2$$

$$I_3 = I_0 N^2 \left[1 + 4 + 4 \cdot 1 \cdot \cos\left(\frac{2\pi}{3} m\right)\right]$$

$m = \pm 1, \pm 2, \pm 4, \pm 5, \pm 7 \ldots \rightarrow I_3 = 3 I_0 N^2$

↳ $\frac{I_3}{I_1} = \frac{1}{3}$

$m = \pm 3, \pm 6, \pm 9, \ldots \rightarrow I_3 = 9 I_0 N^2$

↳ $\frac{I_3}{I_1} = 1$

I_0 irekidura zirkularrak ematen duen intentsitatea izanik!

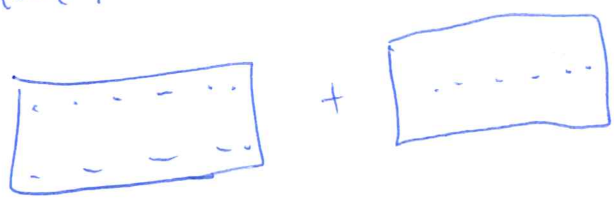
2b) $\frac{a}{3}$ ezkerrera mugitu beharrean,

↳ erdiko lerroan P_y polarizatzailea jarri dugu

↳ besteetan P_x polarizatzailea jarri dugu.

⇒ Maximo nagusien kokapena? Polarizatu gabe argia erabili bada, maximoetako intentsitatea?

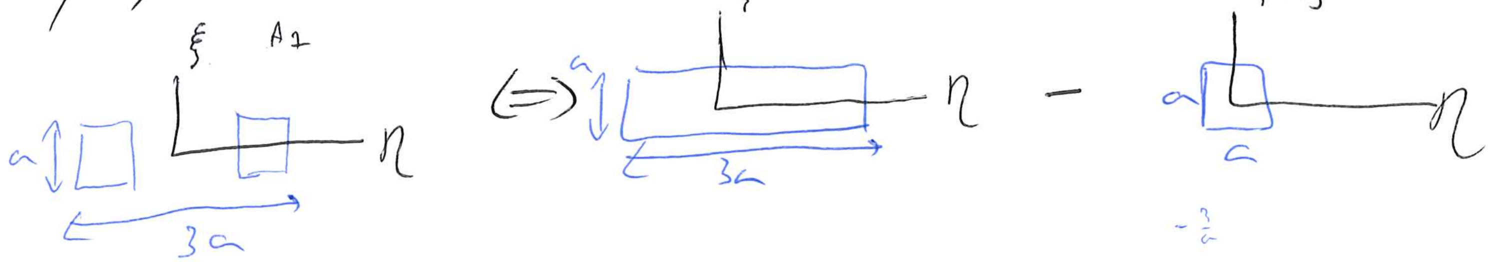
Ortogonalak izatean, ondorengo kasu bezala aztertu daiteke:



$q = 0 - n$: $I = (2^2 + 1^2) N^2 I_0$

$q \neq 0$: $I = 2^2 N^2 I_0$ izango da ← honen ekarpena apenas igarriko baita.

11/ a) Frog-tu $U_{A1}(p,q) = U_{A2}(p,q) - U_{A3}(p,q)$ dele.



$$U_{A_3} = C \cdot a^2 \frac{\sin u}{u} \frac{\sin v}{v} \qquad u = \frac{1}{2}kpa \quad v = \frac{1}{2}kqa$$

$$U_{A_2} = C3a^2 \frac{\sin u'}{u'} \frac{\sin v}{v} \qquad u' = \frac{3}{2}kpa \quad v = \frac{1}{2}kqa$$

$$u' = 3u$$

$$U_{A1} = Ca^2\left[3\frac{\sin u'}{3u'} - \frac{\sin u}{u}\right]\frac{\sin v}{v}$$

$$U_{A1} = Ca^2\left[\cancel{3}\frac{\sin(3u)}{\cancel{3}u} - \frac{\sin u}{u}\right]\frac{\sin v}{v}$$

$$\frac{1+\cos 2u}{2} = \cos^2 u$$

$$\cos(2u) = 2\cos^2 u - 1$$

$$\cancel{\cos(2u) = 1 - 2\cos^2 u}$$

$$U_{A1} = Ca^2 \frac{\sin v}{v}\left[\frac{\sin(u+2u)}{u} - \frac{\sin u}{u}\right]$$

$$U_{A1} = \frac{Ca^2 \sin v}{uv}\left[\sin(u)\cos(2u) + \sin(2u)\cos u - \sin u\right]$$

$$\cancel{U_{A3} = \frac{Ca^2 \sin v}{uv}\left[\sin(u)(1-2\cos^2(u)) + 2\sin(u)\cos^2 u - \sin u\right]}$$

$$\cancel{U_{A3} = \frac{Ca^2 \sin v}{uv}}$$

$$U_{A3} = \frac{Ca^2 \sin v}{uv}\left\{\sin(u)\left[2\cos^2(u) - 1\right] + 2\sin(u)\cos^2(u) - \sin(u)\right\}$$

$$U_{A1} = \frac{Ca^2 \sin v}{uv}\left\{4\cos^2(u)\sin(u) - 2\sin(u)\right\}$$

$$U_{A1} = \frac{Ca^2 \sin v}{uv}\left\{4\sin u - 4\sin^3(u) - 2\sin(u)\right\}$$

$$\boxed{U_{A1} = \frac{2Ca^2}{uv}\sin v\left[\sin(u) - 2\sin^3(u)\right]}$$

V_{A1} Zuzenean kalkulatuz:

~~$V(n) = V_0 \cos$~~

$$\cancel{U(p) = Ca^2 \left(e^{-i\frac{3}{2}kpa} + e^{i\frac{3}{2}kpa} \right) = 2Ca^2 \cos\left(\frac{3}{2}kpa\right)}$$

$$U_{A_1} = Ca^2 \frac{\sin u}{u} \frac{\sin v}{v} \left(e^{-\frac{3}{2}kpai} + e^{\frac{3}{2}kpai} \right)$$

$$U_{A_1} = \frac{2Ca^2}{uv} \sin v \sin u \cos(3u)$$

$$U_{A_1} = \frac{2Ca^2}{uv} \sin v \sin u \left[\cos u \cos(2u) - \sin(u)\sin(2u) \right]$$

$$U_{A_1} = \frac{2Ca^2}{uv} \sin v \sin u \left(\cos(u) \left[-1 + 2\underbrace{\cos^2 u}_{1-\sin^2 u} \right] - 2\sin^2(u)\cos(u) \right)$$

$$U_{A_1} = \frac{2Ca^2}{uv} \sin v \sin u \left[\cos(u) \left[1 - 2\sin^2 u \right] - 2\sin^2(u)\cos(u) \right]$$

$$\cancel{U_{A_1} = Ca^2 \frac{\sin u}{u} \frac{\sin V}{V} \cos(2V) \quad V = \frac{1}{2}kpa}$$

Ondo ari nintzan, baina gaizki jarrita ordea!

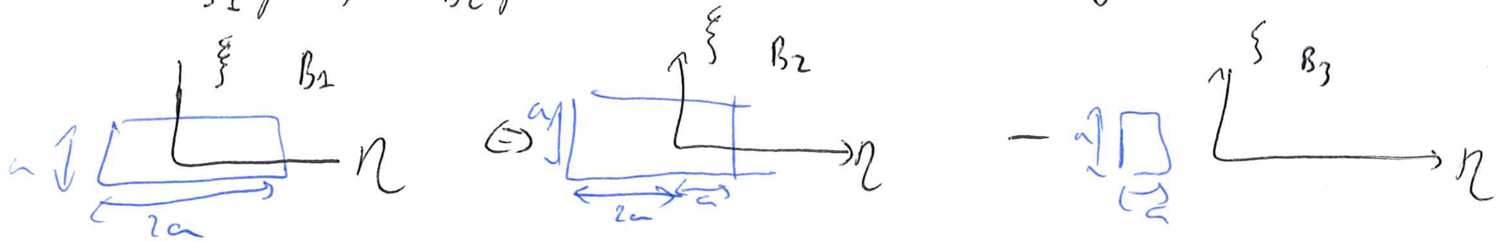
$$U_{A_1} = Ca^2 \frac{\sin u}{u} \frac{\sin V}{V} \left(e^{-akpi} + e^{akpi} \right)$$

$$U_{A_1} = \frac{2Ca^2}{uv} \sin u \sin v \cos(2u)$$

$\cos(2u) = 1 - 2\sin^2(u)$ bete behar da!

$$\cos(2u) = 2\cos^2 u - 1 = 2\left[1 - \sin^2(u)\right] - 1 = 1 - 2\sin^2(u) \quad \boxtimes$$

b) $U_{B_1}(p,q) = U_{B_2}(p,q) - U_{B_3}(p,q)$ dela frogatu



$$U_{B_2}(p,q) = C\,2a^2 \frac{\sin v}{v}\,\frac{\sin u'}{u'} \qquad u' = \underbrace{\frac{1}{2}kpa}_{u}\cdot 2 = 2u$$

$$\boxed{U_{B_2}(p,q) = Ca^2 \frac{\sin v}{v}\,\frac{\sin(2u)}{u}}$$

$$U_{B_3}(p,q) = Ca^2 \frac{\sin v}{v}\,\frac{\sin u}{u}\, e^{-ikp\frac{3}{2}a}$$

$$U_{B_2}(p,q) = C\int_{-\frac{a}{2}}^{\frac{a}{2}} e^{-ikq\xi}\,d\xi \int_{-2a}^{a} e^{-ikp\eta}\,d\eta$$

$$U_{B_2}(p,q) = C\left(\frac{e^{-ikq\xi}}{ikq}\right)_{\frac{a}{2}}^{-\frac{a}{2}}\left[\frac{e^{-ikp\eta}}{ikp}\right]_{a}^{-2a}$$

$$= C\,\frac{e^{ikq\frac{a}{2}} - e^{-ikq\frac{a}{2}}}{ikq}\cdot\frac{e^{2ikpa} - e^{-ikpa}}{ikp}$$

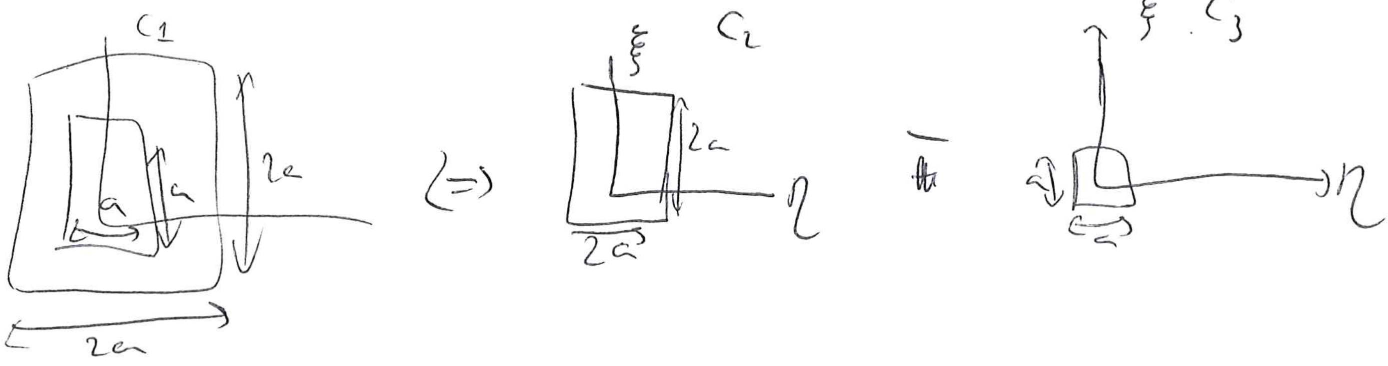
$$= Ca\,\frac{\sin\left(\overbrace{\frac{1}{2}kqa}^{v}\right)}{\underbrace{\frac{1}{2}kqa}_{v}}\cdot\frac{e^{i\frac{3}{2}kpa} - e^{-i\frac{3}{2}kpa}}{ikp}\,e^{i\frac{1}{2}kpa}$$

$$= Ca^2\,\frac{\sin v}{v}\,e^{i\frac{1}{2}kpa}\,\frac{\sin\left(\frac{3}{2}kpa\right)}{\frac{1}{2}kpa} = Ca^2\frac{\sin v}{v}\,\frac{\sin(3u)}{u}\,e^{i\frac{1}{2}kpa}$$

$$U_{B_2} - U_{B_3} = Ca^2\frac{\sin v}{vu}\left[\sin(3u)\,e^{ikp\frac{1}{2}a} - \sin(u)\,e^{-ikp\frac{3}{2}a}\right]$$

$U_{B_2} - U_{B_3} = Ca^2\,\frac{\sin v}{}$ (. . .) eta bide errazagon bat egongo da, azterketak berregitera iristean berriz saiatuko naiz.

c) C_1 irekiduraren amplitudea eta bere minimo baluen posizioak kalkulatu $p=0$ eta $q=0$ norabideetan.



$$V_{C_3} = V_{A_3} = Ca^2 \frac{\sin u}{u}\frac{\sin v}{v} \qquad u = \frac{1}{2}kpa \quad v = \frac{1}{2}kqa$$

$$V_{C_2} = C4a^2 \frac{\sin u'}{u'}\frac{\sin v'}{v'} \qquad u' = \frac{1}{2}kp2a = 2u \quad v' = \frac{1}{2}kq2a = 2v$$

$$V_{C_2} = \cancel{4}Ca^2 \frac{\sin(2u)\sin(2v)}{\cancel{4}uv} = 4\frac{Ca^2}{uv}\sin(u)\cos(u)\sin(v)\cos v$$

$$\boxed{V_{C_1} = \frac{Ca^2}{uv}\sin u \sin v\left[4\cos(u)\cos(v) - 1\right]}$$

$q=0$ denean

$$V_{C_1} = Ca^2 \overbrace{\left(\frac{\sin u}{u}\right)}^{\text{1-eko ekarpena. 0-n}}\left[4\cos(u) - 1\right]$$

$$\boxed{p = n\frac{\lambda}{a} \rightarrow \text{denean minimoak}}$$

$\frac{1}{4} = \cos u \rightarrow$ ~~...~~

$$u = \pm 1{,}32^{+2n\pi} = \frac{1}{2}kpa = \frac{\pi}{\lambda}pa$$

$$\boxed{p = \frac{\lambda}{a}\left(\pm 0{,}42 + \frac{2}{\cancel{\pi}}n\right) \text{-n ere minimoak}}$$

BEREIZMENA

1/

$g = 8\,\mu m$

$f' = 30\cdot 10^{-3}\,m$ } D_B txikiena?

$\lambda = 550\,nm$

$$D_B = \frac{1{,}22\,\lambda f'}{g} \rightarrow \boxed{D_B = 4{,}19\,mm}$$

2/ S izarraren diametroa $d = 3{,}5\cdot 10^{9}\,m$ da eta Lurretik 8,8 argi urtera dago.

→ Zenbatekoa irekidura behar du teleskopio batek izar "puntual" batek emango lukeen difr-irudia eta difr-gabeko tresna "ideal" batek sortuko lukeen Sirio-ren irudia parekoak izateko?

$\varepsilon' = 1' = 3\cdot 10^{-4}$ begiaren bereizmena.

objektu puntuala jasotzen duen teleskopioa:

$$\hookrightarrow \Gamma = \frac{\varepsilon'}{\varepsilon} = \frac{\varepsilon' D}{1{,}22\,\lambda} = \frac{3\cdot 10^{-4}}{1{,}22\cdot 550\cdot 10^{-9}} D$$

Sirio begiztatzen duen teleskopio ideala:

$$\Gamma' = \frac{\tan(w')}{\tan(w)} = \frac{s}{r} \underbrace{\tan(w')}_{\text{ideala}} = \frac{s}{r} 3\cdot 10^{-4}$$

Biak bardindu, eta r eta s ($\frac{d}{2}$ eta 8,8 a.u.) ezagunak izanik,

$$D = \frac{s\cdot 1{,}22\cdot 550\cdot 10^{-9}}{r}$$

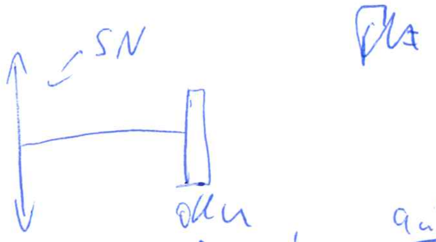
$$\cancel{D = \frac{r}{s\cdot 1{,}22\cdot 550\cdot 10^{-9}} \rightarrow D = 0{,}1181\,m}$$

$$D = 74{,}54\,m$$

3/ • Teleskopio astronomikoa egin dugu

• $D = 12cm$-ko lente konb ($f' = 20cm$) + Ramsden okular batekin.

a) $D_{IN} = 0,5cm$ bada, kalkulatu okularreko osagaiak.



okU

↳ $f'_{oku} = \dfrac{9u^2}{3u+3u-2u} = 2,25u$

Ramsden: $f_1' = 3u$ $\quad e = 2u$

$f_3' = 3u$

$f'_{oku} = 2,25u = \dfrac{f'_{obj} D_{IN}}{D_{SN}} \rightarrow u = \dfrac{10}{27} \rightarrow \boxed{f'_{oku} = \dfrac{5}{6}cm = 0,8\hat{3}cm}$

$\dfrac{f'_{obj}}{f'_{oku}} = \dfrac{D_{SN}}{D_{IN}}$

$\boxed{f_1' = f_3' = \underbrace{\dfrac{30}{27}}_{3u} = 1,\hat{1}cm}$

$\boxed{e = 2u = 0,\overline{740}\ cm}$

b) Ilargiko 2 sumendi 8 km-ra daudenak elkarrengandik, objektiboaren bereizmena nahikoa izango da bi sumendiak bereizteko? ($d_{L-T} = 3,8 \cdot 10^8 m$)

$\Gamma' = \dfrac{D_{SN}}{D_{IN}} = 24$ ⇒ objektua zabala izanik, argitasunari emango diogu lehentasuna.

$\Gamma' \leq \Gamma_B, \Gamma_N \approx 9 \cdot R$

↳ R ▪ sarrerako niniaren erradioa!

↳ 6cm

$\boxed{24 \leq 54}$

↳ betetzen da! Nahikoa izango da, beraz.

c) Teleskopioan zehar begiratzean, ondo bereiziko ditugu sumendiak?

$$\Gamma' = \frac{\tan(w')}{\tan(w)} = 24 \qquad \tan(w) = \frac{r}{s}$$

angelua nahi baitugu!

$$w' \ll 1 \Rightarrow \tan(w') \simeq w' = 24 \tan(w) = 24 \cdot \frac{8 \cdot 10^3/2}{3{,}8 \cdot 10^8}$$

$w' = 2{,}53 \cdot 10^{-4}$ rad $> \varepsilon' = 3 \cdot 10^{-4}$ rad
begiaren bereizmena.

Beraz, bai, bereiziko ditugu.

4/ 1) 0,5 μm ; ZI = ? pot = ? ⇒ Mikroskopioa ondo diseinatua badago. (Δ = 16 cm)

2) Okularrean x10 idatzita badago f'_{obj} = ? f'_{okn} = ?

$$\delta_y = \frac{0{,}61\lambda}{ZI} \rightarrow \boxed{ZI = 0{,}671}$$

(0,5 μm; 550 nm)

$$\Gamma'_{okn} = 10 = \frac{25}{f'_{okn}} \rightarrow \boxed{f'_{okn} = 2{,}5 \text{ cm}}$$

$$\Gamma' = \frac{-160}{f'_{obj}} = \frac{+0{,}25}{f'} = -225\, ZI \Rightarrow \boxed{f'_{obj} = 1{,}0598 \text{ cm}}$$

$$\varphi' = \frac{1}{f'} = -\frac{225\, ZI}{0{,}25}$$

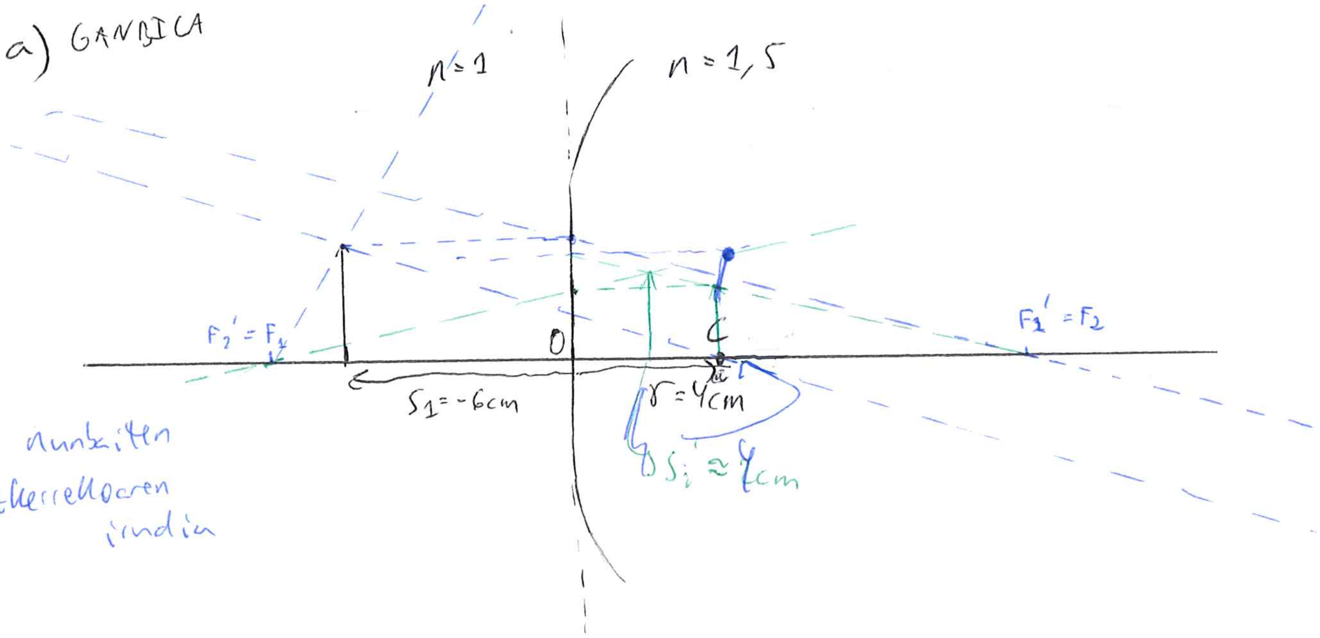
$$\boxed{\varphi' = -603{,}9 \text{ dioptrio}}$$

1. Gaia: Optika geometrikoa

AHURRA) (GANBILA

Oinarrizko ariketak

1/ a) GANBILA



Hemen nunbaiten ezkerrekoaren irudia

ANALITIKOKI:

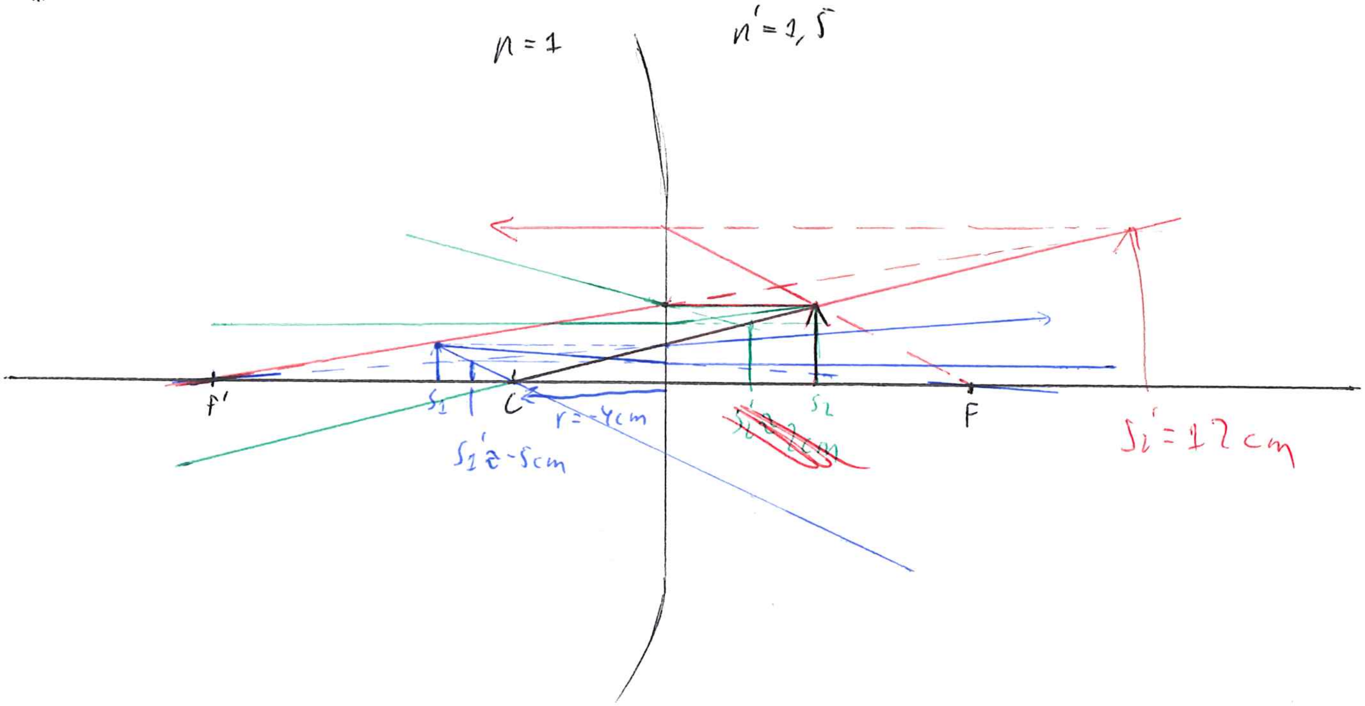
$f_1 = \frac{1}{1-1,5} \cdot 4cm = -8cm$ $\quad f_1' = 12cm$

$\beta_1' = \frac{n s'}{n' s} = 4$

$s_1 = -6cm \qquad s_1' = \frac{n'}{\frac{n'-n}{r} + \frac{n}{s}} \rightarrow s_1' = -36cm \qquad \beta_1' = 6$

$s_2 = 4cm \qquad s_2' = 4cm \qquad \beta_2' = \frac{2}{3}$

b) AURRA



ANALITIKOKI:

$f = 8cm \quad f' = -12cm \quad \rightarrow s_1' = -5{,}14cm \qquad \beta_1' = \frac{4}{7}$

$s_2 = 4cm \qquad s_2' = 12cm \qquad \beta_2' = 2$

2/ Ispilua ahurra $r=-6cm$ $s=-4cm$

$$f = f' = \frac{r}{2} = -3cm \qquad s' = \frac{1}{\frac{2}{r} - \frac{1}{s}} \rightarrow \boxed{s' = -12cm \quad \beta' = -\frac{s'}{s} = -3}$$

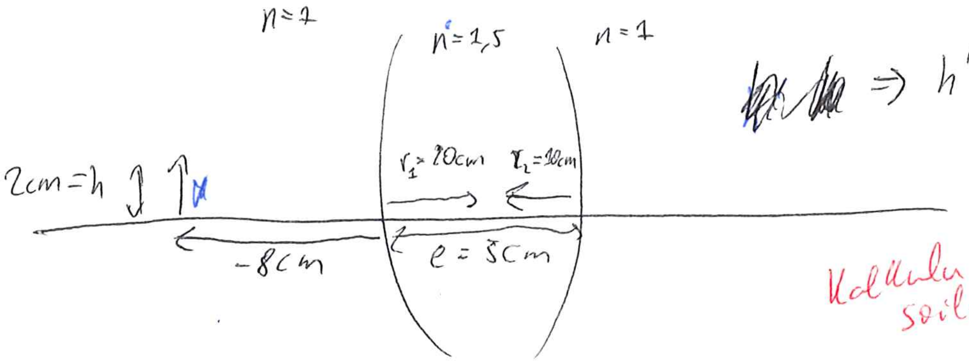
Non kokatu behar da objektua, bere irudia alegiazkoa izan dadin?

$$s' = \frac{1}{\frac{2}{r} - \frac{1}{s}} > 0 \qquad \frac{2}{r} - \frac{1}{s} > 0 \rightarrow \frac{2}{r} > \frac{1}{s} \text{ eta}$$

r negatiboa da!

$$\boxed{s < \frac{r}{2} = -3cm}$$

3/



$\Rightarrow h'$ eta $s' = ?$

Kalkulu errorea soilik izan det!

$$h_0 = 2cm \quad s_0 = -8cm \rightarrow f_1 = -40cm \quad f_1' = 60cm \rightarrow s_0' = \frac{n'}{\frac{n'-n}{r_1} + \frac{n}{s_0}} \rightarrow s_0' = \cancel{40cm}\ -15cm$$

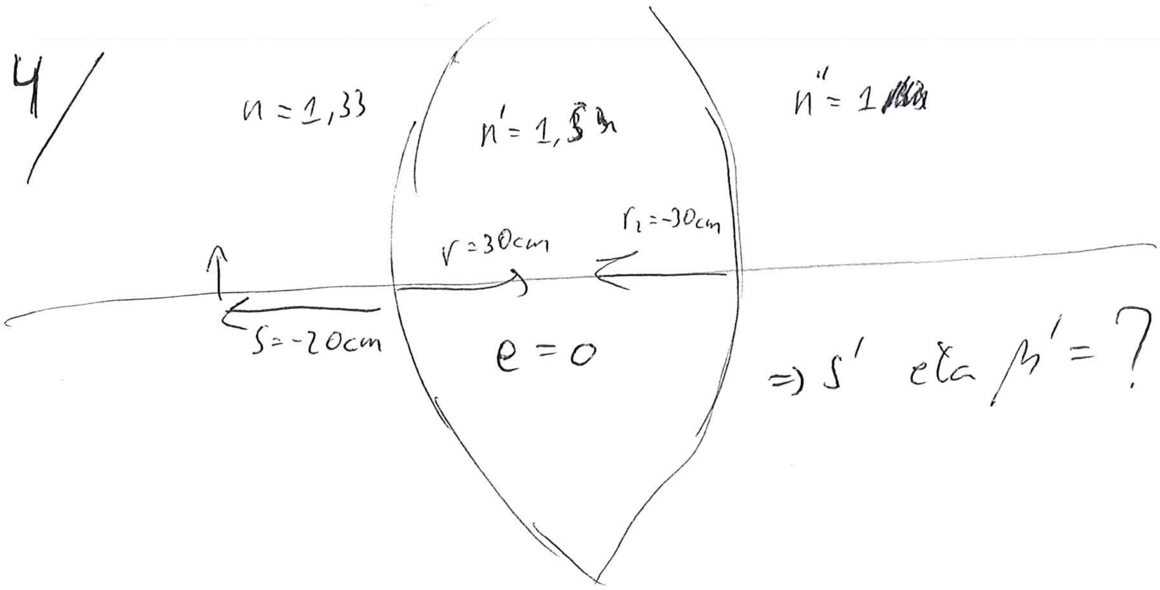
$$\beta_0' = \frac{s_0'}{n' s_0}$$

$$s_1 = -5 \cancel{+10} = \cancel{5cm}\ -15\ -20cm \rightarrow f_2 = -30cm \quad f_2' = 20cm \rightarrow s_1' = \frac{n}{\frac{n-n'}{r_2} + \frac{n'}{s_1}}$$

$$\boxed{s_1' = \cancel{\frac{20}{6}cm = 2,8cm}\ -40cm \qquad \beta_T' = \frac{s_0'}{\cancel{n'} s_0} \cdot \frac{s_1' \cancel{n'}}{s_1} = \cancel{-\frac{143}{200}} = \cancel{-0,7}\ 15/4 = 3,75}$$

$$\boxed{h' = h \cdot \beta_T' = \cancel{1,43cm}\ 7,5cm}$$

4/



$\Rightarrow s'$ eta $\beta' = ?$

$$\left.\begin{array}{l} S_0 = -20cm \\ f_1 = -234,7cm \\ f_2' = 264,71cm \end{array}\right\} \rightarrow S_0' = \frac{n'}{\frac{n'-n}{r} + \frac{n}{S}} = -24,66cm = S_1$$

$$\beta_0 = \frac{n S_0'}{n' S_0}$$

$$\left.\begin{array}{l} s_1 = -24,66cm \\ f_2 = -90cm \\ f_2' = 60cm \end{array}\right\} S_1' = -22,65cm$$

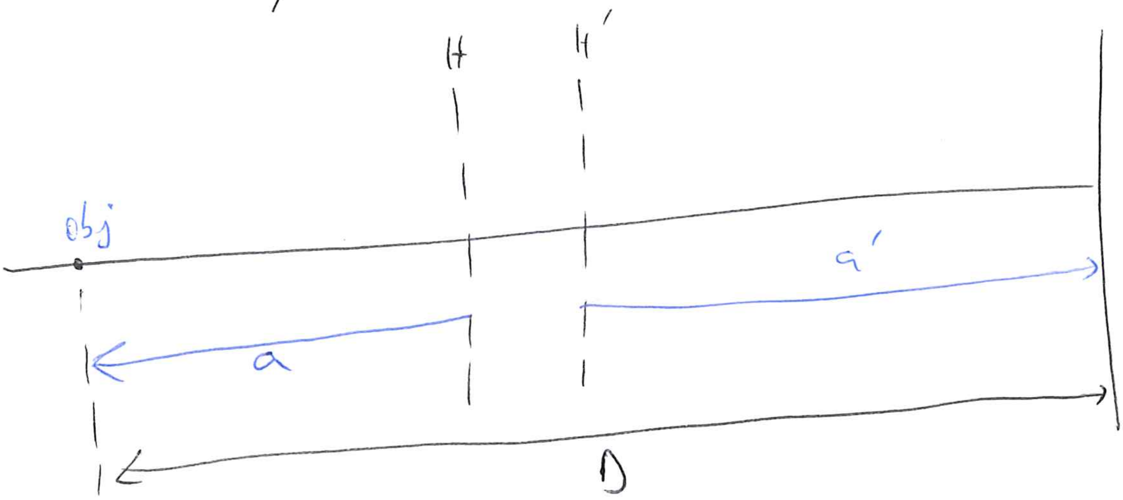
$$\beta_T' = \frac{n \cancel{S_0'}}{\cancel{n'} S_0} \frac{\cancel{n'} S_1'}{\cancel{S_1} n''} = \frac{n S_1'}{S_0 n''}$$

$$\boxed{s_1' = -22,65cm \; ; \; \beta_T' = 1,5}$$

5/ Leiar konbergente batun baten distantzia fokala erdiesteko Besselek proposaturiko metodoa aztertzen da eriketa honetan.

