str. 1

MASS 3. GRUS

$\frac{\sqrt{2}}{\sqrt{2}} = 5$

FIZIKALNA OPTIKA

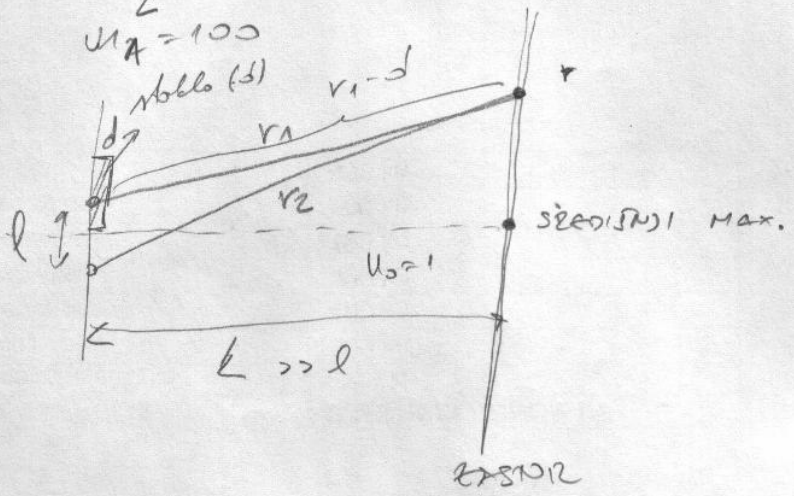
DZ (1)

$\lambda = 600$ nm

$d = 0.1$ mm

$u_2 = 0$ (središnja pruga)

$u_A = 100$



1. slučaj (bez stakla)

$u_0 r_2 - u_0 r_1 = u_1 \lambda$ $\Rightarrow$ POZITIVNA INTERF.

Lorozlika optičkog puta

2. slučaj

$u_0 r_2 - u_0 (r_1 - d) - u d = u_2 \lambda$

$r_2 - r_1 = 100 \lambda$

$r_2 - r_1 + d - u d = 0$ } +

$-d + u d = 100 \lambda$

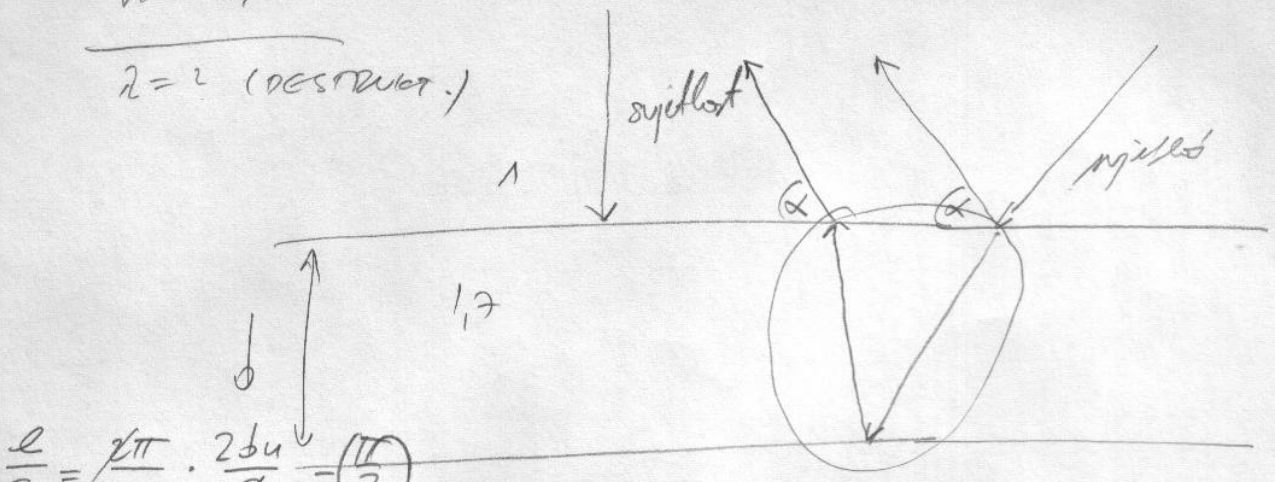
$u = \frac{100 \lambda + d}{d} = 1,6$

③. DZ

$d = 0.4\ \mu m$

$n = 1,7$

$\lambda = ?$ (DESTRUKT.)



$\frac{\varphi}{2} = \frac{2\pi}{\lambda} \cdot \frac{2dn}{\lambda} - \frac{\pi}{2}$

