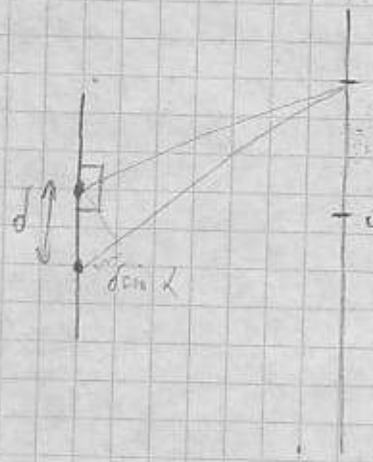
FIZIKALNA OPTIKA

6. CJELINA, ZADACI:

6.1)



$\lambda = 500\,nm$

$n = 1,6$

$d \sin\alpha = m\lambda$ – maximum

$m_1 = 15$

$d \sin\alpha = 15\lambda$

2. optička razlika puta

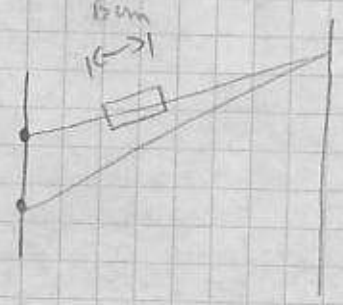
$$\frac{1}{\lambda}\left[\underbrace{(x-t)}_{L_1} + n\cdot t - \underbrace{(x + d\cdot\sin\alpha)}_{L_2}\right] = m_2 \quad /\cdot\lambda$$

$$t(n-1) - d\sin\alpha = m_2\lambda \qquad (15\lambda,\ m_2 = 0)$$

$$t(n-1) = 15\lambda$$

$$t = \frac{15\cdot 500\cdot 10^{-9}}{1,5-1} = 1,25\cdot 10^{-5}\ m$$

6.2)



$\lambda = 585\,nm$

$m_1 = 20$

$m_2 = 5$

1) $(x-\ell) + n_2\cdot\ell - x - d\sin\alpha = 20\lambda$

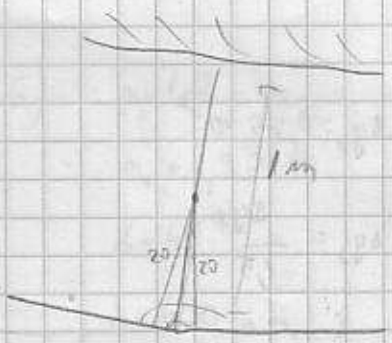
$(n_2 - 1)\cdot\ell - 20\lambda = d\sin\alpha$

$d\sin\alpha = 0,0000302$

2) $n_p\cdot\ell - \ell - d\sin\alpha = 5\lambda$

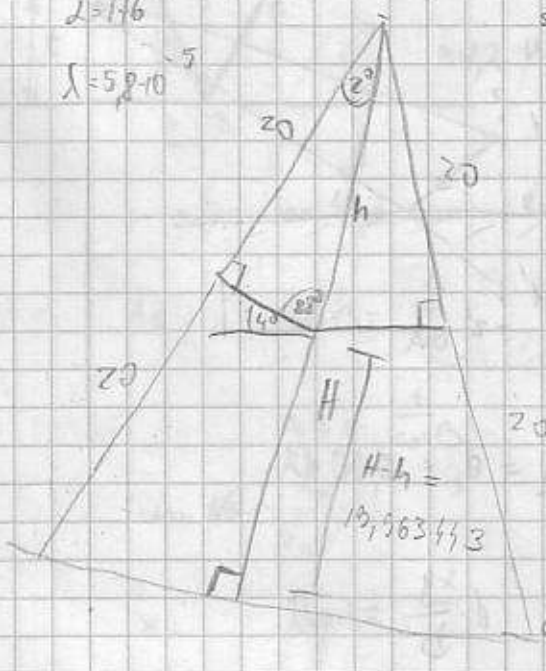
$n_p = \dfrac{\ell + d\sin\alpha + 5\lambda}{\ell}$

6.3)