• Objektutik D distantziara pantaila bat jarri da (leiarra tartean).

↳ Kasu honetarako, lentearen bi kokapenetarako ikusten da irudia pantailan.



1) Zein baldintza bete behar da goikoa egia izan dadin?

$$\frac{1}{a'} - \frac{1}{a} = \frac{1}{f'} \Rightarrow f'a - a'f' = a'a \Rightarrow f'(a-a') = a'a$$

Bestetik, $-a + HH' + a' = D \Rightarrow \boxed{a' = D + a - HH'}$ ordezkatuz gero:

$$f'[\cancel{a} - D - \cancel{a} + HH'] = Da + a^2 - HH'a$$

$$\cancel{a^2 + aD - H} \quad a^2 + a(D - HH') + f'(D - HH') = 0$$

$$a = \frac{D - HH' \pm \sqrt{(D-HH')^2 - 4f'(D-HH')}}{2} \Rightarrow$$

$\Rightarrow (D-HH')^2 - 4f'(D-HH') > 0$ bete beharko da $\Rightarrow$

$\Rightarrow$ $D - HH' > 4f'$ da bete beharreko baldintza.

b) Bi posizio horien arteko distantzia d_B eta leiarraren arteko distantzia HH' izanik, lortu leiarraren distantzia fokalaren adierazpena.

$$\cancel{\frac{1}{a'} - \frac{1}{a} = \frac{1}{f'}}$$

Lehenagoko adierazpenean bi balioen kenketa eginez gero hurrengoa lor dezakegu:

$$a_+ - a_- = d_B = \frac{\cancel{D} - \cancel{HH'} + \cancel{2}\sqrt{(D-HH')^2 - 4f'(D-HH')} - \cancel{D} + \cancel{HH'} + \cancel{\sqrt{(D-HH')^2 - 4f'(D-HH')}}}{\cancel{2}}$$

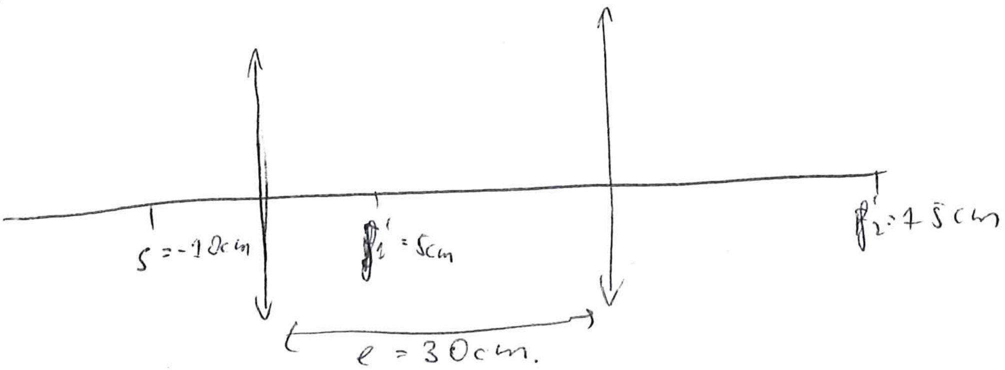
$$d_B^2 = (D-HH')^2 - 4f'(D-HH')$$

$$\boxed{\frac{(D-HH')^2 - d_B^2}{4(D-HH')} = f' \text{ izango da distantzia fokala.}}$$

c) Nola erdietsi daiteke HH' distantzia?

Aipatutakoaren balioa lortu nahi izanez gero, nahikoa izango litzateke esperimentu praktikoa errepikatzea beste D baterako ~~eta~~, beste d_B bat lortuz. Horrela, HH' eta f' kte mantenduko direnez, bi ezezaguneko eta bi ekuazioko sistema askatzea besterik ez genuke izango.

7/



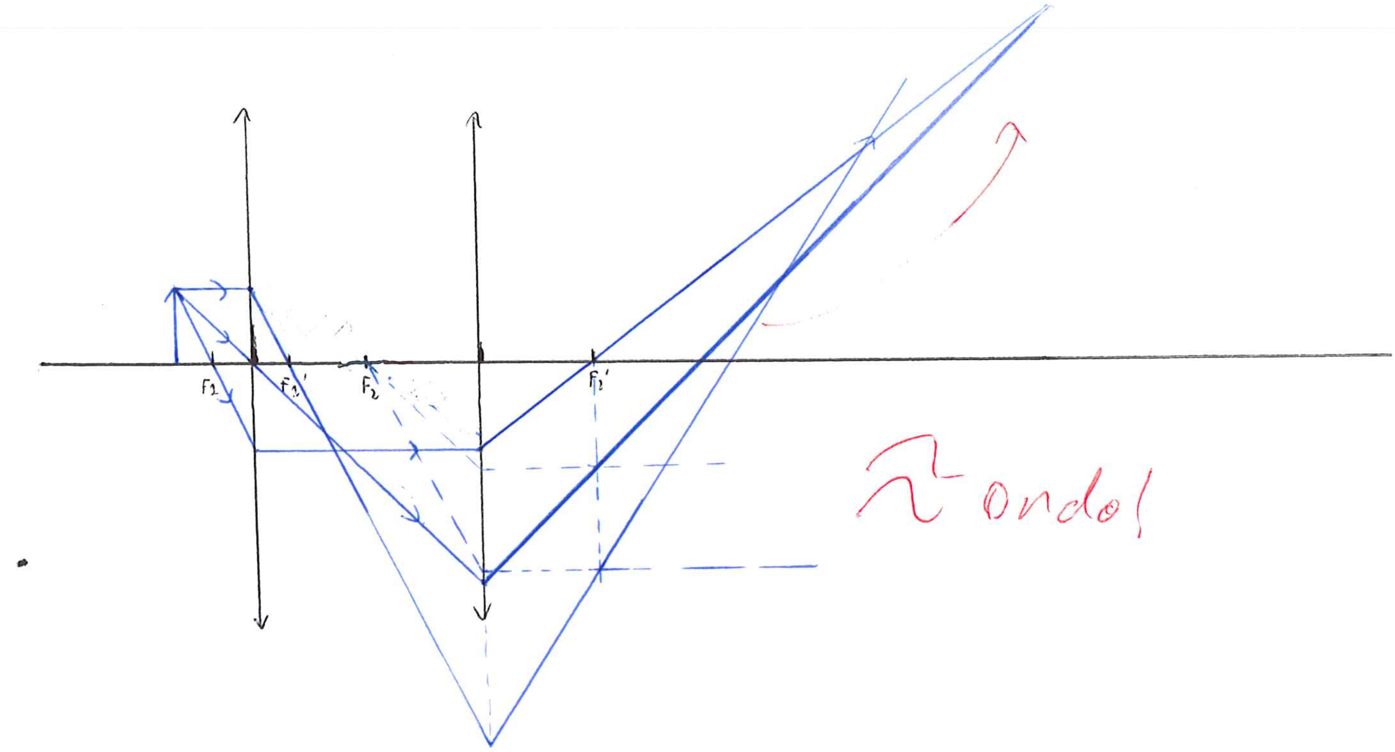
→ Analitikoki eta grafikoki lortu irudiaren posizioa eta β'

$$\frac{1}{a'} - \frac{1}{a} = \frac{1}{f_1'} \Rightarrow \quad s_1' = \frac{1}{\frac{1}{f_1'} + \frac{1}{s}} = 10cm \qquad \beta_1' = \frac{10}{-10} = -1$$

$$s_2 = 10 - 30 = -20cm \qquad s_2' = \frac{1}{\frac{1}{15} - \frac{1}{20}} = 60cm \qquad \beta_2' = -3cm$$

$$\boxed{s_{fin} = 60cm \quad \beta'' = 3}$$ ✓

GRAFIKOA HURRENGO ORRIALDEAN



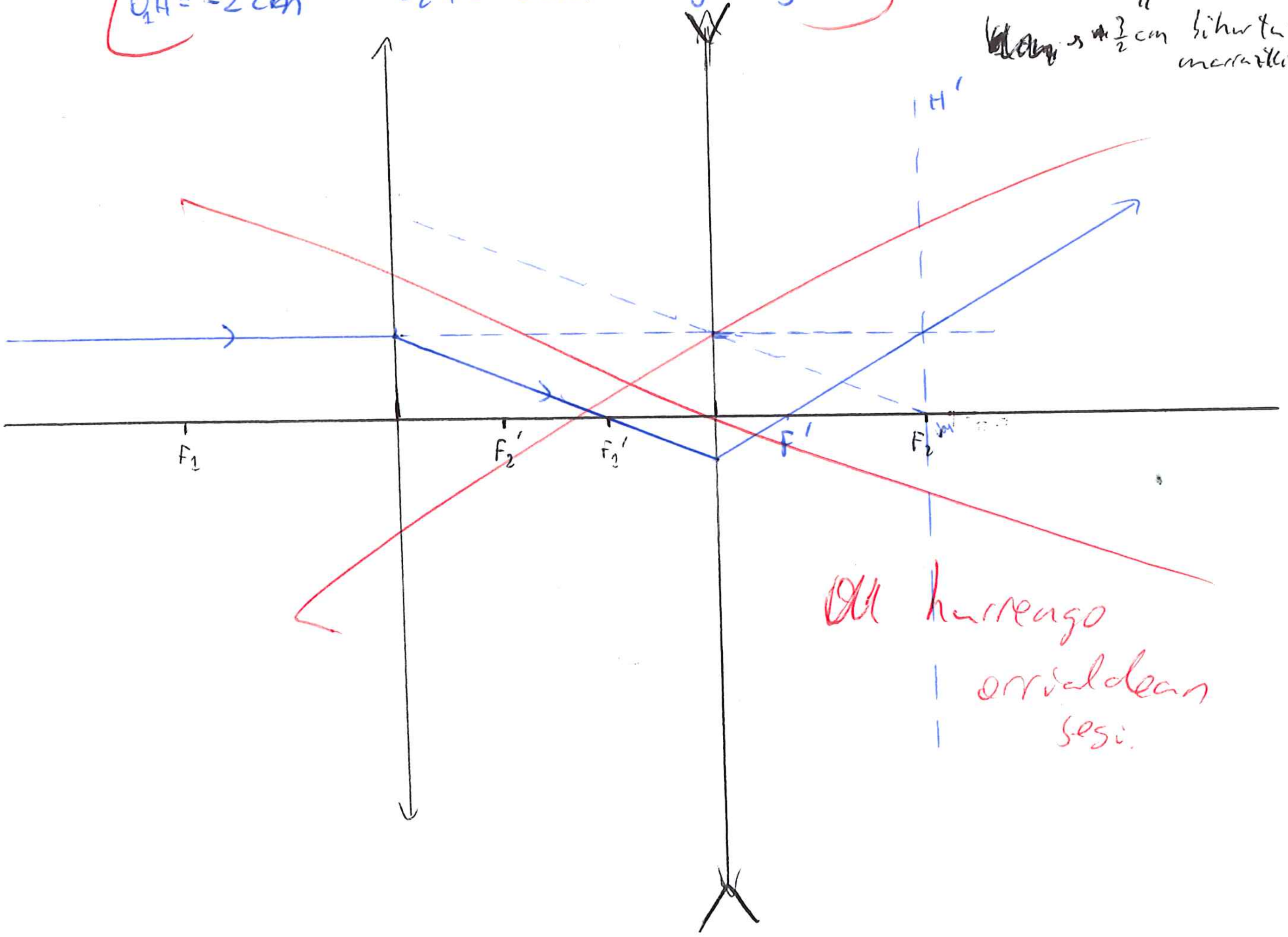
ondo!

8/ (2; 3; -2) -duen lente bikoitzaren elementu kardinalak analitikoki eta grafikoki lortu.

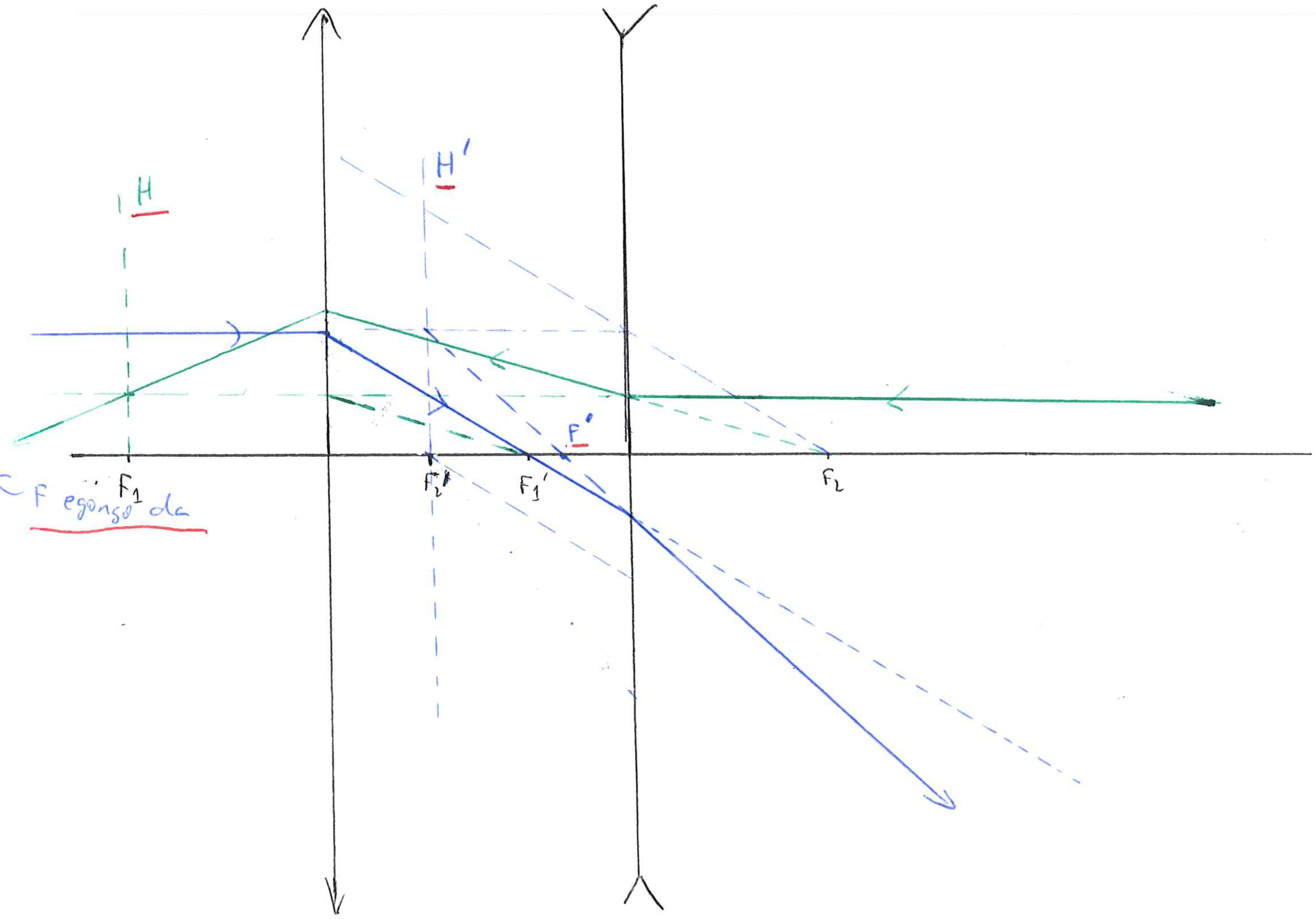
$\frac{f_1'}{2} = \frac{e}{3} = \frac{f_2'}{-2} = u = 1$ cm -tzat hartuz gero.

$O_1H = -2$ cm $O_2H' = -2$ cm $f' = \frac{4}{3}$ cm

u ‖ $\frac{3}{2}$ cm biderkatuz marraztuta



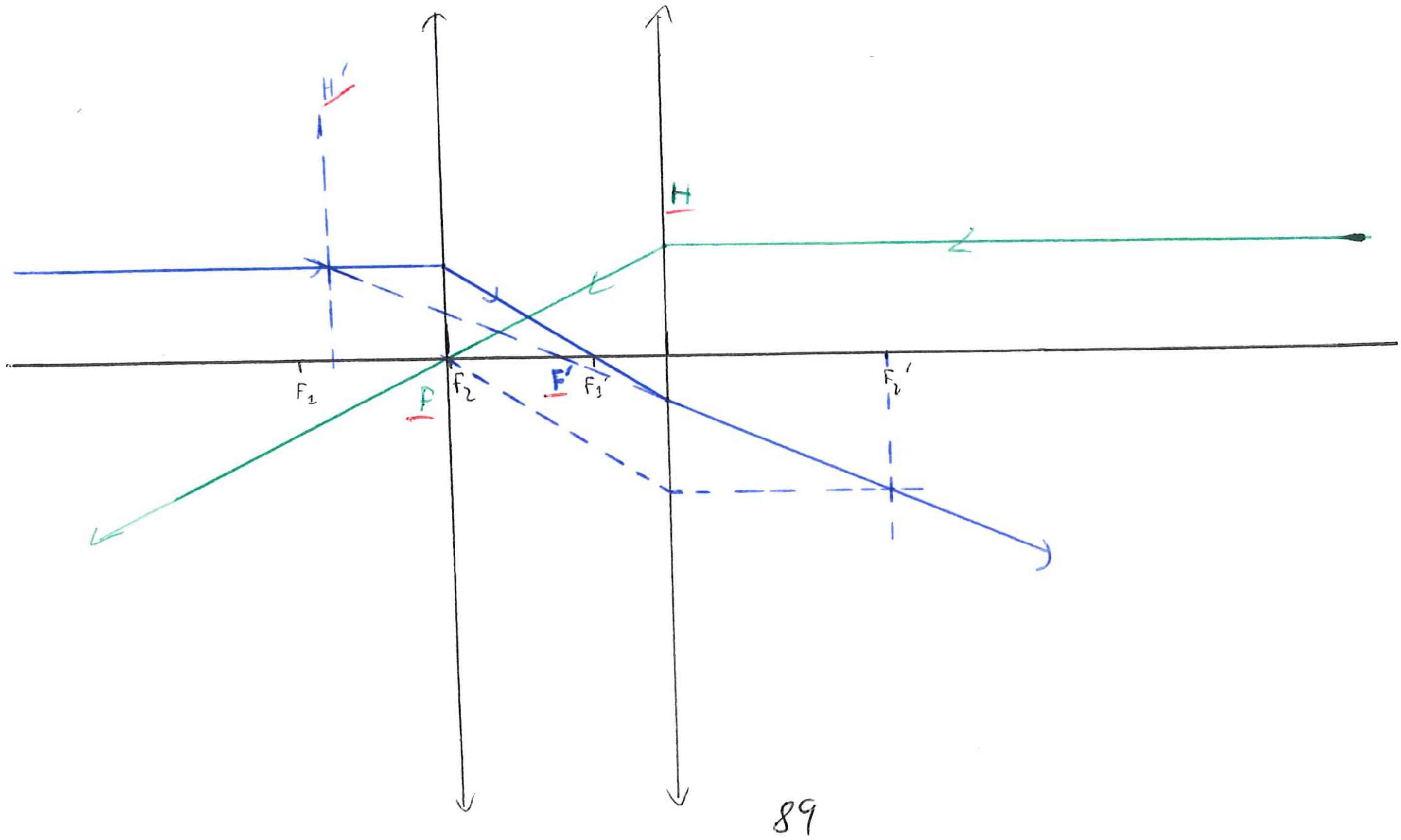
OH hurrengo orrialdean begi.



Berdina (2; 3; 3) lente bikoteratko:

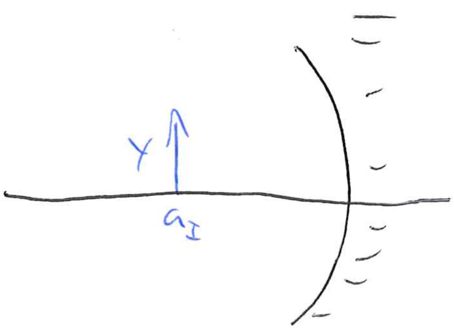
$\frac{f_1'}{2} = \frac{d}{3} = \frac{f_2'}{3} = u$ → $O_1 H = 3u$ $O_2 H' = -\frac{9}{2}u$ $f' = 3u$

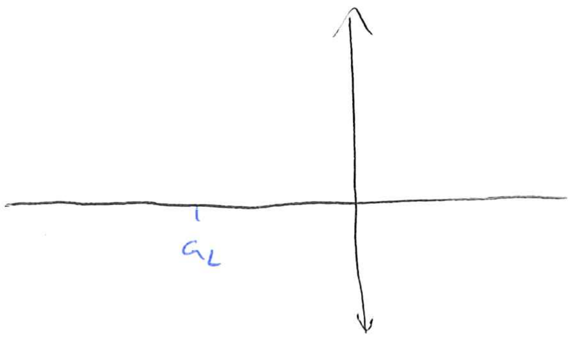
Grafikoratko $u = 1$ cm hartu dut.



9/ • Frogatu ispilu baten ordez $f'_{leiar} = -f'_{ispilu}$ erlazioa betetzen duen leiar mehe bat jartzen bada irudiaren neurria ez dela aldatzen.

• Ispiluek eta lenteek sortutako irudien posizioak, ordea, ~~[illegible]~~ aurkakoak dira: $a'_I = -a'_L$





$$\frac{1}{a'_I} + \frac{1}{a_I} = \frac{1}{f'_I}$$

$$a'_I = \frac{1}{-\frac{1}{a_I} + \frac{1}{f'_I}}$$

$$\cancel{\beta' = a_I f_I}$$

$$\beta'_I = \frac{a'_I}{a_I} = \frac{\cancel{a_I}\, f'_I}{-a_I + f'_I}$$

$a_I = a_L$

$f'_I = -f'_L$

$$\boxed{a'_I = \frac{1}{\frac{1}{f'_I} - \frac{1}{a_I}} = -a'_L = \frac{+1}{-\frac{1}{a_I} + \frac{1}{f'_I}}}$$

D

$$\frac{1}{a'_L} - \frac{1}{a_L} = \frac{1}{f'_L}$$

$$a'_L = \frac{1}{\frac{1}{a_L} + \frac{1}{f'_L}}$$

$$\beta' = \frac{a_L f'_L}{a_L + f'_L}$$

$$\boxed{\beta'_L = \frac{-f'_I}{a_L - f'_I} = \frac{f'_I}{-a_L + f'_I} = \beta'_I}$$

10/

• Sistema optiko batek bi elementu ditu:

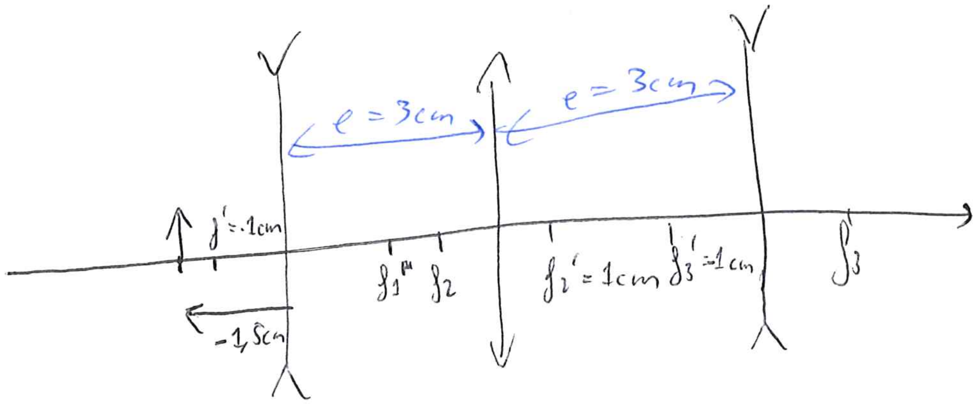
* Lente dib. $f' = -1cm$
* Ispilu ahure: $r = -2cm$

→ bien arteko distantzia 3cm da.

⇒ Kalkulatu lentetik 1,5cm etzkerrera kokatuta dagoen objektuaren irudia eta bere ezaugarriak.

Ariketa hau bi modutara egin daiteke. Lehena, aurreko ariketako estrategia erabiltzea da, ispilua lente batez ordezkatuz.

$$f'_{isp} = \frac{r}{2} = -1cm \rightarrow f'_{lent} = 1cm$$



Kalkulu errorea!

$$\frac{1}{a'} - \frac{1}{a} = \frac{1}{f'} \rightarrow a' = \frac{1}{\frac{1}{f'} + \frac{1}{a}} = -\frac{3}{5}cm \quad \cancel{-0,75cm} \qquad \beta_1' = \frac{3}{5}$$

$$b = -3 - 0,75 = -3,6\,cm \rightarrow b' = \frac{18}{13}cm \approx \cancel{1,...cm} \rightarrow \beta_2' = -\frac{5}{13}$$

$$c = -3 + \frac{15}{11} = -\frac{21}{13}cm \approx \cancel{-1,...cm} \rightarrow c' = -\frac{21}{34}cm = -0,617cm \quad \cancel{-0,621cm} \qquad \beta_3' = \frac{13}{34}$$

$$\boxed{\beta_T = +\frac{3}{34} \approx +0,088 \quad \cancel{+0,103}}$$

bukaeran ezkerreko lentetik 0,617cm ~~0,611cm~~ eskuinera egongo da irudia.

Tresna Optikoak.

1/ • Adineko pertsona baten de $[75, 250]$ cm tartean ikusten du ondo.

→ Nolako betaurrekoak behar ditu?

Puntu urruna gerturatu+ puntu hurbila urrundu

↳ miopia+ hypermetropia izatea ezinezkoa denez, pertsona honek miopia+ presbizia izango du!

⇒ Leiar bifokaleko betaurrekoak behar ditu!

~~$a = -250 \quad a' = \infty \rightarrow \underbrace{\frac{1}{a'}}_{0} - \frac{1}{a} = \frac{1}{f'} \rightarrow f' = 250\,cm = 2{,}5\,m$~~

~~$\hookrightarrow \phi' = 0{,}4\,d$~~

$a = \infty \quad a' = -250\,cm$

∞-an dagona → puntu urrunera ekarri behar da!

$$\frac{1}{a'} - \underbrace{\frac{1}{\infty}}_{0} = \frac{1}{f'} \rightarrow \boxed{f' = -250\,cm = -2{,}5\,m \quad \hookrightarrow \phi' = -0{,}4\,d \text{ goitik.}}$$

$a = -25\,cm \quad a' = -75\,cm$

bere zko puntu hurbila → bere puntu hurbilera ekarri

$$\rightarrow f' = \frac{1}{\frac{1}{a'} - \frac{1}{a}} \rightarrow \boxed{f' = 37{,}5\,cm = 0{,}375\,m \quad \hookrightarrow \phi' = \frac{8}{3} \simeq 2{,}67\,d \text{ behetik.}}$$

→ Betaurrekoak jantzita edozein distantziatara ikusiko du ondo? → Ez!

puntu hau, 250-era eramango du. → beraz a hau baino handiagokoa gaitzki ikusiko du (absolutuki)

Gertukoetatik begiratuz, puntu urruna $a = \dfrac{1}{\frac{1}{a'} - \frac{1}{f'}} = -32{,}6\,cm$ (a' → -250)

Urrutikoekin $a = \dfrac{1}{\frac{1}{a'} - \frac{1}{f'}} = -107{,}14\,cm$ → hau baino handiagoko gaitzki ikusiko du (a' → -75)

↳ $\boxed{a \in [-32{,}6 ; -107{,}14\,cm)}$ tartean gaitzki ikusiko du.

√2/

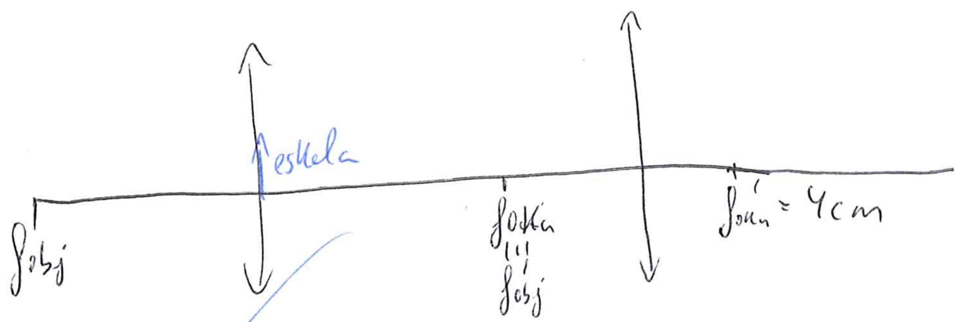
• Betaurreko teleskopiko baten handipen angeluarra neurtzeko Ramsdenen metodoa:

1) Objektiboa dagoen lekuan eskala bat kokatu, okularrak eskalaren irudi erreala emateko.

↳ Honen albo handipena neurtuz, betaurrekoaren handipen angeluarra lor daiteke:

• Teleskopio bat egiteko objektibo ezezagun bat eta $f'_{oku} = 4\,cm$ duen desarra erabili ditugu. Ramsden metodoari segiz, $\beta' = -\frac{1}{3}$ izan da handipena.

a) Teleskopioaren handipen angeluarra & $f'_{obj} = ?$



Soilik leiar bat bagenu, eskalaren handipena:

$a = f_{oku} - f'_{obj}$ izanik,

$$a' = \frac{1}{\frac{1}{a} + \frac{1}{f'_{obj}}} = \frac{1}{\frac{1}{-f'_{oku} - f'_{obj}} + \frac{1}{f'_{obj}}} = \frac{f'_{obj}(-f'_{oku} - f'_{obj})}{f'_{obj} + f'_{oku} - f'_{obj}}$$

$$a' = \frac{1}{\frac{1}{-f'_{oku} - f'_{obj}} + \frac{1}{f'_{oku}}} = \frac{-f'_{oku}(f'_{oku} + f'_{obj})}{f'_{oku} + f'_{oku} + f'_{obj}}$$

$$\rightarrow \beta'_{oku} = \frac{a'}{a} = \frac{2f'_{oku} + f'_{obj}}{+(f'_{oku} + f'_{obj})}$$

$$\boxed{\beta'_{oku} = \frac{f'_{oku}}{2f'_{oku} + f'_{obj}}}$$

$$-\frac{1}{3} = \frac{f'_{oku}}{2f'_{oku} + f'_{obj}}$$

BIDE ZUZENA, KALKULUAK GAIZKI

Objektiboaren informazioa lortzeko:

$$\frac{1}{a'} - \frac{1}{a} = \frac{1}{f'} \rightarrow a = -\infty \text{ denean}, \Rightarrow a' = f_{obj}$$

Ustet aurreko dana eztala beharrezkua, hobeto ondorengoa egitea: GEZURRA, OSO GAIZKI re ENAI JOAN.

$\beta' = -\frac{1}{3}$ eskalan handiyena $\Rightarrow$ soilik 2. leiarran handiyena da.

$$-\frac{1}{3} = \cancel{\frac{f'_{okn}}{2f'_{okn} + f'_{obj}}} \rightarrow f'_{obj} = -3f'_{okn} - 2f'_{okn} \rightarrow f'_{obj} =$$

$$\beta' = \frac{a'}{a} = \frac{\frac{1}{\frac{1}{f'_{okn}} + \frac{1}{a}}}{a} = \frac{\frac{f'_{okn} \cdot \cancel{a}}{a + f'_{okn}}}{\cancel{a}} = \frac{f'_{okn}}{a + f'_{okn}} = -\frac{f'_{okn}}{f'_{obj}}$$

$$a = -f'_{obj} + f'_{okn} = -f'_{obj} - f'_{okn}$$

$$+\frac{1}{3} = \frac{f'_{okn}}{f'_{obj}} \rightarrow \boxed{f'_{obj} = 3f'_{okn} = 12\,cm}$$

$$\Gamma' = -\frac{f'_{obj}}{f'_{okn}} \rightarrow \Gamma' = -\frac{12}{4} \rightarrow \boxed{\Gamma' = -3 \text{ izango da handiyen angeluarra.}}$$

b) Miopa bat e $\varphi = -0{,}5\,d$.-ko betaurrekoak behar ditu. $\Rightarrow$ betaurrekoak ahaztu baizaizkio, zenbat desplazatu behar da okularra ondo ikus dezan? $\varphi = -0{,}5 = \frac{1}{f'} \rightarrow f' = -2m = -200cm$-ko lentea behar du beraz.

$$-\underbrace{\frac{1}{a}}_{0} + \frac{1}{a'} = \frac{1}{f'} \rightarrow \text{orain } a' = +f' = -200\,cm \rightarrow -200 \text{ cm da ikaslearen puntu urruna.}$$

$$a = \frac{1}{\underbrace{\frac{1}{a'}}_{-200} - \frac{1}{f'_{okn}}} = -3{,}92cm \rightarrow$$ okularretik distantzia horretara sortu behar da objektiboaren irudia.

$f_{oku} = -4\,cm$ izanik, okularra 0,08 cm ezkerretara mugitu behar da ikasleak ondo ikus dezan.

3/ • Ondorengo sistema optikoa dugu:

1. Leiera: $f'_{L1} = 9\,cm$, $\phi_{L1} = 6\,cm$

↳ 3 cm eskuinera diafragma 1: $\phi_D = 4\,cm$

↳ 2 cm eskuinera: $f'_{L2} = 3\,cm$ $\phi_{L2} = 3\,cm$.

• Objektua L_1-etik 12 cm ezkerrera dago.

a) Sarrerako niniaren kokapena eta diametroa?