$\Rightarrow$ pomak u fazi (tj. $n=1$ u $n=1,7$)

$$E_0 \cos\left(\omega t - \frac{2\pi}{\lambda} x_1\right) + E_1 \left(\omega t - \frac{2\pi}{\lambda} x_2\right) =$$

$$\ldots \cos\left(\frac{\pi}{\lambda}(n x_1 - n x_2)\right) = \cos\frac{\varphi}{2}$$

$$\frac{\varphi}{2} = \frac{\pi}{\lambda} 2dn - \frac{\pi}{2} = (2m-1)\frac{\pi}{2}$$

$$\cos\left[(2n-1)\frac{\pi}{2}\right] = 0$$

$$\boxed{\lambda = \frac{2dn}{m}}$$

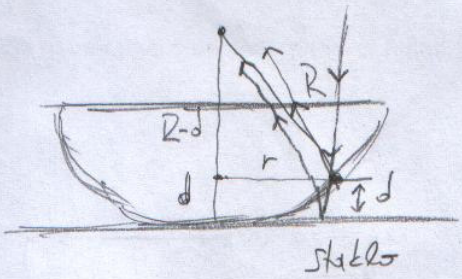
$m = 1 \Rightarrow \lambda = 1360$ nm (bijela svj. = $\lambda =$ 380 – 760 nm)

$m = 2 \Rightarrow \lambda = 680$ nm

$m = 3 \Rightarrow \lambda = 453$ nm

$m = 4 \Rightarrow \lambda = 340$ nm

(5). DZ



$R = 20$ cm

$\lambda = 589{,}3$ nm

$n = 1$

$n_t = 1{,}461$

$\frac{r_z}{r_t} = ?$

$n_z 2d + \frac{\lambda}{2}$?!?

OPTIČKI PUT
- refl. na optičkom kraju ($+\frac{\lambda}{2}$)

$$\Delta = 2 n_z d + \frac{\lambda}{2} = \frac{(2m+1)\cdot\lambda}{2}$$

$$d = \frac{m\lambda}{2n} \Rightarrow \text{TAMNI PRSTENOVI}$$

$$r^2 = R^2 - (R-d)^2$$

$$r^2 = R - R^2 + 2Rd - d^2$$

$$d = \frac{r^2}{2R}$$

$$r = \sqrt{2Rd}$$

$$r = \sqrt{\frac{2Rm\lambda}{2n}}$$

$$r = \sqrt{\frac{Rm\lambda}{n}}$$

$m = 23$

$\frac{r_z}{r_t} = ?$

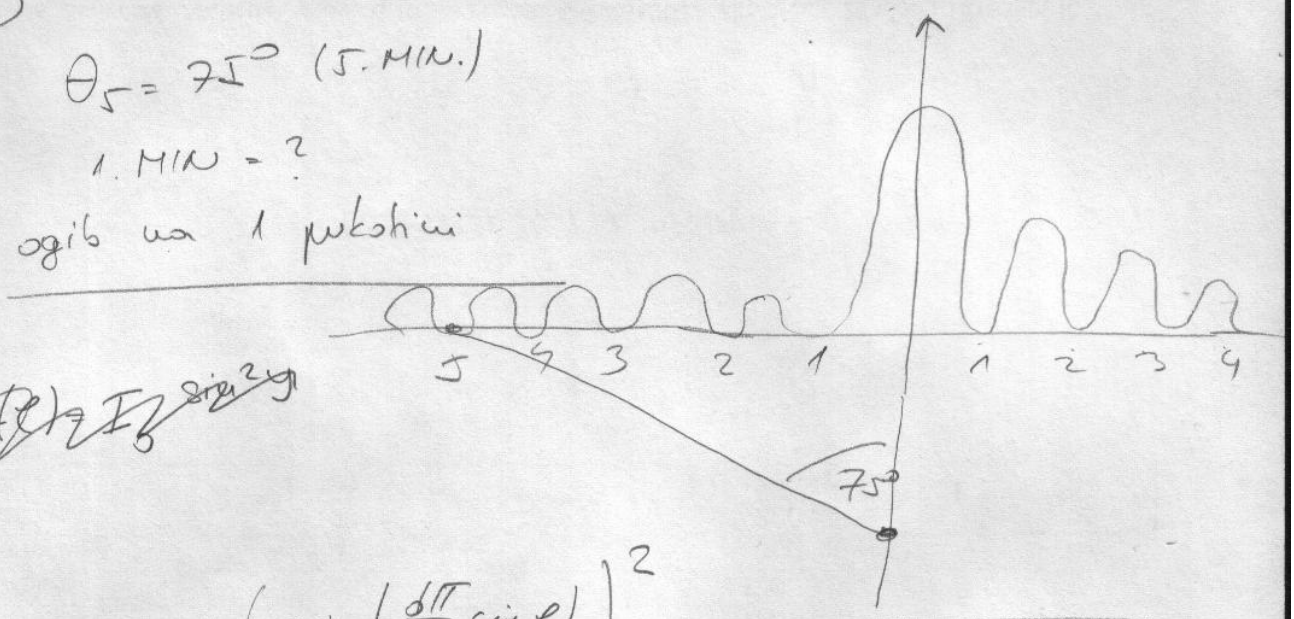
$$\frac{r_z}{r_t} = \sqrt{\frac{\frac{Rm\lambda}{n_z}}{\frac{Rm\lambda}{n_t}}} = \sqrt{\frac{n_t}{n_z}} = 1{,}209$$

DZ. 4

$\theta_5 = 75^\circ$ (5. MIN.)