$\alpha = 176^\circ$

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



$\sin 88^\circ = \frac{20}{h}$

$h = 20{,}012$

$\cos 2 = \frac{H}{40}$

$H = 39{,}9$

$\sin 2 = \frac{\frac{d}{2}}{h_0}$

$d = 80 \cdot \sin 2$

$d = 0{,}027$

$d \sin \alpha = m\lambda$

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

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

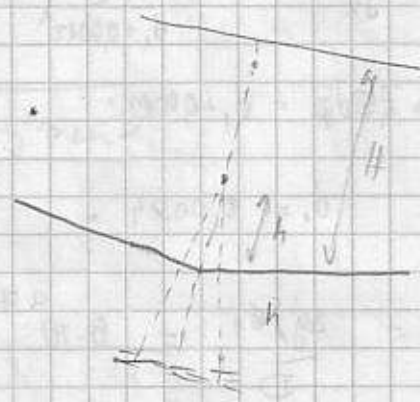
$\Delta y = \frac{D}{d}\lambda = 2{,}5 \cdot 10^{-3}$ cm

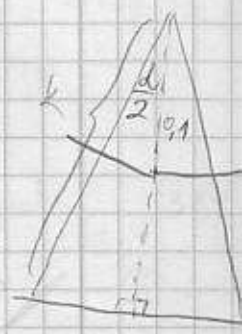
6.4) $\Delta y = 2{,}9$ mm $= 2{,}9 \cdot 10^{-3}$ m

$H = 2{,}7$ m

$\lambda = 0{,}6\,\mu$m

$h = 0{,}1$ m





$\cos \frac{\alpha}{2} = z$

$h = 0{,}2$

$\sin \frac{\alpha}{2} = \frac{d}{2h}$

$d = 0{,}4 \cdot \cos$

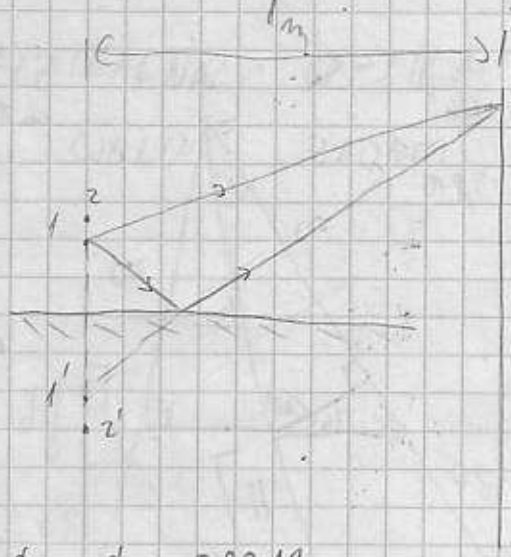
$d = 0{,}2 \cdot \sin \alpha$

$\Delta y = \frac{D}{d}\lambda$ $\quad D = H + h$

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

$d = 0{,}2 \cdot \sin\alpha = \frac{D}{\Delta y} \cdot \lambda = 0{,}16^\circ = 9'57''$

6.5)



$\Delta y_1 = 0{,}25\ 10^{-3}$

$\Delta y_2 = \frac{\Delta y_1}{1{,}5}$

$d_2 = d_1 + 0{,}0012$

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

$\Delta y_1 = \frac{D}{d_1}\lambda \qquad \Delta y_2 = \frac{D}{d_1 + 1{,}2 \cdot 10^{-3}}\lambda \quad /:$

$\frac{\Delta y_1}{\Delta y_2} = 1{,}5 = \frac{\frac{\lambda}{d_1}}{\frac{\lambda}{d_1 + 0{,}0012}} = \frac{d_1 + 0{,}0012}{d_1}$

$1{,}5 d_1 = d_1 + 0{,}0012$

$d_1 = 0{,}0024\ m$

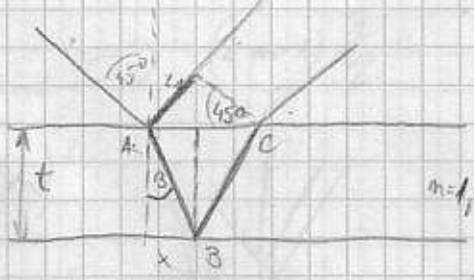
$\lambda = \frac{\Delta y_1 d_1}{D} = 6 \cdot 10^{-7}\ m$