$S_{L1} = -12\,cm$ izango dugu. $\tan\theta = \frac{\phi_{L1}/2}{12} \rightarrow \theta_{L1} = 14{,}036°$

D_1 ~~irudi~~ objektu espaziora eramanez:

~~$a = 3\,cm$ $a' = \frac{1}{\frac{1}{a} + \frac{1}{f'_{L1}}} = 2{,}25\,cm$ $\beta'_T =$~~

(ikuspuntua aldatuz) $\rightarrow$ $a = -3\,cm$ $f'_{L1} = 9\,cm$ $\rightarrow a' = \frac{1}{\frac{1}{a} + \frac{1}{f'_{L1}}} = -4{,}5\,cm$ $\beta'_T = \frac{3}{2}$

↳ Beraz, irudia, ~~berera~~ diafragma objektu espazioan L_1-etik 4,5 cm eskuinera eta 6 cm-ko diametroa izango du

↳ $\tan\theta = \frac{6/2}{12+4{,}5} \rightarrow \theta_{D_1} = 10{,}30°$

L_2 objektu espaziora eramateko berdina eginez:

$a = -5\,cm$ $\rightarrow a' = -11{,}25\,cm$ $\beta'_T = \frac{9}{4}$ $\Rightarrow$ L_1-etik 11,25 cm eskuinera eta ~~[illegible]~~ $\phi_{L2_{obj}} = \frac{27}{4}\,cm$ $\Rightarrow$

$\Rightarrow$ $\theta = \arctan \frac{\frac{27}{8}}{12 + 11{,}25} \rightarrow \theta_{L2_{obj}} = 8{,}26°$

Angelu txikiena hartzen duenez, sarrerako ninia L_2 objektu espazioan izango da: L_1-etik 11,25 cm eskuinera eta $\frac{27}{4}$ cm-ko diametroarekin

↳ Irekidura diafragma eta irteerako ninia L_2 lentea bera izango da.

b) Sarrerako leihoaren kokapen eta diametroa?

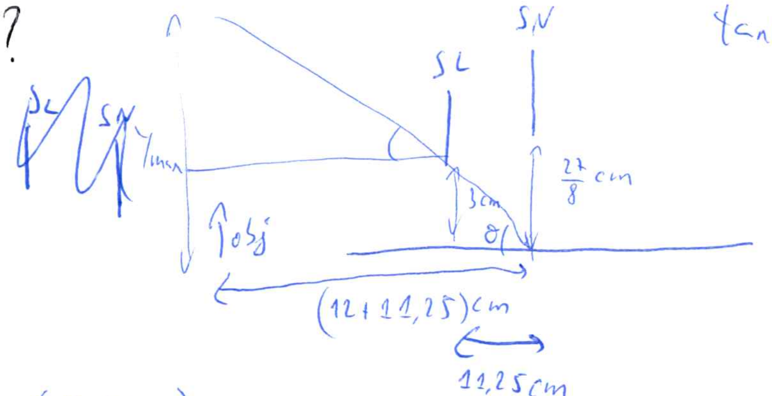
Dena objektu espazioan mantenduz

$$\tan\theta_{D1} = \frac{6/2}{11{,}25-4{,}5} \rightarrow \theta_{D1} = 23{,}96^\circ$$

$$\tan\theta_{L1} = \frac{6/2}{11{,}25} \rightarrow \theta_{L1} = 14{,}93^\circ$$

$\Rightarrow$ Ondorioz, sarrerako leihoa L_1 lentea bera da.

c) Objektuaren altuera maximoa argiztapen erdiko eremuaren barnean sartzeko?



$$\tan\theta = \frac{Y_{max}-3}{12} = \frac{Y_{max}}{12+11{,}25}$$

$$\theta_A = \arctan\left(\frac{3\text{ cm}}{11{,}25\text{ cm}}\right)$$

$$Y_{max} = (12+11{,}25)\tan\theta_A$$

$Y_{max} = 6{,}2$ cm da altura maximoa ardatzetik norabide batean,

↳ obj.max $= 12{,}4$ cm izango da.

4/ • Sistema optikoa, ezkerretik eskuinera:

$A \xleftrightarrow{56mm} B \xleftrightarrow{8mm} C \xleftrightarrow{24mm} D$

A: 8 mm altu den objektua.

B: L_1 leiarra, $f'_1 = 16mm$, $\phi_{L_1} = 30mm$

C: D_1 diafrag., $\phi_{D_1} = 16mm$

D: L_2 leiarra, $f'_2 = 12mm$, $\phi_{L_2} = 30mm$

a) SN, IN eta SL-ren kokapen eta neurriak kalkulatu ondoren, grafikoki adierazi.

1. pausua D_1 eta L_2 objektu espaziora eramatea da:

$a = -8mm$ $a' = \dfrac{1}{\frac{1}{-8} + \frac{1}{16}} = -16mm$ $\beta'_1 = 2$ → D_{1obj} → L_1-etik 16mm eskuinera. $\phi_{D_{1obj}} = 32mm$

$a = -32mm$ $a' = 32mm$ $\beta_T = -1$ → L_{2obj} → L_1-etik 32mm ezkerrera, $\phi_{L_{2obj}} = 30mm$.

$\theta_{L_1} = \arctan\left(\dfrac{30/2}{56}\right) \rightarrow \theta_{L_1} = 15^\circ$

$\theta_{D_{1obj}} = \arctan\left(\dfrac{32/2}{56+16}\right) \rightarrow \theta_{D_{1obj}} = 12,53^\circ$

$\theta_{L_{2obj}} = \arctan\left(\dfrac{30/2}{56-32}\right) \rightarrow \theta_{L_{2obj}} = 32^\circ$

~~L1 beraz da~~ D_{1obj} izango da sarrerako ninia eta ondorioz, D_1 irekidura diafragma.

IN kalkulatzeko irudi espaziora eraman behar dugu.

$a = -24mm$ $a' = \dfrac{1}{\frac{1}{-24} + \frac{1}{12}} = 24mm$ → $\beta' = -1$ → IN $D_{1irud.}$ izango da, L_2-tik 24mm eskuinera eta 16 mm-ko diametroarekin.

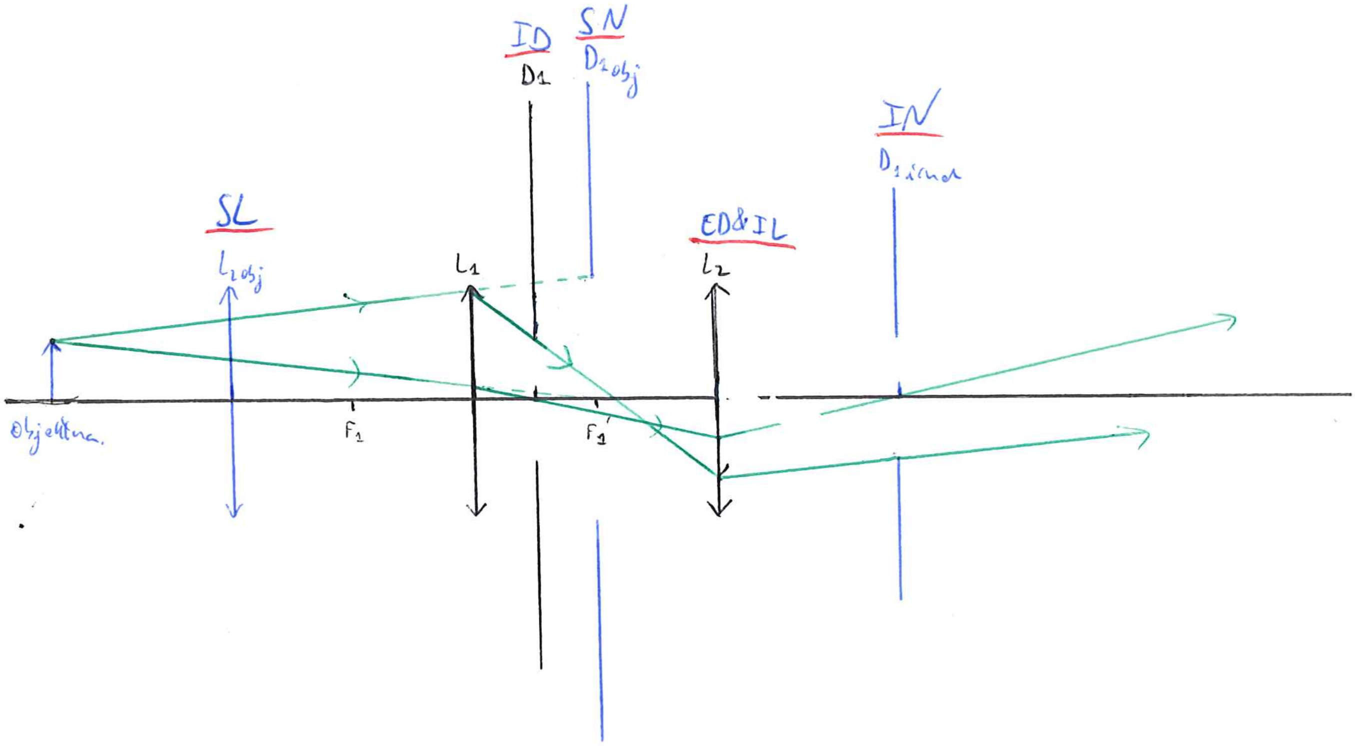
Sarrerako leihoa kalkulatzeko objektu espazioan izan behar ditugu elementu denak.

$$\theta_{L1} = \arctan \frac{32/2}{16} \rightarrow \theta_{L1} = 45°$$

$$\theta_{L2obj} = \arctan \frac{30/2}{16+32} \rightarrow \theta_{L2obj} = 17{,}35°$$

Beraz, L_2 obj izango da sarrerako leihoa, L_1-etik 32mm ezkerrera eta $\phi_{L2obj} = 30mm$ izanik.

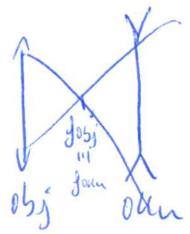
Ondorioz, L_2 izango da eremu diafragma eta baita irteerako leihoa ere, dagoeneko irudi espazioan baitago.



5/ ·Antzoki betaurrekoen objektiboaren eta okularraren fokalak +12cm eta -4cm dira, hurrenez hurren.

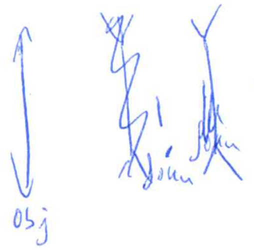
⇒ Kalkulatu betaurrekoen luzera eta handipena behatzailea:

a) Emetropea bada eta ~~∞-an~~ ari bada fokatzen.



∞-ra fokatzen ari bada ikusleа, $s=0$ izan behar da.

⇒ ~~$L = f_{obj} + f_{oku} = 16cm$~~



f'_{obj} ← betetzen da.
f_{oku}

Ondorioz, $e = f'_{obj} - f_{oku} = 12-4$ → $e = 8cm$ da betaurrekoaren luzera

$\Gamma' = \frac{-f'_{obj}}{f'_{oku}} = 3$ da handipen angeluarra.

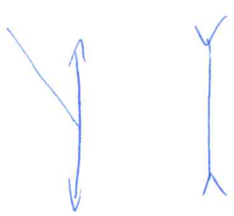
b) miopea bada (4d) eta bere puntu urrunа ari bada fokatzen.

$\varphi = -4d \rightarrow f' = -\frac{1}{4} = -0,25m = -25cm$

$\frac{1}{a'} - \frac{1}{\underset{\infty}{a}} = \frac{1}{f'}$ → $a' = -25cm$ da bere puntu urruna

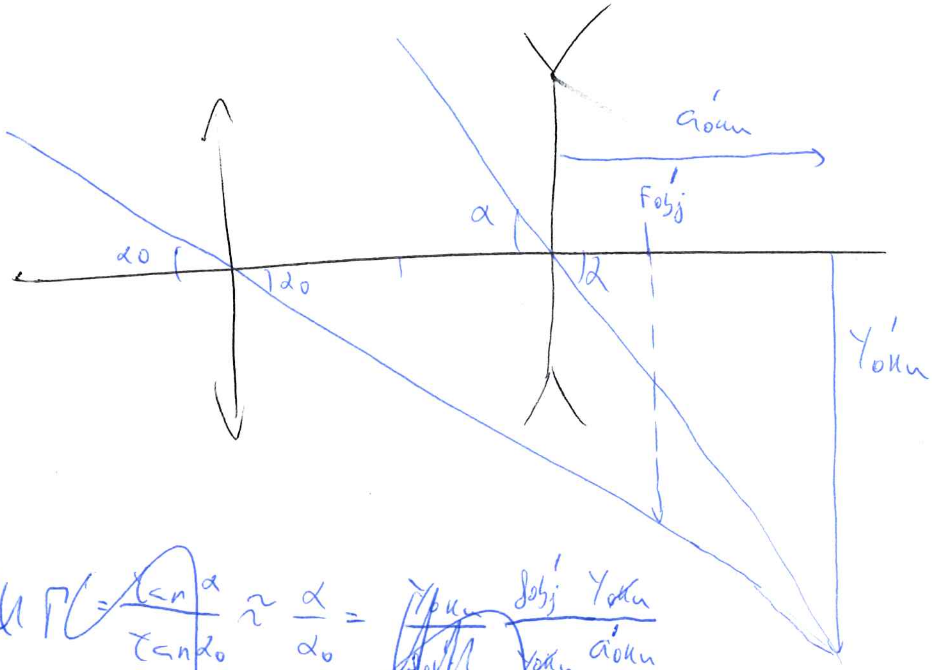
$a = \frac{1}{\frac{1}{a'} - \frac{1}{f_{oku}}} = 4,76cm$-en sortu behar da irudia

~~zuzen~~ miopeak ∞-an ikusteko → which is ~~not~~ possible.



Lehen Y-tik 4cm eskuinera sortzen bazen, orain okularra 0,76cm ~~zentimetro~~ ezkerrera mugitu behar da. ⇒ $e = 7,24cm$

Handipena kalkulatzea is not easy:



$$\Gamma' = \frac{\tan\alpha}{\tan\alpha_0} \approx \frac{\alpha}{\alpha_0} = \frac{f'_{obj}\, y'_{okn}}{y_{okn}\, a'_{okn}}$$

$$\frac{a'_{okn}}{a_{okn}} = \beta \to a'_{okn} = \beta\, a_{okn} = \frac{y'_{okn}\, a_{okn}}{y_{okn}}$$

$$\Gamma' = \frac{\tan\alpha}{\tan(\alpha_0)} \approx \frac{\alpha}{\alpha_0} = \frac{y'_{okn}}{a'_{okn}\,\alpha_0} \to \Gamma' \approx \frac{y'_{okn}\, y_{okn}}{y'_{okn}\, a_{okn}\, \alpha_0} = \frac{y_{okn}}{a_{okn}\,\alpha_0}$$

$$\frac{a'_{okn}}{a_{okn}} = \beta = \frac{y'_{okn}}{y_{okn}} \to \boxed{a'_{okn} = \frac{y'_{okn}\, a_{okn}}{y_{okn}}}$$

$a_{okn} = 4,76\,cm$

$$\alpha_0 = \frac{y'_{obj}}{f'_{obj}} = \frac{y_{okn}}{f'_{obj}} \Rightarrow \Gamma' \approx \frac{y_{okn}\, f'_{obj}}{a_{okn}\, y_{okn}}$$

$$\boxed{\Gamma' \approx \frac{f'_{obj}}{a_{okn}} = 2,521 \text{ da handipen angelarra.}}$$

6/ • Mikroskopio bat dugu: $f'_{obj} = 5mm$ $f'_{oku} = 20mm$ $\Delta = 160mm$

→ Distantzia fokala? Plano nagusien kokapena?

Hau zuzenean formulak aplikatuz lortzen da:

$e = f'_{obj} + \Delta + f'_{oku} = 185$

$f' = -\frac{f'_1 f'_2}{e - f'_1 - f'_2}$ → $f' = -0,625mm$

$O_1H = -5,78mm$

$O_2H' = 23,125mm$

→ Non kokatu behar da objektua behatzaile emetrope baten begia moldatu barik ondo ikus dezan.

$a'_{oku} = \infty$ → $-\frac{1}{a_{oku}} = \frac{1}{f'_{oku}}$ → $a_{oku} = -20mm$

~~$a'_{obj} = e + a_{oku}$~~ = $\boxed{a'_{obj}} = 185 - 20 = \underline{165mm}$

Orduan $a_{obj} = \frac{1}{\frac{1}{a'_{obj}} - \frac{1}{f'_{obj}}}$ → $a_{obj} = -5,1562mm$ (objektibotik dist. hori atzerantz) posizioan egon behar da objektua.

→ Fokapen latitudea = ?

goiko posizioa, irudia puntu urrunean ikusteko zen.

Puntu hurbilean ikusteko:

$a'_{oku} = -250mm$ ← begia okulerrean jartzen baita.

$a_{oku} = \frac{1}{\frac{1}{a'_{oku}} - \frac{1}{f'_{oku}}} = -18,519mm$ → $a'_{obj} = 166,481mm$

$a_{obj} = -5,1548mm$ → $D \sim 0,0014mm = 0,0000014m = 1,4\mu m$ (Kendura)

√7/

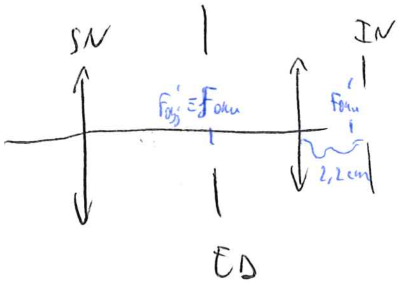
• Teleskopio bat dugu: $f'_{okul} = 2cm$; IN okularretik 2,2cm eskuinera dago.

↳ Zinurrenik sistema fokugabea izango da. (agian ez)

a) Kalkulatu teleskopioaren ikusmen andipena.

$\Gamma' = -\frac{f'_{obj}}{f'_{oku}}$ → f'_{obj} kalkulatu behar dugu.

(Azkenean bai, sistema fokugabea da)



$a' = 2,2cm$
$f'_{oku} = 2cm$
$a = -f'_{obj} + f_{oku}$

objektuaren sarrerako ninian kokatzearen kasua.

$$\frac{1}{2,2} + \frac{1}{f'_{obj}+2} = \frac{1}{2} \rightarrow \cancel{\frac{1}{2,2} - \frac{1}{2,2}}$$

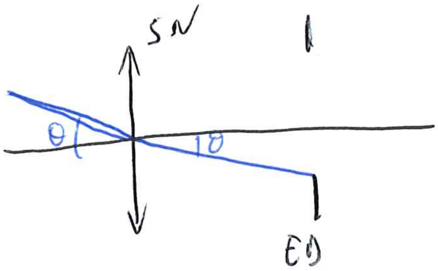
$$\frac{1}{2} - \frac{1}{2,2} = \frac{1}{f'_{obj}+2} \rightarrow \frac{1}{\frac{1}{2} - \frac{1}{2,2}} - 2 = f'_{obj}$$

$\underline{f'_{obj} = 20cm}$

$\Gamma' = -10$ izango da handipen angeluarra.

b) Irudiaren argiztapena uniformea izateko, ED bat kokatu behar da. $r_{min.diaf} = ?$ ⇒ ilargiaren irudi osoa jaso nahi badugu ($d_{L-T} = 3,8 \cdot 10^8 m$; $r_I = 1,74 \cdot 10^6 m$)

~~ED bat~~ objektuak sarrerako leihoan egon behar du hau gerta dadin ⇒ ED tarteko irudi baten posizioan jarten da. Gure kasuan $f'_{obj} = F_{oku}$ puntuan jarriko dugu.



$r_{min\,dif} = ?$

angelua berdina baita bi aldetara

$$\tan\theta = \frac{r_I}{d_{LI}} = \left| -\frac{r_{min\,dif}}{f'_{obj}} \right|$$

$$\cancel{r_{min} = r_I} \quad r_{min\,dif} = \frac{r_I\, f'_{obj}}{d_{LI}} \Rightarrow \boxed{r_{min\,dif} = 9{,}158 \cdot 10^{-4}\,m = 0{,}916\,mm}$$

c) Okularra objektiboarekiko desplazatu da, Ilargiaren irudia pantaila batean jaso ahal izateko. Pantaila okularretik 1m-ra dago.

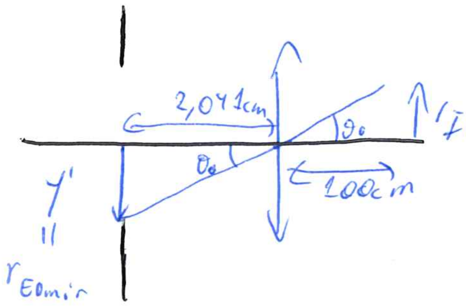
⇒ Zein da okular eta objektiboaren arteko distantzia? Eta pantailako ilargiaren erradioa?

$a'_{okn} = 1m \quad f'_{okn} = 2cm \qquad a = \dfrac{1}{\frac{1}{a'} - \frac{1}{f'_{okn}}} \rightarrow a_{okn} = -2{,}041\,cm$

~~Ez~~ $f_{okn} = -2\,cm$ izanik, okularra 0,041 cm ezkerrera mugitu dugula esan nahi du

↳ $d_{okn\,obj} = f'_{obj} + f'_{okn} + 0{,}041\,cm = 22{,}041\,cm$ da

$$\cancel{M(8),5 = \frac{\tan\theta_{orig}}{\tan\theta_{okn}} = \frac{r_I / d_{LI}}{r_{IP} / 100cm} \rightarrow r_{IP} = \frac{r_I \cdot 100cm}{d_{LI} \cdot 4438{,}5} \rightarrow r_{IP} =}$$



$$\frac{r_{EDmin}}{2{,}041\,cm} = \frac{r_{IP}}{100\,cm} \rightarrow \boxed{r_{IP} = 4{,}488\,cm}$$

d) Ilargiaren irudia pantailan ondo fokatuta dagoenean, ametrope batek betaurreko gabe begiratu du teleskopiotik eta irudia ondo ikusten duela dio. Zer graduazio du?

~~$a' = 100cm$.~~ Ikusleak irudia infinituan ikusten du, bere 100 cm-tan dagoenean:

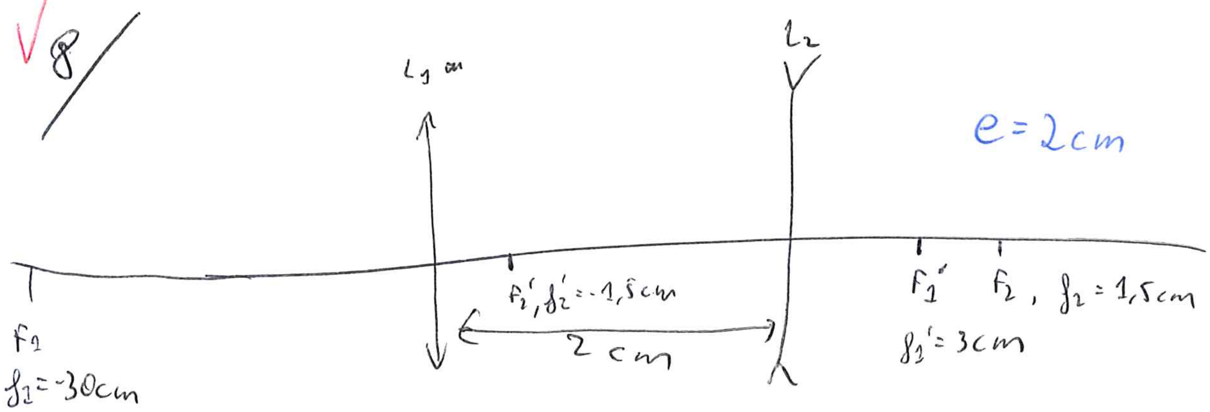
$a' = 100cm$ $a = \infty$ $f' = ?$ $\varphi = 1d$

↓ bere begiak ∞-an ikustea eragiten dio.

→ $f' = 100cm$

↳ $\boxed{\varphi = 1d}$ Hipermetropea da

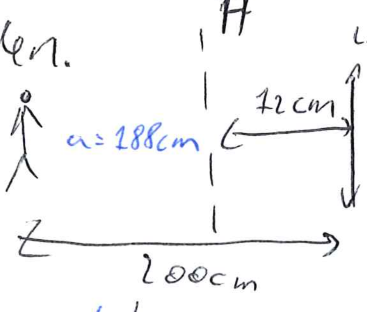
8

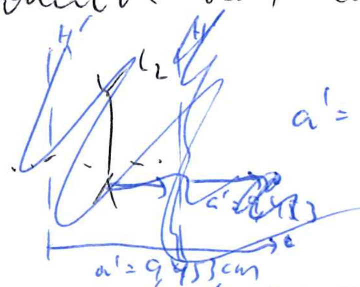


a) sistema baliokidea lortu:

$O_1H = -12cm$ $O_2H' = -6cm$ $f' = 9cm$

b) Aipatutako sistema optikoa argazki kamera baten objektiboa da. 1. lentetik 2 m-ra dagoen pertsona baten erretratua egite aldera, kalkulatu filma fokutik zein distantziara kokatu behar den.

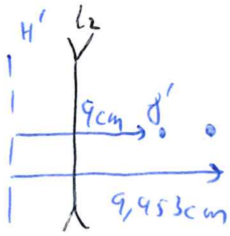




$$a' = \frac{1}{\frac{1}{a} + \frac{1}{f'}}$$ → $a' = 9,453 cm$

↳ H'-tik irudia sortzen den lekurako distantzia.

x' → fokutik zein distantziara kokatu behar den.



$\boxed{x' = 0,453cm = 4,53mm \text{ izango da.}}$

c) Lortu eremu bertikal eta horizontalak, 24x36mm-ko filma erabiltzen bada.

$$\tan\theta_B = \frac{12mm}{d} = \frac{12mm}{\cancel{90mm}\ (90+4{,}53)mm} = \frac{Y/2}{\cancel{2000mm}\ 1880}$$

$Y = 477{,}31\,mm$ eremu bertikala

$$\tan\theta_H = \frac{18mm}{d} = \frac{18mm}{(90+4{,}53)mm} = \frac{X/2}{1880mm}$$

$\hookrightarrow X = 715{,}96mm$ eremu horizontala.

9/ · Prismatiko batentan: 8 (ikusmen-handipena) x 30 (SN-aren diametroa) dago idatzita.

· Benetako eremua 20° da.

=> IN-aren diametroa eta ~~...~~ itxurazko eremua?

$$|\Gamma'| = \frac{D_{SN}}{D_{IN}} \rightarrow D_{IN} = \frac{30mm}{8} \rightarrow \boxed{D_{IN} = 3{,}75mm}$$

$$\Gamma' = \frac{\tan\theta'}{\tan\theta} = 8 = \frac{\tan\theta'}{\tan\left(\frac{20°}{2}\right)} \rightarrow \theta' = 7{,}95° \Rightarrow$$

x2 => Eremua: 15,9° da.

10/ $\underbrace{f'_{obj} = 5cm \quad N=6}_{\text{OBJEKTIBOA}}$ + Huygensen okularra (x10 ikusmen handipena)

• Goikoa badugu ($e = H_{obj}' H_{okn} = 16cm$ izanik) OJO! $\Delta \neq 16cm$.

a) Lortu:

- Betaurrekoaren handipena.
- Lan distantzia.
- ZI
- Fokapen latitudea.

$\Gamma' = \Gamma'_{okn} \cdot \beta_{obj}$
↓
ezaguna.

Huygensen okularra: $f' = 1,5u$ $O_1H = 3u$
$u = cm$ $O_2H' = -u$

$N = \frac{1}{A} = \frac{f'_{obj}}{D_{SN}} \rightarrow \boxed{D_{SN} = \frac{f'_{obj}}{N} = \frac{5}{6}cm}$

$\Gamma'_{okn} = 10 = \frac{d_{PH}}{f'_{okn}}$
↓
$\boxed{f'_{okn} = +2,5cm}$

~~$\Gamma' = \frac{-f'_{obj}}{f'_{okn}} = -\frac{5cm}{-2,5cm}$~~

~~$\Gamma' = 2$ izango da.~~

$\Delta = e - f'_{obj} + f_{okn} = ~~13,5cm~~ \ 8,5cm$

$\Gamma' = -\frac{\Delta}{f'_{obj}} \cdot \Gamma'_{okn}$

$\hookrightarrow$ $\Gamma' = -17$-koa da handipena.

$a'_{okn} = \infty$ $\quad a_{okn} = \frac{1}{\frac{1}{a'} - \frac{1}{f'_{okn}}} = -2,5cm$ $\quad a'_{obj} = 13,5cm \rightarrow a_{obj} = -7,9412 cm$

Lan distantzia

$ZI = n_0 \sin\theta_{max} \xrightarrow{SN_{L1}} ZI = \sin\theta_{max} \simeq \tan\theta_{max} = \frac{D_{SN}/2}{|a_{obj}|} \rightarrow ZI = 0,052$

$\lambda = 500nm$

~~$\delta y = \frac{0,61\lambda}{ZI} =$~~ ~~$\delta y =$~~

Fokapen labitudea. Suposatuz bestea puntu urrunekoa zela, puntu hurbilekoa:

$$a'_{oku} = -25\,cm \to a_{oku} = -2,27\,cm \to a'_{obj} = 13,72\,cm \to \underline{a_{obj} = -7,8670\,cm}$$

Fokapen latidudea: $D \approx 0,0742\,cm = 742\,\mu m$
bi a_{obj}-en kenketa.

$D = A(f')^2$ erabiliz. $\to D = 0,86\,mm$
y   m-tan

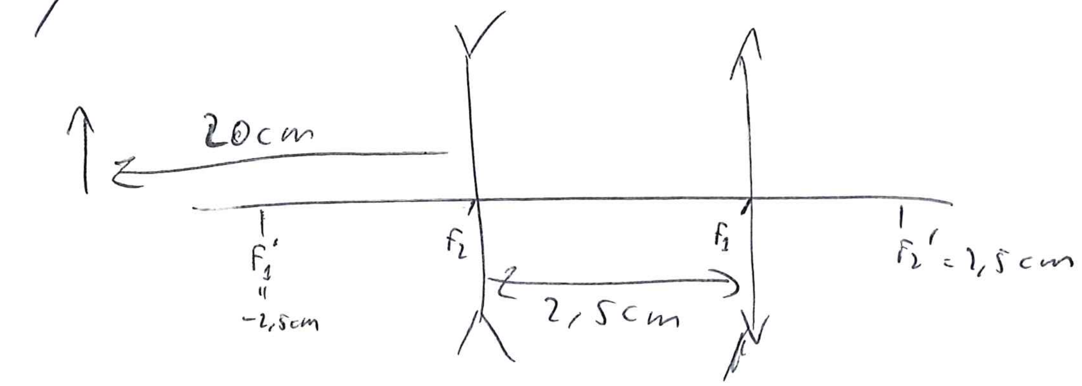
b) Tutuaren luzera aldatu gabe, zer distantzia fokal izan beharko luke objektiboak a) ataleko betaurrekoa teleskopio bihurtzeko?

↳ Horretarako $F'_{obj} = F_{oku}$ izan behar da.

$e = 16\,cm$ $\Delta = 0$ izateko

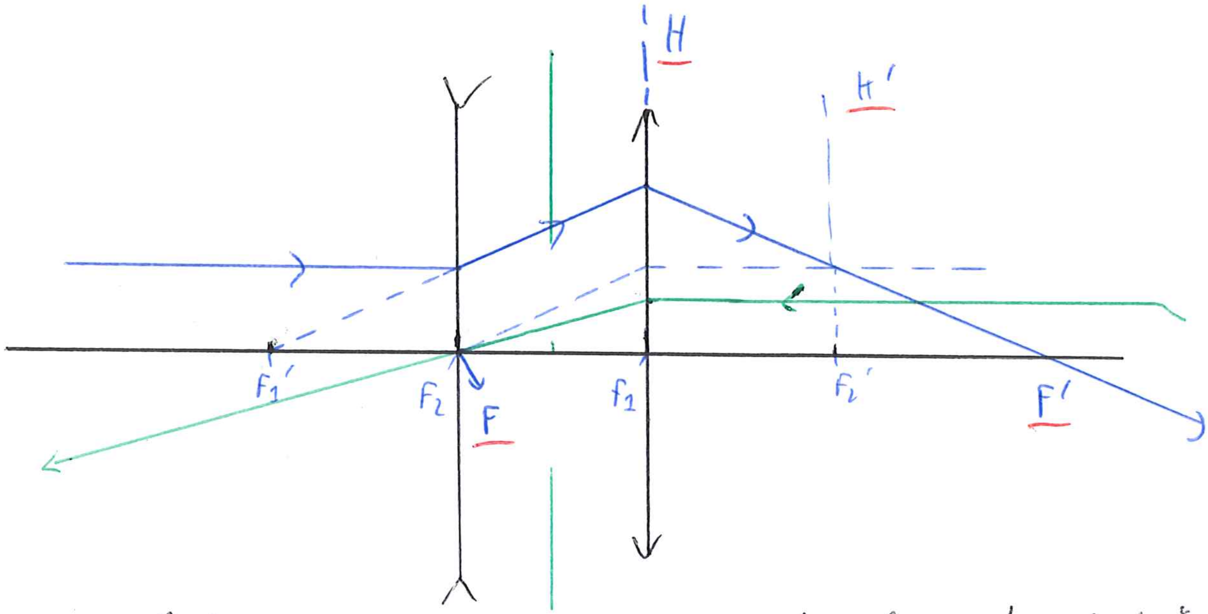
↳ $16 = f'_{obj} + f'_{oku} \to f'_{obj} = 13,5\,cm$

11/



a) Kalkulatu ittatu sistemaren elementu kardinalak eta kalkulatutakoa erabilit, lortu irudia grafikoki.

$f' = +2,5\,cm$ $O_1 H = 2,5\,cm$ $O_2 H' = 2,5\,cm$



b) Bi leiarretatik distantziakidea den leiar bat kokatu dugu $\phi = 3\,cm$ → Lenteen $\phi_{min} = ?$ Jarritako diafragma izan dadin irekidura diafragma.

→ Nireniea posizioak eta objektiboaren irekidura zenb. kalkulatu.

Lehenik, dena objektu espaziora eraman behar da:

$a_D = -1,25\,cm$ $a_D' = -0,83\,cm$ $\beta_D' = \frac{2}{3}$ → D_{obj}: L_1-etik 0,83cm eskuinera $\phi_{D_{obj}} = 2\,cm$

$a_{L_2} = -2,5\,cm$ $a_{L_2}' = -1,25\,cm$ $\beta_{L_2}' = \frac{1}{2}$ → L_{2obj} L_1-etik 1,25cm eskuinean $\phi_{L_1} = 2\,\phi_{L_{2obj}}$

Angeluak kalkulatzen:

$$\theta_{L1} = \arctan\left(\frac{\phi_{L1}/2}{20}\right)$$

$$\tan(\cancel{28,64}\ 2,75^\circ)\cdot 40 < \phi_{L1}$$

$$\hookrightarrow \cancel{19,19cm}\ 1,92cm < \phi_{L1}$$

$$\theta_{L2obj} = \arctan\left(\frac{\phi_{L2}/4}{21,25}\right) \rightarrow \cancel{28,64}\ 2,75^\circ < \arctan\left(\frac{\phi_{L2}/4}{21,25}\right)$$

$$\hookrightarrow \phi_{L2} > \cancel{40,798cm}\ 4,08cm$$

$$\theta_{Dobj} = \arctan\left(\frac{20/2}{20,83}\right) = \cancel{28,64^\circ}\ 2,7485^\circ$$

~~$r_{min_{L2}} = 40,798cm$~~ ~~$r_{min_{L1}} = 19,19cm$~~

$\boxed{r_{min_{L2}} = 4,08cm}$ $\boxed{r_{min_{L1}} = 1,92cm}$

IN lortzeko ID irudi espaziora eraman behar da:

$$\frac{1}{a'} - \frac{1}{a} = \frac{1}{f'}$$

$a_D = -1,25cm$; $a_D' = -2,5cm$ $\beta' = 2$

IN → 1. lentearen parean, 6cm-ko diametroarekin

L_1-en irekidura zenbakia: $N = \frac{1}{A} = \frac{f'}{D_{SN}}$

$\boxed{N = 1,25}$

c) Gure sistema argazki-kamera baten objektiboa da (24×36-ko filmeko kamera). Kalkulatu 3 eremu bertikalak.