1. MIN = ?

ogib na 1 pukotini



~~$I(\varphi) = I_0 \sin^2 \varphi$~~

$$I(\varphi) = I_0 \left(\frac{\sin\left(\frac{d\pi}{\lambda}\sin\varphi\right)}{\frac{d\pi}{\lambda}\sin\varphi} \right)^2$$

MINIMUM
→ uvjet brojnik = 0
⇒ $\sin(\ldots) = m\pi$

$m = 1, 2, 3, \ldots$

$$\frac{d}{\lambda}\sin\varphi = m$$

$$d\sin\varphi = m\lambda$$

$$\sin\varphi = \frac{m\lambda}{d}$$

$$\sin 25^\circ = \frac{5\cdot\lambda}{d} \Rightarrow \frac{\lambda}{d} = \frac{\sin 25^\circ}{5}$$

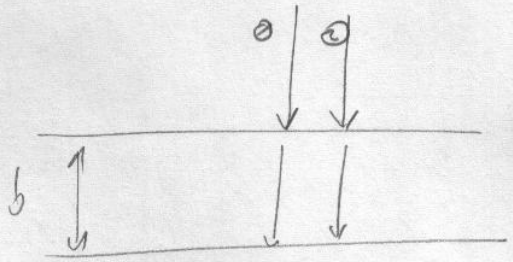
$$\sin\alpha = \frac{\lambda}{d} = \frac{\sin 75^\circ}{5}$$

$$\alpha = 11{,}14^\circ$$

(5) $n_1 = 1{,}544$, $\lambda_1 = 590\ nm$ } rednja zraka

$n_2 = 1{,}553$ => izvanredna zraka

$\Delta\varphi = 60^\circ = \frac{\pi}{3}$ => $d_{min} = ?$



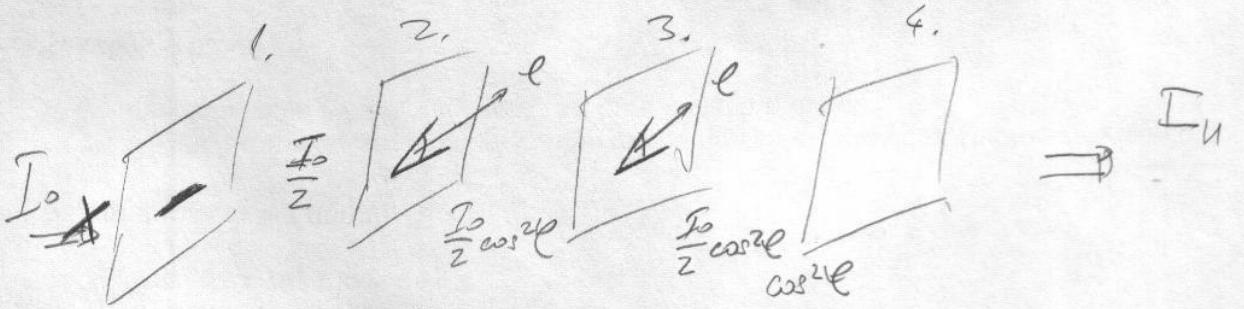
$n_2 d$ => opt. put 1. zrake

$n_1 d$ => -11- 2. zrake

$$\Delta\varphi = \frac{2\pi}{\lambda}\Delta = \frac{2\pi}{\lambda}\left(n_2 d - n_1 d\right) = \frac{\pi}{3}$$

$$d = 1{,}0925 \cdot 10^{-5}\ m$$

(6)



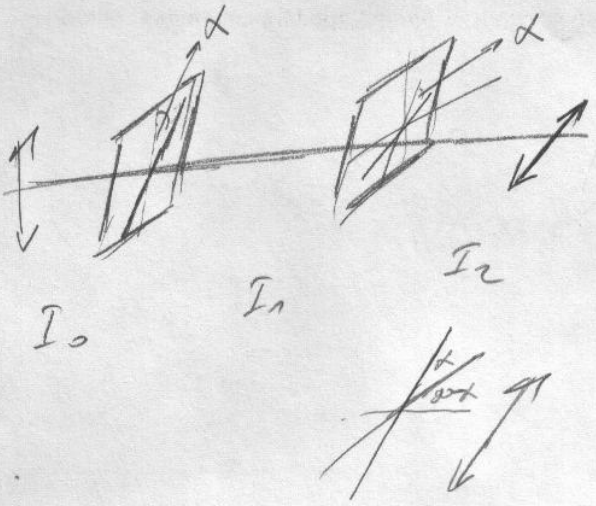
ZBOG POLARIZATORA

$\frac{I_0}{2}\cos^4\varphi$ $\frac{I_0}{2}\cos^6\varphi$

$$I = I_0 \cos^2\varphi$$

$$\frac{I}{I_0} = \frac{I_0(\cos)^{2(4-1)}I}{2I_0} = \frac{I_0}{2}(\cos\varphi)^{2(N-1)} = \frac{1}{2}(\cos\varphi)^{2(N-1)}$$

(7)



2 IN. POL. SUCCESSIVI

$I_1 = I_0 \cos^2\alpha$

$I_2 = I_0 \cos^2\alpha \cos^2(90-\alpha^\circ) = I_0 \cos^2\alpha \sin^2\alpha$

$= I_0 (\cos\alpha \sin\alpha)^2$

$= I_0 \left(\frac{2\cos\alpha\sin\alpha}{2}\right)^2 = \frac{1}{4} I_0 \sin^2 2\alpha$