6.6) $n_4 = 1.2$

$n_v = 1,33$

$\alpha = 45^\circ$

$\lambda = 630\ nm$



$n = 1,2$ ✓

$n = 1,33$ ✓

$L_2 = n_4 \overline{AB} + n_4 \overline{BC} = 2\overline{AB} \cdot n_4$

$= \frac{2t \cdot n_4}{\cos\beta}$

$L_1 = 2x \cdot \sin\alpha$

$= 2 tg\beta \cdot \sin\alpha$

AB: $\cos\beta = \frac{t}{AB}$

$AB = \frac{t}{\cos\beta}$

$\sin\alpha = \frac{L_1}{2x}$

x: $tg\beta = \frac{x}{t}$

$x = t \cdot tg\beta$

$\frac{\sin\alpha}{\sin\beta} = 1,2$

$\beta = 36,1^\circ$

$\frac{\Delta\varphi}{2} = \frac{\pi}{\lambda}\left(\frac{2t n_4}{\cos\beta} - 2t tg\beta \sin\alpha\right) = m \cdot \pi$

$t\left(\frac{2n_4}{\cos\beta} - 2 tg\beta \sin\alpha\right) = m\lambda \qquad m = 1$

$t = \frac{\lambda}{\frac{2n_4}{\cos\beta} - 2 tg\beta \sin\alpha} = 325\ nm$ ✓

324,29

6.8) $t = 0,3\ \mu m$

$n = 1,5$

$\frac{\varphi}{2} = \frac{\pi}{\lambda}(2 \cdot t \cdot n) + \frac{\pi}{2} = (2m+1)\frac{\pi}{2}$ $\boxed{2 \cdot t \cdot n}$

$\frac{2tn}{\lambda} = m + \frac{1}{2}$

$2tn = m \cdot \lambda$

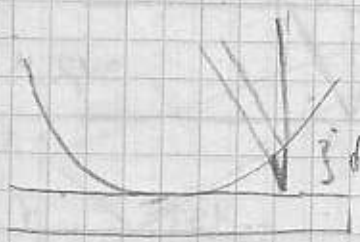
$\lambda = \frac{2tn}{m}$

$m = 1$ $\lambda = 954\ nm$

$m = 2$ $\lambda = 477\ nm$

$m = 3$ $\lambda = 318\ nm$

6.9)



$$\frac{\delta}{2} = \frac{\pi}{\lambda}(2 \cdot d \cdot n) + \frac{\pi}{2} = m\pi$$

$$\frac{2dn}{\lambda} = \frac{2m-1}{2}$$

$$2d_m = \frac{2m-1}{2} \cdot \lambda \qquad m = 1, 2, \ldots$$

znak: $m=1$, $m=5$

$$2d = \frac{9}{2}\lambda \quad /:$$

–

tlačno m, $m=6$

$$2d_m = \frac{11}{2}\lambda$$

$$n = \frac{11}{9} = 1{,}222$$

6.11)

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

$\beta = 30°$

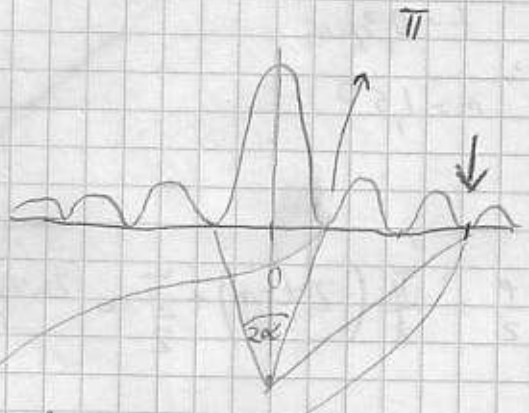
za minimume → $\frac{d\pi}{\lambda}\sin\alpha = m\pi$

$\sin\frac{\beta}{2} = \frac{m}{d\lambda}$

β → kotna širina $\quad \sin 15 = \frac{1}{d\lambda}$

γ → ogibni kot $\quad \sin\gamma = 3 \cdot \frac{1}{d\lambda} = 3 \cdot \sin 15$

$$\gamma = 50{,}94°$$



6.12)