~~$\tan\theta = \frac{y/2}{20cm} = \frac{1,2cm}{f'+2,5cm}$~~ $\tan\theta = \frac{y/2}{22,5cm} = \frac{1,2cm}{f'+2,5cm}$

~~$y = 10,8cm$ izango da~~

3-rentzat eremu bertikala berdina izango da:

$a = -22,5cm$ $a' = 2,8125cm$ $\beta_T = -\frac{1}{8}$ $\tan\theta = \frac{y/2}{22,5} = \frac{1,2}{2,8125} \rightarrow$

$\rightarrow \boxed{y = 192mm}$

12/ → Bukaeraka lagekoet, zarlenetaka baite.

13/ • Obj & oku lente konbegenteak dira, ~~x10-eko handipen angeluarreko~~ okularrak x10-eko handipen.ang.

• Irudia behaltai emetrope baten puntu urrunean eratzeko, objektua objektibotik 5 cm-ra kokatu behar da.

a) $e = 10cm$ bada lenteen arteko distantzia, $f'_{obj} = ?$

$a_{obj} = -5cm \quad a'_{obj} = \frac{1}{\frac{1}{a_{obj}} + \frac{1}{f'_{obj}}} \rightarrow a_{oku} = -e + a'_{obj}$

$a'_{oku} = \infty$ izanik, $a_{oku} = -f'_{oku}$ da.

$\Gamma'_{oku} = 10 = \frac{d_{PH}}{f'_{oku}} \Rightarrow \boxed{f'_{oku} = 2{,}5cm}$

$a_{oku} = -2{,}5cm = -e + a'_{obj} = -10 + \frac{1}{\frac{1}{-5} + \frac{1}{f'_{obj}}}$

$7{,}5 = \frac{-5 f'_{obj}}{f'_{obj} - 5} \rightarrow 7{,}5 f'_{obj} + 5 f'_{obj} = 7{,}5 \cdot 5 \Rightarrow$

$\Rightarrow \boxed{f'_{obj} = 3cm \text{ da}}$

b) Zenbatekoa da tresnaren ikusmen handipena? $\boxed{\cancel{\Gamma' = -\frac{f'_{obj}}{f'_{oku}} = -\frac{6}{5} = -1{,}2 \text{ aldiz}}}$

ez da balio,

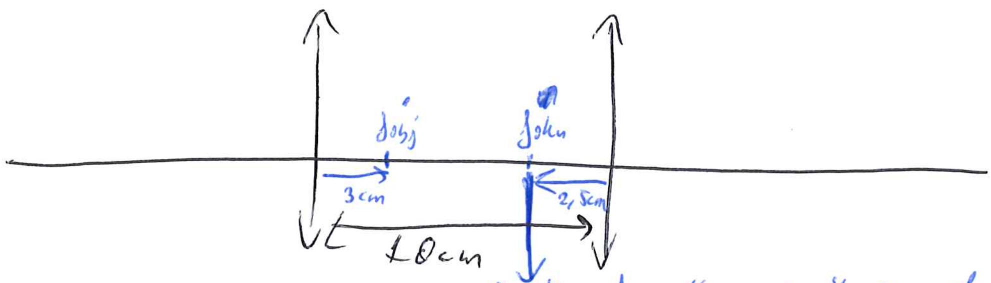
ez da sist. fokugabea!

$\Gamma' = -\frac{\Delta d_{PH}}{f'_{oku} f'_{obj}} = \frac{-(e - f'_{obj} - f'_{oku}) d_{PH}}{f'_{oku} f'_{obj}}$

$\boxed{\Gamma' = -15}$

c) Objektu eta objektiboaren arteko dist. aldatu gabe, zenbat desplazatu behar da okularra irudia behatzailearen puntu hurbilean ezartzeko?

Lehengo egoera



Puntu honetan sortuko da objektiboaren irudia!

$a_{obj} = -5cm \rightarrow a'_{obj} = 7,5cm$

$a'_{oku} = -25cm \rightarrow a_{oku} = \cancel{2,2778cm}$ $-2,27cm$ -n egon behar du irudiak.

$|2,\cancel{2778}cm - 2,5cm| \approx 0,227\cancel{8}cm$ ~~eskuinera~~ ezkerrera mugitu okularra

d) Objektiboak 2µm-ko tartea bereizten badu, bere diametroa?

$\delta y = 2\mu m$

$$\delta y = \frac{0,61\lambda}{ZI} = \frac{0,61\lambda}{\frac{n}{1}\sin\theta} \approx \left(\frac{0,61\lambda}{\tan\theta} = \frac{0,61\lambda}{r_{obj}/5cm}\right)$$

Hurbilketa gabe egin!

~~$r_{obj} = \frac{0,61\cdot\lambda\cdot 5cm}{\delta y} \xrightarrow{x2} \phi_{obj} =$~~

Sinu $\frac{0,61\lambda}{\delta y} = \sin\theta = \sin\left[\arctan\left(\frac{\phi_{obj}/2}{5}\right)\right]$

$$10\cdot\tan\left[\arcsin\left(\frac{0,61\lambda}{\delta y}\right)\right] \underset{\lambda=550nm}{=} \phi_{obj} = 1,7\ cm$$

e) Tresnan zehar begira baguade, objektiboen bereizitako begiak ondo bereiziko du?

Usoztea eman!

14/ $\Gamma'_{okn} = 10$, $\Delta = 16cm$ $a_{obj} = -2cm$

Mikroskopio bat da!

a) $f'_{obj} = ?$

$a'_{okn} = \infty$ izan behar da!

$$a'_{obj} = \frac{1}{\frac{1}{a_{obj}} + \frac{1}{f'_{obj}}}$$

$a_{okn} = -e + a'_{obj}$

$a_{okn} = -f'_{okn}$

$e = f'_{obj} + \Delta + f'_{okn}$

$\Gamma'_{okn} = 10 = \frac{d_{PH}}{f'_{okn}}$

$f'_{okn} = 2,5cm$

$$\frac{1}{\frac{1}{-2} + \frac{1}{f'_{obj}}} - f'_{obj} - \Delta - \cancel{f'_{okn}} = -\cancel{f'_{okn}}$$

$$\Delta + f'_{obj} = \frac{-2 f'_{obj}}{f'_{obj} - 2} \rightarrow f'^2_{obj} + f'_{obj}(\cancel{-2} + \Delta + \cancel{2}) - 2\Delta = 0$$

$$f'_{obj} = \frac{-16 \pm \sqrt{16^2 + 8 \cdot 16}}{2} = \frac{-16 \pm 8\sqrt{6}}{2} = \frac{-8 \pm 4\sqrt{6}}{1}$$

$f'_{obj} > 0$ izateko, $\boxed{f'_{obj} = -8 + 4\sqrt{6} = 1{,}798 cm}$

b) $\phi_{obj\,min} \rightarrow$ bere bereizmena, gutxienez, 1μm-koa izan dadin?

$$\delta y = \frac{0{,}61\lambda}{1 \cdot \sin\theta} \rightarrow 1\mu m \leq \frac{0{,}61\lambda}{\sin\left[\arctan\left(\frac{\phi_{obj\,min}/2}{+2}\right)\right]}$$

$$4 \cdot \tan\left[\arcsin\left(\frac{0{,}61\lambda}{1\mu m}\right)\right] = \boxed{\phi_{obj\,min} = 1{,}45 cm}$$

c) Ahal han ez dugu eman.

15/ Mikroskopio inprobisatu bat egin dugu:

- Objektiboa: beirazko lente hortua, erdiesfera: n=1,5 r=2,5mm
- Okularra: Lagun hypermetrope(8d) baten lente bat.
- Tarte optikoa: $s = 16cm$

a) objektiboaren fokutik zer distantziara kokatu behar da alkaroa?

1) f'_{obj} kalkulatuko dugu: $e = f'_{obj} + s + f'_{oku}$

$$\frac{1}{f'_{obj}} = 0,5\left(\frac{1}{0,25cm} - \underbrace{\frac{1}{\infty}}_{0}\right) + \underbrace{\frac{0,5^2}{1,5} \cdot \frac{f'_{obj} + 28,5}{0,25 \cdot \infty}}_{0}$$

$f'_{oku} = ? \rightarrow \varphi = 8d = \frac{1}{f'_{oku}} \rightarrow f'_{oku} = \frac{1}{8}m = 12,5cm$

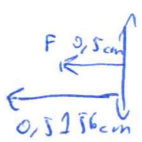
$$f'_{obj} = \frac{0,25}{0,5} \qquad \boxed{f'_{obj} = 0,5cm}$$

$a'_{oku} = -\infty \rightarrow a_{oku} = -f'_{oku} \rightarrow a'_{obj} = e - f'_{oku}$

$$a_{obj} = \frac{1}{\frac{1}{a'_{obj}} - \frac{1}{f'_{obj}}} = \frac{1}{\frac{1}{29-12,5} - \frac{1}{0,5}} \rightarrow$$

$a_{obj} = -0,5156cm$
Objektibotik 0,5156cm ezkerrera jarri behar da alkaroa.

Galdera ordea objektiboaren fokutik zer distantziara galdetzen digute.



↳ 0,0156cm = 156μm-ra jarri behar da (ezkerrera)

b) Zein da mikroskopioaren handipena?

$$\Gamma' = -\frac{\Delta}{f'_{obj}}\frac{d_{PH}}{f'_{ok}} \rightarrow \Gamma' = -64$$ da handipen angeluarra

c) Alkarren begiak 1μm-ko tartera badaude, objektiboak ondo bereiziko ditu?

$\delta y = 1\mu m$ al da?

$$\delta y = \frac{0{,}61\lambda}{n\sin\theta} = \frac{0{,}61\lambda}{\sin\left[\arctan\left(\frac{0{,}25}{0{,}5156}\right)\right]}$$

$\lambda = 500\,nm$

$\delta y = 0{,}7\mu m$ da mikroskopioaren bereizmena, beraz, bai bereiziko ditu 1μm-ra dauden begiak.

d) Kalkulatu mikroskopioaren fokapen-latitudea:

$D \sim -A f f'$ izan daiteke, edo $P_u - P_H$ kenketa.

Lehen puntu urruna kalkulatu dugu.

Hurbila kalkulatuz:

$a'_{ok} = -25\,cm$ $\quad a_{ok} = -\frac{25}{3}\,cm$ $\quad a'_{obj} = e + a_{ok} = \frac{62}{3}\,cm$

$a_{obj} = -0{,}5124\,cm$

$D = 3{,}23\cdot 10^{-3}\,cm = 0{,}323\mu m$

bere metodoa hau da, ez dakit zergatik ez duten lortzen 61 μm

Beste aukera $D \sim A(f')^2 = 4\left(\frac{f_1' f_2'}{f_2' + f_1' + e}\right)^2 = ~~0{,}61\,cm~~$

~~61\cdot 10^{-3}\,mm~~

bere garaian ezin hola kalkulatu, $f' = -\frac{f_1' f_2'}{\Delta}$ -rekin baizik!

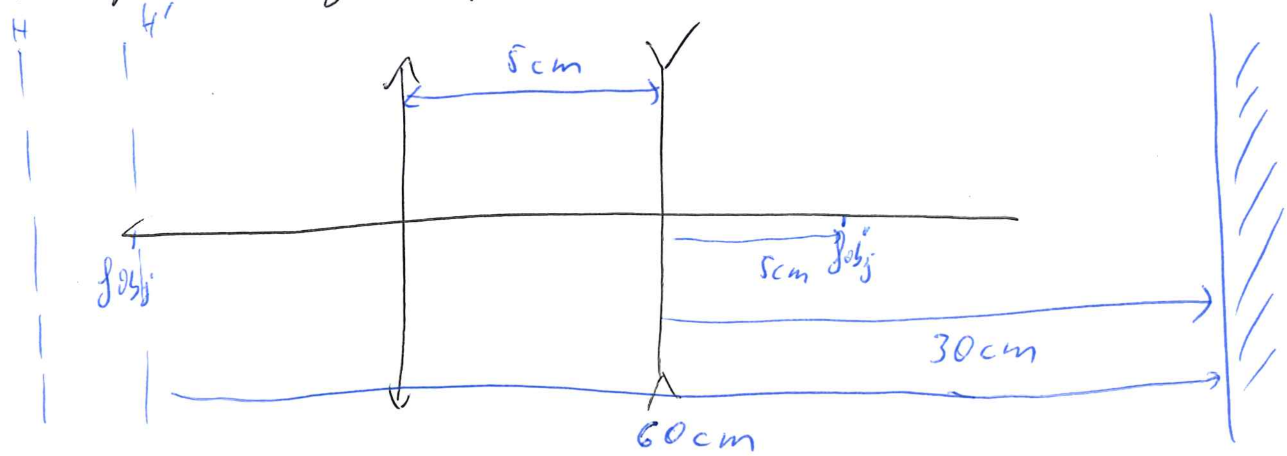
16/ Teleobjektibo batean bi leiar daude, ~~[illegible]~~

$e = 5cm$ {
- 10d-ko lente konbergente bat
- lente dibergente bat

· ∞-ra fokatuz, filma bigarren lentetik 30cm-ra dago.

a) Lente dibergentearen eta sistema osoaren distantzia fokalak? Eta plano nagusiak?

$f'_{obj} = \frac{1}{10} = 0,1m = 10cm$



$a_{obj} = -\infty$; $a'_{obj} = f'_{obj} = 10cm$ → $a_{okul} = -e + a'_{obj} = 5cm$

$-\frac{1}{5} + \frac{1}{30} = \frac{1}{f'_{okul}}$ → $\boxed{f'_{okul} = -6cm}$

$f' = 60cm$ $O_1H = -50cm$ $O_2H' = -30cm$

b) ID bigarren leiarra bada (IN ere izango da, beraz), kalkulatu bere diametroa, sistemaren irekidura zenbakia $N = 10$ izan dadin.

$N = 10 = \frac{1}{A} = \frac{f'_{osoarena}}{\phi_{SN}}$ → $\phi_{SN} = 6cm$

~~$N = 10 = \frac{1}{A} = \frac{f'_{obj}}{\phi_{SN}}$~~ → ~~[illegible]~~ ~~$\phi_{SN} = 1cm$~~ $\phi\ 6cm$ → orain han objektu eremutik atera behar da.

$a = -5$ $a' = -10$ → $\beta' = 2$ → $\phi_{L_2} =$ ~~1,5cm~~ 3 cm izango da.

c) a) ateleko geometrian 2 itzaren dist handiegia da biak batera sartzeko. Hala ere, l eta e aldatu daitezke.

⇒ Zein dira l eta e filmeko irudiaren diametroa erdira jaisteko?

~~$\tan\theta =$~~ ~~$\tan\theta = \phi/2$~~

~~$\tan\theta = \frac{\phi_0/2}{60\,cm}$ hasieran. ⇒ θ konstante izango da,~~

~~ondorioz, ϕ_0 erdira jaisteko $f' = 60cm$ ere erdira jaitsi beharko da!~~

~~f'_{obj}, f'_{okn}, y_1, $y_1' = y_2$ ⇒ finko ; e, l ⇒ aldatu.~~

~~$y_2' \Rightarrow \frac{y_2'}{2}$~~
~~$e, l \Rightarrow e', l'$~~ ~~aldaketa gertatzea nahi dugu.~~

~~$s_1 = 10cm$ bet ⇒ $s_2 = 10 - e$ izango dugu.~~

~~$-\frac{1}{10-e} + \frac{1}{3(10-e)} = \frac{1}{-6}$~~

~~$\frac{y_2'}{y_2} = \left(\frac{s_2'}{s_2}\right)^{berriak} = \left(\frac{s_2'}{s_2}\right)^{zaharrak} \frac{1}{2}$~~

Ez dakit oso ondo, baino inaldu.

Errexena hola: (ustet)

Goian urdinez jarrita daon bezela, f' erdira jaitsi behar da

$$f' = l + O_2H' = l - \frac{e f_2'}{f_1' f_2' - e}$$

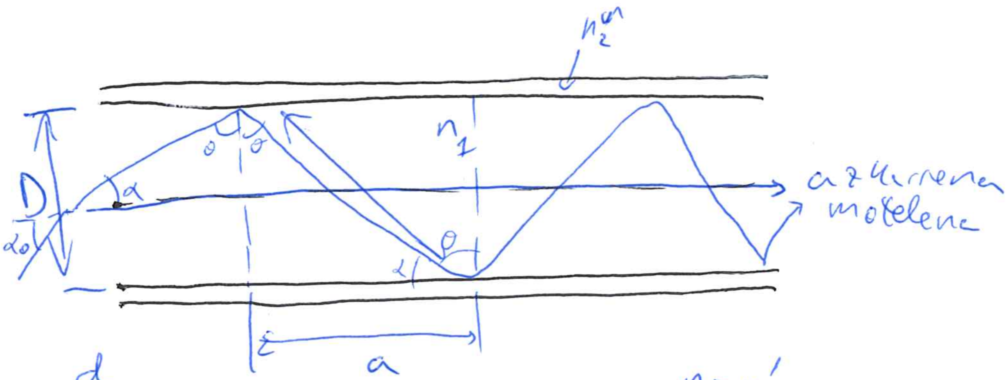
$30 = l - 2$

$$\begin{cases} 30 = l + \dfrac{e \cdot 6}{4 - e} \\ 30 = -\dfrac{f_1' \cdot f_2'}{\Delta} = \dfrac{60}{4 - e} \Rightarrow \end{cases}$$

⇒ $120 - 60 = 30e$

↳ $e = 2cm \Rightarrow l = 32\ cm$

17/



$t_{azk} = \frac{d}{V}$ $\qquad n > n'$

$\sin\theta = \cos\alpha$ $\qquad n \sin\theta_M = n'$

$\quad \hookrightarrow \theta_M = \arcsin\left(\frac{n'}{n}\right)$

$$\tan\alpha = \frac{D/2}{a/2} \rightarrow a = \frac{D}{\tan\alpha}$$

$d_{min} = a$

$d_{max} = \frac{a}{\sin\theta_m}$ $\qquad \delta t = \frac{a}{V}\left(\frac{1}{\sin\theta_m} - 1\right)$

$$\sin\theta_M = \frac{n_2}{n_1}$$

$$\delta t = \frac{a}{V}\left[\frac{n_1}{n_2} - 1\right]$$

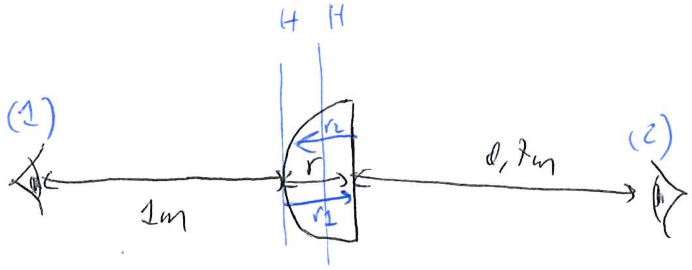
$V = \frac{c}{n_1}$ $\qquad \frac{\delta t}{a} = \frac{n_1}{c}\left(\frac{n_1}{n_2} - 1\right)$

$$\boxed{\frac{\delta t}{a} = \frac{n_1}{c\, n_2}(n_1 - n_2)}$$

b) $n_1 = 1{,}46$ eta $n_2 = 1{,}4$ diren kasuan?

$$\boxed{\frac{\delta t}{a} = 0{,}208 \frac{ns}{m} = 208 \frac{ns}{km}}$$

12/



a) Kalkulatu errefrakzio-indizea eta lehenengo gainazalaren kurbadura erradioa, leiharrean tear eta puntu urrunera fokatuz biak elkar ondo ikusten badira.

~~1) $a = -1\,m$ $\quad a' = -\infty$~~

~~$\frac{1}{f'} = (n-1)\left(\frac{1}{r}\right) + 0$~~

~~2) $a = 0{,}7\,m$ $\quad a' = \infty$~~

~~$\frac{1}{f'} = (n-1)\frac{1}{r}$~~

$r_1 = r = e$

$r_2 = \infty$

$V_1H = 0$

$V_2H' = -\frac{e}{n} = -\frac{r}{n}$

$\frac{1}{f'} = \frac{n-1}{r}$

Aurretik ditugun adierazpenak.

(1) Begiaren kasuan.

$-\frac{1}{a} + \frac{1}{a'} = \frac{1}{f'} \Rightarrow +\frac{1}{100} = \frac{1}{f'} \rightarrow f' = 100cm$

(2) $\rightarrow$ $-\underbrace{\frac{1}{-\infty}}_{0} + \frac{1}{70+\frac{r}{n}} = \frac{1}{100} \rightarrow$ $\boxed{100 = 70 + \frac{r}{n}}$ 1. adierazpena.

$\boxed{\frac{1}{100} = \frac{n-1}{r}}$ 2. adierazpena.

~~$\frac{1}{70+\frac{r}{n}} = \frac{n-1}{r} \rightarrow r = 70n + r - 70 - \frac{r}{n}$~~

$r = \frac{(n-1)100}{100} = r$ ~~$100 = 70 + \frac{n-1}{100n} \rightarrow 3000n - n = -1$~~

~~$\hookrightarrow n =$~~

$\hookrightarrow 30 = \frac{1}{n}(n-1)\,100 \rightarrow 70 = \frac{100}{n} \rightarrow \boxed{n = 1{,}4285}$

$\boxed{r = 42{,}857cm}$

b) Berdina gertatzen da, baina ezberdina miopea (0,1d) da.

$a \; -0{,}1 = \frac{1}{f'} \rightarrow f'_1 = -10m = -1000cm$

↳ Puntu urrunaren kokapena.

$\frac{1}{f'} = \frac{n-1}{r}$

$-\frac{1}{-1000} + \frac{1}{100} = \frac{1}{f'} \rightarrow f' = 90{,}91cm$

BUKATZEKE.

b) Berdina gertatzen da, baina ezkerreko miopea (0,1d) da.

~~$-0,1 = \frac{1}{f'} \rightarrow f'_1 = -10m = -1000cm$~~

~~↳ Puntu urrunaren kokapena.~~

~~$\frac{1}{f'} = \frac{n-1}{r}$~~ ~~$-\frac{1}{-1000} + \frac{1}{100} = \frac{1}{f'} \rightarrow f' = 90,91cm$~~

~~BUKATZEKE.~~

~~$0,1d = P \Rightarrow f' = -10m = -1000cm$~~

Fokuak berdina izaten jarraituko du $\Rightarrow f' = 100cm$

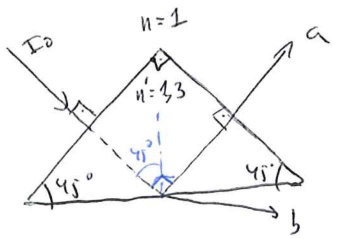
~~$+\frac{1}{+100} - \frac{1}{1000} = \frac{1}{f'} \rightarrow f' =$~~

$-\frac{1}{900} + \frac{1}{a'} = \frac{1}{100} \rightarrow a' = 90cm$

BUENO, BUKATZEKE

3. gaiko islapeneko ariketa bat berreginda

√ 10/



Hasierako argia partzialki polarizatutako argia lineala da: $\delta = m\pi$; $(\chi = 0)$

• $V_0 = 0{,}5$, $\psi = 45°$ osatzen du irudiaren planoarekiko.

a) Kalkulatu a argi sortaren I, pol.-egoera eta pol.-maila.

$$\vec{S}_0 = \left[0{,}5\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0{,}5\begin{pmatrix}1\\0\\1\\0\end{pmatrix}\right] I_0 \Rightarrow \text{Erasoa perpendikularra denez, } \mathcal{T} = \frac{4n_1n_2}{(n_1+n_2)^2}$$

$$\boxed{\mathcal{T}_1 = 0{,}983}$$

$$\vec{S}_1 = \left[0{,}5\,\mathcal{T}_1\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0{,}5\,\mathcal{T}_1\begin{pmatrix}1\\0\\1\\0\end{pmatrix}\right] I_0$$

$$\theta_i = 45° = \theta_r \Rightarrow \boxed{\theta_t = 64{,}82°} \rightarrow \begin{matrix}\alpha_1 = 45°\\ \delta_1 = n\pi\end{matrix} \rightarrow \boxed{\begin{matrix}\alpha_r = 21{,}82\\ \delta_2 = n\pi\end{matrix}}$$

$$R_\perp = 0{,}1603 \qquad R_\parallel = 0{,}0257 \rightarrow \boxed{R_N = R_P = 0{,}093}$$

$$\vec{S}_2 = 0{,}5\,\mathcal{T}_1 R_{N=P}\left[\begin{pmatrix}1\\V'\\0\\0\end{pmatrix} + \begin{pmatrix}1\\0{,}724\\0{,}690\\0\end{pmatrix}\right] I_0 \Rightarrow$$

Bukaeran eraso normala, $\mathcal{T}_1$ izango dugu berriz eta α ez da aldatuko.

$$V' = \left|\frac{R_\perp - R_\parallel}{R_\perp + R_\parallel}\right| = 0{,}7237$$

$$\vec{S}_a = 0{,}5\,\mathcal{T}_1^2 R_{N=P}\left[\begin{pmatrix}1\\V'\\0\\0\end{pmatrix} + \begin{pmatrix}1\\0{,}724\\0{,}690\\0\end{pmatrix}\right] I_0 \Rightarrow \vec{S}_a = I_0\begin{pmatrix}0{,}089\\0{,}065\\0{,}031\\0\end{pmatrix} = 0{,}089\,I_0\begin{pmatrix}1\\0{,}730\\0{,}348\\0\end{pmatrix}$$

$V = 0{,}8$ da pol. maila eta $I_a = 0{,}089 I_0$ intentsitatea

$$0{,}730 = V_0\cos(2\alpha) \rightarrow \alpha = 12{,}07\,;\quad \delta = \chi = 0\,,\ \psi = 12{,}07°$$

3) ~~Bta~~ Argi berdina bada hasieratik, kalkulatu aurreko bera

b izpiarentzat.

$$\vec{S}_1 = I_0 \cdot 0{,}5\, \gamma_1 \left[\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 1 \\ 0 \\ 1 \\ 0 \end{pmatrix} \right]$$

$\theta_i = \theta_r = 45^\circ \qquad \theta_t = 66{,}82^\circ$

$\gamma_{\parallel} = 0{,}9743$

$\gamma_{\perp} = 0{,}8397$

$\alpha_i = 45 \quad \delta = 0 \rightarrow \alpha_t = 47{,}13^\circ \quad \delta = 0$

$$\boxed{\gamma_t = \gamma_N = \gamma_p = 0{,}907}$$

$$V' = \left| \frac{\gamma_{\parallel} - \gamma_{\perp}}{\gamma_{\perp} + \gamma_{\parallel}} \right| = 0{,}0742$$

$$\vec{S}_b = I_0 \cdot 0{,}5\, \gamma_1 \gamma_t \left[\begin{pmatrix} 1 \\ -V' \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 1 \\ -0{,}074 \\ 0{,}9972 \\ 0 \end{pmatrix} \right]$$

$$\vec{S}_b = I_0 \cdot 0{,}5\, \gamma_1 \gamma_t \begin{pmatrix} 2 \\ -0{,}1482 \\ 0{,}9972 \\ 0 \end{pmatrix} = I_0 \begin{pmatrix} 0{,}892 \\ -0{,}066 \\ 0{,}443 \\ 0 \end{pmatrix} = 0{,}892\, I_0 \begin{pmatrix} 1 \\ -0{,}0740 \\ 0{,}497 \\ 0 \end{pmatrix}$$

$I_b = 0{,}892\, I_0$ eta $V = 0{,}5$

$\alpha = 40{,}74^\circ$

$\chi = 0$

$\delta = 0^\circ$

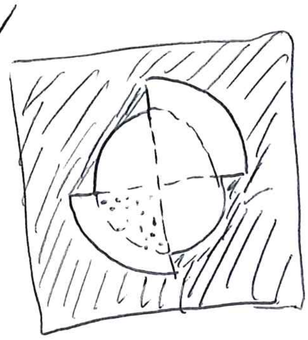
BESTE URTETAKO AZTERKETAK

~~BESTE URTETAKO~~

~~AZTERKETAK~~

2018ko azaroko kontrola.

2/



$r_1 = 0{,}71mm$

$r_2 = 1mm$

· Erreduira $\lambda = 632{,}8nm$-ko uhin lau batez argitu da, perpendikularki.

· Eremu grisean Φ-ko atzerapena sortzen da.

· 80cm-ra dagoen pantaila batean ikusten dugu irudia.

$\Rightarrow \Phi = ?$ intentsitatea $\frac{I_0}{2}$ izan dadin?

Lehenik, Fresnel difrakzioa dugunez, zona erdiperiodikoak kalkulatuko ditut.

$$\rho_i = \sqrt{\lambda s_0 j} \rightarrow j = \frac{\rho_i^2}{\lambda s_0} \Rightarrow \begin{array}{l} r_1 \Rightarrow j = 0{,}99 \simeq 1 \\ r_2 \Rightarrow j = 1{,}97 \simeq 2 \end{array}$$

Beraz, bi zona erdiperiodiko ditugu.

$$U(P) = \frac{3}{4}U_1 + \frac{1}{4}U_1 e^{i\Phi} + \frac{1}{2}U_2 = \frac{3}{2}U_0 + \frac{1}{2}U_0 e^{i\Phi} - U_0$$

$$U(P) = U_0\left[\frac{1}{2} + \frac{1}{2}e^{i\Phi}\right] = \frac{U_0}{2} e^{i\frac{\Phi}{2}}\left[e^{-i\frac{\Phi}{2}} + e^{i\frac{\Phi}{2}}\right]$$

$$U(P) = \frac{U_0}{\cancel{2}} e^{i\frac{\Phi}{2}} \cdot \cancel{2}\cos\left(\frac{\Phi}{2}\right)$$

$$\hookrightarrow I = I_0 \cos^2\left(\frac{\Phi}{2}\right) = \frac{I_0}{2}$$

datua da.

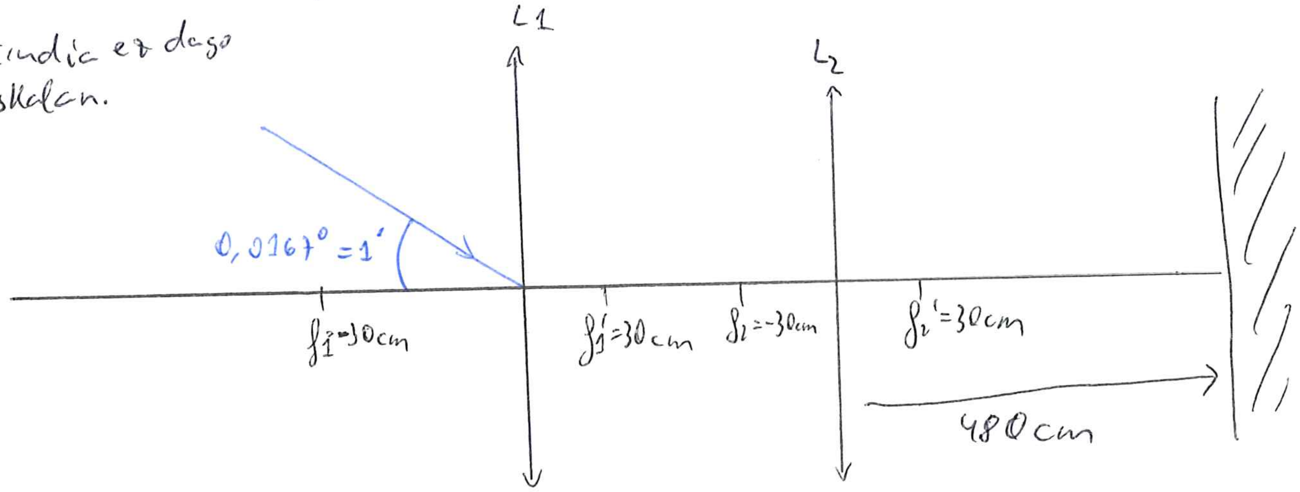
$$\cos\frac{\Phi}{2} = \frac{1}{\sqrt{2}} \rightarrow \frac{\Phi}{2} = 45^\circ \rightarrow$$ $\boxed{\Phi = 90^\circ\text{-koa da sortzen duen desfasea.}}$

1/ Artizar eta Eguzkiaren irudiak pantaila batean proiektatu nahi ditugu tresna optiko bat erabiliz.

- 2 lente konbergente berdin erabili ditugu ($f_1' = f_2' = 30cm$)
- Pantaila L_2-tik 480cm-ra jarri dugu.
- Lurretik ikusita, Artizarrak 2'' angelua osatzen du.

⇒ Zein da pantailako irudiaren diametroa?

*Irudia ez dago eskalan.



Hasteko, ez dakigu sistema fokugabea den ala ez. Teleskopioak normalean fokugabeak izaten badira ere; ez da zertan beti hala izan. Gainera, izpiak ez doazenez okularretik ∞-ra, ziurrenik sistema fokuduna izango da.

$\Gamma'_{oku} = ?$ $\qquad \Gamma'_{oku} = \frac{d_{PH}}{f_2'} = \frac{5}{6} = 0,83$ → ez nago ziur $d_{PH} < 0$ ez den horrela behar, baina ez digu inportako, ez digulako ardura irudiak buelta ematen duen hala ez.

$\Gamma'_{totala} = \beta'_{obj} \Gamma'_{oku}$ dugu.