$I_2 = \frac{I_0}{4} \sin^2 2\alpha$

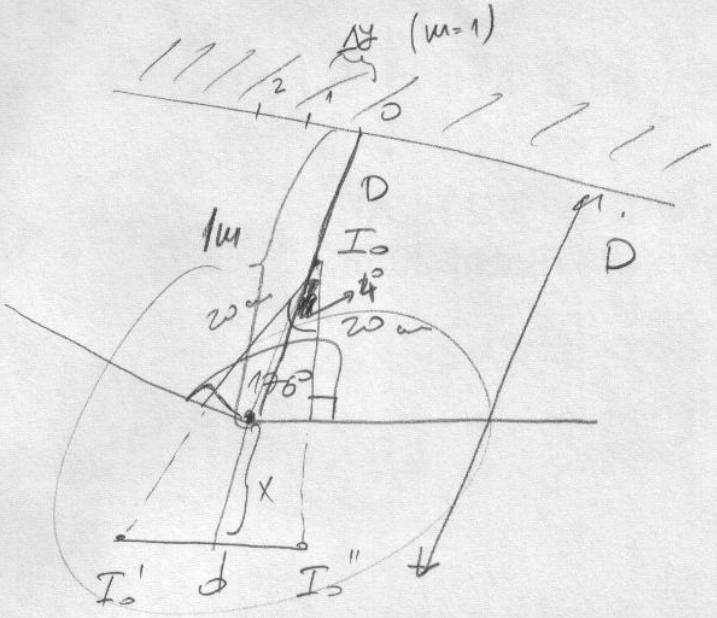
$\alpha = ?$ ($I_2 \Rightarrow$ MAX)

↳ $\sin^2 2\alpha \Rightarrow$ MAX

↳ $2\sin^2 2\alpha = 1$

$\boxed{\alpha = \frac{I}{4}}$

6.3



$\lambda = 5{,}8 \cdot 10^{-5}$

YOUNGOV POWS

$d \sin\alpha = m\lambda$ (MAX.)

$d \cdot \frac{y}{D} = m\lambda$

$\Delta y = \frac{D}{d}\lambda$

$\Delta y = 2{,}5 \cdot 10^{-3}$ m

$D = 1m + X$

$x = h - a$

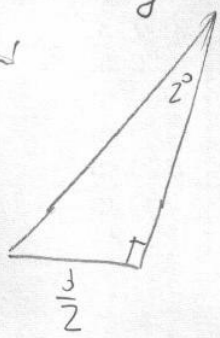
$\cos 2° = \frac{h}{40} \Rightarrow \boxed{h = 39{,}9756 \text{ cm}}$

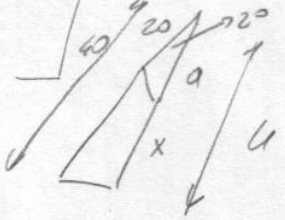
$\sin^2 2° = \frac{d}{2 \cdot 0{,}4}$

$d = 2{,}792$ cm

$\cos 2° = \frac{20}{a}$

$a = 20{,}01219$ cm

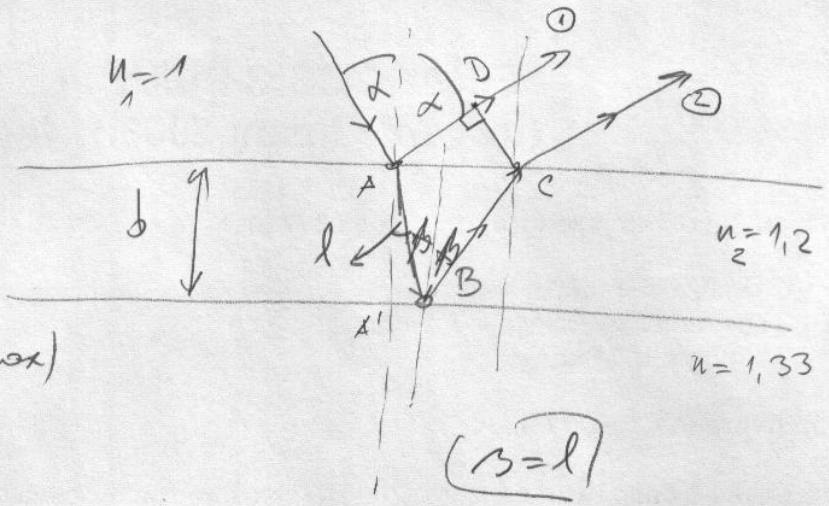




$D = 100 + (h - a)$

$D = 119{,}963$ cm

Z. 6. 6 $\alpha = 45°$



$d = ?$ (crvena max)