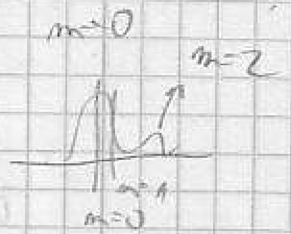
$$I(\alpha) = I_0 \frac{\sin^2\left(\frac{d\pi}{\lambda}\sin\alpha\right)}{\left(\frac{d\pi}{\lambda}\sin\alpha\right)^2} \Rightarrow (2m-1)\frac{\pi}{2}$$

max:

$$\frac{d\pi}{\lambda}\sin\alpha = (2m-1)\frac{\pi}{2}$$

$m=2$ $m=3$ $m=4$

ne $m=1$, ker tu spa…
pod glavni maximum …

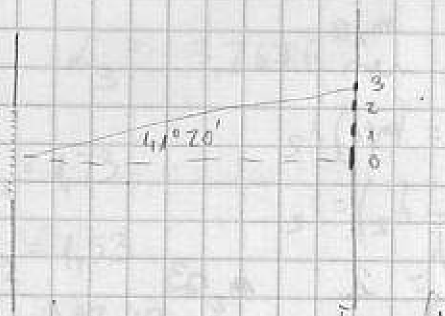


$$I_1 = \frac{I_0}{\left((4-1)\frac{\pi}{2}\right)^2} = 0{,}045\ I_0$$

$$I_2 = \frac{I_0}{\left((6-1)\frac{\pi}{2}\right)^2} = 0{,}016\ I_0$$

$$I_3 = \frac{I_0}{\left((8-1)\frac{\pi}{2}\right)^2} = 0{,}0083\ I_0$$

6.13)



a)
$$I(\alpha) = I_0 \left[\frac{\sin\left(\frac{N\pi d}{\lambda}\sin\alpha\right)}{\sin\left(\frac{\pi d}{\lambda}\sin\alpha\right)}\right]^2$$

max: $d\sin\alpha = m\cdot\lambda$ $m=3$

$$d = \frac{3}{\sin\alpha}\cdot\lambda$$

$$d = 4{,}543\ \lambda$$

b) ⇒ $\lambda = 600\ nm$ Št. zarez po mm $= \frac{1}{d}\cdot\frac{1}{1000}$

$d = 2{,}725\ \mu m$

$= 367\ mm^{-1}$

6.14) $\lambda_1 = 656,3\,nm$ $\quad \alpha = 40^0$

$\lambda_2 = 410,2\,nm$

$d \sin\alpha = m\lambda$

$m_1 \cdot \lambda_1 = m_2 \lambda_2$

$\frac{m_1}{m_2} = \frac{\lambda_2}{\lambda_1} = \frac{10}{16} = \frac{5}{8}$ $\quad m_1 = 5, \; m_2 = 8$

$d = \frac{m_1 \lambda_1}{\sin\alpha} = \frac{5 \cdot 656,3 \cdot 10^{-9}}{\sin 40} = 5,105\,\mu m$

6.15) $\lambda_1 = 7,5 \cdot 10^{-7}\,m$ $\quad \alpha = 45$

$\lambda_2 = 5 \cdot 10^{-7}\,m$

$d \sin\alpha = m\lambda$ $\quad \Rightarrow \quad m_1 \lambda_1 = (m_1 + 1)\lambda_2$