β'_{obj} kalkulatzea falta zaigu.

x_2': f_2'-tik pantailarako distantzia da: $x_2' = 450cm$

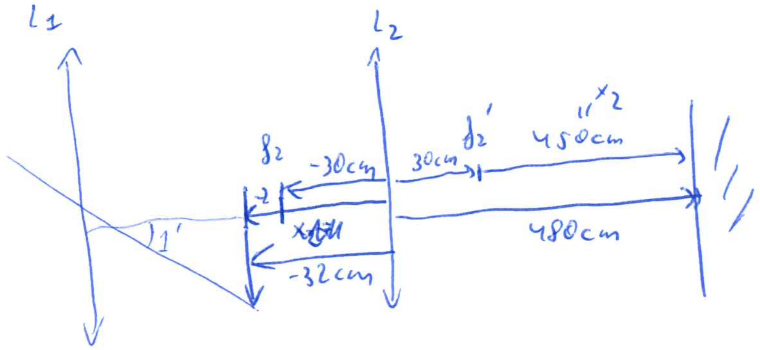
Jakinik $x_i x_i' = -f_i'^2$ betetzen dela,

$$x_2 = -\frac{(f_2')^2}{x_2'} \Rightarrow x_2 = -2\,cm$$ izango dugu f_2-tik

L_1-ek sortutako irudirako distantzia ($\leftarrow$)

$\boxed{a_{L_2} = -32\,cm}$

$a_{L_2} = -e + a_{L_1}'$



$a_{L_2} = -32\,cm$ dugu. $e = a_{L_1}' - a_{L_2}$ izango dugu.

(ez dakit goikoak zerbaiterako balio digun?)

$e = f_1' + x_1' - a_{L_2}$

$$\beta_2' = \frac{y_2'}{y_2} = \frac{n}{n'}\frac{a_{L_2}'}{a_{L_2}} = -15$$

$$\tan(1') = \frac{y_1'}{a_{L_1}'} = \frac{y_2}{a_{L_1}'}$$

$$y_2' = -15\,y_2$$

$$\tan(1') = -\frac{y_2'/15}{a_{L_1}'}$$ $\Rightarrow$ hau ezezaguna da, ordea.

$$f' = -\frac{f_1' f_2'}{\Delta} \qquad y_2' = f'\theta \rightarrow \tan(1') = -\frac{f'\theta}{15\,a_{L_1}'}$$

$$a_{L_1}' = e + a_{L_2} \xrightarrow{\text{ezezaguna}} = f_1' + f_2' - \frac{f_1' f_2'}{f'} + a_{L_2}$$

$$f' f_1' + f' f_2' - e f' = f_1' f_2' \Rightarrow e = \frac{f'(f_1' + f_2') - f_1' f_2'}{f'} \rightarrow e = f_1' + f_2' - \frac{f_1' f_2'}{f'}$$

$$\tan(0{,}0167°) = -\frac{f' \cdot \theta^{\rightarrow \text{radietan!}}}{15\left(f_1' + f_2' - \frac{f_1' f_2'}{f'} + a_{L_2}\right)} = -\frac{2{,}91 \cdot 10^{-4} f'}{420 - \frac{13500}{f'}} = 2{,}91 \cdot 10^{-4}$$

$$\frac{-(f')^2}{420f' - 13500} = 1 \Rightarrow -(f')^2 = 420f' - 13500 \Rightarrow$$

$$\Rightarrow 0 = (f')^2 + 420f' - 13500$$

$$f' = \frac{-420 \pm \sqrt{420^2 - 4 \cdot 13500}}{2} = \frac{-420 \pm 60\sqrt{34}}{2}$$

$$f' = -210 \pm 30\sqrt{34}$$

$$e = f_1' + f_2' - \frac{f_1' f_2'}{f'}$$

+ -ellen erabiliz: $e = 85{,}66\,cm \rightarrow \Delta = 25{,}66$

- ellen eabiliz: $e = 62{,}338\,cm \rightarrow \Delta = 2{,}338\,cm$

$$\frac{e}{\Delta} f_2' = \frac{e f_2'}{e - f_1' - f_2'}$$

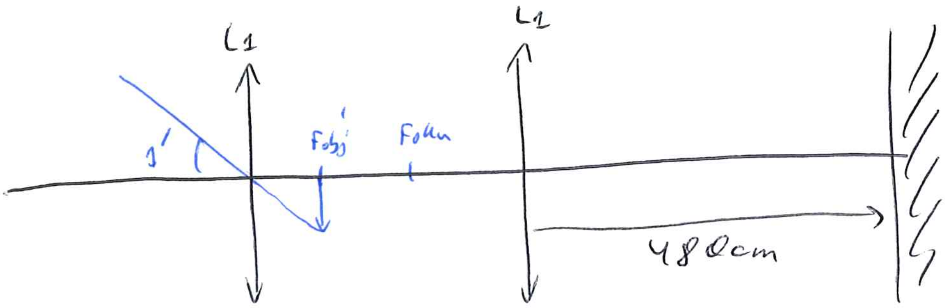
$$\left.\begin{aligned} \frac{e}{\Delta} f_2' &= \frac{e f_2'}{e - f_1' - f_2'} \\ + \frac{e}{\Delta} f_1' &= \frac{+e f_1'}{e - f_1' - f_2'} \end{aligned}\right\}$$

Andeítuz.

$\rightarrow$ $f_2' - f_1'$

1/ berriro.

$f_1' = 30cm = f_2'$



$y'_{obj} = f'_{obj}\,\theta = 30 \cdot 2{,}9 \cdot 10^{-4} = 8{,}7 \cdot 10^{-3}\,cm$

$\Gamma'_{okn} = \frac{d_{PH}}{f_i'} = 0{,}83 \rightarrow \Gamma'_{okn} \equiv \beta'_{okn}$ bi aldetan airea badago.

$y'_{obj} = y_{okn}$ $\qquad y_{okn}\,\beta'_{okn} = y'_{okn} = \phi/2$

$\beta'_{okn} = \frac{a'}{a} = \frac{480}{a}$

$\frac{1}{a'} - \frac{1}{a} = \frac{1}{f_2'} \rightarrow \frac{1}{480} - \frac{1}{a} = \frac{1}{30} \rightarrow \boxed{a = -32cm}$

$\boxed{\beta'_{okn} = \frac{480}{-32} = -15}$

$2\,|y_{okn}\,\beta'_{okn}| = \boxed{\phi = 0{,}261\,cm\text{-ko diametroa du.}}$

2019-ko urtarrila (gurea)

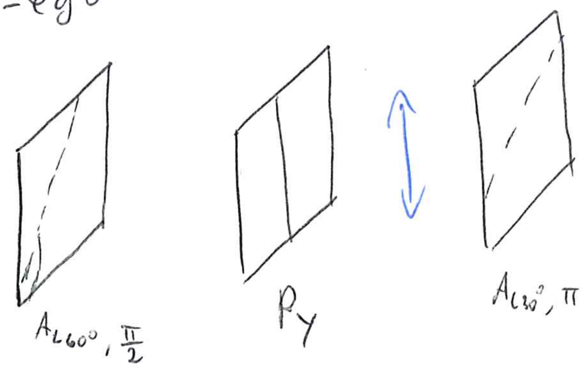
3/

• Argi sorta bateko, 30°an linealki polarizatua, $\frac{\lambda}{4}$-ko xafla zeharkatzen du (60°-an du ardatz lasterra).

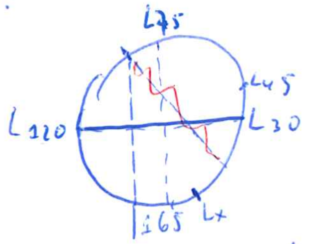
• Gero P_Y batetik pasatzen da.

• Azkenik, $\frac{\lambda}{2}$ xafla batetik, 30°-tan egonik ardatz azkarra.

a) Sistemaren irteeran zein da argi-sortak duen polarizazio-egoeraren Jonesen normalizatutako bektorea?



Poincaré-ren esfera erabiliz soilik azken pausuan fijatuz lor dezakegu emaitza, ez baitigu intentsitate edo antzekorik eskatzen.



L_{150} izango da

L_{-30} alegia

$\Rightarrow L_{-30} \Rightarrow |e_{-30,0}\rangle = \begin{bmatrix} \sqrt{3}/2 \\ 1/2 \end{bmatrix} = \frac{1}{2}\begin{bmatrix} \sqrt{3} \\ 1 \end{bmatrix}$

$\delta = 180°$ izango dugu.

Beste aukera matrizeekin kalkuluak egitea da.

$$A_{L30,\pi} = \begin{bmatrix} -\frac{3}{4}+\frac{1}{4} & -2\frac{\sqrt{3}}{4} \\ -2\frac{\sqrt{3}}{4} & -\frac{1}{4}+\frac{3}{4} \end{bmatrix} = \begin{bmatrix} -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ -\frac{\sqrt{3}}{2} & \frac{1}{2} \end{bmatrix} \qquad L_Y = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$

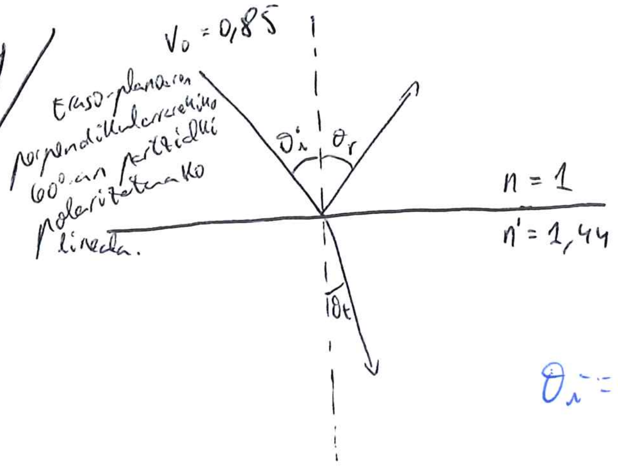
$$|e\rangle = -\frac{1}{2}\begin{bmatrix} 1 & \sqrt{3} \\ \sqrt{3} & -1 \end{bmatrix}\begin{bmatrix} 0 \\ 1 \end{bmatrix} = -\frac{1}{2}\begin{bmatrix} \sqrt{3} \\ -1 \end{bmatrix} \rightarrow L_{-30} \text{ dugu!}$$

$\delta = 0$ edo $\delta = 180°$ izateak ez digu inporta!

b) Kalkulatu bektore hori sarrerako argi-sorta erasotzailea argi aleatorioa bada.

Tarteko P_Y polarizatzailea dela eta, aurreko emaitza bera lortuko da kasu honetan.

4/



· Islagarritasuna eta argi islatuaren polarizazio-egoera eraso angelua 40° bada?

$\theta_i = \theta_r = 40°$ $\qquad$ $\underline{\theta_t = 26,51°}$

$R_\perp = 0,065 \qquad R_\parallel = 0,0109$

Eraso planoaren perpendikularrarekiko 60°-an partzialki polarizatutako argi lineala denez, $\alpha_i = 60°$ da. $\delta_i = 0°$ hartuko dut.

$$R_N = \frac{1}{2}(R_\perp + R_\parallel) = 0,03795$$

$$R_p = R_\perp \cdot \cos^2(60) + R_\parallel \sin^2(60) = 0,0243$$

$$R_T = 0,15 \cdot R_N + 0,85 \cdot R_P \Rightarrow \boxed{R_T = 0,0263 \text{ da isladantzia.}}$$

$$-0,70996\, e^{-i\cdot 0} = 0,70996\, e^{-i\pi} = \tan\alpha_r\, e^{i\delta_r}$$

$\boxed{\underline{\delta_r = \pi \text{ rad}}}$ $\qquad$ $\boxed{\underline{\alpha_r = 35,37°}}$ $\qquad$ $\boxed{\psi = \alpha_r \quad \chi = 0 \text{ rad}}$

$\cancel{\vec{A_N} = \frac{0,15}{2}\left[\begin{pmatrix}1\\1\\0\\0\end{pmatrix} + \begin{pmatrix}1\\-1\\0\\0\end{pmatrix}\right]}$

$$\vec{S_0} = 0,15\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0,85\begin{pmatrix}1\\0,174\\0,985\\0\end{pmatrix} \Rightarrow$$

$$\vec{S}_1 = 0{,}15\, R_N \begin{pmatrix}1\\ V'\\ 0\\ 0\end{pmatrix} + 0{,}85 \cdot R_p \begin{pmatrix}1\\ 0{,}3297\\ -0{,}944\\ 0\end{pmatrix} \qquad V' = \left|\frac{R_\perp - R_\parallel}{R_\perp + R_\parallel}\right| = 0{,}713$$

$$\boxed{\vec{S}_1 = \begin{pmatrix}0{,}02634\\ 0{,}0109\\ -0{,}0195\\ 0\end{pmatrix}}$$

$V = 0{,}848$ da polarizazio-maila, hots, partzialki linealki polarizatua dago.

2/ • A sarea: 0,2 μm-ko N zirrikituk osatzen dute (difr.-sarea)

• Difrakzatutako intentsitatea aztertzeko sentsorea leiar konbergente baten irudi fokuan kokatu dugu. Horrexegatik, sentsorea ardatz optikoan dago eta eraso perpendikularrean argiztatuz gero, $m=0$ ordenaren intentsitatea jasotzen da, $I_{m=0}$.

a) Info. espektroskopikoa lortzeko eraso angelua aldatu da.

↳ 2. ordena eraman da sentsorera eta $I_A = 0{,}9\, I_{m=0}$ izan da.

⇒ Zenbatekoa da sarearen periodoa? $\left(\overset{0{,}2\mu m}{D} \ll d \,;\ \sin x = x - \frac{x^3}{6}\right)$

Lehenik, $m=0$ ordenako intentsitatea kalkulatuko dugu eraso perpendikularrean.

$$I(p) = I_1(p)\left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2 = I_1(0)\left[\frac{\sin(v)}{v}\right]^2\left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2 \qquad v = \frac{1}{2}k p D \quad \varphi = \frac{1}{2} k p d$$

$m=0$ ordenan: $p=0$

$$\boxed{I_{m=0} = I(0) = I_1(0)\, N^2}$$

Gero eraso angelua aldatu dugu, $p = 2\frac{\lambda}{d}$ izanik eta

$p = \sin\theta - \sin\theta_0$

Beraz, $\sin\theta - \underbrace{\sin\theta_0}_{0} = 2\frac{\lambda}{d}$ dugu norabide berria.

$$I(p) = I_1(p)\left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2 = I_1(0)\left[\frac{\sin(v)}{v}\right]^2\left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2$$ dugu oraindik

$$I\left(2\frac{\lambda}{d}\right) = I_1(0)\left[\frac{\sin\left(\frac{1}{\cancel{2}}\frac{2\pi}{\cancel{\lambda}}2\frac{\cancel{\lambda}}{d}D\right)}{\left(\frac{1}{\cancel{2}}\frac{2\pi}{\cancel{\lambda}}\cancel{2}\frac{\cancel{\lambda}}{d}D\right)}\right]^2\left[\frac{\sin\left(\frac{1}{\cancel{2}}\frac{2\pi}{\cancel{\lambda}}2\frac{\cancel{\lambda}}{\cancel{d}}\cancel{d}N\right)}{\sin\left(\frac{1}{\cancel{2}}\frac{2\pi}{\cancel{\lambda}}2\frac{\cancel{\lambda}}{\cancel{d}}\cancel{d}\right)}\right]^2$$

$$I\left(2\frac{\lambda}{d}\right) = I_1(0)\left[\frac{\sin\left(\frac{2\pi}{d}D\right)}{\frac{2\pi}{d}D}\right]^2\left[\frac{\sin(2\pi N)}{\sin(2\pi)}\right]^2 = \underbrace{I_1(0)N^2}_{I_{m=0}}\left[\frac{\sin\left(\frac{2\pi}{d}D\right)}{\frac{2\pi}{d}D}\right]^2 = 0{,}9\, I_{m=0}$$

$\sqrt{(0,9)}\, x = \sin(x)$ non $x = \frac{2\pi}{d}D$ den.

$\sin(x) \approx x - \frac{x^3}{6} \Rightarrow \sqrt{(0,9)}\,\cancel{x} = 1 - \frac{x^2}{6} \Rightarrow \frac{x^2}{6} = 1 - \sqrt{0,9}$

~~$x = \pm\sqrt{[1-(0,9)^2]\cdot 6} \to x = 1{,}068 = \frac{2\pi}{d}D$~~

~~positibo da beti x!~~

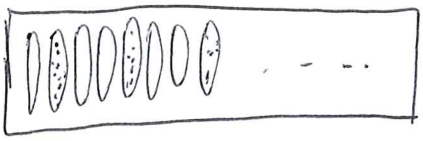
~~$\hookrightarrow d = 1{,}177\,\mu m$~~

$x = +\sqrt{6[1-\sqrt{0,9}]} \to x = 0{,}555 = \frac{2\pi D}{d}$

x positiboa baita!

$\hookrightarrow$ $d = 2{,}26\,\mu m$ da periodoa

b) Aurreko eraso angelua aldatu gabe, B sarea erabili dugu, non zirrikituen herenak $\frac{\pi}{3}$-ko atzerapena eman dion argiari. Zenbateko intentsitatea neurtuko genuke I_A-ren funtzioan?



Sarea irudian banatuko dut oraingoan!

$$I(p) = I_1(p)\left[\frac{\sin(N/3\,\varphi)}{\sin(\varphi)}\right]^2 \qquad \varphi = \tfrac{1}{2}kpd \text{ izanik.}$$

$I_1(p)$ lortzeko, amplitudeetatik hasiko naiz, sarea 3 zirrikituka zatitan banatuz:

$$U(p) = U_0\left(e^{ikpd} + e^{i\frac{\pi}{3}} + e^{-ikpd}\right) = U_0\left(2\cos(kpd) + e^{i\frac{\pi}{3}}\right) \rightarrow U_0 = cs\,\frac{\sin V}{V} \text{ izanik.}$$

$$\cancel{I_1(p) = \underbrace{I_1(0)}_{c^2s^2}\left[\frac{\sin V}{V}\right]^2\left(4\cos^2(kpd) + 1 + 2\cos(kpd)e^{i\frac{\pi}{3}} + 2\cos(kpd)e^{-i\frac{\pi}{3}}\right)}$$

$$\cancel{I_1(p) = J_1(0)\left(\frac{\sin V}{V}\right)^2\left[4\cos^2(kpd) + \right.}$$

$$U_T(p) = cs\left(\frac{\sin V}{V}\right)\left[2\cos(kpd) + e^{i\frac{\pi}{3}}\right]\frac{\sin\left(\frac{N}{3}\varphi\right)}{\sin(\varphi)}$$

$p = 2\frac{\lambda}{d}$ izanik

$$U_T\left(2\frac{\lambda}{d}\right) = cs\underbrace{\sqrt{0{,}9}}_{\frac{\sin(V)}{V}\text{ (aurreko zatian)}}\left[2\cos\left(\frac{2\pi}{\lambda}\frac{2\lambda}{d}d\right) + e^{i\frac{\pi}{3}}\right]\frac{\sin\frac{N}{3}\frac{1}{2}\frac{2\pi}{\lambda}\frac{2\lambda}{d}3d}{\sin\left(\frac{1}{2}\frac{2\pi}{\lambda}\frac{2\lambda}{d}3d\right)}$$

$$U_T\left(2\frac{\lambda}{d}\right) = cs\sqrt{0{,}9}\left[2 + e^{i\frac{\pi}{3}}\right]\frac{\sin(2\pi N)}{\sin(6\pi)}$$

$$I_T\left(2\frac{\lambda}{d}\right) = \underbrace{c^2s^2}_{I_1(0)}\,0{,}9\left[4 + 1 + \cancel{2}4\cos\left(\frac{\pi}{3}\right)\right]\left(\frac{N}{3}\right)^2 = \overbrace{I_{m=0}}^{c^2s^2N^2}\,\frac{0{,}9}{9}\cdot\cancel{6}7$$

$$I_T\left(2\frac{\lambda}{d}\right) = I_{m=0}\cdot 0{,}7 = \frac{I_A}{0{,}9}\cdot 0{,}7 \rightarrow \boxed{I_1\left(2\frac{\lambda}{d}\right) = \frac{7}{9}I_A \text{ izango da.}}$$

c) Orain C sarea erabili dugu, non zirrikitu bertikalak $\Delta y = \frac{d}{8}$ desplazatu ditugun bertikalki. Zenbatekoa intentsitatea izango genuke I_A-ren funtzioan?

$$U_c(p,q) = C \cdot S \frac{\sin V}{V} \frac{\sin\left(\frac{N}{2}\varphi'\right)}{\sin(\varphi')} \left[1 + e^{i\frac{d}{8}k_q}\right] \qquad \varphi' = \frac{1}{2} k_p 2d = k_p d$$

q = 0 norabidean aztertu behar da!

Ni itea nijuan soilik bikoitiyak bertikalki desplazatu baziran bezala eta hortako ondorengo adierazpena da:

$$U_c(p,q) = C \cdot S \cdot \frac{\sin V}{V} \frac{\sin\left(\frac{N}{2}\varphi'\right)}{\sin(\varphi')} \left[e^{ik_p d} + e^{-ik_p d} e^{ik_q \frac{\Delta y}{8}}\right]$$

Hori in beharren behak iten bakoitiak $\frac{\Delta y}{2}$ jaitsi eta bikoitiak $\frac{\Delta y}{2}$ igo.

$$U_c(p,q) = C \cdot S \cdot \frac{\sin V}{V} \frac{\sin\left(\frac{N}{2}\varphi'\right)}{\sin(\varphi')} \left[e^{i\left(\frac{k_p d}{2} + \frac{k_q \Delta y}{2}\right)} + e^{-i\left(\frac{k_p d}{2} + \frac{k_q \Delta y}{2}\right)}\right]$$

$\frac{k_p d}{2}$ ere desfasean jarri beharra dago, bi zirrikitu izatean, bien horizontaleko desfasea ere kontuan izan behar delako.

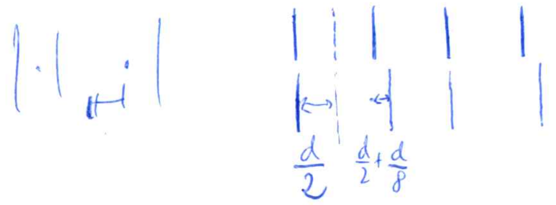
$$U_c\left(2\frac{\lambda}{d}, 0\right) = C \cdot S \cdot \underbrace{\sqrt{0{,}9}}_{\text{aurrekokoz in}} \frac{\sin\left(\frac{N}{2}\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{d}2d\right)}{\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{d}2d} 2 \cdot \cos\left[\frac{1}{2}\frac{2\pi}{\lambda}2\frac{\lambda}{d}d + 0\right]$$

$$U_c\left(2\frac{\lambda}{d}, 0\right) = C \cdot S \sqrt{0{,}9}\, N \cdot 1 \Rightarrow I_c\left(2\frac{\lambda}{d}, 0\right) = |C \cdot S|^2\, 0{,}9\, N^2 = I_{m=0} \cdot 0{,}9$$

$\boxed{I_c = I_A \text{ izango da!}}$

d) Eta D sarea bagenu? Hemen bikoitiek $\Delta x = \frac{d}{8}$ desplazatu dira.

$$\text{III} \quad U_D(p) = C \cdot S \cdot \frac{\sin v}{v} \, \frac{\sin\left(\frac{N}{2}\frac{1}{2}k p \, 2d\right)}{\sin\left(\frac{1}{2}k p \, 2d\right)} \left[e^{ikp\left(\frac{d}{2}+\frac{\Delta x}{2}\right)} + e^{-ikp\left(\frac{d}{2}+\frac{\Delta x}{2}\right)} \right]$$



$$U_D\left(\frac{2\lambda}{d}\right) = C \cdot S \cdot \sqrt{0{,}9} \cdot \frac{\sin\left(\frac{N}{\cancel{2}}\frac{1}{\cancel{2}}\frac{2\pi}{\cancel{\lambda}}\frac{\cancel{2\lambda}}{\cancel{d}}2\cancel{d}\right)}{\frac{1}{2}\frac{2\pi}{\cancel{\lambda}}\frac{\cancel{2\lambda}}{\cancel{d}}2\cancel{d}} \cdot 2\cos\left[\frac{2\pi}{\cancel{\lambda}}\frac{\cancel{2\lambda}}{d}\frac{1}{\cancel{2}}(\Delta x + d)\right]$$

$$U_D\left(\frac{2\lambda}{d}\right) = C \cdot S \cdot \sqrt{0{,}9}\, N \cdot \cos\left[\underbrace{\frac{2\pi}{d}(\Delta x + d)}_{2\pi\frac{\Delta x}{d} + 2\pi\frac{d}{d} = 2\pi\frac{\Delta x}{d}}\right]$$

$$I_D\left(\frac{2\lambda}{d}\right) = 0{,}9\, I_{m=0} \cos^2\left[\frac{2\pi}{8}\right] = \frac{0{,}9}{2}\, I_{m=0} \Rightarrow \cancel{I_D = I_A}$$

$$\cancel{I_D = \frac{\sqrt{2}}{2} I_A = 0{,}7 I_A} \qquad \boxed{I_D = \frac{I_A}{2}}$$

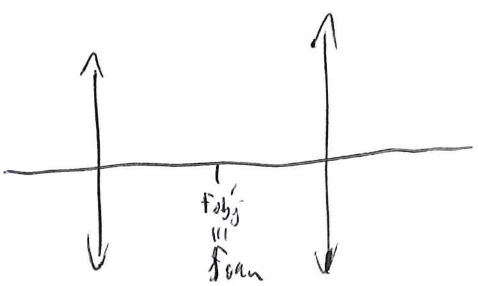
1/ • Teleskopio astronomikoarekin ($\Gamma' = 75$) Merkurioren igarotzea ikusi nahi dugu ⇒ Noski, teleskopioari konfigurazioa aldatuz.

a ↳ okularra objektibotik urrunduz, pantaila batean $d\phi = 15$ cm-ko irudia lortu dugu.

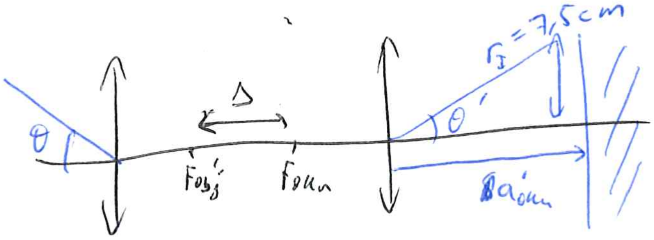
a) $\frac{d_{L-E}}{\phi_E} \approx 100$ $\qquad f'_{oku} = 2cm$

⇒ zenbat desplazatu dugu okularra lehen kokatuta zegoen positzioarekiko, eta pantaila L_2-tik zein distantziara dago?

HASIERAN



ONDOREN



$\Gamma' = 75 = -\frac{f'_{obj}}{f'_{oku}}$ → eta - kendu daiteke $f'_{obj} < 0$ ez baita posible.

$\boxed{f'_{obj} = 150cm}$

$\tan\theta = \frac{\phi_E/2}{d_{L-E}} \approx \frac{1}{2\cdot 100} = \frac{1}{200}$

↳ $\boxed{\theta \approx 0,286°}$

$\Gamma' = -\frac{\Delta}{12} = \frac{\tan\theta'}{\tan\theta} = 200\tan\theta'$

$\Gamma'_{berria} = -\frac{\Delta\cdot 25}{f_1'\cdot f_2'} = -\frac{\Delta}{12}$ ~~cm~~

→ eta agian hau ere ez da behar.

$-\frac{\Delta}{12\cdot 200} = \tan\left(\frac{7,5}{a'_{oku}}\right)$ → 1. ekuazioa dugu. 2.a?

~~tarteko irudia, bai baita bai, 1. lentearen plano fokalean eratuko da.~~

~~$a_{oku} = -\Delta - 2 \qquad a'_{oku} = \frac{1}{\frac{1}{a_{oku}} + \frac{1}{f'_{oku}}} = \frac{1}{\frac{1}{-\Delta-2} + \frac{1}{2}} = \frac{-4-2\Delta}{2-\Delta-2}$~~ $= \boxed{\frac{4-2\Delta}{\Delta} = a'_{oku}}$

Hau beste adierazpenean ordezkatuko dugu.

$-\frac{\Delta}{12\cdot 200} = \tan\left(\frac{7,5\cdot\Delta}{4-2\Delta}\right) \approx \frac{7,5\cdot\Delta}{4-2\Delta}$

$$\cancel{-4\Delta + 2\Delta^2 = 18000\Delta}$$

$$\cancel{2\Delta^2 - 18000\Delta = 0 = \Delta(2\Delta - 18000)}$$

$y'_{obj} = f'_{obj}\,\theta_E$ izanik, $\boxed{y'_{obj} = 150\,cm \cdot 5 \cdot 10^{-3}\,rad = \underline{0{,}75\,cm}}$

$\cancel{M_{obj} = \wedge A}$ $\beta'_{okn} = \dfrac{\overbrace{\phi_E/2}^{15}}{0{,}75} = 10 \rightarrow$ baina buelta emango

dionez, $\beta = -10$ izango da!

$\cancel{M}$ $\beta = \dfrac{a'}{a}$ ere beteko denez,

$$-\frac{1}{a} + \frac{1}{a'} = \frac{1}{f'_{okn}} \rightarrow -\frac{1}{a} + \frac{1}{\beta a} = \frac{1}{f'_{okn}} \rightarrow \frac{1-\beta}{\beta a} = \frac{1}{f'_{okn}}$$

$a = -2{,}2\,cm$ $\rightarrow$ $\underline{a' = +22\,cm}$ da pantailara dagoen distantzia

$\hookrightarrow$ $\underline{\Delta = 0{,}2\,cm}$ eskuinera mugitu dugu okularra.

b) Konfigurazioa mantenduz, objektiboaren fokuan eremu-diaf. jarri dugu.

$\rightarrow$ zer ϕ izan behar du ED-k pantailan soilik 1cm-ko eguzki zati bat ilustzeko?

~~$\phi_{ED} \rightarrow$ Irudi eremua pasatz: $a = -2{,}2\,cm$~~

$y'_{okn} = 1\,cm$ izan behar du $\rightarrow \beta' = -10 \rightarrow |y_{okn}| = 0{,}1\,cm$ da $\Rightarrow$

$\underline{\phi_{ED} = 0{,}1\,cm \text{ izango da.}}$

SL objektuan dagoenez, 3 eremuak berdinak izango dira.

c) $\phi_{obj} = 10cm$ bada, $\phi_{okn\text{-}min} = ?$ aurreko atalekoTD eta ED-ek berdin jarrai dezaten.

Dena objektu espaziora eramanez:

$a'_{ED} = 150cm \rightarrow a_{ED} = -\infty$

$a'_{L_2} = 150+0{,}242 \rightarrow a_{L_2} = -1037{,}27cm \rightarrow \beta' = -0{,}0147$

$$\frac{\phi_{okn}}{|\beta'|} > \phi_{obj} = 10cm \Rightarrow \boxed{\phi_{okn} > 0{,}147cm}$$

2018ko uztaila.

1/ Dugun betaurrekoa (mikroskopioa) bi lente konbergentez osatua dago ($f'_{obj} = 5cm$)

a) $a_{obj} = -10cm$ $\quad \Gamma' = 10$ behar dugu.

$\Rightarrow f'_{ok} = ?$ (behatzaile emetrope baten urruneko puntuan fokua dadin)

$$\Gamma' = 10 = -\frac{\Delta \cdot 25cm}{5cm \cdot f'_{ok}} = -\frac{5\Delta}{f'_{ok}} \overset{*}{=} 10 = \beta_{obj}\,\Gamma'_{ok}$$

$$a'_{obj} = 10cm \to \beta_{obj} = \frac{10}{-10} = -1 \Rightarrow \Gamma' = +10 = -1 \cdot \Gamma'_{ok}$$

$$|\Gamma'_{ok}| = 10 = \frac{d_{pu}}{f'_{ok}} \to \boxed{f'_{ok} = 2,5cm} \Rightarrow$$

* erabiliz $\boxed{\Delta = 5cm}$

$$a'_{ok} = \infty \to a_{ok} = -f'_{ok} = -2,5cm$$

b) Non kokatu beharko genuke objektua behatzaile emetrope baten puntu hurbilean egoteko?

$$a_{ok} = -e + a'_{obj}$$

$$e = f'_1 + f'_2 + \Delta = 12,5cm$$

$$a'_{ok} = -25cm \to a_{ok} = -2,27cm \to a'_{obj} = a_{ok} + e = 10,23cm$$

$$\boxed{a_{obj} = -9,78cm}$$

c) Zenbatekoa da foku-sakoneraren latitudea?

Aurreko biren kendura.

$$D = 10 - 9{,}78 = 0{,}022 \text{ cm} = 2{,}2 \text{ mm} = D$$

d) Kalkulatu objektiboaren erradio minimoa 10μm-ko tartea bereiz dezan.

$$\delta y = \frac{0{,}61\,\lambda}{n \sin\theta} \rightarrow \quad 10\mu m > \frac{0{,}61\,\lambda}{\sin\left[\arctan\left(\frac{\phi/2}{10}\right)\right]}$$

$n = 1$

$$20 \cdot \tan\left[\arcsin\left(\frac{0{,}61\,\lambda}{10\mu m}\right)\right] < \phi \qquad \lambda = 550 \text{nm hartut}$$

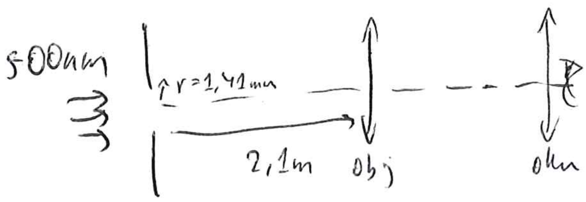
$$\phi > 0{,}6713 \text{cm} \quad \phi_{min}$$

$$\hookrightarrow r_{min} = 0{,}336 \text{ cm}$$

2/ Aurreko ariketako betaurrekoan difrakzio-behaketa bateratuko erabili dugu.

- Pantaila batean $r=1,41mm$-ko zulo zirkularra ireki dugu.
- $\lambda=500nm$-ko argiaz eraso dugu perpendikularki.
- Betaurrekoen objektiboa ardatzean irekiduratik $2,1m$-ra jarri dugu.

a) Deskribatu behatzaile emetrope batek bere punturik urrunean ikusten duen irudia betaurrekoan zehar begiratzean.



$a'_{okn} = -\infty$

$\boxed{a_{okn} = -f'_{okn} = -2,5cm}$

$a_{okn} = -e + a'_{obj} \Rightarrow \boxed{a'_{obj} = 10cm}$

$a_{obj} = -10cm$ beraz, irekiduratik 2 m-ra sortzen den irudia ikusiko da.