$\lambda = 630$ nm

$\beta = l$

$|AD|$ = ~~opt.~~ put 1. zrak. geom

optički $= |AD| n_1 + \frac{\lambda}{2}$ A → refl. na optič. krajšo

$2|AB| n_2 + \frac{\lambda}{2}$ B → optično krajšo

$\Delta = 2|AB|n_2 - |AD|n_1$

$= 2n \frac{d}{\cos l} - 2d n \frac{\sin^2 l}{\cos l}$

$= 2nd \cos l$

$= 2nd \sqrt{1 - \sin^2 l}$

$= 2nd \sqrt{1 - \frac{\sin^2 \alpha}{n^2}}$

$= 2d \sqrt{n^2 - \sin^2 \alpha}$

$|AB| = \frac{d}{\cos l}$

$|AD| = |AC| \sin \alpha$

$n = \frac{\sin \alpha}{\sin l}$

$\operatorname{tg} l = \frac{|AC|}{2d}$

$|AC| = 2d \operatorname{tg} l$

$|AD| = 2d \operatorname{tg} l \sin \alpha$

$= 2d n \frac{\sin^2 l}{\cos l}$

$\Delta = m\lambda$

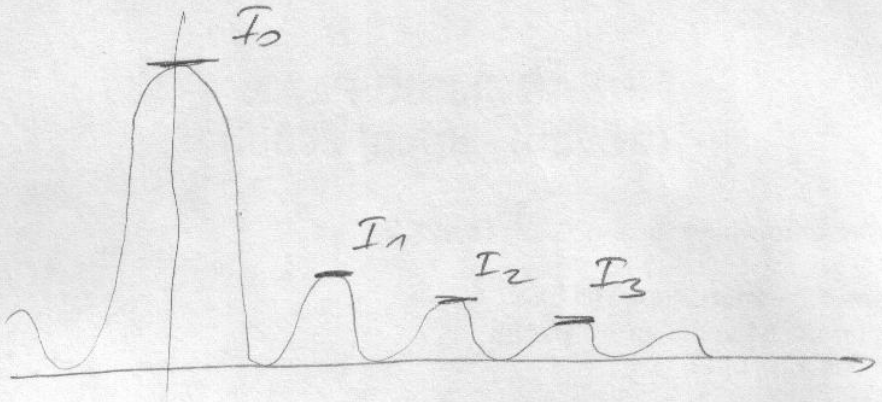
$2d \sqrt{n^2 - \sin^2 \alpha} = m\lambda$

$d = \frac{m\lambda}{2\sqrt{n^2 - \sin^2 \alpha}}$

$d = min \Rightarrow m = 1$

$\boxed{d = 3{,}25 \cdot 10^{-7}\ m}$

2. 6. 12



$$I(\alpha) = I_0 \frac{\sin^2\left(\frac{b\pi}{\lambda}\sin\alpha\right)}{\left(\frac{b\pi}{\lambda}\sin\alpha\right)^2}$$

zasto se 1 ne uzima?

$$(2m-1)\frac{\pi}{2} = \frac{b\pi}{\lambda}\sin\alpha \qquad m = 2, 3, \ldots$$

MAXIMUM

$$\frac{I_0}{I_A} = \left[\frac{1}{(2m-1)\frac{\pi}{2}}\right]^2$$

$$\frac{I_1}{I_0} = \frac{1}{\left(\frac{3}{2}\pi\right)^2} = 0{,}045$$

$$\frac{I_2}{I_0} = \frac{1}{\left(\frac{5}{2}\pi\right)^2} = 0{,}016$$

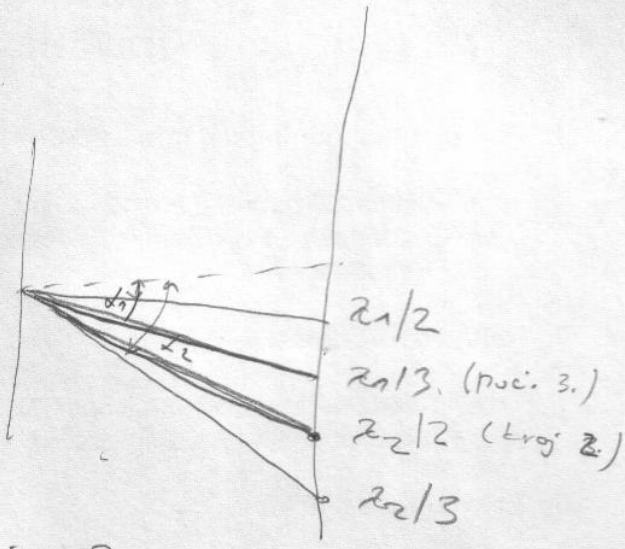
$$\frac{I_3}{I_0} = 0{,}0083$$

Z 6.16

$d = \frac{1\,mm}{50} = 2 \cdot 10^{-5}\,m$ (konst. rešetke)