$m_1(\lambda_1 - \lambda_2) = \lambda_2$

$m_1 = 2 \quad m_2 = 3$

$d = \frac{2 \cdot 7,5 \cdot 10^{-7}}{\sin 45}$

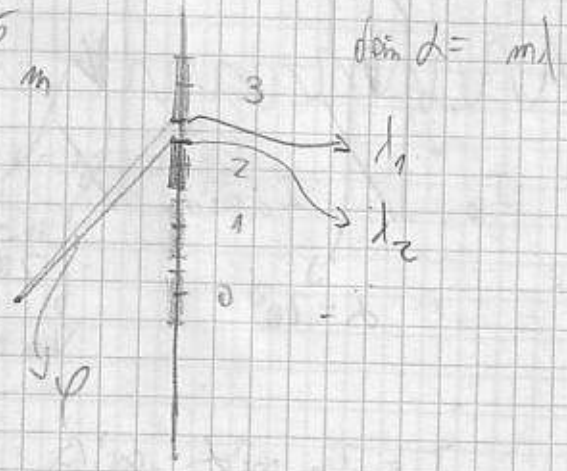
$d = 2,121\,\mu m$

6.16) $\frac{1}{d} = 50$

$d = 0{,}02 \text{ mm} = 2 \cdot 10^{-5} \text{ m}$

$\lambda_1 = 380 \text{ nm}$

$\lambda_2 = 780 \text{ nm}$



$\sin\alpha = m\lambda$

2 ↓ 780 ↓

$\sin\alpha_2 = \frac{m_2 \lambda_2}{d}$

$\alpha_2 = 4{,}4736^\circ$

$\sin\alpha_3 = \frac{m_3 \cdot \lambda_1}{d}$

$\alpha_3 = 3{,}2676^\circ$

$\varphi = \alpha_2 - \alpha_3 = 1{,}206^\circ$ //

6.17) $n_1 = 1{,}73$

$n_2 = 1{,}53$

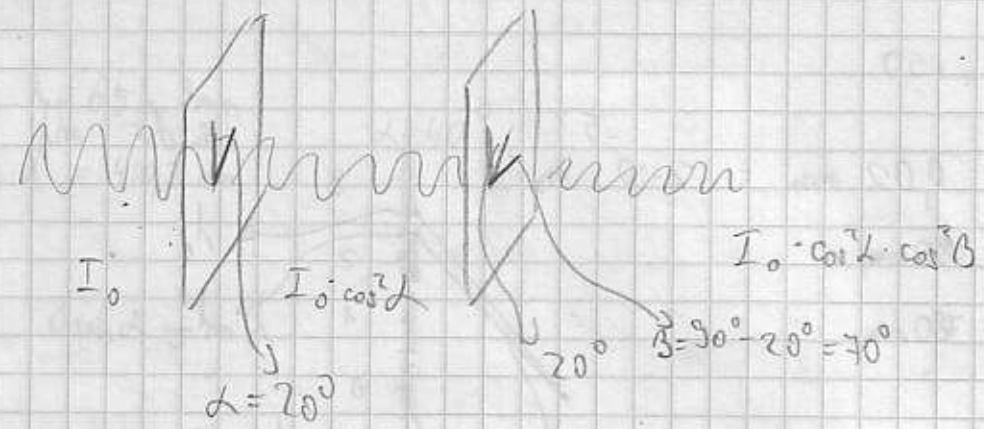
$d = 4{,}42 \cdot 10^{-6} \text{ m}$

$\lambda = 589 \text{ nm}$

$\delta = n_1 d - n_2 d = 884 \text{ nm}$ //

$\Delta\phi = \frac{2\pi}{\lambda} \cdot \delta = 3\pi = \pi$ //

6.18)



$$I = I_0 \cos^2\alpha \cdot \cos^2\beta$$
$$= I_0 \cos^2 20 \cdot \cos^2 70$$
$$= 0{,}103\, I_0$$

6.20) $\rho = 1\,g/cm^3$

$l = 30\,cm$ $\qquad \phi = 66{,}5\,°/cm$

$d = 2\,cm$

$\varphi = 39{,}7°$

$$\phi_2 = \frac{\varphi}{l} = 1{,}323\,°/cm$$

$$\frac{\phi}{\phi_2} = \frac{\rho}{\rho_2}$$

$$\rho_2 = \rho \frac{\phi_2}{\phi} = 0{,}019899\ g/cm$$

$$m = \rho_2 \cdot V = \rho_2 \cdot \left(\frac{d}{2}\right)^2 \cdot \pi \cdot l = 1{,}8755\ g$$

8. KVANTNA PRIRODA SVETLOSTI

8.2) $W_i = 0$??? $\quad \nu = 1{,}23 \cdot 10^{20}\ Hz$

$$E_k = h\nu = 8{,}15 \cdot 10^{-14}\ J$$
$$= 0{,}509\ MeV$$

$$E_k = mc^2\left(\frac{1}{\sqrt{1-\beta^2}} - 1\right)$$

$$\sqrt{1-\beta^2} = 0{,}50113$$

$$\beta = 0{,}86537 = \frac{v}{c}$$

$$v = 0{,}86537\ c = 2{,}59 \cdot 10^{8}\ m/s$$

8.4)

$d = 2\,cm \quad r = 1\,cm = 0{,}01\,m$

$T_0 = 400\,K$

$T_k = 100\,K$

$c_{Cu} = 350\ J/kg\,K$

$\rho_{Cu} = 8500\ kg/m^3$

$W = mc\,T(t)$

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

$P = S \cdot I = S \cdot \sigma T^4$

$S = 4\pi^2 11$

$dW = P\,dt$

$mc\,dT = S \cdot \sigma T^4\,dt$

$$mc\frac{dT}{T^4} = S\sigma\,dt \quad \Big| \int_{T_0}^{T_k}$$

$$-\frac{mc}{3T^3}\Big|_{T_0}^{T_k} = S\sigma \cdot \Delta t$$

$$\Delta t = \frac{-mc}{3S\sigma}\left(\frac{1}{T_k^3} - \frac{1}{T_0^3}\right)$$