$N_j = \frac{\rho_j^2}{\lambda s_{2m}} = 1,98 \simeq 2$ zona erdi periodiko igaroko dira $\Rightarrow$

$\Rightarrow$ zentruan iluna eta eraztun distiratsuz inguratuko irudia ikusiko da.

Baina handipena ere kalkulatu!

$\cancel{\beta'_T = \beta'_{obj}\beta'_{okn}} = \frac{10}{-10}$ Aurreko ariketan lortu dugunez handipena

↳ benetako irudia baino 10 aldiz handiagoa ikusiko da.

b) Orain, aurreko objektu difraktatzailearen osagarria jarri dugu. Deskribatu, orain, betaurrekoak emango duen irudia

Babineten teoremagatik, alderantzizko irudia lortuko genuke, Ardatzean puntu distiratsua eraztun ilunez inguratua.

c) Zenbat urrundu beharko genuke betaurrekoa ardatzeko anplitudea (b) atalekoarekiko) aurkako fasean egoteko? Eta koadraturan egoteko?

Aurkako fasean egoteko, zona erdiperiodiko bat gehiago egon behar du,

↳ $j = 1$ behar dugu! ⇒

$$1 = \frac{r^2}{\lambda s_1} \rightarrow s_1 = 3{,}9762\,m \rightarrow$$ 1,9762m eskuinera mugitu betaurrekoa.

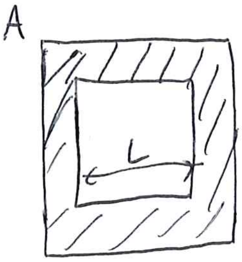
Koadraturarako, $j = 1{,}5$ behar denez:

$$1{,}5 = \frac{r^2}{\lambda s_{1,5}} \rightarrow s_{1,5} = 2{,}651\,m \rightarrow$$ 0,651m eskuinera betaurrekoa.

B/ • Irekidura $\lambda = 600nm$-rekin perpendikularki erasotu dugu.

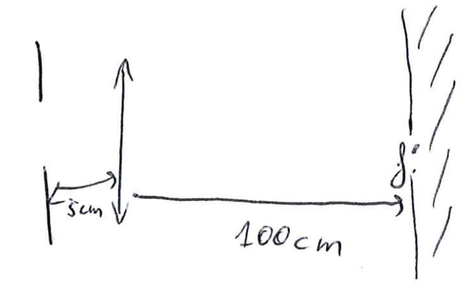
↳ Irekiduratik 5cm-ra $f' = 100cm$-ko lente konbergentea jarri dugu, eta honen plano fokalean pantaila bat.

↳ Pantailako $\vec{P} = (3mm, 9mm)$ puntuan I neurtzean I_P lortu da.



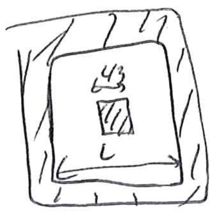
$\ell = 0,1mm$

⇒



$$\left.\begin{array}{l} X = 3mm \\ Y = 9mm \end{array}\right\} I_P$$

Gero, B irekidura erabiliz, zein intentsitate neurtuko genuke P puntu berdinean?



Goazen A-ko intentsitatea kalkulatzera:

$$U_A(p,q) = \underbrace{C \cdot S}_{L^2} \frac{\sin v}{v} \frac{\sin u}{u} \Rightarrow \begin{array}{l} v = \frac{1}{2} k p L \\ u = \frac{1}{2} k q L \end{array}$$

$$I_A(p,q) = \underbrace{I_0}_{|CS|^2} \left(\frac{\sin v}{v}\right)^2 \left(\frac{\sin u}{u}\right)^2$$

X = 3mm denean, → $p = \sin\theta = 3mm$
Y = 9mm " → $q = \sin\varphi = 9mm$

↳ $v = \frac{1}{\cancel{2}} \frac{\cancel{2}\pi}{\lambda} 3mm \cdot L = v = \frac{\pi}{2}$

$u = \frac{1}{\cancel{2}} \frac{\cancel{2}\pi}{\lambda} 9mm \cdot L = u = \frac{3}{2}\pi$

$$I_A(3mm, 9mm) = I_0 \left[\frac{\sin\left(\frac{\pi}{2}\right)}{\frac{\pi}{2}}\right]^2 \left[\frac{\sin\left(\frac{3}{2}\pi\right)}{\frac{3}{2}\pi}\right]^2 = I_0 \frac{4}{\pi^2} \cdot \frac{4}{9\pi^2} = \boxed{I_0 \frac{16}{9\pi^4} = I_P}$$

Orain, B kasuko intentsitatea kalkulatuko dut. Horretarako, A-ko anplitudeari irekidurak B-n estalitakoak azalera bakarrik izango lukeen anplitudea kenduko diot.

$$U_B(p,q) = C\cdot \overset{S}{L^2}\,\frac{\sin v}{v}\,\frac{\sin u}{u} - C\cdot L'^2\,\frac{\sin v'}{v'}\,\frac{\sin u'}{u'}$$

$L' = \frac{L}{3}$ den

ela $v' = \frac{v}{3}$ $u' = \frac{u}{3}$

$$\cancel{U_B(p,q) = C L^2\left[\frac{\sin v}{v}\,\frac{\sin u}{u} - \frac{1}{9}\,\frac{3\sin(v/3)}{v}\right.}$$

$$U_B(p,q) = C\cdot\underbrace{L'^2}_{S/9}\left[\cancel{9}\,\frac{\sin(3v')}{\cancel{3}v'}\,\frac{\sin(3u')}{\cancel{3}u'} - \frac{\sin(v')}{v'}\,\frac{\sin(u')}{u'}\right]$$

$$U_B(p,q) = \frac{C\cdot S}{9}\left[\sin(3v')\sin(3u') - \sin(v')\sin(u')\right]\cdot\frac{1}{u'\cdot v'}$$

$$I_B(p,q) = \frac{I_0}{9^2}\,\frac{1}{(u'v')^2}\left[\sin(3v')\sin(3u') - \sin(v')\sin(u')\right]^2$$

$x = 3mm \to$ $p = 3mm \to v' = \frac{1}{\cancel{3}}\cdot\frac{1}{\cancel{2}}\frac{2\pi}{\lambda}\,1mm\cdot L \to v' = \frac{\pi}{6}$

$y = 9mm$ $q = 9mm \to u' = \frac{1}{\cancel{3}}\,\frac{1}{\cancel{2}}\frac{2\pi}{\lambda}\cdot 3mm\cdot L \to u' = \frac{\pi}{2}$

$$I_B(3mm, 9mm) = \frac{I_0}{9^2}\,\frac{12^2}{\pi^4}\left[\sin\left(\frac{\pi}{2}\right)\sin\left(\frac{3\pi}{2}\right) - \sin\left(\frac{\pi}{6}\right)\sin\left(\frac{\pi}{2}\right)\right]^2$$

$$I_B(3mm, 9mm) = \underbrace{I_0\,\frac{16}{9\pi^4}}_{I_p}\cdot\left[-1-\frac{1}{2}\right]^2 = I_p\cdot\left(-\frac{3}{2}\right)^2 = \frac{9}{4}I_p$$

Beraz, $I_B = \frac{9}{4}I_p$ izango dugu.

4/ ·Partz. pol. argi sorta ($I=I_0$, $V_0=0,9$, $\psi=-\frac{\pi}{6}$, $\chi=0$) desfasatzaile batean zehar igarotakoan $\vec{S}=\left(2,0,0,\frac{1}{2}\right)$ argiarekin gainezarri da inkoherenteki.

· Gainezarpenaren ondorioz argi aleatorioa lortu da.

=> Kalkulatu I_0 eta esan desfasatzailea nolakoa den.

$$\vec{S_0} = 0,1\, I_0 \begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0,9\, I_0 \begin{pmatrix}1\\1/2\\-\sqrt{3}/2\\0\end{pmatrix}$$ dugu hasieran → L_{-30} dugu!

$$\vec{S_1} = 0,1\, I_0 \begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0,9\, I_0 \begin{pmatrix}1\\a\\b\\c\end{pmatrix}$$

$$\cancel{\vec{S} = \begin{pmatrix}2\\0\\0\\1/2\end{pmatrix} = 0,75} \qquad \vec{S} = \begin{pmatrix}2\\0\\0\\1/2\end{pmatrix}$$ → Zo da!

$$\cancel{\vec{S_3} = \begin{pmatrix}I_0+2\\0,9\, I_0\, a\\0,9\, I_0\, b\\0,9\, I_0\, c+\frac{1}{2}\end{pmatrix} = I_0 \begin{pmatrix}1\\0\\0\\0\end{pmatrix}} \qquad \cancel{I_0+2=I_0} \quad \cancel{a=b=0}$$

Ondorioz, desfasatzaileak $\begin{pmatrix}1\\1/2\\-\sqrt{3}/2\\0\end{pmatrix}$ Z_C bilakatu behar du!

↳ Horretarako, desfasatzaileak $\frac{\pi}{2}$-ko desfasea eragin behar du, ~~L45~~ ~~ketla~~ L_{-75} izanik ardatz azkarra:

$\boxed{\text{Beraz, } A_{\frac{\pi}{2}, L_{-75}} \text{ edo } A_{\frac{3\pi}{2}, L_{15}} \text{ izango dugu.}}$

Beraz, $\vec{S_1}$: $\vec{S_1} = 0,1 I_0 \begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0,9 I_0 \begin{pmatrix}1\\0\\0\\-1\end{pmatrix}$

$$\vec{S_2} = \begin{pmatrix}2\\0\\0\\1/2\end{pmatrix}$$

$$\vec{S_2}+\vec{S_1} = \begin{pmatrix}I_0+2\\0\\0\\\frac{1}{2}-0,9I_0\end{pmatrix}$$

$\rightarrow \boxed{I_0 = \frac{5}{9} = 0,56 \text{ izango da intentsitatea.}}$

5/ · Sarreran Brewster angeluz erasoten dugu argi aleatorioarekin.

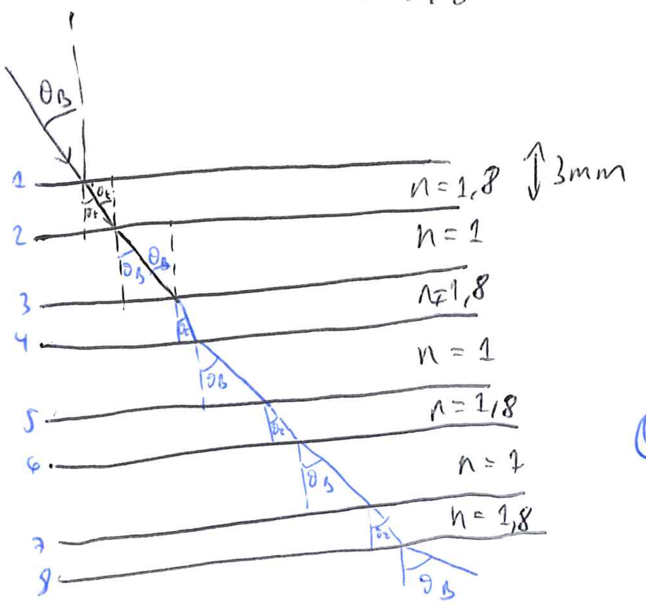
· 4 xaflan zehar igaro da.

↳ d=3mm-ko lodiera

↳ n=1,8

$$\boxed{\theta_B = \arctan\left(\frac{1,8}{1}\right) = 60,95^\circ}$$

$\cancel{\theta_t = 38,63^\circ}$ $\boxed{\theta_t = 29,05^\circ}$



⇒ Argiaren polarizazio maila irteeran?

(1) $\tau_\perp = 0,721$ $\tau_\parallel = 1$

$\boxed{\tau_1 = 0,8605}$ $V' = \left|\frac{\tau_\perp - \tau_\parallel}{\tau_\perp + \tau_\parallel}\right| = 0,162$

$$\vec{S_0} = \begin{pmatrix}1\\0\\0\\0\end{pmatrix} \rightarrow \vec{S_1} = \begin{pmatrix}1\\-V'\\0\\0\end{pmatrix}\cdot\tau_1 = \tau_1\begin{pmatrix}1\\-0,162\\0\\0\end{pmatrix} = \tau_1\left[0,838\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0,162\begin{pmatrix}1\\-1\\0\\0\end{pmatrix}\right]$$

(2) $\tau_2 = \tau_1 \rightarrow \vec{S_2} = \tau_2\left[0,838\cdot\tau_1\begin{pmatrix}1\\-V'\\0\\0\end{pmatrix} + 0,162\cdot\tau_\parallel^{1}\begin{pmatrix}1\\-1\\0\\0\end{pmatrix}\right]$

$$\vec{S_2} = \tau_1\left[\begin{pmatrix}0,883\\-0,244\\0\\0\end{pmatrix}\right]$$

$$\boxed{\vec{S_2} = \tau_1\cdot 0,883\begin{pmatrix}1\\-0,276\\0\\0\end{pmatrix}} = \tau_1\cdot0,883\left[0,724\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0,276\begin{pmatrix}1\\-1\\0\\0\end{pmatrix}\right]$$

(3) $\gamma_3 = \gamma_1$ $\quad \vec{S_3} = \gamma_1 \cdot 0,883 \left[0,724 \cdot \gamma_1 \begin{pmatrix} 1 \\ \cancel{-0} \\ 0 \\ 0 \end{pmatrix} + 0,276 \underbrace{\gamma_{11}}_{1} \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix} \right]$

$$\vec{S_3} = \gamma_1 \cdot 0,883 \cdot \begin{pmatrix} 0,899 \\ -0,276 \\ 0 \\ 0 \end{pmatrix} = \gamma_1 \cdot \underbrace{0,883}_{A} \cdot \underbrace{0,899}_{B} \begin{pmatrix} 1 \\ -0,307 \\ 0 \\ 0 \end{pmatrix}$$

$$\vec{S_3} = \gamma_1 \cdot A \cdot B \cdot \left[0,693 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + 0,307 \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix} \right]$$

(4) $\gamma_4 = \gamma_1$ $\quad \vec{S_4} = \gamma_1 A \cdot B \cdot \left[0,693 \cdot \right.$

✗ Baina bana ibiz oso errisketsua da, γ'-ak ahantz daitezkelako.

Hobeto horrela:

$$\vec{S_0} = I_0 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} = \frac{I_0}{2} \begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix} + \frac{I_0}{2} \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix}$$ dugu.

$$\vec{S_1} = \frac{I_0}{2} \gamma_1 \begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix} + \frac{I_0}{2} \underbrace{\gamma_{11}}_{1} \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix}$$

$$\vec{S_2} = \frac{I_0}{2} \gamma_1^2 \begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix} + \frac{I_0}{2} 1^2 \cdot \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix} \rightarrow \vec{S_F} = \frac{I_0}{2} \begin{pmatrix} \gamma_1^{2m} + 1 \\ \gamma_1^{2m} - 1 \\ 0 \\ 0 \end{pmatrix}$$

Eta beraz, polarizazio maila:

$$\boxed{V = \left| \frac{\gamma_1^{2m} - 1}{\gamma_1^{2m} + 1} \right|_{m=4} = 0,864 \text{ dugu.}}$$

2018ko uztaila.

1/ • Teleobjektibo baten (fokal positiboko) ondorengo osagaiak ditu:

→ obj: L_1 konb 10d
→ okn: L_2 dib.

$\Big\} e = 5cm$

• Infinitura fokatzeko, CCDa L_2-tik 30cm-ra dago.
"filma"

a) Irudi-plano nagusiaren posizioa? (H') Sistema osoaren f'?

$f'_{okn} = ?$

$L_1 \rightarrow \varphi = 10d = \frac{1}{f'_{obj}} \rightarrow f'_{obj} = 0{,}1m = 10cm$

$a_{obj} = -\infty \rightarrow a'_{obj} = f'_{obj} = 10cm \rightarrow a_{okn} = -e + a'_{obj} = -5+10 = \boxed{5cm = a_{okn}}$

$a_{okn} = 5cm;\ a'_{okn} = 30cm \rightarrow -\frac{1}{5} + \frac{1}{30} = \frac{1}{f'_{okn}} \Rightarrow \boxed{f'_{okn} = -6cm}$

$O_2H' = -\frac{e f_2'}{f_1' + f_2' - e} \rightarrow O_2H' = -30cm$ (2. lentetik 30cm ezkerrera)

$f' = \frac{f_1' f_2'}{f_1' + f_2' - e} = \boxed{60cm = f'}$

b) Superteleobjektibo bat egin nahi dugu:

LEIHARREN ARTEKO DIST. ERE ALDATU DA

1) L_1 eta $L_2 \leftrightarrow$ CCD-ra distantzia, biak kontserbatu.
2) L_2-n $f_2' = -2cm$ lentea jarri dugu lehengokoaren ordez.

• Atezaina L_1-etik 105m-ra dago. CCD 24x36 bada,

Kalkulatu premua:

$a_{obj} = -10500cm;\ a'_{obj} = 10{,}0095cm \ \|\ a'_{okn} = 30cm \Rightarrow a_{okn} = 1{,}875cm$

$a_{okn} = -e + a'_{obj} \Rightarrow \boxed{e = 8{,}1345cm \text{ dugu}}$

$$f' = + \frac{f_1' f_2'}{f_1' + f_2' - e} = 148{,}699\ cm$$

$\rightarrow \tan\theta = \frac{d}{2f'} = \frac{\sqrt{2{,}4^2 + 3{,}6^2}}{2f'} \rightarrow$

$\rightarrow$ Eremua: $2\theta = 2\arctan\left(\frac{\sqrt{2{,}4^2 + 3{,}6^2}}{2f'}\right) = 1{,}667°$ -ko eremua

Eremu horizontala: $2\theta = 2\arctan\left(\frac{2{,}4}{2f'}\right) = 0{,}462°$ -ko eremua

$\tan\theta = \frac{y}{10500} \rightarrow y =$

Teleskopioaren handipena: $\beta_T' = \beta_1' \beta_2' = \frac{a_{obj}'}{a_{obj}} \frac{a_{ok}'}{a_{ok}}$

$\beta_T' = -0{,}0152$ dugu handipena.

$\rightarrow$ Eremu horizontala: $a' = 3{,}6cm \rightarrow a = 2{,}37m$

Eremu bertikala: $a' = 2{,}4cm \rightarrow a = 1{,}58m$

c) Berriz L_1 eta L_2-rako aldatu gabe, aztertu teleobjektiboaren balio energetikoa eta distantzia fokalaren, f_{ok}'-ren eta e-ren balio limiteak.

P.U. $a_{obj} = -\infty \rightarrow \underline{a_{obj}' = 10cm}$; $a_{ok} = \frac{1}{\frac{1}{30} - \frac{1}{f_2'}}$

P.H. $a_{obj} = -25cm \rightarrow \underline{a_{obj}' = 16{,}67cm}$; $a_{ok} = \frac{1}{\frac{1}{30} - \frac{1}{f_2'}}$

$a_{ok} = -e + a_{obj}'$

$f' = \frac{f_{obj}' f_{ok}'}{f_{obj}' + f_{ok}' - e}$

P.U: $\frac{1}{\frac{1}{30} - \frac{1}{f_2'}} = 10 - e \Rightarrow \frac{30f_2'}{f_2' - 30} = 10 - e$

P.H: $\Rightarrow \frac{30f_2'}{f_2' - 30} = 16{,}67 - e$

Zati hau zail xamarra.

Beall definitzen duene:

$$O_2F' = \ell = \frac{(f_1'-e)\,f_2'}{f_1'+f_2'-e} \Rightarrow \begin{cases} f_2' = \dfrac{\ell(e-f_1')}{\ell-f_1'+e} \\[2ex] e = \dfrac{\ell(f_1'+f_2')-f_1'f_2'}{\ell-f_2'} \end{cases}$$

$$f_2'<0 \Rightarrow \ell(e-f_1')<0 \Rightarrow \boxed{e<f_1'}$$

$$e>0 \Rightarrow \ell(f_1'+f_2')-f_1'f_2'>0 \Rightarrow \cancel{\ell f_1'+\ell f_2' > f_1'f_2' \Rightarrow}$$

$$\cancel{\Rightarrow (\ell-f_1')f_2' > -\ell f_1' \Rightarrow f_2' > -\frac{\ell f_1'}{\ell-f_1'}}$$

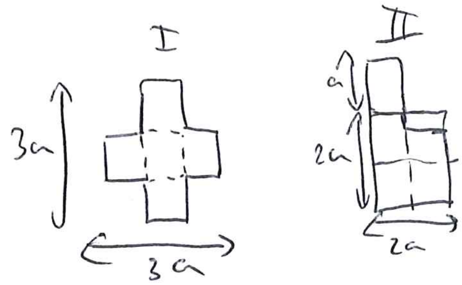
$$(\ell-f_1')f_2' > -\ell f_1' \Rightarrow f_2' > \frac{\ell f_1'}{(\ell-f_1')} = -15$$

↳<) tetian lortua.

$$0<e<10\,\text{cm} \qquad -15<f_2'<0$$

$$\underbrace{\qquad\qquad\qquad}_{30\,\text{cm}<f'<\infty}$$

2/ Bi difrakzio sare ezberdin ditugu bakoitzaren zuloak ezberdinak izanik:



a) Kalkulatu I eta II objektu difraktatzaileek emango luketen amplitude difraktatuen adierazpenak.

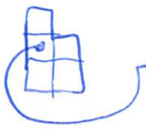
$$U_I(p,q) = C\cdot \underset{a\cdot a}{S} \cdot \frac{\sin u}{u}\,\frac{\sin v}{v}\left[1+e^{ikpa}+e^{-ikpa}+e^{ikqa}+e^{-ikqa}\right]$$

$$\left(u=\tfrac{1}{2}kpa \qquad v=\tfrac{1}{2}kqa\right)$$

$$\boxed{U_I(p,q) = C\cdot S\,\frac{\sin u}{u}\,\frac{\sin v}{v}\left[1+2\cos(kpa)+2\cos(kqa)\right]}$$

$$U_{II}(p,q) = C\cdot S\cdot \frac{\sin u}{u}\cdot\frac{\sin v}{v}\left[1+e^{-ikpa}+e^{-ikqa}+e^{-ikpa+ikqa}+e^{-ikpa}e^{-ikqa}\right]$$

$$U_{II}(p,q) = C\cdot S\,\frac{\sin u}{u}\,\frac{\sin v}{v}\left[1+e^{-ikpa}+e^{-ikqa}+2e^{-ikpa}\cos(kqa)\right]$$

Polito geratzeko, hobe da  kan hartzea 0,0.

$$U_{II}(p,q) = C\cdot S\,\frac{\sin u}{u}\,\frac{\sin v}{v}\left[1+e^{ikqa}+e^{-ikqa}+e^{-ikpa}+e^{-ikpa+ikqa}\right]$$

$$\boxed{U_{II}(p,q) = \text{''}\quad\text{''}\quad\text{''}\left(\underbrace{1+2\cos(kqa)+2e^{-ikpa}\cdot e^{+ikq\frac{a}{2}}\cos\left(kq\frac{a}{2}\right)}_{1+2+2\cdot 1\cdot e^{-ikpa}}\right)}$$

b) Sareak egiteko I eta II objektuak X ardatzean errepikatu ditugu $d=5a=4{,}0\,\mu m$-ko periodoarekin. Ondorioz, $q=0$ lerroa erabiliko dugu.

Zein norabideetan agertuko dira ordena galduak bi sareetan? Zeintzuk dira?

Hau jakiteko, bakoitzaren intentsitateak kalkulatu behar ditugu $u = \frac{1}{2}kpa$

$$I_I(p,0) = \underbrace{I_0}_{|ks|^2} \left(\frac{\sin u}{u}\right)^2 \left[3+2\cos(kpa)\right]^2 \left[\frac{\sin(N\varphi)}{\sin(\varphi)}\right]^2$$ non $\varphi = \frac{1}{2}kp\,5a$ den.

Maximoak, berez, $p = m\frac{\lambda}{5d}$ puntuetan dugu →

$m\frac{\lambda}{5d} = n\frac{\lambda}{a}$ dugunean, ordea, ~~minimo nuluak~~ ordena galdua izango dugu.

$$\frac{m}{n} = 5 \Rightarrow \boxed{m = 5 \to p = 5\frac{\lambda}{5d} = \frac{\lambda}{d} \text{ norabidean O.G.}}$$

edota $3+2\cos(kpa) = 0$ denean.

↳ $\cos(kpa) = -\frac{3}{2}$ → ez da inoiz zerotuko!

$\cancel{I_{II}(p,0) = I_0\left(\frac{\sin u}{u}\right)^2}$

$$|3+2e^{-ikpa}|^2 = 9+4+2e^{ikpa}+2e^{-ikpa} = 13+4\cos(kpa)$$

$$I_{II}(p,0) = I_0\left(\frac{\sin u}{u}\right)^2 \left(13+4\cos(kpa)\right) \left(\frac{\sin(N\varphi)}{\sin(\varphi)}\right)^2 \to \varphi = \frac{1}{2}kp5a$$

↓ kasu honetan ere hau ez denez zerotuko ⇒

$\Rightarrow m = 5n \Rightarrow$ $p = n\frac{\lambda}{d}$ norabideetan izango ditugu ordena galduak

c) $\lambda \sim$ ~~Ø~~ $550\,nm$ inguruan dauden bi λ_1, λ_2 bereizi nahi ditugu eraso perpendikularrean. $\lambda_1 - \lambda_2 \sim 1 Å$

Sareen luzera 3mm bada, lortuko al dugu bi λ-ak bereiztea?

$5d = 4\mu m$ da periodoa $\frac{3mm}{4\mu m} = 750$ zuloko sareak ditugu. $N = 2500$

Behar dugun bereizmena: $R = mN = \frac{\lambda}{\Delta\lambda} \simeq 5500$ dugu!

$\Rightarrow$ Horretarako, behar den ordena minimoa: $\frac{R}{N} = 7,333 \rightarrow$

$\rightarrow$ 7.ean agian bereiziko dira ondo, 8.an seguru.

$\sin\theta_M = 1 > m\frac{\lambda}{5d} = 0,22$ $\rightarrow$ betetzen

$m=8$

~~$1 = m_M \underbrace{\frac{\lambda}{5d}}$ $\rightarrow$ $m_M = 36,36$ $\rightarrow$ balio, erraz balioko digu.~~

~~↳ Hau hala da ala?~~

7-kin nahikoa bagenau ✓

~~$1 = m_M \frac{\lambda}{5d}$ balio $\rightarrow m_M = 7,27 \Rightarrow$~~ 8 behako bagenitu X

$1 = m_M \underbrace{\frac{\lambda}{5d}}_{4\mu m}$ $\rightarrow m_M = 7,27$ $\rightarrow$ 7 kin nahikoa bada ✓

$\rightarrow$ 8-kin " bada X

d) Intentsitateari dagokionez, zer sare hautatuko zenuke, A ala B?

m=7 kasurako suposatzen dut galdetzen duela.

$$I_I\left(7\frac{\lambda}{5d},0\right) = I_0 \left(\frac{\sin\left(\frac{1}{2}\frac{2\pi}{\lambda}\frac{7\lambda}{5d}d\right)}{\frac{1}{2}\frac{2\pi}{\lambda}\frac{7\lambda}{5d}d}\right)^2 \left[3+2\cos\left(\frac{2\pi}{\cancel{\lambda}}\frac{7\cancel{\lambda}}{5\cancel{a}}\cancel{a}\right)\right]^2 \underbrace{\left(\frac{\sin\left(N\frac{1}{\cancel{2}}\frac{4\pi}{\cancel{\lambda}}\frac{7\cancel{\lambda}}{\cancel{5a}}5a\right)}{\sin\left(\frac{1}{\cancel{2}}\frac{2\pi}{\cancel{\lambda}}\frac{7\cancel{\lambda}}{\cancel{5a}}5a\right)}\right)^2}_{N^2}$$

~~$I_I\left(\frac{7\lambda}{5a},0\right) = I_0 N^2$~~

Dana ez da kalkulatu behar! Soilik desberdina duten zatia kalkulatu, edozein m-rako!

$$\frac{I_B}{I_A} = \frac{13+4\cos\left(\frac{2\pi}{\cancel{\lambda}}\frac{m\cancel{\lambda}}{5\cancel{a}}\cancel{a}\right)}{\left[3+2\cos\left(\frac{2\pi}{\cancel{\lambda}}\frac{m\cancel{\lambda}}{5\cancel{a}}\cancel{a}\right)\right]^2} = \frac{13+4\cos\left(\frac{2\pi m}{5}\right)}{\left[3+2\cos\left(\frac{2\pi m}{5}\right)\right]^2}$$

BUKAERA HAU NOLA?

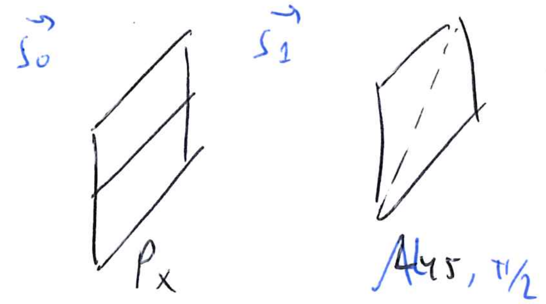
B-n maximo nagusien ~~m~~ $p=\frac{m\lambda}{5a}$

$N_B =$

3/ a) Partzialki pol. argi-sorta bateK ($I = I_0, V = 0{,}9, \psi = 0, \chi = 0$)

P_x bat zeharkatzen du lehenik eta $A_{\frac{\pi}{2}, L45}$ bat ondoren.

↳ Irteerako argiaren I, V eta pol. egoera?



$$\vec{S_0} = 0{,}1 I_0 \begin{pmatrix}1\\0\\0\\0\end{pmatrix} + 0{,}9 I_0 \begin{pmatrix}1\\1\\0\\0\end{pmatrix}$$

↳ L_x

$$\vec{S_1} = 0{,}1 \frac{I_0}{2} \begin{pmatrix}1\\1\\0\\0\end{pmatrix} + 0{,}9 I_0 \begin{pmatrix}1\\1\\0\\0\end{pmatrix} = 0{,}95 I_0 \begin{pmatrix}1\\1\\0\\0\end{pmatrix}$$

Poincaré erabiliz, ZD izango dugu irteeran.

$$\vec{S_2} = 0{,}95 I_0 \begin{pmatrix}1\\0\\0\\1\end{pmatrix}$$

Beraz, $V = 1$, $I = 0{,}95 I_0$

$\sin(2\chi) = 1 \rightarrow$ $\chi = \pi/4$ rad $\quad \delta = \frac{\pi}{2}$ rad

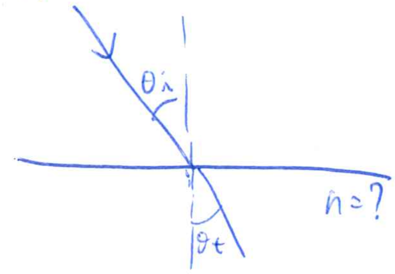
$\alpha = \frac{\pi}{4}$ rad. $\psi < \psi$

ZD guztiz. pol.

b) · Lortutako argi-sorta material ezezagunoko xaflan batean islatzen da, islatutakoa Pol. lineal birakor batez aztertzen dakriu.

· θ_i baterako, $I_B = \frac{I_0}{10}\cos^2(\varphi)$ da non φ polarizatzailearen biraketa angelua den.

⇒ Zein da islatutako argi-sortaren pol-egoera?
Kalkulatu xaflaren errefrakzio-indizea.



$$R_\perp = \frac{\sin^2\left[\theta_i - \arcsin\left(\frac{\sin\theta_i}{n}\right)\right]}{\sin^2\left[\theta_i + \arcsin\left(\frac{\sin\theta_i}{n}\right)\right]}$$

$\theta_i = ?$ $\arcsin\left(\frac{\sin(\theta_i)}{n}\right) = \theta_t$

$$R_\parallel = \frac{\tan^2\left[\theta_i - \arcsin\left(\frac{\sin\theta_i}{n}\right)\right]}{\tan^2\left[\theta_i + \arcsin\left(\frac{\sin\theta_i}{n}\right)\right]}$$

$R = \frac{1}{2}(R_\parallel + R_\perp)$ izango dugu.

$I' = \frac{I_0}{10}$ → Islapenean $0{,}95\, I_0$-tik $0{,}1\, I_0$-ra pasa da →

→ $R = \frac{2}{19}$ da islagarritasuna.