$\lambda_1 = 380\ nm$

$\lambda_2 = 780\ nm$



$d \sin\alpha = n\lambda$

$\Delta\alpha = \alpha_1 - \alpha_2$

$= 4,736 - 3,2676$

$= \dots$

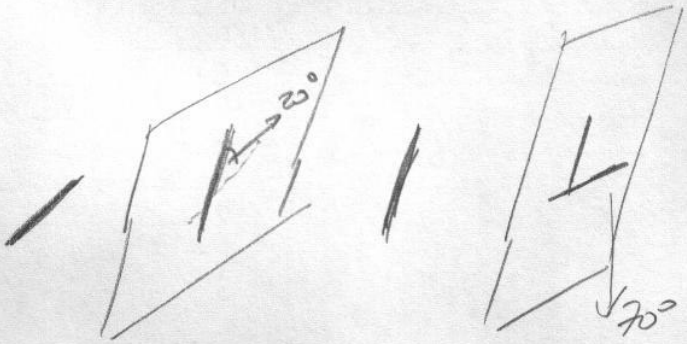
$d \sin\alpha_1 = 2 \cdot 780\ nm$

$\alpha_1 = 4,736°$

$d \sin\alpha_2 = 3 \cdot 380\ nm$

$\alpha_2 = 3,2676°$

Z. 6.18



KVANTNA PRIRODA SVJETLOSTI

(8) DZ

$l = 10$ cm
$\delta = 1$ mm
$U = 12$ V
$I = 0{,}01$ A
$T = ?$
$T_0 = 300$ K

INTENZITET ZRAČENJA

$I = \sigma T^4$ → TEMPERATURA

$I = \frac{P}{S} \Rightarrow P = I \cdot S$

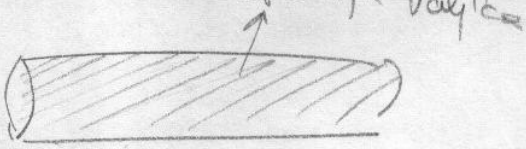
$S = 2 \cdot \pi \cdot l$
$= \delta \pi l =$

$P_1 = U \cdot I = 0{,}12$ W

$P_2 = (\text{okolina}) = I_0 S = \sigma T_0^4 \cdot \delta \pi l = 0{,}143$ W

$P = P_1 + P_2 = 0{,}263$ W

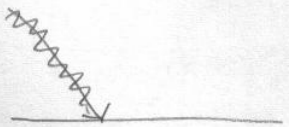
$I = \frac{P}{S} = \frac{0{,}263}{\delta \pi l}$



$\frac{0{,}263}{\delta \pi l \sigma} = T^4 \Rightarrow T = 349$ K

(9) DZ

$E_F = \frac{hc}{\lambda} = hf$



$E_k = hf - W_i$

λ_2

$W_i = 3$ eV 1 eV $= 1{,}6 \cdot 10^{-19}$ J

$\lambda_1 = 340$ nm, v_1

$\lambda_2 = ?$, $v_2 = 1{,}5 v_1$

$\frac{m v_1^2}{2} = \frac{hc}{\lambda_1} - W_i$

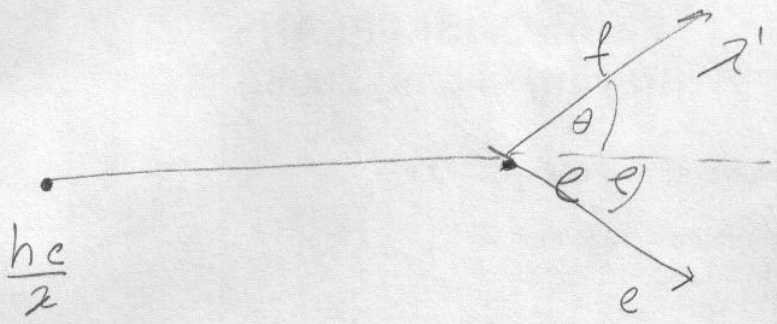
$v_1 = 427{,}939 \cdot 10^3$ m/s

$\frac{m v_2^2}{2} = \frac{hc}{\lambda_2} - W_i$

$\lambda_2 = 309$ nm

(10) COMPTONOV EFEKT

DZ



$$\Delta\lambda = \lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$$

$3\lambda_1' = \lambda_2'$

$\theta_1 = 30°$

$\theta_2 = 120°$

$$\lambda_1' = \lambda + \frac{h}{mc}(1 - \cos\theta_1)$$

$$\lambda_2' = \lambda + \frac{h}{mc}(1 - \cos\theta_2)$$

$$\lambda_2' = 3\lambda_1'$$

$$3\left(\lambda + \frac{h}{mc}(1 - \cos\theta_1)\right) = \lambda + \frac{h}{mc}(1 - \cos\theta_2)$$