$$= 66956\ s$$

8.5) $\lambda_1 = 0{,}35\,\mu m$

$\lambda_2 = 0{,}54\,\mu m$

$N_1 = 2N_2 \Rightarrow E_{k1} = 4E_{k2}$

$W_i = ?$

$$\frac{hc}{\lambda_1} = W_i + E_{k1}$$

$$\frac{hc}{\lambda_2} = W_i + E_{k2}$$

$$\frac{hc}{\lambda_1} - 4E_{k2} = \frac{hc}{\lambda_2} - E_{k2}$$

$$E_{k2} = \frac{1}{3}\left[hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)\right] = 6{,}656 \cdot 10^{-20} = 0{,}415\,4\,eV$$

$$W_i = \frac{hc}{\lambda_2} - E_{k2}$$

$$= 1{,}88\,eV = 3{,}01 \cdot 10^{-19}\,J$$

8.6) $\lambda = 300\,nm$

$S = 4\,cm^2 = 0{,}000\,4\,m^2$

$I = 15 \cdot 10^{-2}\,W/m^2$

$$P = S \cdot I = 6 \cdot 10^{-5}\,W$$

$$P = \frac{W}{t} = \frac{\frac{hc}{\lambda}}{t}$$

$$t = \frac{hc}{\lambda P} = 1{,}1 \cdot 10^{-14}\,s$$

87) $U = 150\,V$

$E_k = q \cdot U = 150\,eV$ /

$$E_k = mc^2 \left(\frac{1}{\sqrt{1-\beta^2}} - 1 \right)$$

$\sqrt{1-\beta^2} = 0{,}9997$

$\beta = 0{,}024224 = \frac{v}{c}$

$v = 0{,}024224\,c = 7{,}26 \cdot 10^6\ m/s$ //

88) $E_k = 10^5\,eV$

$$E_k = mc^2 \left(\frac{1}{\sqrt{1-\beta^2}} - 1 \right)$$

$\beta = 0{,}54822 = \frac{v}{c}$ $\qquad v = 0{,}54822\,c$ /

$v = 1{,}64 \cdot 10^8\ m/s$ //

89) $\lambda = 325\,nm$

$U = 1{,}91\,V \rightarrow E_k = 1{,}91\,eV$

$\frac{hc}{\lambda} = W_i + E_k \rightarrow W_i = \frac{hc}{\lambda} - E_k$

$W_i = 1{,}905\,eV$ /

8.10) $\lambda_{max} = 545\,nm$

$\lambda = 200\,nm$

$$W_i = \frac{hc}{\lambda_{max}} = 3{,}645 \cdot 10^{-19}\,J$$

$$E_k = \frac{hc}{\lambda} - W_i = 6{,}279 \cdot 10^{-19} = 3{,}924\,eV$$

$$U = \frac{E_k}{q} = 3{,}924\,V$$

8.11) $\lambda = 450\,nm$

$\lambda_{1max} = 600\,nm$

$$W_{i1} = \frac{hc}{\lambda_{1max}} = 2{,}066\,eV$$

$$W_{i2} = 2W_{i1} = 4{,}133\,eV$$

$$E_{k1} = \frac{hc}{\lambda} - W_{i1} = 0{,}689\,eV \Rightarrow U_{z1} = 0{,}689\,V$$

$$E_{k2} = \frac{hc}{\lambda} - W_{i2} = -1{,}377\,eV \rightarrow \text{nema fotoefekta}$$

8.13) $E_\gamma = 662\,keV$

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

$$\max \Delta\lambda = \cos\theta = -1 \qquad \theta = 180^\circ$$

$$\Delta\lambda = 2 \cdot \frac{h}{mc} = 4{,}84 \cdot 10^{-12}$$

$$\lambda = \frac{hc}{E_\gamma} = 1{,}87 \cdot 10^{-12}$$

$$\lambda' = 6{,}71 \cdot 10^{-12}$$

$$E_k = \frac{hc}{\lambda} - \frac{hc}{\lambda'} = 477{,}303\,keV \;//$$

8.14) $\nu = 1{,}2 \cdot 10^{18}$

$E_e = 0{,}85\,eV$

$$E_e = h\nu - h\nu'$$

$$\nu' = \nu - \frac{E_e}{h} = 1{,}19575 \cdot 10^{18}$$

$$\frac{c}{\nu'} - \frac{c}{\nu} = \frac{h}{mc}\left(1 - \cos\theta\right)$$

$$\frac{mc^2}{h}\left(\frac{1}{\nu'} - \frac{1}{\nu}\right) = 1 - \cos\theta$$

$$\theta = \arccos\left[1 - \frac{mc^2}{h}\left(\frac{1}{\nu'} - \frac{1}{\nu}\right)\right]$$