$\varphi = \frac{\pi}{2}$ rad denean, $I_B = 0$ denez, argiak lineala izan behar du ⇒ Brewsterren angeluan erasota dugu. $R_\parallel = 0$

~~$R_\parallel = 0 \Rightarrow \theta_i - \arcsin\left(\frac{\sin\theta_i}{n}\right) = 0 \rightarrow$~~

$$I_r = I_I \cdot \frac{1}{2} R_\perp = I_I \cdot \frac{1}{2} \underbrace{\cos^2(2\theta_B)}_{\text{Sinistu behako}} = \frac{I_0}{10} = \frac{0{,}95}{2} I_0 \cdot \cos^2(2\theta_B)$$

$$\sqrt{\frac{4}{19}} = \cos(2\theta_B) \rightarrow \qquad \frac{1}{2}\arccos\left(\sqrt{\frac{4}{19}}\right) = \theta_B = 0{,}547\,rad = 31{,}34^\circ$$

edo $= 58{,}65^\circ$

orduan $\tan\theta_B \cdot \overset{1}{n_1} = n_2 \rightarrow$ $\boxed{n_2 = 1{,}64 \text{ da erref. ind.}}$

zeukatenduna 58,65° gatik

Eta islatutako argia lineala ($v=1$) izango da

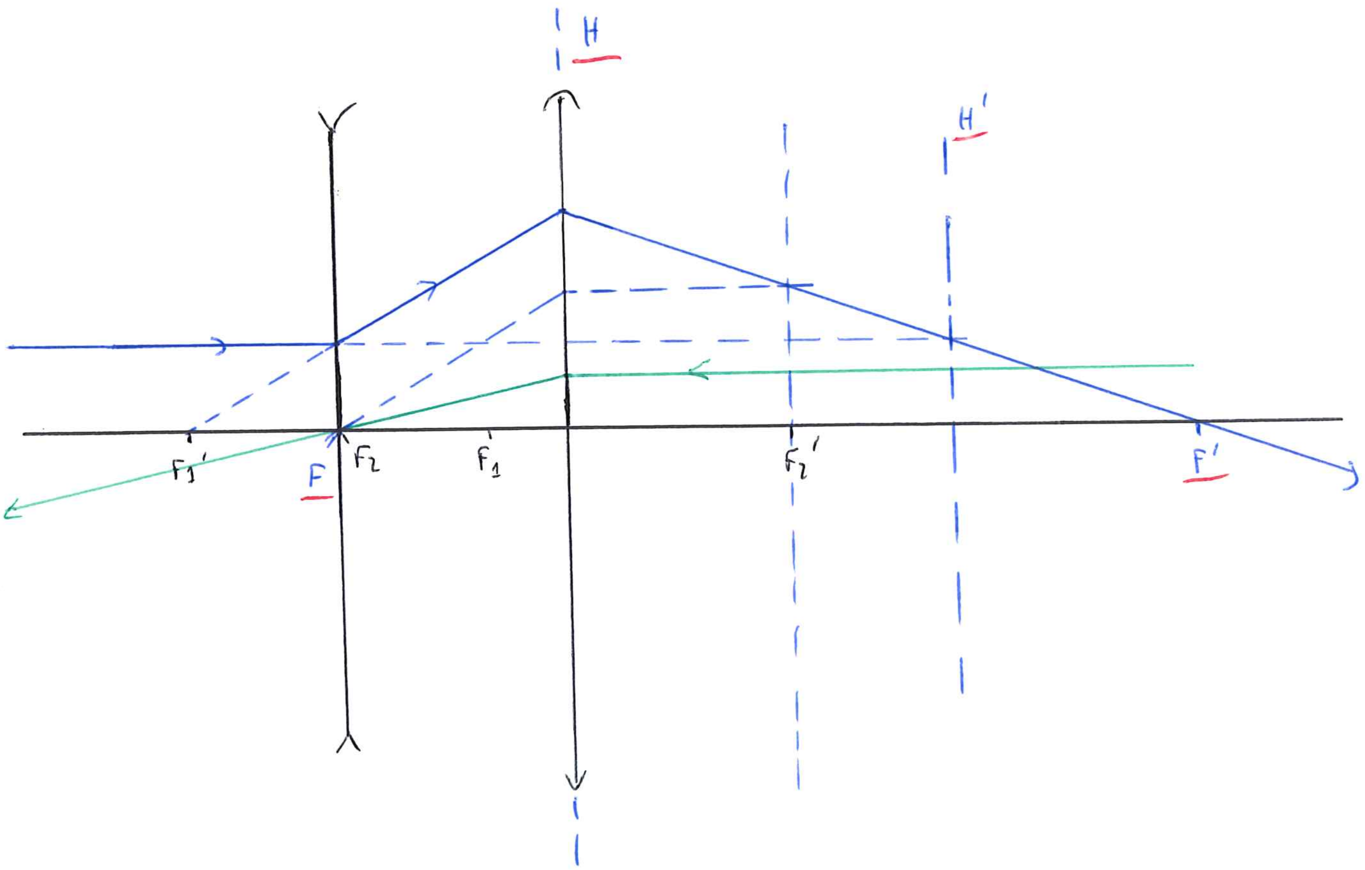
2016ko uztaila

1/ (-2,3,3) leiar bikotea landuko dugu.

a) $u = 10mm$ bada, kalkulatu elementu kardinalak grafikoki.

$f_1' = -20mm = -2cm$ $\qquad f_2' = 30mm = 3cm$ $\qquad e = 3cm$

$O_1H = 3cm$ $\qquad O_2H' = 4{,}5cm$ $\qquad f' = 3cm$ $\Rightarrow$ Hauek grafikoki lortu beher dira.



b) Lente bikotea argazki-kamera baten objektiboa da.

→ objektiboaren $N = 1,5$

→ L_2 ID da

→ objektua ∞-an dagoenean ED irudiaren posizioan dago.

⇒ Kalkulatu L_2-ren diametroa.

$$N = \frac{1}{A} = \frac{f'_{obj}}{\phi_{SN}} = 1,5 \rightarrow \underline{\phi_{SN} = 2\,cm}$$

L_2 ID bada, bere objektu eremuko konjokatua da

SN → $a' = 3\,cm \rightarrow a = 1,2\,cm \rightarrow \beta' = 2,5$ ⇒

⇒ SN-a 2,5 aldiz txikiagoa da L_2 baino.

$$\boxed{\underline{\phi_{L_2} = 5\,cm}}$$

c) Filma 24x36 da eta $\phi_{L1} = 3\,cm$ → Aztertu lente honen eragina argiztapen eremuetan.

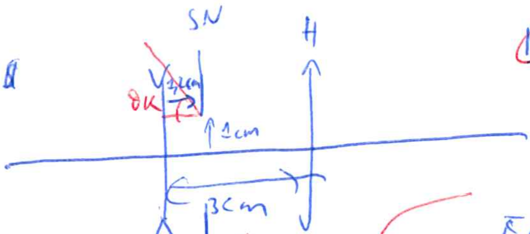
$$\tan\theta = \frac{1,2}{f'} \rightarrow \theta_{bert} = 21,8^{\circ}$$

↑ angelu erdia!

angelu hauek sarrerako ~~minitik hasten dira.~~ H-tik (L_2-tik) hasten dira

$$\tan\theta_H = \frac{1,8}{f'} \rightarrow \theta_H = 30,96^{\circ}$$

Dena SN atera tzen denez berdin egin behar da!



~~→ $\theta_H = \arctan\left(\frac{1,5}{1,2}\right) \rightarrow \theta_H = 2?,055^{\circ}$~~

θ_H → L_1 onartzen duen malda handiena

$$\theta_H = \arctan\left(\frac{0,5}{1,2}\right) = 22,62^{\circ} \rightarrow \text{Beraz}$$

↗ Eremu bertikal osoa ondo argiztatuko bada ere, eremu horizontalean L_1-ek intentsitatea jaitsiko du.

2/ Ariketa ~~k~~ orrillo berdina bada ere berregin egingo dut. (marrazkiak ez ditut kopiatuko)

a) $U_{A2}(p,q) = U_{A2}(p,q) - U_{A3}(p,q)$

$$U_{A1}(p,q) = \underbrace{C \cdot S}_{U_0}\ \frac{\sin u}{u}\ \frac{\sin v}{v}\left(e^{-ikpa} + e^{ikpa}\right) \qquad u = \frac{1}{2}kpa \quad v = \frac{1}{2}kqa$$

$$\boxed{U_{A1}(p,q) = U_0\ \frac{\sin u}{u}\ \frac{\sin v}{v}\ 2\cos(kpa)}$$

$$U_{A2}(p,q) = C \cdot 3a^2\ \frac{\sin u'}{u'}\ \frac{\sin v}{v} \qquad \text{non } u' = \frac{1}{2}kp\,3a = 3u$$

$$\boxed{U_{A2}(p,q) = \underbrace{Ca^2}_{U_0}\ \cancel{3}\ \frac{\sin(3u)}{\cancel{3}u}\ \frac{\sin v}{v}}$$

$$\boxed{U_{A3}(p,q) = U_0\ \frac{\sin u}{u}\ \frac{\sin v}{v}}$$

$$\frac{1-\cos(2u)}{2} = \sin^2(u)$$
$$\hookrightarrow 1 - 2\sin^2(u) = \cos(2u)$$

$$U_{A2} - U_{A3} = U_0\ \frac{\sin v}{uv}\left[\sin(3u) - \sin(u)\right]$$

Frogatu beharrekoa: $2\sin u\cos(\overbrace{kpa}^{2u}) = \sin(3u) - \sin(u)$

$$2\sin(u)\left[1 - 2\sin^2(u)\right] = 2\sin(u)\left[1 - 2\left(1 - \cos^2(u)\right)\right] = 2\sin u\left(1 - 2 + 2\cos^2 u\right)$$

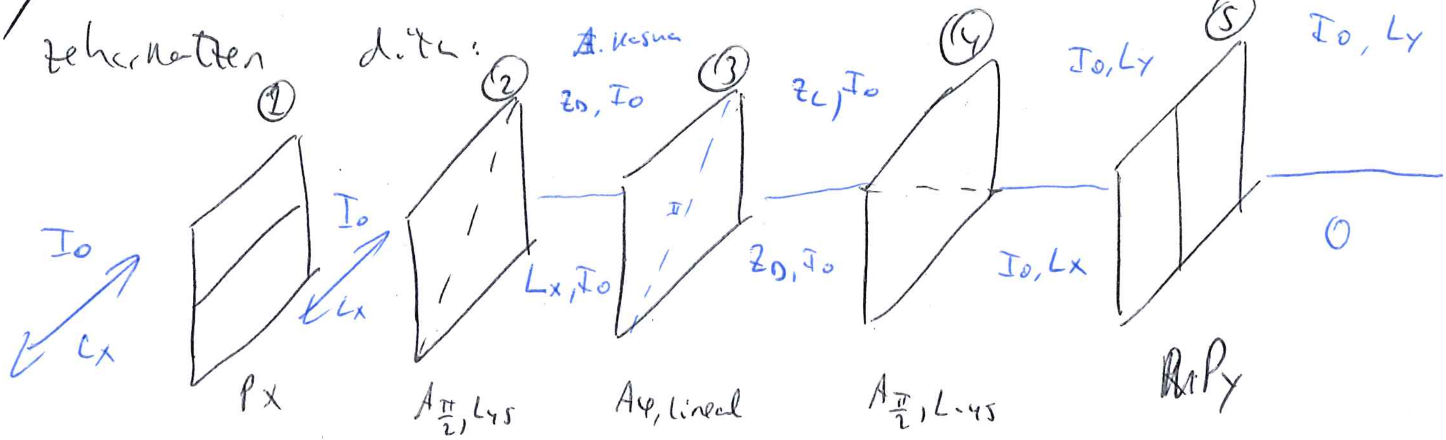
$$\cancel{2\sin(u)\left(-1 + 2\cos^2 u\right) \stackrel{?}{=} \sin(3u) - \sin(u)}$$

$$2\left(\sin u - 2\sin^3(u)\right) = \sin(3u) - \sin(u)$$
$$\sin(3u) = \sin(2u)\cos(u) - \sin(u)\cos(2u) - \sin(u)$$

$\hookrightarrow$ berdina emango dute.

(besteak ariketetatik begiratu)

3/ I_0-ko ~~...~~ int. duen L_x argi-sorta batek dispositibo hauek zeharkatzen ditu:



a) • Hasierako muntaian sistema gardena da.
• ② ↔ ③ trukatuz gero opakua.

⇒ Nolakoa da ③?

1. kasuan ③-k → $Z_D \to Z_C$ bihurtu du.
2. kasuan ③-k → $L_x \to L_x$ → ez du aldaketarik eragin

Ondorioz, desfasatzailea $A_{Lx,\pi}$ dugu (ardatz lastera L_y ere izan daiteke)

b) Hasierako muntaiara itzuliz, hasierako L_x argia koherenteki gainezarri dugu Z_D argi-sorta batekin. Dispositiboa opakua bada, kalkulatu gainezarri diren argien arteko desfasea eta Z_D-ren intentsitatea:

$$\cancel{|e\rangle = \frac{a_z}{\sqrt{2}}\begin{bmatrix}1\\-i\end{bmatrix} + \frac{\sqrt{I_0}}{1}\begin{bmatrix}1\\0\end{bmatrix} e^{i\delta}}$$

$$|e\rangle = \sqrt{I_0}\begin{pmatrix}1\\0\end{pmatrix} + \frac{a_z}{\sqrt{2}}\begin{bmatrix}1\\-i\end{bmatrix} e^{i\delta}$$

~~$|e'\rangle = a_6\begin{pmatrix}0\\1\end{pmatrix}$ izango dugu amaieran, bai hala bai.~~

Lehen ikusi dugu nola ① -en L_x sartzen bada dispositiboa gardena dela. Beraz, L_y sartzean izango da grafikoa, hots:

$|e'\rangle = a_G \begin{pmatrix} 0 \\ 1 \end{pmatrix}$ izango dugu ~~ama~~ sartzen den argia.

$$\sqrt{I_0} + \frac{a_2}{\sqrt{2}} e^{-i\delta} = 0 \rightarrow \delta = \pi \text{ rad}$$ kenketa egon ahal izateko!

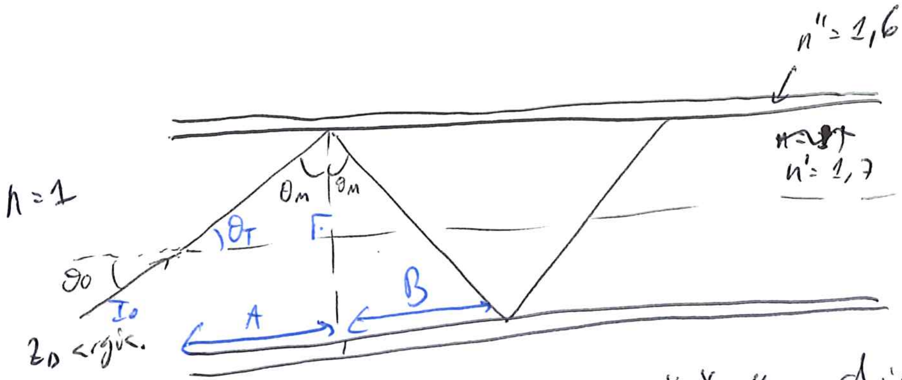
$$-\frac{a_2}{\sqrt{2}} i e^{-i\delta} = a_G = \cancel{\frac{a_2}{\sqrt{2}} e^{-i(\delta - \frac{\pi}{2} - \pi)} \rightarrow \delta = \frac{3\pi}{2}}!$$

~~$\delta = \frac{3\pi}{2}$ rad da desfasea~~

$$\sqrt{I_0} = \frac{a_2}{\sqrt{2}} \Rightarrow$$

$$\Rightarrow \sqrt{2 I_0} = a_2 \rightarrow I_{2_D} = 2 I_0$$ dugu

4/ Zuntz optikoa: $L = 1\,cm$
$\phi = 50\,\mu m$



⇒ $\theta_0 = ?$ Zenbat islapen gertatuko dira? I/ hasierako argiaren polarizazio egoera eta intentsitatea eman:

$\theta_M\ n' \sin(\theta_M) = n'' \rightarrow \theta_M = 70,25^\circ \Rightarrow \theta_T = 19,75^\circ$

$n \sin(\theta_0) = n' \sin(\theta_T) \rightarrow$ Eraso angelua: $\theta_0 = \operatorname{asin}\left[\frac{n'}{n}\sin(\theta_T)\right] = 35,06^\circ$ da.

~~An eskalarik~~ $\tan(\theta_M) = \frac{A}{\phi/2} \rightarrow A = 69,63\,\mu m$; $B = 139,26\,\mu m \Rightarrow$

$\Rightarrow \left.\begin{matrix} A \times 1 \\ B \times 71 \end{matrix}\right\}$ 72 barne islapen egongo dira.

1. Transmisioan: $\mathcal{T}_\perp = 0,896$ $\quad \mathcal{T}_\parallel = 0,963$

Erasoltzailea t_D denez, $\boxed{\mathcal{T} = \frac{1}{2}(\mathcal{T}_\perp + \mathcal{T}_\parallel) = 0,9295}$

$\tan(\alpha_t)\, e^{-i\delta_t} = \cancel{0,036}\ 1,037\, e^{-i\frac{\pi}{2}}$ $\Rightarrow$ $\boxed{\begin{aligned} \alpha_t &= 46,041^\circ \\ \delta_t &= \frac{\pi}{2} \text{ rad} \end{aligned}}$

$\alpha_i = \frac{\pi}{4}$; $\delta_i = \frac{\pi}{2}$

t_D baita

$$\vec{S_1} = I_0 \mathcal{T} \begin{pmatrix} 1 \\ -0,036 \\ 0 \\ 0,999 \end{pmatrix} \rightarrow V = 0,9996$$

Islapen osotan intentsitatea ez da aldatzen eta

$$tg\left(\frac{\delta}{2}\right) = \frac{\cos(\theta_i)\sqrt{\sin^2\theta_i - n^2}}{\sin^2\theta_i} \simeq 0 \qquad n = \frac{n_2}{n_1}$$

↳ Fase aldaketa nulua da.

Beraz, irten aurretik adierazpena goikoa da.

$\theta_i = 19,75^\circ$ $\quad \theta_t = 35,06^\circ$ izango ditugu

$\mathcal{T}_\perp$ eta $\mathcal{T}_\parallel$ aurreko berdinak.

$$\vec{S_1} = I_0 \mathcal{T} \left[0,0004 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \begin{pmatrix} 0,9996 \\ -0,036 \\ 0 \\ 0,999 \end{pmatrix} \right] = I_0 \mathcal{T} \left[0,0004 \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + 0,9996 \begin{pmatrix} 1 \\ -0,036 \\ 0 \\ 0,999 \end{pmatrix} \right]$$

Oraingo $\mathcal{T}_2 = \cos^2(46,041)\, \mathcal{T}_\perp + \sin^2(46,041)\, \mathcal{T}_\parallel = 0,931$

Beraz, $I = I_0 \mathcal{T}_1 \mathcal{T}_2 = 0,865\, I_0$ izango dugu

b) Airetik zuntzera Brewsterren eraso an sartzen bada, berriz polarizazio egoera eta intentsitatea kalkulatu.

$\theta_B = \arctan\left(\frac{1,7}{1}\right) = \boxed{59,53^\circ = \theta_B} \Rightarrow \boxed{\theta_t = 30,47^\circ} \Rightarrow \boxed{\theta_E = 59,53^\circ}$

$\theta_E < \theta_m$ denez, ez da islapen osoa gertatuko!

$\boxed{\theta_{tE} = 66,31^\circ}$

1) Airetik zuntzera:

$\mathcal{T}_\perp = 0,764 \qquad \mathcal{T}_\parallel = 1 \rightarrow \boxed{\mathcal{T}_1 = 0,882}$

2) ~~$R_\perp = R$~~ $\quad \alpha_i = 45^\circ$, $\delta_i = \frac{\pi}{2}$ $\rightarrow \tan(\alpha_t)\, e^{i\delta_t} = 1,058\, e^{i\frac{\pi}{2}\text{rad}}$

$\boxed{\delta_{rt} = \frac{\pi}{2}\ \text{rad} \qquad \alpha_t = 46,61^\circ}$

2) Barruan

$R_\perp = 0,021 \qquad R_\parallel = 0,007 \rightarrow R = 0,014$

$I_3 = \mathcal{T}_1 R^{71} \mathcal{T}_2 \approx 0$ (71 → behar eskaten baita 71 barne islapen daudelako)

Amaieran ez dugu argirik izango.

2016ko uztaila

1/. Teleobjektibo batean bi lente daude: ~~[illegible]~~

$e=5cm$ $\left\{ \begin{array}{l} \hookrightarrow L_1 \quad \varphi=10d \text{ koberg.} \\ \hookrightarrow L_2 \text{ dibergentea} \end{array} \right.$

· Infinitura fokatuta, filma ~~ko~~ L_2-tik $l=30cm$-ra dago.

a) f_2', f', H, H'?

$$\varphi_1 = 10d = \frac{1}{f_1'} \rightarrow \boxed{f_1' = 0{,}1\,m = 10cm}$$

$$\left.\begin{array}{l} a_{obj} = -\infty \Rightarrow a_{obj}' = f_1' = 10cm \\ a_{oku}' = 30cm \Rightarrow a_{oku} = \dfrac{1}{\frac{1}{30} - \frac{1}{f_2'}} \end{array}\right\} a_{oku} = -e + a_{obj}'$$

$$-5+10 = \frac{f_2' 30}{f_2' - 30} \Rightarrow 5f_2' - 150 = f_2' 30 \Rightarrow f_2' = \frac{-150}{25} \Rightarrow$$

$$\Rightarrow \boxed{f_2' = -6cm} \qquad f' = \frac{f_1' f_2'}{f_1' + f_2' - e} \Rightarrow \boxed{f' = 60cm}$$

$\underline{O_1H = -50cm}$ $\qquad$ $\underline{O_2H' = -30cm}$

b) ID L_2 bada, zein da ϕ_{L_2} $N=10$ izan dadin?

$$N = \frac{1}{A} = \frac{f'}{\phi_{SN}} = 10 \rightarrow \boxed{\phi_{SN} = 6cm}$$

L_2 objektu espaziora eraman behar da.

$a' = 5cm \qquad a = 10cm \rightarrow \beta' = \frac{1}{2} \rightarrow \underline{\phi_{L_2} = 3cm \text{ izango da.}}$

c) • a) ataleko geometrian 2 Ø-en arteko dist. handiegia da biak batera ikusteko.

• Teleobjektiboak zooma izanik, l eta e alda ditzakegu, irudi txikiagoak lortzeko.

⇒ Irudiaren diametroa erdira jaisteko, $e = ?$ eta $l = ?$

$$\cancel{Y_{obj} = Y_{okul} \quad M'_{okul}} = \frac{Y'_{okul}}{Y_{okul}} = \frac{a'_{okul}}{a_{okul}}$$

θ angeluarra badute, $y' = f'\theta$ dugu. Ondorioz, y' erdira jaisteko modua f' erdira jaistea da:

$$f' = \frac{f_1' f_2'}{f_1' + f_2' - e}$$

$$\cancel{f_1' + f_2' - e =} \quad \cancel{f_1' + f_2' - e' =} \quad \cancel{\rightarrow e =}$$

~~lehen~~ ~~orain~~

$$2(f_1' + f_2' - e) = 4(f_1' + f_2' - e')$$

$$-2 = 4 - e' \rightarrow \boxed{e' = 6\,cm}$$

$\cancel{a_2 F' = a_2 t' + f_2' =} -e' + a_{obj} = a_{okul} = 4\,cm$ izango dugu ⇒

$$a'_{okul} = l = \frac{1}{\frac{1}{a_{okul}} + \frac{1}{f_2'}} \rightarrow \boxed{l = 12\,cm}$$

2/ • Irekidura zirkular batetik d distantziara Fresnelen difrakzio irudia ikus daiteke pantaila batean, non erdiko puntuan intentsitatea ia nulua baita.

• Laser sintonizagarri bat erabiliz, $(\lambda \to \lambda + \Delta\lambda)$ egitean berriz ere minimo bat agertu behar da.

⇒ Zein noranzkotan egin behar da aldaketa, $\Delta\lambda$ ahalik eta txikiena izan dadin?

$j = \dfrac{r^2}{\lambda d}$ → j bikoitia izango da ardatzean minimo bat egon dadin.

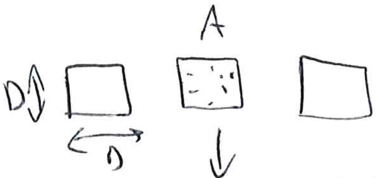
↳ $\lambda \uparrow$ → $j \downarrow$ (2 zenbaki oso jaitsi behar)

↳ $j-2 = \dfrac{r^2}{(\lambda+\Delta\lambda)d}$ ⇒ $\lambda + \Delta\lambda = \dfrac{r^2}{(j-2)d}$ → $\boxed{\Delta\lambda = \dfrac{r^2}{(j-2)d} - \lambda}$

↳ $\lambda \downarrow$ → $j \uparrow$ (2 zenbaki oso igo)

$j+2 = \dfrac{r^2}{(\lambda+\Delta\lambda)d}$ ⇒ $\lambda + \Delta\lambda = \dfrac{r^2}{(j+2)d}$ → $\boxed{\Delta\lambda = \dfrac{r^2}{(j+2)d} - \lambda}$

$\Delta\lambda$ txikiagoa izango denez 2. kasuan, λ txikiagotu egin behar da.

3/ 

Difrakzio sarea dugu.

Beirak desfasea sortuko du!

a) Kalkulatu beirak sortutako desfasea $(p=0, q=\frac{\lambda}{2d})$ eta $(p=\frac{\lambda}{2d}, q=0)$ norabideetan difraktatutako intentsitateak berdinak badira.

$$U_A(p,q) = \overbrace{C\cdot \underbrace{S}_{D^2}}^{U_0} \frac{\sin u}{u}\frac{\sin v}{v}\left(e^{ikpd} + e^{+i\Phi} + e^{-ikpd}\right) \qquad u = \tfrac{1}{2}kpD,\quad v = \tfrac{1}{2}kqD$$

$$U_A(p,q) = U_0 \frac{\sin u}{u}\frac{\sin v}{v}\left[e^{i\Phi} + 2\cos(kpd)\right]$$

$$I_A(p,q) = I_0 \left(\frac{\sin u}{u}\frac{\sin v}{v}\right)^2 \left[1 + 4\cos^2(kpd) + 2\cos(kpd)\left(e^{i\Phi} + e^{-i\Phi}\right)\right]$$

$$I_A(p,q) = I_0 \left(\frac{\sin u}{u}\frac{\sin v}{v}\right)^2 \left[1 + 4\cos^2(kpd) + 4\cos(kpd)\cos(\Phi)\right]$$

$$I_A\left(0, \frac{\lambda}{2d}\right) = I_0\, 1 \cdot \left[\frac{\sin\left(\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{2d}D\right)}{\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{2d}D}\right]^2 \left(5 + 4\cos(\Phi)\right)$$

$$I_B\left(\frac{\lambda}{2d}, 0\right) = I_0 \cdot \left(\frac{\sin\left(\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{2d}D\right)}{\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{2d}D}\right)^2 \cdot 1 \cdot \underbrace{\left[1 + 4\cos^2\left(\frac{2\pi}{\cancel{\lambda}}\frac{\cancel{\lambda}}{2\cancel{d}}\cancel{d}\right) + 4\cos(\pi)\cos(\Phi)\right]}_{1+4-4\cos(\Phi) = 5 - 4\cos\Phi}$$

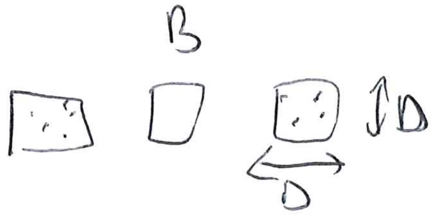
$$\frac{I_B}{I_A} = 1 = \frac{5 - 4\cos\Phi}{5 + 4\cos\Phi} \Rightarrow \cos\Phi = -\cos\Phi \text{ betetzeko}$$

aukera bakarra, $\Phi = \frac{\pi}{2}$ edo $\Phi = \frac{3\pi}{2}$ izatea da.

Hobeto adierazita: $\Phi = \pm\frac{\pi}{2} + 2\pi n$

b) B irudian muturretako karratuak estali dira.

⇒ Frogatu $U_A = U_B$ ($I_A = I_B$) dela beiren desfasea bera bada:



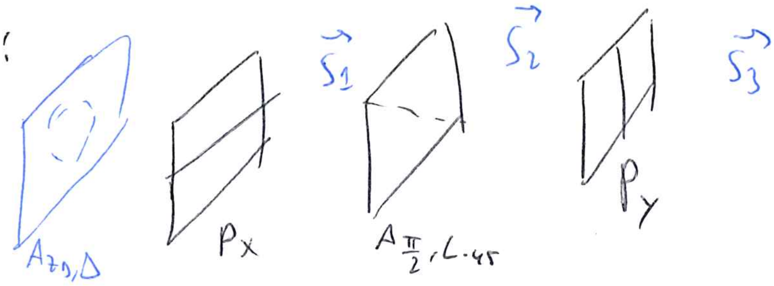
$$U_B(p,q) = U_0 \frac{\sin u}{u} \frac{\sin v}{v} \left(e^{i(\Phi + kpd)} + 1 + e^{i(\Phi - kpd)} \right)$$

$$U_B(p,q) = U_0 \frac{\sin u \sin v}{uv} \left[1 + 2e^{i\Phi} \cos(kpd) \right]$$

$$\boxed{I_B(p,q) = I_0 \left(\frac{\sin u \sin v}{uv} \right)^2 \left[1 + 4\cos^2(kpd) + 4\cos(kpd)\cos(\Phi) \right]}$$

$I_A(p,q)$-ren berdina da!

4/ $\vec{S_0} = I_0 (1 \quad 1/3 \quad \sqrt{3}/3 \quad 0)$ -k ondorengo sistema optikoa zeharkatu du:



a) Kalkulatu irteerako argiaren polarizazio-maila, pol.-egoera eta intentsitatea.

$\cos^2(30) = \frac{3}{4}$

$$\vec{S_0} = I_0 \begin{pmatrix} 1 \\ 1/3 \\ \sqrt{3}/3 \\ 0 \end{pmatrix} = \frac{I_0}{3} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + I_0 \begin{pmatrix} 2/3 \\ 1/3 \\ \sqrt{3}/3 \\ 0 \end{pmatrix} = \frac{I_0}{3} \begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + \frac{2I_0}{3} \begin{pmatrix} 1 \\ 1/2 \\ \sqrt{3}/2 \\ 0 \end{pmatrix} \rightarrow \alpha = 30^\circ$$

LL_{30} dugu zati polarizatua

$$\vec{S_1} = \frac{I_0}{6} \begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix} + \frac{I_0}{2} \begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix} = \frac{2I_0}{3} \begin{pmatrix} 1 \\ 1 \\ 0 \\ 0 \end{pmatrix} \xrightarrow{A_{\frac{\pi}{2}, L\cdot 45}} ZL \text{ aterako da.}$$

$$\vec{S}_2 = \frac{2I_0}{3}\begin{pmatrix}1\\0\\0\\-1\end{pmatrix} \Rightarrow \boxed{\vec{S}_3 = \frac{I_0}{3}\begin{pmatrix}1\\-1\\0\\0\end{pmatrix}}$$

da irteerako argia, $V=1$, L_Y izango dugu eta $I = \frac{I_0}{3}$

b) Sarrerako argia I_N sorta aleatorio batekin gainezarrita gero, dispositibo osoaren transmitantzia $T = \frac{3}{10}$ da. $I_N = ?$

$$\vec{S}_0 = \frac{I_0}{3}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \frac{2I_0}{3}\begin{pmatrix}1\\1/2\\\sqrt{3}/2\\0\end{pmatrix} + I_N\begin{pmatrix}1\\0\\0\\0\end{pmatrix}$$

$$\vec{S}_1 = \frac{I_0}{6}\begin{pmatrix}1\\1\\0\\0\end{pmatrix} + \frac{I_0}{2}\begin{pmatrix}1\\1\\0\\0\end{pmatrix} + \frac{I_N}{2}\begin{pmatrix}1\\1\\0\\0\end{pmatrix} = \left(\frac{2}{3}I_0 + \frac{I_N}{2}\right)\begin{pmatrix}1\\1\\0\\0\end{pmatrix}$$

$$\vec{S}_2 = \left(\frac{2}{3}I_0 + \frac{I_N}{2}\right)\begin{pmatrix}1\\0\\0\\-1\end{pmatrix} \Rightarrow \vec{S}_3 = \left(\frac{I_0}{3} + \frac{I_N}{4}\right)\begin{pmatrix}1\\-1\\0\\0\end{pmatrix}$$

$$I_B = \frac{I_0}{3} + \frac{I_N}{4} \qquad I_H = I_0 + I_N$$

$$\frac{\frac{I_0}{3} + \frac{I_N}{4}}{I_0 + I_N} = \frac{3}{10} = \frac{4I_0 + 3I_N}{12(I_0 + I_N)} \rightarrow 36I_0 + 36I_N = 40I_0 + 30I_N \Rightarrow$$

$$\Rightarrow 6I_N = 4I_0 \Rightarrow \boxed{I_N = \frac{2}{3}I_0}$$

c) Hasieran $A_{\Delta,30}$ bat ghitu dugu. a) ataleko argi erasotzailea erabilita, $\Delta = ?$ $I_T = \frac{5}{12}I_0$ bada.

$$\vec{S}_0 = \frac{I_0}{3}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \underbrace{\frac{2I_0}{3}\begin{pmatrix}1\\1/2\\\sqrt{3}/2\\0\end{pmatrix}}_{L_{30}} \longrightarrow \vec{S}_1 = \frac{I_0}{3}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \frac{2I_0}{3}\begin{pmatrix}1\\?\\?\\?\end{pmatrix}$$

Hobe orain bukaeratik segitzea:

$$\cancel{\vec{S_4} = \frac{5}{12} I_0 \begin{pmatrix} 1 \\ -1 \\ 0 \\ 0 \end{pmatrix} \Rightarrow}$$

Ez! Jonesen bektoreak erabili polarizatzaren nondik noraakoak aztertzeko!

$$L_{30} \to \frac{1}{2} \begin{bmatrix} \sqrt{3} \\ 1 \end{bmatrix} \cdot \sqrt{I_0}\sqrt{\frac{2}{3}} \qquad A_{20,\Delta} = \begin{bmatrix} \cos\frac{\Delta}{2} & \sin\frac{\Delta}{2} \\ -\sin\frac{\Delta}{2} & \cos\frac{\Delta}{2} \end{bmatrix}$$

$$A_{20,\Delta} L_{30} = \frac{1}{2} \left[\sqrt{3}\cos\left(\frac{\Delta}{2}\right) + \sin\left(\frac{\Delta}{2}\right) \quad -\sqrt{3}\sin\left(\frac{\Delta}{2}\right) + \cos\left(\frac{\Delta}{2}\right) \right] \sqrt{I_0}\sqrt{\frac{2}{3}}$$

↳ Bertikalean da berez, baino bueno.

$$|e_1\rangle = \sqrt{\frac{2I_0}{3}}\,\frac{1}{2} \begin{bmatrix} \sqrt{3}\cos\left(\frac{\Delta}{2}\right) + \sin\left(\frac{\Delta}{2}\right) \\ -\sqrt{3}\sin\left(\frac{\Delta}{2}\right) + \cos\left(\frac{\Delta}{2}\right) \end{bmatrix} \qquad P_x = \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$$

$$P_x|e_1\rangle = |e_2\rangle = \sqrt{\frac{2I_0}{3}}\,\frac{1}{2} \begin{bmatrix} \sqrt{3}\cos\left(\frac{\Delta}{2}\right) + \sin\left(\frac{\Delta}{2}\right) \\ 0 \end{bmatrix} \to P_x \text{ da!}$$

$$\cancel{A_{\frac{\pi}{2}, L_{-45}} = \begin{bmatrix} 1 & 0 \\ 0 & -i \end{bmatrix} \to ZL \text{ ~~alera beher du!~~}}$$

$$\cancel{|e_3\rangle = \sqrt{\frac{2I_0}{3}}\,\frac{1}{2} \begin{bmatrix} \sqrt{3}\cos\left(\frac{\Delta}{2}\right) + \sin\left(\frac{\Delta}{2}\right) \\ 0 \end{bmatrix}}$$

$$A_{\frac{\pi}{2}, L_{-45}} = \begin{bmatrix} -\frac{i}{2} + \frac{1}{2} & (+i+1)\frac{1}{2} \\ \frac{i+1}{2} & \frac{-i+1}{2} \end{bmatrix} = \frac{1}{2} \begin{bmatrix} 1-i & 1+i \\ 1+i & 1-i \end{bmatrix}$$

$$|e_3\rangle = \frac{1}{4}\sqrt{\frac{2I_0}{3}} \begin{bmatrix} (1-i)\left[\sqrt{3}\cos\left(\frac{\Delta}{2}\right) + \sin\left(\frac{\Delta}{2}\right)\right] \\ (1+i)\left[\sqrt{3}\cos\frac{\Delta}{2} + \sin\frac{\Delta}{2}\right] \end{bmatrix} = \frac{\sqrt{3}\cos\left(\frac{\Delta}{2}\right) + \sin\left(\frac{\Delta}{2}\right)}{4}\sqrt{\frac{2I_0}{3}} \begin{bmatrix} 1-i \\ 1+i \end{bmatrix}$$

$$P_y = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$$

$$|e_4\rangle = \frac{\sqrt{3}\cos\left(\frac{\Delta}{2}\right) + \sin\left(\frac{\Delta}{2}\right)}{4}\sqrt{\frac{2I_0}{3}} \begin{pmatrix} 0 \\ 1+i \end{pmatrix}$$

Hasieran, Naturala: $\frac{I_0}{3}\begin{pmatrix}1\\0\\0\\0\end{pmatrix} \to \frac{I_0}{6}\begin{pmatrix}1\\1\\0\\0\end{pmatrix} \to \frac{I_0}{6}\begin{pmatrix}1\\0\\0\\-1\end{pmatrix} \to \frac{I_0}{12}\begin{pmatrix}1\\-1\\0\\0\end{pmatrix}$

$$I_B = \frac{5}{12} I_0 = I_N + I_P = \frac{I_0}{12} + I_P$$

$$\hookrightarrow \boxed{I_P = \frac{1}{3} I_0}$$

$$(1-i)(1+i) = 1+1 = 2$$

$$\langle e_u | e_u \rangle = \frac{1}{3} I_0$$

$$\| $$

$$\frac{\cancel{2} I_0}{3} \; \frac{3\cos^2\left(\frac{\Delta}{2}\right) + \sin^2\left(\frac{\Delta}{2}\right) + 2\sqrt{3}\sin\left(\frac{\Delta}{2}\right)\cos\left(\frac{\Delta}{2}\right)}{4} \underbrace{\begin{pmatrix}0 & 1-i\end{pmatrix}\begin{pmatrix}0\\1+i\end{pmatrix}}_{\cancel{2}}$$

$$\frac{3\cos^2\left(\frac{\Delta}{2}\right) + \sin^2\left(\frac{\Delta}{2}\right) + \sqrt{3}\sin(\Delta)}{12} I_0$$

$$\cos^2\left(\frac{\Delta}{2}\right) = 1 - \sin^2\left(\frac{\Delta}{2}\right)$$

$$\|$$

$$\frac{1 + 2\cos^2\left(\frac{\Delta}{2}\right) + \sqrt{3}\sin(\Delta)}{12} I_0 = \cancel{\frac{3 - 2\sin^2\left(\frac{\Delta}{2}\right) + \sqrt{3}\sin(\Delta)}{12} I_0 = \frac{I_0}{3}}$$

$$\cancel{4 = 3 - 2\sin^2\left(\frac{\Delta}{2}\right) + \sqrt{3}\sin(\Delta)} \qquad \frac{1 + 1 + \cos(\Delta) + \sqrt{3}\sin(\Delta)}{12} I_0 = \frac{I_0}{3}$$

$$\cos(\Delta) + \sqrt{3}\sin(\Delta) = 2$$

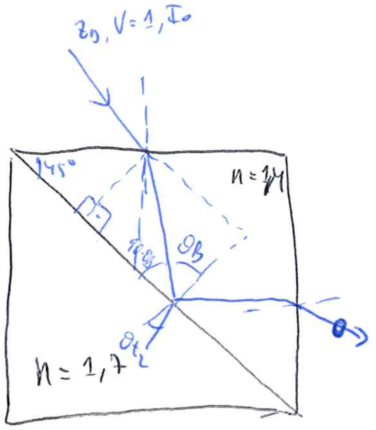
$\hookrightarrow$ Balioak probatuz, $\Delta = 60^\circ$ da.