$$\lambda = 1{,}33 \cdot 10^{-12}\ m$$

DZ

(11) $E_0 = 1\ MeV$

$\lambda' = 1{,}25\lambda$

$E_{ke} = ?$

$$E_{ke} = E_0 - E_0'$$

$$= \frac{hc}{\lambda} - \frac{hc}{\lambda'}$$

$$= \frac{hc}{\lambda} - \frac{hc}{1{,}25\lambda}$$

$$= E_0 - \frac{E_0}{1{,}25}$$

$$= E_0\left(1 - \frac{1}{1{,}25}\right)$$

$$= 0{,}2\ MeV$$

J, 6, 13

(Z 8.4) $d = 2\ cm$

$T_0 = 0\ K$

$T_p = 400\ K$

$C = 390\ J/kg$

$\rho = 8900\ kg/m^3$

$I = \sigma T^4$

$W = m c \Delta T$

$S = 4\pi r^2$

$V = \frac{4}{3}\pi r^3$

$P = \frac{I \cdot S}{\sigma T^4}$

$P = \frac{dW}{dt}$

$dW = -P\, dt$

$m c\, dT = \sigma T^4 S\, dt$

$m c \frac{dT}{T^4} = \sigma S\, dt \Big/ \int_{T_p}^{T_k}$

$\frac{m c}{3T^3}\Big|_{T_p}^{T_k} = \sigma S \Delta t$

$\Delta t = 66956\ s$

(8.7) $U = 150\ V$

$E_k = qU$ / $\frac{mv^2}{2}$

\ $mc^2\left(\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right)$

$qU = \frac{mv^2}{2}$

$v = \sqrt{\frac{2qU}{m}} = 7{,}26 \cdot 10^6 = 0{,}029\,c$

(8.11) $\lambda = 450\,nm$

$\lambda_{g_1} = 600\,nm$

$W_{i_2} = 2\,W_{i_1}$

$U = ?$

$W_{i_1} = \frac{hc}{\lambda_g} = 2{,}066\ eV$

$W_{i_2} = 4{,}122\ eV$

$$qU = E_{k_1} \Rightarrow \frac{hc}{\lambda} = W_{i_1} + E_k$$

$$E_k = \frac{hc}{\lambda} - W_{i_1} = qU$$

$$~~U = \frac{hc}{q\lambda} - \frac{W_i}{q}~~ = 0{,}0689\ eV$$

$$qU = E_k \Rightarrow \boxed{U = \frac{E_k}{q} = 0{,}0689\ V}$$

$$E_{k_2} = \frac{hc}{\lambda_1} - W_{i_2} = ~~-1{,}377~~\ eV$$

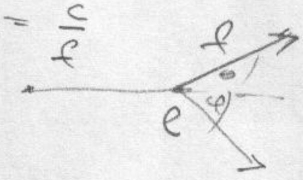
NEMA FOTOEFEKTA

(8.18) $f = 3 \cdot 10^{19}\,Hz$ $\Rightarrow c = \lambda f$

$\theta = 60^\circ$ $\quad \lambda = \frac{c}{f}$

$e = ?$

$E_k = ?$



$$E_k = \frac{hc}{\lambda} - \frac{hc}{\lambda'}$$

$$= hc\left(\frac{1}{\lambda} - \frac{1}{\lambda'}\right)$$

$$= 2{,}15 \cdot 10^{-15}\ J$$

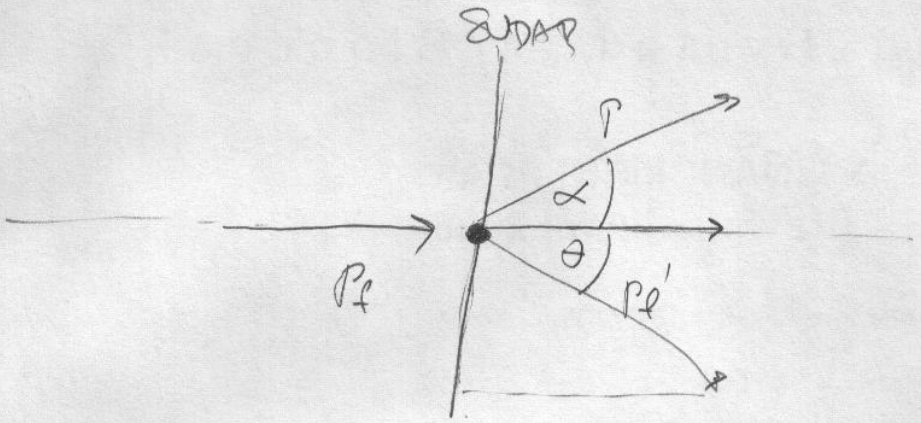
$$\Delta\lambda = \frac{h}{mc}(1 - \cos\theta)$$

$$\lambda' - \lambda = \ldots$$

$$\lambda' = \lambda + \frac{h}{mc}(1 - \cos\theta)$$

$$\lambda' = 1{,}12 \cdot 10^{-11}\ m$$

$\Longrightarrow$



$p_x = p\cos\alpha$

$p_y = p\sin\alpha$

$p_f = \frac{h}{\lambda}$. $p_f' = \frac{h}{\lambda'}$

$p_{f_x}' = \frac{h}{\lambda'}\cos\theta$

$p_{fy}' = \frac{h}{\lambda'}\sin\theta$

X - SMJER

$p_f = p_x + p_{f_x}'$

Y - SMJER

$0 = p_y - p_{fy}'$

$p_{fy}' = p_y$

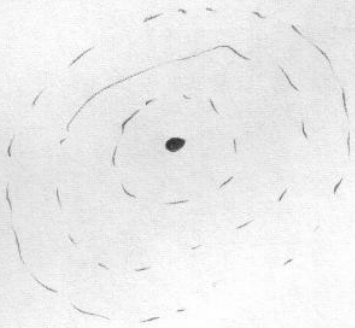
$\frac{h}{\lambda'}\sin\theta = p\sin\alpha = \frac{1}{c}\sqrt{E_k^2 + 2mc^2E_k}\sin\alpha$