$$\theta = 10{,}78^\circ \;//$$

8.15) $\Delta\nu = 1{,}233 \cdot 10^{20}\ Hz$

$E_k = h\nu - h\nu' = h\Delta\nu$

$E_k = 8{,}17 \cdot 10^{-14}\ J$

$E_k = mc^2\left(\frac{1}{\sqrt{1-\beta^2}} - 1\right)$

$\beta = 0{,}866$

$v = 0{,}866\,c$

$v = 2{,}6 \cdot 10^{8}\ m/s$ //

8.16) $E_k = 0{,}44\ MeV$

max $\rightarrow$ $\theta = \pi$ $\quad 1 - \cos\theta = 2$

$\Delta\lambda = \lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta) = 4{,}84 \cdot 10^{-12}$

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

$\frac{1}{\lambda} - \frac{1}{\lambda + \Delta\lambda} = \frac{E_k}{hc}$

$\frac{\Delta\lambda}{\lambda(\lambda+\Delta\lambda)} = \frac{E_k}{hc}$

$\lambda^2 + \lambda\Delta\lambda - \frac{\Delta\lambda\, hc}{E_k} = 0 \qquad 5{,}4553 \cdot 10^{-23}$

$\lambda = \frac{-\Delta\lambda \pm \sqrt{\Delta\lambda^2 + 4\frac{\Delta\lambda\, hc}{E_k}}}{2}$

$\lambda = 1{,}9953 \cdot 10^{-12}\ m$ //

8.17) $\Theta = 30° \rightarrow \lambda'$

$\Theta = 120° \rightarrow 3\lambda'$ $\quad 1 - \frac{\sqrt{3}}{2}$

$\lambda' - \lambda = \frac{h}{mc}(1 - \cos 30)$

$3\lambda' - \lambda = \frac{h}{mc}(1 - \cos 120)$ $\quad \rightarrow 1 + \frac{1}{2}$

$2\lambda' = \frac{h}{mc}\left(\frac{3}{2} - 1 + \frac{\sqrt{3}}{2}\right)$

$\lambda' = 1{,}65 \cdot 10^{-12}\ m$

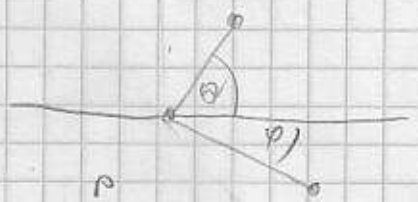
$\lambda = \lambda' - \frac{h}{mc}(1 - \cos 30)$

$\lambda = 1{,}3286 \cdot 10^{-12}\ m$

8.18) $\nu = 3 \cdot 10^{19}\ Hz \qquad \lambda = 9{,}993 \cdot 10^{-12}\ m$

$\Theta = 60°$

$\lambda' = \lambda + \frac{h}{mc}(1 - \cos 60) = 1{,}17 \cdot 10^{-11}\ m$



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

$E_k = 2{,}14 \cdot 10^{-15} = 13{,}369\ keV$

$\frac{h}{\lambda'} \cdot \sin\Theta = \frac{1}{c}\sqrt{E_k^2 + 2mc^2E_k} \cdot \sin\varphi \qquad E_k = mc^2\left(\frac{1}{\sqrt{1-\beta^2}} - 1\right)$

$\beta = 0{,}224$

$\sin\varphi = 0{,}815$ $\quad v = 6{,}72 \cdot 10^{7}\ m/s$

$\varphi = 54{,}61°$

8.19) $\theta = 90°$

$\frac{hc}{\lambda'} = 0{,}4\ MeV$

$\lambda' = 3{,}1 \cdot 10^{-12}\ m$

$\lambda' - \lambda = \frac{h}{mc}(1 - \cos 90)$

$\lambda = \lambda' - \frac{h}{mc} = 6{,}73 \cdot 10^{-13}$

$E = \frac{hc}{\lambda} = 1{,}841\ MeV$