(askoz ere sinpleago egin zitekeen)

5/

• Argia $V=1$ eta z_0 da, I_0 intentsitatekoa.

⇒ Kalkulatu ibilbide osoaren transmitantzia amaieran argiaren polarizazioa intzidentzia planoarekiko perpendikularra bada.



~~Erazo planoarekiko~~ $\left\{ \begin{array}{l} \parallel \to \alpha = 90° \\ \perp \to \alpha = 0 \end{array} \right.$

~~Intzidentzia planoarekiko~~ $\left\{ \begin{array}{l} \parallel \to \alpha = 0° \\ \perp \to \alpha = 90° \end{array} \right.$

~~Beraz, amaieran $\alpha = 90°$ dugu~~

Sarrerakoa zirkularra denez eta irteerakoa perpendikularki polarizatua islapenean Brewsterren angelua behar dugu.

$$\theta_B = \arctan\left(\frac{1,7}{1,4}\right) = \boxed{\theta_B = 50,53°} \Rightarrow \boxed{\theta_{t_2} = 39,47°}$$

Iruditik: $180° = 45° + 90° - \theta_B + 90° + \theta_{t_1} \Rightarrow \boxed{\begin{array}{c} \theta_{t_1} = 5,53° \\ \Downarrow \\ \theta_{i_1} = 7,75° \end{array}}$ $\boxed{\begin{array}{c} \theta_{i_2} = 5,53° \\ \Downarrow \\ \theta_{t_2} = 7,75° \end{array}}$

$T_\perp = 0,972 \quad T_\parallel = 0,973$

↳ zirkularra denez: $\underline{T_1 = 0,9725}$

$\cancel{\text{Zirk}}$ $\tan(\alpha_t) e^{-i\delta_t} = 1 \cdot e^{-i\frac{\pi}{2}} \Rightarrow \underline{\delta_t = \frac{\pi}{2}} \quad \underline{\alpha_t = 45°}$

$R_{2\perp} = 0,037 \quad R_{2\parallel} = 0 \quad \Rightarrow \quad R = \cos^2(45) \cdot 0,037 = \underline{0,0185 = R_2}$

$\tan(\alpha_r) e^{-i\delta_r} = 0 \, e^{-i\frac{\pi}{2}} \to \begin{array}{l} \alpha_r = 0° \\ \delta_r = 0 \end{array}$

$T_{3\perp} = 0,97 \quad T_{3\parallel} = 0,972 \to \alpha_r = 0 \to \underline{T_3 = 0,97}$

Transmitantzia: $T_1 R_2 T_3 = 0,0175$

2015eko ekaina

1/ • Tresna optiko batek L_1 eta L_2 ditu.

• Indian behatzaile emetrope baten P.U.-ean sortzeko, $a_{obj} = -1{,}76$ cm da.

• $\Delta = 16$ cm eta IN L_2-tik 2,6 cm eskuinera dago.

$a_{okn} = -e + a'_{obj}$

a) Kalkulatu f_1'

$$a_{obj}^{un} = -1{,}76\text{cm} \rightarrow a'_{obj} = \frac{1}{\frac{1}{-1{,}76} + \frac{1}{f_1'}} = \frac{-1{,}76 f_1}{f_1' - 1{,}76} = a_{okn} + e$$

$$a'_{okn} = -\infty \rightarrow a_{okn} = -f_{okn} = -f_2' \qquad ; \; e = f_1' + f_2' + \Delta^{\swarrow 16}$$

$$\frac{-1{,}76 f_1'}{f_1' - 1{,}76} = -\cancel{f_2'} + f_1' + \cancel{f_2'} + 16 \Rightarrow -\cancel{1{,}76} f_1' = (f_1')^2 + 16 f_1' - \cancel{1{,}76 f_1'} - 28{,}16$$

$$0 = (f_1')^2 + 16 f_1' - 28{,}16 \qquad f_{1_1}' = \frac{8}{5} = 1{,}6\text{cm}$$

$$f_{1_2}' = -\frac{88}{5} = -17{,}6\text{cm}$$

~~IN L_2-tik eskubira badago, ID L_1 izango da.~~

$$\cancel{a_{okn} = -e \qquad a'_{okn} = \frac{1}{\frac{1}{-e} + \frac{1}{f_2'}} = \frac{-e f_2'}{f_2' - e} = 2{,}6 = \frac{-(f_1' + f_2' + 16)\Delta}{-f_2' - \Delta} = 2{,}6}$$

Beak han ingabe, zuzenian $f_1' = 1{,}6$cm hartzen.

b) Zenbatekoa da tresnaren ikusmen handipena?

~~L_1 ID eta SN irango da eta irudi planora eramanez gero, IN. Haren $|\Gamma'| = \frac{\phi_{SN}}{\phi_{IN}}$ da baino ez dakidanez haren nola lortu,~~

Gezurra! hori fokugabeko sistemetan betetzen da.

$$\Gamma' = -\frac{\Delta\, d_{PH}}{f_1' f_2'} = \beta_{obj}'\,\Gamma_{oun}'$$ → f_2' falta zaigu jakiteko!

~~$a_{oun} = \infty$ → $a_{oun}' = -f_2'$ ⇒ $-e + a_{obj}' = a_{oun} = -f_2'$~~

Esan digute irteerako ninia dagoela L_2-tik 2,6cm eskuinera:

$a_{oun} = -e = -(f_2' + f_1' + \Delta)$ $\qquad a_{oun}' = 2{,}6\text{cm}$

$$2{,}6\text{cm} = \frac{1}{\frac{1}{-f_1' - f_2' - \Delta} + \frac{1}{f_2'}} = \frac{-f_2'(f_2' + f_1' + \Delta)}{\cancel{f_2'} - f_1' - \cancel{f_2'} - \Delta}$$

$$2{,}6 = \frac{-f_2'(f_2' + 17{,}6)}{-17{,}6} \Rightarrow -45{,}76 = -f_2'^2 - 17{,}6 f_2' \Rightarrow$$

$$\Rightarrow f_2'^2 + 17{,}6 f_2' - 45{,}76 = 0 \quad \begin{cases} f_2' = 2{,}30\text{cm} \\ f_2' = -19{,}9\text{cm} \end{cases}$$

→ $f_2' = 2{,}3\text{cm}$ ⇒ $\Gamma' = -108{,}7$ da handipena.

c) $\varnothing_{IN} = 1mm$ bada, objektiboaren bereizmena?

$$\delta y = \frac{0{,}61\ \lambda}{1 \cdot \sin\theta} \rightarrow \varnothing_{SN} \text{ behar dugu}$$

$a'_{okn} = 2{,}6cm \quad a_{okn} = -e = -19{,}9cm \rightarrow \beta' = -0{,}131$

$$\frac{\varnothing_{IN}}{\beta'} = \varnothing_{SN} = 0{,}00763\ m = 7{,}63mm$$

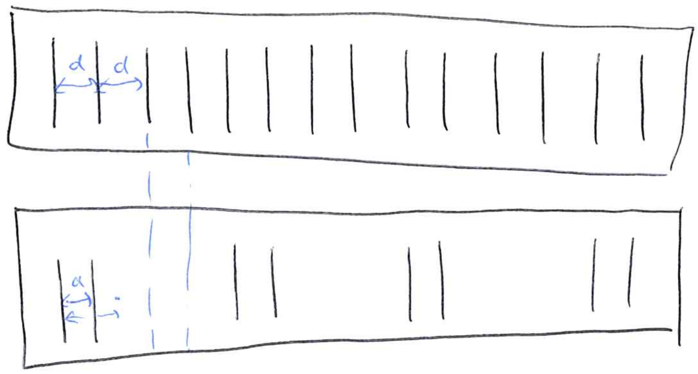
$$\delta y = \frac{0{,}61 \cdot 550 \cdot 10^{-9}}{\sin\left[\arctan\left(\frac{\varnothing_{SN}}{2a_{obj}}\right)\right]} \Rightarrow \boxed{\delta y = 1{,}58\mu m}$$

d) Zerk mugatzen du bereizmena, objektiboak, ~~Mala~~ begiak?

Eztet uste eman dezanik.

2/

A sarea



N zirrikitu
d periodoa

$\frac{N}{2}$ zirrikitu

B sarea

a) Kalkulatu B sarearen intentsitatea I 1, I 2, I 3 ordenetan.

Horretarako, lehenik A sarearen intentsitatea kalkulatuko dut.

$u = \frac{1}{2} k p D$

$\varphi = \frac{1}{2} k p d$

$$U_A(p,q) = \underbrace{U_0}_{C\cdot S} \frac{\sin u}{u} \frac{\sin(N\varphi)}{\sin(\varphi)}$$

$$I_A(p,q) = \underbrace{I_0}_{|CS|^2} \left(\frac{\sin u}{u}\right)^2 \left(\frac{\sin(N\varphi)}{\sin(\varphi)}\right)^2$$

B sarearen kasuan, "launaka" hartuko dut sarea:

$$\cancel{U_B(p,q) = U_0 \frac{\sin u}{u}\left(e^{\frac{3}{2} ikpd} + e^{\frac{1}{2} ikpd}\right) \frac{\sin(\frac{N}{2\cdot 4}\varphi')}{\sin(\varphi')}} \quad \cancel{d' = 4d} \quad \cancel{\varphi' = \frac{1}{2} kp4d}$$

$$U_B(p,q) = U_0 \frac{\sin u}{u} \underbrace{\frac{\sin(2\varphi)}{\sin(\varphi)}}_{2\cos\varphi} \frac{\sin(\frac{N}{4}\varphi')}{\sin\varphi'}$$

$\varphi = \frac{1}{2} k p d$

$\varphi' = \frac{1}{2} k p 4d$

$$I_B(p,q) = I_0 \left(\frac{\sin u}{u}\right)^2 \cdot 4 \cdot \cos^2(\varphi) \left(\frac{\sin(\frac{N}{4}\varphi')}{\sin\varphi'}\right)^2$$

$$I_B\left(\frac{\lambda}{4d}, 0\right) = I_0 \underbrace{\left(\frac{\sin \frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{4d} D}{\frac{1}{2}\dots}\right)^2}_{\text{kte.}} \cdot 4\cos^2\left(\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{4d} d\right) \left(\frac{\sin(\frac{N}{4}\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{4d}4d)}{\sin(\frac{1}{2}\frac{2\pi}{\lambda}\frac{\lambda}{4d}4d)}\right)^2$$

1 Sefela → Berak ez du horiiten!

$$\cancel{I_B(m=1,0) = 4\cos^2\left(\frac{\pi}{4}\right)\frac{N^2}{16} I_0 \rightarrow I_B(m=1,0) = \frac{I_0 N^2}{8}}$$

$$I_3(m=1,0) = \frac{I_0 N^2}{8}\left(\frac{\sin\left(\frac{\pi D}{4d}\right)}{\frac{\pi D}{4d}}\right)^2$$

$$\hookrightarrow I_3(m=1,0) = \frac{2}{\pi^2}\frac{d^2}{D^2} I_0 N^2 \sin^2\left(\frac{\pi D}{4d}\right)$$

$$I_3(m=2,0) = 4 I_0 \left[\frac{\sin\left(\frac{1}{2}\frac{2\pi}{\lambda}\frac{2\lambda}{4d}D\right)}{\frac{1}{2}\frac{2\pi}{\lambda}\frac{2\lambda}{4d}D}\right]^2 \underbrace{\cos^2\left(\cancel{\tfrac{1}{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}\frac{\cancel{2\lambda}}{2\cancel{d}}\cancel{d}\right)}_{0}\left[\frac{\sin\left(\frac{N}{4}\varphi'\right)}{\sin(\varphi')}\right]^2$$

$I_3(m=2,0)=0$, ordena galdua da.

$$I_3(m=3,0) = 4 I_0 \underbrace{\cos^2\left(\frac{\pi 3}{4}\right)}_{\frac{1}{2}}\left(\frac{\sin\left(\frac{3\pi}{4}\frac{D}{d}\right)}{\frac{3\pi}{4}\frac{D}{d}}\right)^2 \underbrace{\left(\frac{\sin\left(\frac{N}{4}\cancel{\tfrac{1}{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}\frac{3\cancel{\lambda}}{\cancel{4d}}\cancel{4d}\right)}{\sin\left(\cancel{\tfrac{1}{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}\frac{3\cancel{\lambda}}{\cancel{4d}}\cancel{4d}\right)}\right)^2}_{\frac{N^2}{4^2}}$$

$$I_3(m=3,0) = \frac{2}{9\pi^2}\frac{d^2}{D^2} N^2 I_0 \sin^2\left(\frac{3\pi D}{4d}\right)$$

b) B sarearen lehen 10 ordenak aztertuz, hauek ditugu

$I=0$: $\pm 2, \pm 6, \pm 7, \pm 10$ ....

$\Rightarrow$ Zeintzuk izango dira A sarearen ordena galduak?

1, 3, 5, 8, 9.

B-kasuan: $m\frac{\lambda}{4d} = n\frac{\lambda}{D} \Rightarrow \frac{d}{D} = \frac{m}{4n}$

B-n $\cos^2\left(\cancel{\tfrac{1}{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}} m\frac{\cancel{\lambda}}{4\cancel{d}}\cancel{d}\right)$ $\frac{m\pi}{4} \to$ $\frac{m\pi}{4} = \frac{\pi}{2} \to m=2$

$\frac{m\pi}{4} = \frac{3\pi}{2} \to m=6$

$\frac{m\pi}{4} = \frac{5\pi}{2} \to m=10$

maximo nagusietan

$$I_A(n,1) = I_0\cdot\left(\frac{\sin\left(\frac{1}{2}\frac{2\pi}{\lambda}m\frac{\lambda}{d}D\right)}{\frac{1}{2}\frac{2\pi}{\lambda}m\frac{\lambda}{d}D}\right)^2\cdot\left(\frac{\sin\left(N\cancel{\tfrac{1}{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}m\frac{\cancel{\lambda}}{\cancel{d}}\cancel{d}\right)}{\sin\left(\cancel{\tfrac{1}{2}}\frac{\cancel{2}\pi}{\cancel{\lambda}}m\frac{\cancel{\lambda}}{\cancel{d}}\cancel{d}\right)}\right)^2$$

NAHIGABE SALTATU NUN ☹

Hasieran ondo ari nintzen:

$$\cos^2\left(\frac{1}{\cancel{\lambda}}\frac{\cancel{\lambda}\pi}{\cancel{\lambda}} m \frac{\cancel{\lambda}}{4\cancel{d}} \cancel{d}\right) = \cos^2\left(\frac{\pi m}{4}\right) \rightarrow \left.\begin{matrix} m=2 \\ m=6 \\ m=10 \end{matrix}\right\}$$ terminoek sortzen dituzte ordenekin extrak B-n.

$m = \pm 7$. ordenekoa ordea A-n ere agertuko da:

$$\sin\left(\frac{1}{\cancel{\lambda}}\frac{\cancel{\lambda}\pi}{\cancel{\lambda}} m7 \frac{\cancel{\lambda}}{4d} D\right) = \sin\left(\frac{7\pi D}{4d}\right) = 0 \Rightarrow$$

$\frac{7\pi D}{4d} = n\pi \quad n \in \mathbb{N}$ izango dugu.

$\hookrightarrow D = \frac{4d}{7} n \quad \rightarrow \underline{n > 2}$ ez da posible $D < d$ baita.

$\hookrightarrow n$ soilik ± 1 edo 0

A sarearen maximo nagusi denak $\beta = \frac{\lambda}{d} m$ norabideetan daude:

$$\sin\left(\frac{1}{\cancel{\lambda}}\frac{\cancel{\lambda}\pi}{\cancel{\lambda}} \frac{\lambda}{d} m D\right) = \sin\left(\frac{\pi m}{d} \frac{4d}{7} n\right) = \sin\left(\frac{4m\pi}{7} n\right) \Rightarrow$$

$m = \frac{7}{4} n$ izango dituzu ordena galduak.

Beraz, A-ko ordena galduak $m = \pm 7k$ dira, $n = 4k$ izanik.

c) Na-ren $\lambda_1 = 5890 Å$ eta $\lambda_2 = 5896 Å$ lerroak bereizi nahi baditugu, kalkulatu sareen zabalera minima d-zuen denean.

$(\Delta\lambda)_{min} = 6 Å \rightarrow R = \frac{\lambda}{\Delta\lambda} \sim 980$ da. $R = mN$ izanik, m handituta lortuko dugu N txikiena.

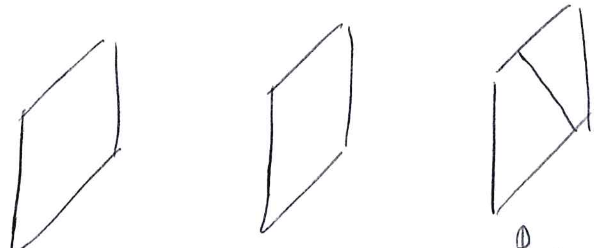
$A \rightarrow \sin\theta_{max} = 1 = m\frac{\lambda}{d} \rightarrow m_{max} = 3,39 \rightarrow m_{max} = 3 \rightarrow \frac{980}{3} = N \approx 327 \rightarrow Nd = L_A = 0,654 \text{ mm}$

$B \rightarrow \sin\theta_{max} = 1 = m\frac{\lambda}{4d} \rightarrow m_{max} = 13,58 \rightarrow m_{max} = 13 \rightarrow \frac{980}{13} = N \approx 76 \rightarrow L_B = 0,152 \text{ mm}$

3/

V_0, $\psi = 0$, $\chi = 30^\circ$ -ko argia ondorengo dispositiboa zeharkatzen du.

$\vec{S_0}$



$A_{\frac{\pi}{2}, Lx}$ $A_{\pi, 2\eta}$ P_{-60}

$J = 5/6$

a) $V_0 = ?$

$$\vec{S_0} = I_0(1 - V_0)\begin{pmatrix} 1 \\ 0 \\ 0 \\ 0 \end{pmatrix} + V_0 I_0 \begin{pmatrix} 1 \\ 1/2 \\ 0 \\ \sqrt{3}/2 \end{pmatrix} \rightarrow \begin{matrix} \alpha = 30^\circ \\ \delta = 90^\circ \end{matrix}$$

Poincaré-ren esferarekin egin!

↳ Honen Jonesen bektorea: $|e\rangle = \frac{1}{2}\begin{bmatrix} \sqrt{3} \\ -i \end{bmatrix}$

$$A_{\frac{\pi}{2}, Lx} = \begin{bmatrix} -i & 0 \\ 0 & 1 \end{bmatrix} \quad A_{\pi, 2\eta} = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \quad P_{-60} = \begin{bmatrix} 3/4 & \sqrt{3}/4 \\ \sqrt{3}/4 & 1/4 \end{bmatrix} = \frac{1}{4}\begin{bmatrix} 3 & \sqrt{3} \\ \sqrt{3} & 1 \end{bmatrix}$$

$$|e'\rangle = P_{-60} A_{\pi, 2\eta} A_{\frac{\pi}{2}, x} |e\rangle$$

$$P_{-60} A_{\pi, 2\eta} A_{\frac{\pi}{2}, x} = \frac{1}{4}\begin{bmatrix} 3 & \sqrt{3} \\ \sqrt{3} & 1 \end{bmatrix}\begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}\begin{bmatrix} -i & 0 \\ 0 & 1 \end{bmatrix} = \frac{1}{4}\begin{bmatrix} -\sqrt{3} & 3 \\ -1 & \sqrt{3} \end{bmatrix}\begin{bmatrix} -i & 0 \\ 0 & 1 \end{bmatrix} = \frac{1}{4}\begin{bmatrix} i\sqrt{3} & 3 \\ i & \sqrt{3} \end{bmatrix}$$

$$|e'\rangle = \frac{1}{4} \cdot \frac{1}{2}\begin{bmatrix} i\sqrt{3} & 3 \\ i & \sqrt{3} \end{bmatrix}\begin{bmatrix} \sqrt{3} \\ -i \end{bmatrix} = \frac{1}{8}\begin{pmatrix} 3i - 3i \\ \sqrt{3}i - \sqrt{3}i \end{pmatrix} = 0$$ ez da argirik irristen! → soilik naturalaren zatia irtsiko da!

$$\frac{I_0(1-V)}{2} = I_3 \quad \frac{I_3}{I_A} = \frac{\frac{I_0(1-V_0)}{2}}{I_0} = \frac{1-V_0}{2} = \frac{5}{6} \rightarrow V_0 =$$

Naturala: $I_N \rightarrow I_N \rightarrow I_N \rightarrow L_{60} \Rightarrow I_{3N} = \frac{I_0}{2}(1 - V_0)$

ez du intentsitaterik galduko!

PoL : K_{30} $\begin{matrix} \chi = 30^\circ \\ \psi = 0^\circ \end{matrix} \longrightarrow \begin{matrix} \psi = 30^\circ \\ \chi = 0^\circ \end{matrix} \longrightarrow \begin{matrix} \psi = -60^\circ \\ \chi = 0^\circ \end{matrix} \longrightarrow \begin{matrix} \psi = -60^\circ \\ \chi = 0^\circ \end{matrix}$

$$I_{BT} = V_0 I_0 + \frac{(1-V_0) I_0}{2} \qquad I_{HT} = I_0$$

$$\frac{I_{BT}}{I_{HT}} = \frac{1}{2} + \frac{V_0}{2} = \frac{5}{6} \rightarrow V_0 = \frac{2}{3} \text{ dugu pol. maila.}$$

b) Lehen bi dispositiboak trukatuz gero, zein da transmitantzia?

$I_{NH} = \frac{I_0}{3}$ | Nat → Nat → L. 60 $I_{NB} = \frac{I_0}{6}$

$I_{PH} = \frac{2I_0}{3}$ | $\chi = 30^\circ$, $\psi = 0^\circ$ → $\chi = 60^\circ$, $\psi = 0$ → $\chi = 0^\circ$, $\psi = +60^\circ$ → ~~0 1 izango baita!~~

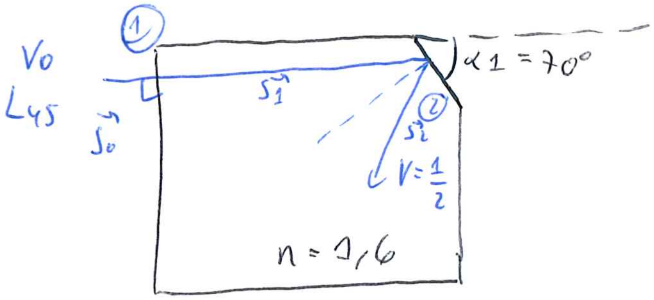
ez da 1!

$\alpha = 60^\circ$

~~$T = \frac{I_0/6}{I_0} \rightarrow T = \frac{1}{6}$ koa da.~~

$$I_{PB} = \frac{2I_0}{3}\cos^2(60) = \frac{I_0}{6} \rightarrow I_T = \frac{I_0}{3} \rightarrow T = \frac{1}{3}$$

4/



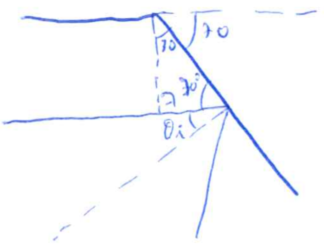
$V_0 = ?$

$$\vec{S_0} = (1-V_0)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + V_0\begin{pmatrix}1\\0\\1\\0\end{pmatrix} \Rightarrow \text{Esaso perp} \quad \mathcal{T} = \frac{4n_1n_2}{(n_1+n_2)^2} = 0,947$$

$\cancel{\operatorname{tg}\alpha = 45^\circ}$
$\delta = 0$

$$\vec{S_1} = \mathcal{T}(1-V_0)\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \mathcal{T}V_0\begin{pmatrix}1\\0\\1\\0\end{pmatrix} \to \alpha = 45$$

Fallua 40' nellen!



$$\Rightarrow \boxed{\begin{array}{l}\theta_i = \theta_r = 30^\circ \\ \theta_t = \cancel{53,13^\circ}\ 33,177\end{array}}$$

→ ez da muga angelua!

$R_\perp = \cancel{0,1154}$ 0,081 $\quad R_\parallel = 0,030$

$R_N = R_p = R = \cancel{0,1089}$ 0,0555

$\alpha_i = 45^\circ$
$\delta_i = 0^\circ$ → $\tan(\alpha_r)\, e^{-i\delta_r} = 0,73\, e^{-i\cdot 0}\cdot e^{-i\pi}$

$\hookrightarrow \alpha_r = \cancel{7,41^\circ}$ 31,61° $\quad \delta = 180^\circ$

$V' = \cancel{0,9625}$

$V' = 0,459$

→ ≈ polarizatua!

$$\vec{S_2} = \mathcal{T}R(1-V_0)\begin{pmatrix}1\\ \cancel{0,0...}\ 0,459\\0\\0\end{pmatrix} + \mathcal{T}RV_0\begin{pmatrix}1\\0,45\\-0,893\\0\end{pmatrix}$$

$$\cancel{\vec{S_2} = \mathcal{T}R\left\{(1-V_0)\left[\cancel{0,0375}\ 0,541\right]\begin{pmatrix}1\\0\\0\\0\end{pmatrix} + \left[\cancel{0,9625}\ 0,459\right]\begin{pmatrix}1\\1\\0\\0\end{pmatrix} + V_0\begin{pmatrix}1\\0,967\\-0,256\\0\end{pmatrix}\right\}}$$

$$\vec{S_2} = \gamma R \left\{ (1-V_0)\,\cancel{0{,}0375}\,0{,}541 \begin{pmatrix}1\\0\\0\\0\end{pmatrix} + (1-V_0)\,\cancel{0{,}9625}\,0{,}459 \begin{pmatrix}1\\1\\0\\0\end{pmatrix} + V_0 \begin{pmatrix}1\\0{,}967\\-0{,}256\\0\end{pmatrix} \right\}$$

Bati polarizatua erdia bada, ez-polarizatua beste erdia izango da:

$$(1-V_0)\,\cancel{0{,}0375}\,0{,}541 = \frac{1}{2} \rightarrow V_0 =$$

$$\vec{S_2} = \gamma R \begin{pmatrix} 1 \\ (1-V_0)0{,}459 + V_0\,0{,}45 \\ -0{,}893\,V_0 \\ 0 \end{pmatrix}$$

$$V = \sqrt{\left[(1-V_0)\cdot 0{,}459 + V_0 \cdot 0{,}45\right]^2 + 0{,}893^2 V_0^2}$$

$$\frac{1}{4} = (1-V_0)^2 \cdot 0{,}459^2 + V_0^2 \cdot 0{,}45^2 + 2(1-V_0)V_0 \cdot 0{,}459 \cdot 0{,}45 + 0{,}893^2 V_0^2$$

$\cancel{\frac{1}{4} = (1-V}$ ↳ Eta hau askatzen → $V_0 = 0{,}24$

2015 Uztaila

1/ Mikroskopio batean $\beta'_{obj}=10$; $\Delta=16cm$ $\Gamma_{oku}=10$.

a) Kalkulatu lan distantzia & f'_{obj} behatzaile emetropearentzat.

$\Gamma_{oku}=10=\frac{d_{PH}}{f'_{oku}} \to f'_{oku}=2,5cm$

$e=f_1'+f_2'+\Delta=$ ↓ ?

$a'_{oku}=\infty \to a_{oku}=-f'_{oku}=-2,5cm$

$e=20,1cm$

$\beta'_{obj}=-\frac{\Delta}{f_1'} \Rightarrow f'_{obj}=1,6cm$

$a'_{obj}=17,1cm$ $a_{obj}=-1,76cm \Rightarrow \boxed{L_D=1,76cm}$

b) L_D eta ~~f'_{obj}~~ -4d-ko behatzaile miopearentzat.

~~$a_{oku}=-2,5cm \to a_{obj}$~~

~~$-4d=\frac{1}{f_m}\to f_m=-0,25m=-25cm \to$ P.U. 25 cm-ra~~ da.

~~$a'_{oku}=-25cm \to a_{oku}=-2,27cm \to a'_{obj}=17,83cm \Rightarrow$~~

~~$\Rightarrow a_{obj}$ Eta puntu hurbila → P.H.: $-12,5cm$-ra dago $\Rightarrow$~~

~~$10=\Gamma_{oku}=\frac{d_{PH}}{f'_{oku}} \to f'_{oku}=+1,25cm$~~

P.U. → $-25cm$-ra da: $a'_{oku}=-25cm \to a_{oku}=-2,27cm$

$a'_{obj}=17,83cm \to |a_{obj}|=L_D=1,757cm$

c) $\phi_{obj} = 2mm$ $\phi_{okn} = 100mm$ → Argitzepen erdiko eremua?

$a'_{okn} = 20,1 cm$ → $\underline{s_{okn} = -1,738 cm}$ → $|\beta'| = 11,565 cm$

Objektu espazioan $\underline{\phi_{L_2 obj} = 0,865 mm}$

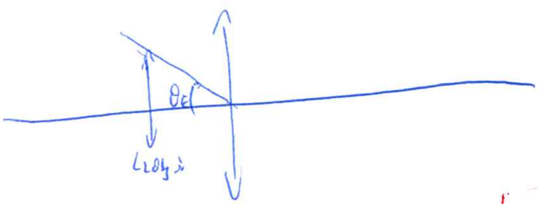
$$\theta_{L_1} = \arctan\left(\frac{\phi_{obj}}{2 \cdot L_D}\right) = 3,25°$$

$$\theta_{L_2 obj} = \arctan\left(\frac{\phi_{L_2 obj}}{2 \cdot (L_D - 1,738 cm)}\right) = 63,04°$$

<u>L_1 da serrerako ninia</u>

$L_2 obj$ → S. Leihoa izango da

$$\theta_E = \arctan\left(\frac{\phi_{L_2 obj}}{2 \cdot 1,738}\right) = 1,425°$$



$\tan(1,425) = \frac{Y}{L_D}$ →

$Y = 0,435 mm$

↳ x2 → $Y_{ERDIA} = 0,871 mm$

d) Bunz indet

Geattezan aztertzeko honez zatiya gainetik Seitu det.