$p = \frac{1}{c}\sqrt{E_k^2 + 2mc^2E_k}$

$\sin\alpha = \frac{hc\sin\theta}{\lambda'\sqrt{E_k^2 + 2mc^2E_k}} \Rightarrow \alpha = 54{,}41°$

STRUKTURA ATOMA

Bohrov model atoma



gl. kvantni broj n

$$L_n = r_n \cdot m \cdot v_n = n \cdot \frac{h}{2\pi}$$

$n = 1, 2, \ldots$

$$r_n = r_0 \cdot n^2$$

r_0 — Lokalizacija

$$\epsilon_n = -\frac{\epsilon_0}{n^2} = 13{,}6\ eV \Rightarrow \text{energija ionizacije}$$

(12) DZ $\quad n = 3$

$$T = \frac{1}{\nu} = \frac{2r\pi}{v}$$

$$f = \frac{1}{T} = \frac{v}{2r\pi}$$

$$v_n = \frac{n \cdot h}{m \cdot r_n}$$

$$= \frac{n\,h}{2r\pi\, m\, r_n}$$

$$= \frac{3\,h}{2\pi m\, r_3^2}$$

$$r_3 = r_0 \cdot 3^2 = 9 r_0$$

$$= \frac{3h}{2\pi m\, 9 r_0^2} = \frac{h}{6\pi m r_0^2}$$

$$= 2{,}437 \cdot 10^{14}\ Hz$$

(13) DZ $\quad \lambda_{32} =$

$\lambda_{41} = x\, \lambda_{32}$

$n = 3 \longrightarrow n = 2$ $\quad \lambda_{32} = ?$

$n = 4 \longrightarrow n = 1$ $\quad \lambda_{41} = ?$

$\Rightarrow$

$$E_n = \frac{-E_0}{n^2} \qquad \frac{hc}{\lambda} = E_n - E_k \qquad n > k$$

$$\frac{hc}{\lambda_{32}} = \frac{-E_0}{9} + \frac{E_0}{4} = E_0\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5E_0}{36}$$

$$\frac{hc}{\lambda_{41}} = \frac{-E_0}{16} + \frac{E_0}{1} = E_0\left(1 - \frac{1}{16}\right) = \frac{15E_0}{16}$$

$$E_0 = \frac{36hc}{5\lambda_{32}}$$

$$\frac{hc}{\lambda_{41}} = \frac{15 \cdot 36 hc}{16 \cdot 5 \cdot \lambda_{32}}$$

$$\boxed{\lambda_{41} = \frac{4\lambda_{32}}{27}}$$

(14) DZ

$E_{NE} = 21{,}5\ eV$

$V = ?$

$E = \frac{hc}{\lambda} \Rightarrow \lambda_1 = \frac{hc}{E}$

energ. ion = izborni rad

$\lambda_2 = \frac{1}{2}\lambda_1 =$ ~~$\frac{1}{2}\frac{hc}{E_{NE}} = \frac{hc}{E}$~~

$$\frac{hc}{\lambda_2} = 2\frac{hc}{\lambda_1} \Rightarrow 2E_{NE} = E_{NE} + E_k$$

$$E_k = E_{NE} = 21{,}5\ eV$$

$$\frac{mv^2}{2} = 21{,}5\ eV$$

$$V = \sqrt{\frac{2E_{NE}}{m}}$$

$$V = 2{,}75 \cdot 10^6\ m/s$$

(10.8) $d = 5 \cdot 10^{-4}$ cm

$\alpha = 41°$

$m = 5$

OPTICKA REŠETKA
↓
STRUKTURA ATOMA

$$d \sin\alpha = m\lambda$$

$$\lambda = \frac{d \sin\alpha}{m} = 656{,}06 \text{ nm}$$

$$E_f = \frac{hc}{\lambda} = 1{,}89 \text{ eV}$$

$n = 1 \Rightarrow 13{,}6$ eV
$n = 2 \Rightarrow 3{,}4$ eV
$n = 3 \Rightarrow 1{,}51$ eV
$n = 4 \Rightarrow 0{,}85$ eV

(10.9) $p = \frac{h}{\lambda}$ $\quad \lambda = 10$ pm

$$E_k = \frac{mv^2}{2} = \frac{(mv)^2}{2m} = \frac{p^2}{2m}$$

$$= \frac{h^2}{2m\lambda^2} = 15{,}041 \text{ eV}$$

$$U = \frac{E_k}{e} = 15041 \text{ V}$$

(10.13) $\lambda = 0{,}0733$ nm

$n = 1$ (K)
$n = 2$ (L)
$n = 3$ (M)
$n = 4$ (N)

$\uparrow$ L–K

$$\frac{hc}{\lambda} = E_2 - E_1$$

$= [illegible]$

$[illegible]$

$$E_n = \frac{-E_0}{n^2} \cdot Z^2$$

$$\frac{Ue}{2} = \frac{-E_0 Z^2}{4} + \frac{E_0 Z^2}{1}$$

$$= E_0 Z^2 \left(\frac{3}{4}\right)$$

$$\frac{40}{2} = 13{,}6\, Z^2 \left(\frac{3}{4}\right)$$

$$Z^* = 39{,}\ldots = \boxed{39}$$